TECHNICAL SPECIFICATIONS

for

1,125 MW Dorjilung Hydroelectric Power Project

Main Works Dorjilung Contract Package-I (DCP-I):Construction of Dam, Coffer Dams, Intake Structures, Plunge Pool, Feeder Tunnels, HRT from Chainage 129 m to 2,485 m, including Construction Adit-I, Connection tunnel to Dam Top and associated Hydro-Mechanical Works

May 2026

Contracts & Procurement Division
Dorjilung Hydro Power Limited

Technical Specifications

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1. PREAMBLE TO THE TECHNICAL SPECIFICATIONS

1.1. GENERAL

1) The following Specifications are part of the requirements for the work related to the Permanent and Temporary Works, which are to be provided by the Contractor according to the stipulations of the Contract. Hence, the instructions given herein form an integral part of, and are applicable to, all technical and Contract Documents issued for the Works. Addenda to these Specifications may be issued as required during bidding and construction phases.

2) These Specifications shall be read in conjunction with the Conditions of Contract, the Drawings and the Bill of Quantities, consisting of Quantities, Rates and Amounts, and the Contractor shall comply with all provisions contained within the Contract Documents and Engineer's instructions.

3) It is the intent of these Specifications, together with other relevant documents issued as part of the Tender and Contract Documents or to follow later on, to provide the Contractor with complete and detailed information and subsequent instructions necessary to enable him to submit a well planned Tender, to carry out the design, where and when required, and to execute properly the work prescribed.

4) It is the intent of these Specifications to establish acceptable standards of quality. Minor deviations in details due to manufacturer's standard shop process will be considered for acceptance provided that, in the opinion of the Engineer, the proposed substitutions are equal in quality to those specified. All deviations shall be called out in writing in the Tender, and shall be specifically indicated on the shop drawings.

5) All work shall be executed according to the AFC drawings and/or Construction Drawings and requirements released for construction, in a professional and diligent manner, and all supplies and work shall comply with the quality requirements defined in the relevant sections of these Specifications and other Contract Documents. The Contractor shall make all necessary efforts to comply with the intent of these Specifications to the satisfaction of the Engineer.

6) Any approval given by the Engineer of the Contractor's methods and equipment shall not relieve the Contractor of his full responsibility for the proper and safe execution of any work covered by these Specifications, or his liability for injuries to or death of persons, or any other obligation under this contract.

1.2. SUBMITTALS

1) The Contractor shall provide the Engineer with all submittals as requested for in these Specifications and other Contract Documents. Although their extent shall be to the discretion of the Contractor, they shall be

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complete enough to illustrate adequately the problem of the aspect concerned for the understanding of the Engineer.

2) At any time, the Engineer may call either for additional information, completion of the submittals or request the Contractor not to submit some of them.

3) The Contractor shall submit these documents to the Engineer so that, even if not specifically expressed, reasonable time will be given to the Engineer to comment or approve the submittals.

1.3. STANDARDS AND CODES

1.3.1. GENERAL

1) Indian/Bhutanese Standards as far as possible are generally referred to in these Specifications. Pertinent provisions of these standards shall apply to the work and are hereby incorporated in these Specifications. Where a manufacturer is named, other manufacturers' product will also be acceptable provided the designated material or workmanship is of equivalent or better quality and do satisfy the relevant Bhutanese Codes.

2) All standards and codes employed or referred to, shall be the latest current issue in effect at the date 28 days prior to the tender submission date.

3) One complete set of standards and codes adopted for the Works shall be submitted free of charge by the Contractor to the Engineer, immediately after the Contract has come into force or upon the Engineer's request. Such copies shall also be available at the Contractor's business domicile(s) and at Site, for the use also of the Engineer.

4) In case of discrepancies between these Specifications and National or International Standards and Codes, these Specifications being part of Contract Documents shall govern, unless otherwise established by the Engineer in each particular case.

1.3.2. STANDARDS, CODES, LAWS AND REGULATIONS

1) Throughout the duration of the Contract, the materials, equipment, services, design and workmanship shall conform to applicable Indian/Bhutanese codes, standards read with Bhutanese laws and regulations as applicable, if not otherwise specified.

2) It is the Contractor's duty to acquaint himself with all available Indian/Bhutanese codes, standards, laws and regulations related to the Works in any way, and he shall procure and keep at the Site a copy of each of such applicable documents.

1.3.3. INTERNATIONAL STANDARDS AND CODES

1) The following International Standards/Codes series may be adopted:

a) International Organisation for Standardisation (ISO)

b) Japanese (JIS)

c) US (ACI, ASTM, ANSI, USACE, USBR, AASHO)

d) German (DIN, VDI)

e) Swiss (SIA, SEV)

f) British (BS)

g) International Commission on Large Dams (ICOLD)

h) Engineering Guidelines for the Evaluation of Hydropower Projects (FERC)

Provided that:

a) The standards/codes proposed are at least as stringent as the equivalent Indian/Bhutanese ones relevant to the Works, or if there is no applicable Indian/Bhutanese Standard/Code for the specific item concerned.

The main National Standard/Code are the following:

- Bhutan Dam Safety Guidelines for Hydropower
- Bhutanese Guidelines for Development of Hydropower Projects
- National Environment Commission (NEC) of Bhutan Acts and Guidelines

b) The Contractor states, prior to starting the work, the International Standard/Code he proposes to apply, giving full identification of each of them. These proposals are subject to the approval by the Engineer.

2) Where reference is made in the technical documents to standards/codes of the country of origin for a supply item, it shall be a recognised National Standard/Code of the country where the specific supply item is manufactured. To be acceptable under these Specifications, such standards/codes must comply in all respects with the quality requirements of above mentioned Bhutanese/Indian standards/codes. In case the Bhutanese/Indian codes are not available, other International Standards as mentioned above must be approved by the Engineer.

1.4. SYSTEM OF UNITS

1) The SI system of units has been used throughout these Specifications and this system of units shall be used consequently throughout the duration of Contract for all technical or contractual purposes.

2) Following abbreviations are used in these Specifications and other related Contract Documents:

	Unit	Abbreviation
Length	millimeter	mm
	centimeter	cm

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	Unit	Abbreviation
	meter	m
	kilometer	km
Area	square millimeter	mm^2
	square centimeter	cm^2
	square meter	m^2
Volume	cubic meter	m^3
Mass	kilogram	kg
	ton Metric ton	t MT
Density	ton per cubic meter	t/m^3
Force	Newton	N
	Kilo-Newton	kN
	Mega-Newton	MN
Moment	Newton meter	N.m
Stress	Newton per square millimeter	N/mm^2
	Kilo-Newton per square millimeter	kN/mm^2
Pressure	bar	bar
	Pascal	Pa
	Mega-Pascal	MPa
Time	second	s
	hour	hr
Rate of Flow	litres per second or minute	l/s, l/min
	cubic meters per second	m^3/s
	cubic meters per minute	m^3/min
Velocity	meter per second kilometer per hour	m/s Km/h
Speed of rotation	revolutions per minute	rpm
Temperature	degree Celsius	°C
luminous Intensity	lux	Lx
Energy	Kilowatt hour	kWh
Power	Watt	W
	Kilowatt	kW
	Megawatt	MW
Slope	Vertical: horizontal	v: h
Gradient	Percentage (Vertical: horizontal)	%

(3) The term "day" as used in these Specifications means calendar day.

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(4) Any other system of units utilised shall have only a descriptive value and shall in no case replace the above-mentioned SI system.

1.5. DEFINITION OF TIME AND KEY DATES

1) The periods of time and key dates used throughout these Specifications have the meanings as assigned to them in the General Conditions of Contract and the Particular conditions of Contract (PCC).

1.6. PROGRAMMING REQUIREMENTS

1.6.1. GENERAL

1) Programmes shall be realistic and adequately detailed and shall be used by the Engineer as a base for the schedule of issuing working drawings to the Contractor and for monitoring progress.

2) In case access should be given to subcontractors or other contractors while his own operations are still in progress, the Contractor shall programme the work in such a manner that the operations can be carried out in safety and without undue obstruction or hindrance.

1.6.2. CONSTRUCTION PROGRAMME

1) The detailed Construction Programme to be submitted as per the Conditions of Contract shall be based on updating and expansion of the Tender Programme.

2) The programme should be computerized using conventional construction planning software (Oracle Primavera or equivalent).

3) The programme shall include as a minimum:

- A network diagram, computer produced indicating critical activities;
- A tabular listing of:
  - early starts and finishes
  - late starts and finishes
  - free and total floats;
- Computer generated bar chart(s);
- Periods required for work to be carried out by other parties involved and subcontractors;
- Information on assumed shutdown periods, vacation days and other non-working time.

4) The detailed Construction Programme to be submitted in accordance with the Conditions of Contract shall be in the form of a bar chart in sufficient detail to show when the main components of each section of the Works will be constructed and commissioned. Periods when construction will not take place shall be clearly

shown. The programme shall incorporate the Sectional Completion Dates set out in the Tender Schedule, or such variations as may be agreed with the Engineer, and any other key dates as specified by the Engineer for the proper monitoring of progress.

5) In addition, a statement of the planned type, number and output of resources shall be submitted to substantiate each programme activity duration.

6) Until such time as the Programme has been agreed and accepted, work shall commence and proceed and progress shall be monitored against the Tender Programme as amended at the award of Contract. During the progress of the Works, the Contractor shall monitor the activities relative to the Programme or an approved Revised Programme and progress shall be reported on a monthly basis. All variances shall be promptly reported. The future impact of major variances shall be determined and analysed by the Contractor, and necessary corrective measures established, subject to the consent of the Engineer.

1.6.3. PROGRESS MEETINGS

1) The Contractor's authorized representatives or its key staff shall be required to attend regular Site Progress Meetings with the Engineer where the progress of construction will be reviewed. Such meetings shall normally be held monthly and may be attended by representatives of the Employer. The Contractor shall present a report on progress to the Engineer before the meeting at a time to be agreed for circulation to participants by the Engineer.

2) The progress meeting agenda will include approval of the minutes of previous meetings, a report on progress of construction in relation to the construction programme and matters arising from any difficulties encountered in the construction of the Works.

3) When the minutes of the meeting prepared by the Engineer have been accepted by the other participants, the minutes will be deemed to be a true record of the declarations, instructions and decisions taken during the meeting.

4) When requested by the Engineer, the Contractor shall also attend a weekly meeting with the Engineer and provide, four working hours before each meeting, detailed programmes showing separately the parts of work anticipated over the forthcoming two weeks period as well as the progress achieved over the preceding week. The Contractor will be required to attend other meetings from time to time on special subjects.

1.7. DRAWINGS

1.7.1. TENDER DRAWINGS

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1) The Tender Drawings are those issued with the Tender Documents. The drawings show the scope of work to be performed by the Contractor. The Tender Drawings issued with the Tender Documents are of a general nature only but are sufficient for the purpose of tendering. The Tender Drawings shall not be used as a basis for construction but may be used as a basis for planning and placing initial orders for materials.

1.7.2. CONSTRUCTION DRAWINGS

1) The Engineer, based on the following timing, will issue the Construction drawings. The Tender Drawings may be modified by the Engineer and re-issued, together with any other additional drawings that may be necessary to develop the work in greater detail.

2) The Construction drawings will be issued by the Engineer at least 45 days before the construction of the individual works to which the Construction drawings refer.

3) The Engineer and the Contractor, to facilitate the construction process, may agree together on the delivery dates of the Construction drawings based on the construction programme (developed with PRIMAVERA Software or similar).

4) Once the Construction drawings have been issued, it will be the Contractor's responsibility to produce all necessary internal drawings required for execution based on contractor's erection and construction methodology, preparation of shop drawings etc, which are to be submitted to the Engineer for review and approval. The Engineer's approval shall in no way relieve the Contractor from any of his contractual obligations.

5) Moreover, the Contractor shall produce the following:

- Drawings of temporary works;
- Stability calculations and drawings of support measures for temporary excavations;
- Stability calculations and drawings of temporary structures;

6) The cost for producing and submitting, the Contractor's internal drawings and temporary work drawings is deemed to be included in the unit prices in the Bills of Quantities.

1.7.3. AS BUILT DRAWINGS

1) Preparation of As-built drawings shall be the responsibility of Main Design Consultant (DC), however the Contractor shall be responsible for supplying all relevant, accurate and complete information, records, inputs, including red marked drawings reflecting the work as executed , necessary for preparation of as-built drawings.

2) The Contractor shall submit the complete set of inputs necessary for preparation of As-Built Drawings within 30 days before the date of Taking Over or as otherwise agreed with the Engineer. The submission shall include:

- Three (3) hard copies in A3 format, signed by the Contractor;
- One (1) complete digital copy in both ".dwg" (editable AutoCAD) and ".pdf" (non-editable) formats.

3) The cost for producing and submitting, all necessary inputs for preparation of As-Built Drawings is included in the unit prices in the Bills of Quantities.

1.8. METHOD STATEMENTS

1.8.1. GENERAL

1) Unless otherwise confirmed in writing, acceptance of the Tender will not signify acceptance of the Contractor's proposed methods of construction or materials, nor will it in any way relieve the Contractor of any of his responsibilities for the Works. Further it will not be accepted as a basis for claiming additional compensation where the proposed methods of construction, its end results, or the proposed materials do not comply with the Specifications and are not approved.

2) Unless otherwise directed, the Contractor shall submit to the Engineer for consent full details concerning the methods, equipment and quality assurance procedures proposed for each section of the work, including but not limited to temporary offices, buildings, access roads, Contractor's Equipment, power arrangements, aggregate storage, cement handling, and environmental mitigation. These shall be referred to as Method Statements and details shall be submitted sufficiently in advance before the programmed commencement of work in the area concerned.

3) The Engineer will give his consent or comment on the proposals within two weeks of receipt. The Engineer's consent will not be unreasonably withheld, provided the methods and equipment proposed may be expected to produce an acceptable end result, but such consent shall not relieve the Contractor of his responsibilities for safety, adherence to the programme, compliance with the Specifications and Drawings or any other requirements of the Contract.

4) After operations have commenced, it is possible that modifications to the construction methods originally agreed upon will be found desirable and such modifications will be made from time to time by agreement in writing between the Engineer and the Contractor. If any equipment, appliances, types or quality of scaffolding, forms, and the like are, in the opinion of the Engineer, either unsafe or unsuitable for accurate and efficient construction, the Engineer may instruct the Contractor to replace or modify the item or items concerned, whether or not the Contractor is in agreement with such opinion, and the Contractor shall forthwith make the required alterations without any additional payment.

1.8.2. APPROVAL, CONSENT, AGREEMENT ETC.

1) Any approval, consent, acceptance or agreement, by the Engineer of Contractor's Equipment or its operations, or of any construction procedure, or of any materials to be used in construction, or of any temporary work will not imply any relaxation of the Clauses of the Specification governing the quality of the materials or of any requirement of the Contract.

1.8.3. CONTRACTOR'S DESIGN

1) Where an alternative design is initiated by the Contractor he shall be responsible for timeously obtaining any design criteria from the Engineer.

1.9. CONTRACTOR'S DOCUMENTS

1.9.1. DAILY RECORDS OF WORK PERFORMED

1) When requested by the Engineer in writing, the Contractor shall submit to the Engineer by midday of the following day accurate records detailing work carried out the previous day on Permanent and Temporary Works. This record shall include the following for each portion of the Works, separately and in sufficient detail to establish the man-hours and equipment hours expended:

- Extent of work done;
- The time and duration of any significant delays or breakdowns of any Contractor's Equipment;
- Any other events relevant to the progress of the Works.

2) The reports shall be in a format acceptable to the Engineer.

3) Notwithstanding the foregoing, the Engineer may employ members of his own staff to record some or all of the above data in addition to the Contractor's records. The Contractor shall also provide such further information as may be requested by the Engineer.

1.9.2. RETURNS OF LABOR AND EQUIPMENT

WEEKLY

1) The Contractor shall maintain weekly record detailing for each portion of the Works separately the numbers of the various classes of workmen employed by him on the Site, the Contractor's Equipment on Site and any other information that may reasonably be required. The number of days Contractor's Equipment is out of order shall be noted.

2) When requested by the Engineer in writing, these weekly records shall be submitted to the Engineer.

FORTNIGHTLY

1) The Contractor shall submit to the Engineer for statistical purposes a fortnightly return of the number of the various classes of workmen employed by him on the Site.

MONTHLY

1) The Contractor shall maintain a monthly, or at shorter intervals as required, record of principal materials ordered and stocks on Site and further Contractor's Equipment to be delivered to the Site. The returns shall be in a format agreed with the Engineer.

2) When requested by the Engineer in writing, these monthly records shall be submitted to the Engineer.

1.9.3. RETURNS OF WORKS CARRIED OUT

1) The Contractor shall submit a report detailing the works carried out, with the contents, format, and submission frequency defined in the relevant chapters of these Technical Specifications.

END OF SECTION A.1

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2. SITE INSTALLATION, SERVICES AND ENVIRONMENTAL OBLIGATIONS

2.1. SCOPE OF WORK

1) The Contractor shall be responsible for providing plant, equipment, materials and labour for the provision of all necessary Temporary works, site installations and services required for the realisation of the Works under this Contract.

2) The Contractor shall design, furnish, set-up, maintain and operate at the Site all Temporary Works, site installations and Contractor's Equipment for his own use as specified in this Section, or required by the Contractor, including camps, workshops, warehouses, storage and assembly areas, all machinery, vehicles, scaffolding, equipment, water and power supply, etc.

3) Temporary Works and services provided and operated by the Contractor shall conform to the applicable Kingdom of Bhutan laws, regulations, standards, codes and sanitary requirements stipulated for such purpose. In addition, they shall comply fully with National Environment Commission (NEC) Acts of Bhutan and necessary guidelines relating to environmental protection, mitigating measures for reducing environmental impacts and remedial works on completion of the Works.

4) The design, construction, operation and maintenance of the Contractor's Temporary Works and services may be subject to inspection by the Engineer.

5) All plants, camp facilities, installations and services provided by the Contractor shall at all time remain his property, except when otherwise specified hereinafter. Should, after the Completion of Contract, the Contractor wish to sell his plants, facilities and equipment, he shall pay all taxes and duties required by law as stipulated in the Conditions of Contract, and have to obtain relevant permission from the Royal Government of Bhutan for such sale.

6) The temporary site roads which the Contractor shall construct, and maintain for the various working areas, camps, facilities and other temporary works are covered in the Pre-Construction Works Technical Specifications.

2.2. SUBMITTALS

1) Within 21 days from the date of receipt of the Letter of Acceptance, the Contractor shall submit to the Engineer updated layout plans showing, at adequate scale, the locations and arrangement of all Temporary Works and facilities. These plans shall be consistent with the plan submitted by the Contractor with his Tender

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as well as with any amendments and additions subsequently agreed to by the Engineer and the Contractor, and shall include:

a) Camps for Contractor's employees,

b) Offices, parking areas, warehouses, storage areas, and medical care services,

c) Water supply, sewerage, sewage treatment and disposal, power supply and illumination, telephone service (radio, cable and walkie talkie),

d) Temporary roadwork, including public road diversions,

e) Equipment pools and mechanical workshops,

f) Spoil areas, borrow, quarry and stockpile areas,

g) Concrete and materials processing plants, including cement storage,

h) Materials testing laboratory,

i) Explosives magazines,

j) Underground ventilation system,

k) Security and safety arrangements,

2) Within 42 days from the date of receipt of the Letter of Acceptance, the Contractor shall submit to the Engineer the following:

a) Detailed drawings at scale 1:500 showing the camp layout, buildings, roads, recreation areas, all utilities, etc., and drawings at scale 1:50 showing typical building construction details,

b) Drawings and specifications for the establishment of an infirmary and first aid stations, and details of the ambulances,

c) Detailed design for industrial and potable water supply to the camps and working areas as well as sewerage systems, sewage treatment and disposal with an estimate of number of people to be supplied with water,

d) Detailed layout drawings for electrical installations and distribution systems at the Site, showing voltages, outlets, and routing of power lines,

e) Detailed design and drawings including manufacturer's drawings for concrete and materials processing plants in accordance with the requirements of the pertinent Sections of these Specifications,

f) Detailed break-up of all equipment to be used for material testing and in the field laboratory in accordance with the requirements of the pertinent Sections of these Specifications,

g) Details of the drilling and grouting equipment,

h) Details of the underground ventilation system.

i) Details of the dewatering system

3) Within 42 days from the date of receipt of the Letter of Acceptance, the Contractor shall submit to the Engineer an Environmental and Social Management Plan (ESMP) which will describe all measures to be taken

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by the Contractor to comply with the requirements of § 2.18 of this Section. This plan will cover all measures to be taken by the Contractor to prevent, minimize or make good all possible environmental effects of the construction work, in particular:

a) Deterioration of the quality of water in rivers and streams, and of ground water.

b) Accumulation and pollution by solid and liquid waste material anywhere in the project area.

c) Undesirable levels of noise, air pollution and dust both at the construction site as well as along the access road, in quarries and borrow areas.

d) Occurrence amongst site workers and their families of water-borne and other communicable illnesses, and the deterioration of levels of hygiene in the camps and construction areas.

This environmental plan will also describe the procedures to be adopted by the Contractor for reporting on the environmental protection programme and for informing and communicating with government institutions. The plan will also give details of arrangements made by the Contractor with local landowners for the leasing of land for site installations, camps etc., and will include drawings detailing the areas in question.

2.3. SITE OFFICES, STORES, WAREHOUSES, MATERIALS YARDS

1) The Contractor shall provide and equip, for his own and his subcontractors' use, main and secondary offices, warehouses, materials storage areas, fuel storage areas and explosives magazines, all of which shall be maintained in good conditions until the Completion of Works.

3) Listed hereunder are the buildings, shops and warehouses expected to be constructed and equipped by the Contractor for use in the performance of the Work under this Contract, in addition to facilities explicitly specified elsewhere in these Specifications:

a) Mechanical repair shop,

b) Electrical repair shop,

c) Metalwork and wood fabrication shop,

d) Main warehouse and parts store,

e) Bulk cement silo,

f) Bagged cement store,

g) Spare parts store,

h) Gasoline and oil stations.

i) Explosive Magazine.

j) Communication & instrumentation items.

k) Reinforcement storage and bar bending.

L) Diesel Generator sets.

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4) The Contractor is required to have at the Site at least two month's minimum reserve of materials both for construction activity and other requirements. For the monsoon months, from May to September, when transport to and from site may be made difficult, his reserve requirements may need to be increased to 3-4 months.

2.4. CONCRETE AND MATERIALS PROCESSING PLANTS

1) The Contractor shall install and erect all necessary concrete and materials processing plants of sufficient capacity to meet the planned peak requirements during construction. The plants shall be subject to approval by the Engineer and shall be well designed and fabricated and kept in good running order to ensure compliance with the materials quality specifications. All control and measuring equipment shall be regularly serviced and calibrated.

2.5. MATERIALS TESTING LABORATORY

1) The Contractor shall build and equip an adequate field laboratory for the sampling and for testing of materials for concrete, steel reinforcement, earth, rock or any other materials as specified in the pertinent Sections of these Specifications.

2) The laboratory shall be located in a dust-free building properly equipped with electricity, water, etc., and shall have enough room for storing the samples tested as required.

3) The equipment to be supplied and the methods of testing shall be in accordance with the relevant Bhutan standards Bureau (BSB), Indian Standards or with requirements of the US Army Corps of Engineers (USACE), or USBR Concrete Manual and USBR Earth Manual. All apparatuses and equipment shall be brand new, of the latest design, manufactured by a reputed manufacturer, and properly calibrated with calibration certificate from Indian or International Authority. The proposed type and number of items of laboratory equipment shall be presented to the Engineer prior to purchase.

4) The Contractor shall operate and maintain the laboratory until the Completion of Works and make all facilities and services available to the Engineer as required. All sampling and testing to be undertaken shall be under the direct supervision of the Engineer. The laboratory shall be run by Contractor's personnel experienced in sampling and testing of materials, and quality control.

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5) Specialized testing which may be required and which cannot be performed in the Contractor's laboratory due to lack of time or equipment shall be assigned to an independent organization at Contractor's Cost. The Contractor shall accept all results, instructions or restrictions stipulated by the Engineer based on such tests.

6) The Owner reserves the right to station qualified personnel within the Contractor's laboratory to observe testing activities and, where deemed necessary, independently collect samples for submission to external laboratories for conformity or verification testing. The Contractor shall provide adequate space, access, and all necessary facilities to accommodate the Owner's personnel within the laboratory.

7) Upon the Completion of Works, all laboratory equipment shall remain the property of the Contractor. However, the Employer reserves the right to purchase some or all of the equipment.

2.6. COMMUNICATION SYSTEMS

2.6.1. SITE COMMUNICATIONS

1) The Contractor shall supply, install, operate and maintain a telephone switchboard, and wireless mode as alternative communication system, complete with standby power supply, to connect his offices with the Engineer, campsite, laboratories, workshops, stores, aggregate plants, quarry/borrow areas, batching plants, ice plant, adit portals, tunnel portals, tunnel headings, infirmary and first aid stations and all other work areas within the Site.

2) The Contractor shall furnish a directory of the telephones installed at the Site and make it available to the Engineer.

3) The Contractor shall provide Broadband internet services and Wi-Fi services, to connect his offices with the Owner's/Project Manager, campsite, laboratories, workshops, stores, aggregate plants, quarry/borrow areas, batching plants, ice plant, adit portals, tunnel portals, tunnel headings, dam site, infirmary and first aid stations and all other work areas within the Site.

2.6.2. COMMUNICATION SYSTEM IN UNDERGROUND WORKS

1) The Contractor shall install and maintain operational a communication system by telephone or preferably an underground radio system approved by the Engineer between each heading face and entrance to the tunnel or shaft.

2) An intermediate intercom station shall be located at least every 500 m along the tunnel.

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3) This communication system shall have its source of energy independent of the main energy supply for underground works.

4) The availability of the communication with open air shall be ensured at all times throughout the whole duration of underground construction.

2.6.3. OUTSIDE COMMUNICATIONS

1) The Contractor, after seeking necessary approval from concerned agencies of the Royal Government of Bhutan, may install, operate and maintain a radiotelephone system(s), UHF and/or microwave, at the Site to provide the access to the National and International telephone grid.

2) The Employer will endorse the necessary license applications of the Contractor.

3) Upon the Completion of Works, the Contractor shall dismantle and remove from the Site the installed outside communications. However, the Employer reserves the right to purchase some or all of the equipment.

2.7. SERVICE & INSPECTION VEHICLES

The Contractor shall operate and maintain sufficient service vehicles with reverse horn for use by its own staff and employees in the management for the supervision and performance of the work.

2.8. CAMPS FOR CONTRACTOR'S EMPLOYEES

1) The Contractor shall design, construct, provide furnishings, maintain, and operate two separate construction camps; one for Officers and the other for Laborers employed at the site. A minimum number of existing camp facilities will be handed over to the Contractor on a cost recovery basis, as specified in the Particular Conditions of the Contract.

2) The construction camps shall provide for the housing, feeding and recreation of the Contractor's employees and those of his subcontractors as per Labour Act of Bhutan and other relevant regulations. The camps shall be large enough to accommodate the anticipated peak work force.

3) The required land shall be acquired by the Client/Employer.

4) The Contractor shall be responsible for the necessary topographical surveys, clearing, and work required for the landscaping and to provide satisfactory foundations for buildings, streets and auxiliary facilities.

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5) Food handling, preparation and serving shall be arranged by the Contractor in properly equipped canteen buildings for all subcontractors' employees.

6) The Contractor shall be responsible for keeping the camp and the buildings in good hygienic conditions. The standards and regulations presently in force in the project area with regard to personnel treatment, sanitary conditions, and fire and accident prevention shall be duly taken into account.

7) The prices charged by the Contractor for food, beverages, etc., available in the camp shall be calculated on a non-profit basis.

2.9. COMMERCIAL CONCESSIONS

1) Commercial concessions such as for laundry, catering, shops, etc., granted to a third party by the Contractor for the use of the employees and residents at the Site, shall be subject to approval by the Engineer. Any concession shall be revoked if the concessionaire violates the law or the provisions governing the granting of the concession. Concessions shall automatically terminate upon Completion of the Works or in the event of the termination of the Contract.

2) No concession shall be granted for activities that are contrary to statutory regulations or law of the land or are declared by the Engineer to be offensive to the community.

3) Concessionaires will be regarded as subcontractors of the Contractor.

2.10. MEDICAL CARE FACILITIES

1) The Contractor shall comply with laws and health standards presently in force in Bhutan. In the event of illness of an epidemic nature breaking out, the Contractor shall carry out and comply with all orders, arrangements or regulations which may be issued by the Government or local authorities.

2) The Contractor shall construct, equip, and maintain at the Site, the following medical care facilities:

a) One clinic and infirmary with ambulance and driver within his main camp. All necessary approvals for establishing and operating these facilities shall be obtained by the Contractor.

b) One first aid station at each work site.

3) The construction of these facilities shall be such as to provide reasonable quiet, privacy, communications, adequate ventilation, heating, light, hot and cold water, toilet facilities, electrical outlets, and impervious floors, walls and roofs.

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2.11. POWER SUPPLY AND ILLUMINATION

1) The Contractor shall provide, install and keep operational throughout the time for completion, own generating facilities of such capacity necessary to supply all participants at the Site and in the camps. The power generating sets (550 kVA- minimum 3 nos.) shall be installed in separate concrete or steel structure buildings on concrete foundations. The power supply to the construction sites, camps etc. shall be designed for continuous operation, 24 hours a day, with sufficient capacity to satisfy peak and emergency demands. The Employer shall provide the power supply point; the exact location, voltage, and capacity of which shall be provided by the Engineer. The scope of the DHPP shall extend up to the transformer, and the Contractor shall be responsible for all power distribution and supply beyond this point. Electricity consumption shall be charged at the prevailing Bhutan Power Corporation tariff.

2) The Contractor shall install, operate and maintain electrical distribution systems which shall include all other necessary transformers, circuit breakers, disconnect and safety switches, voltage regulators, transmission lines, poles, pole hardware, conductors, meters, Cables, lugs, 20-Meter-high Mast sufficient numbers (12X600 Watts), Treated Earth pits, DOL / Star / Delta Starter, distribution Boards, with required Earth fault and over current relays, ACB for 415 V 600 Amps incomer, etc. ELCB 30 mA for all equipment like welding Machine & cutting, grinding tools for safety GI Flats, Copper cables, 5 KV Insulation tester, Multi meter, Clamp Meter, Earth Pit tester, Discharge rod, Neon tester, PPE, Arc suit, etc. and other equipment necessary for power distribution throughout the Site and temporary facilities.

3) Local standby generating units to prevent the interruption of work during the failure of the primary power source and capable of maintaining minimum services such as illumination, water supply, dewatering, etc., safety and security (CCTV for 24/7 monitoring at least 15 days recording to avoid theft issues) shall also be provided.

4) The Contractor shall ensure adequate illumination for all his operations at the Site and at the camp, including illumination of the streets. The minimum intensities for illumination in general shall be as follows:

	Area or Operation	Luminous Intensity
a)	Excavation and spoil areas, and outdoor access ways	35 Lux
b)	General construction areas, outdoor concrete placement, active storage areas, loading, platforms, refuelling, and field maintenance areas	55 Lux
c)	Indoor construction areas	110 Lux

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d)	Tunnel and general underground work areas	55 Lux
e)	Tunnel and shaft headings during drilling, mucking and scaling	110 Lux
f)	General construction plant and shops, e.g. batching plants, mechanical and electrical, equipment rooms, carpentry shops, active storerooms, barracks or living quarters, lockers or dressing rooms, mess halls, and indoor toilets	110 Lux
g)	First aid stations, infirmaries, and offices	550 Lux
h)	General interiors warehouses, corridors, hallways and exit ways	55 Lux
i)	Welding	330 Lux

2.12. WATER SUPPLY

1) The Contractor shall design, install, operate and maintain two separate water supply systems at the Site:
   a) Industrial water: for general construction use, treated to the extent necessary to meet specified requirements. (e.g. for concrete),
   b) Potable water: for supply to all buildings and plants requiring high quality water meeting statutory requirements for drinking water.

2) Water shall be supplied by the Contractor from suitable natural sources available within the Project area. The water shall be free of contamination and unaffected by the Site construction work. In isolated areas with no natural sources, the Contractor shall provide sufficient number of water carts to cover the requirements on both the industrial as well as potable water.

3) The Contractor shall furnish, install, operate and maintain all pumps, piping, fittings, valves, storage tanks, purification plant and chlorination for the water supply and distribution systems, adequate in quantity and pressure. Industrial water shall be used for construction purposes only if of adequate quality. There shall be no cross connections of any kind between the industrial and potable water supply systems. Only potable water shall be piped into buildings.

4) Throughout the duration of the construction, the Contractor shall take regular samples from all water supplies to examine it for suitability and treatments required, and make the bacteriological tests periodically from potable water systems. The monitoring frequency shall vary according to the type of water source: for example, drinking water distributed in the camps shall be tested weekly, while other parameters (such as drainage and wastewater) may be monitored on a monthly basis. Compliance monitoring shall be carried out

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against the applicable standards of the Royal Government of Bhutan (RGoB) and the requirements specified in the ESIA.

2.13. SANITATION AND SEWERAGE

1) All offices, workshops, laboratory and other occupied work buildings shall be provided with toilets connected to properly constructed and regularly maintained septic tanks approved by the Engineer.

2) The campsites shall be provided with a complete, properly maintained and operated sewerage system, including septic tanks, cesspool and disposal facilities. Facilities for washing clothes shall also be provided and linked to the sewerage system.

2.14. WASTE AND GARBAGE DISPOSAL

1) The Contractor shall collect waste material and garbage from camp, offices and workshops on a daily basis and transport it to an area approved by the Engineer where it shall be incinerated and buried.

2) The Site shall be kept clean and free of refuse at all times. No waste shall be dumped in areas other than those approved by the Engineer for waste disposal. No waste of any kind shall be deposited in any watercourses.

2.15. FENCING AND SITE SECURITY

1) The Contractor's offices, workshops and storage compounds, campsites and all construction areas where exclusion of unauthorized personnel is necessary for safety and security, shall be adequately fenced, gated and guarded.

2) The Contractor shall employ an adequate force of properly trained security guards at the work site and at the construction camp on 24-hour duty including Sundays and holidays. Storage areas shall be fenced, lighted and regularly patrolled by security guards. Warehouse buildings and explosive magazines shall be kept locked and keys accounted for at all times.

3) All employees engaged in the execution and maintenance of the Works shall wear identification badges when at the work site.

4) The Contractor shall be responsible for the losses occurring in his installations and those of the Employer resulting from carelessness on the Contractor's part.

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5) Contractors shall arrange personnel to carry out daily maintenance of the storage areas, including repairs and maintenance of the drainage system and fences and the removal of plant growth and debris to prevent the development of fire and health hazards.

2.16. INSPECTION BY THE ENGINEER

The Owner and the Owner's Engineer have the right at any time to inspect any part of the Contractor's temporary facilities, without advance notification, and to require immediate rectification of any contravention of the specified requirements.

2.17. FINAL CLEAN UP

1) Upon the Completion of Works, or when any plant has completed its functions the Contractor shall dismantle and demobilise all temporary facilities erected by himself or his subcontractors, and remove all debris, objectionable material, and all other refuse which may have been deposited on Site during the construction period. Such materials may be deposited only in areas approved by the Engineer.

2) All excavated areas shall be filled, graded and dressed in a clean and orderly condition acceptable to the Engineer. As far as possible, such areas should conform to the natural appearance of the landscape.

3) No demobilisation or removal of temporary facilities and equipment shall be made without prior approval of the Engineer.

2.18. ENVIRONMENTAL OBLIGATIONS

1) The Contractor shall, during the whole period of the Works comply fully with all Bhutanese laws and regulations relating to environmental protection, mitigating measures for reducing environmental impacts and remedial works on completion of the Works. This obligation shall extend to the construction sites, all the Contractor's site installations, all quarries, borrow areas and spoil tips.

2) Notwithstanding any specific obligations as these may be specified in prevailing Bhutanese laws and regulations, the Contractor shall at all times comply with the following particular requirements for the protection of the environment, the local population and the workers at the construction site:

a) Collect, treat, remove from site and dispose of in accordance with the regulations and to the satisfaction of the Engineer all domestic and industrial waste and excess construction materials (both solid and liquid), fuel, chemicals and other matters.

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b) Make every effort to minimise the harmful effects of transport to and from the site, in particular vehicle emissions and noise and the control of dust on roads.

c) Provide its work force with fuel for cooking and heating and ensure that workers on the site do not cut wood or other vegetation as firewood.

d) Take measures and construct works, on the instructions of the Engineer, to prevent soil erosion from slopes in the construction area.

e) Not clear any areas of forest or woodland without the authority of the Engineer and statutory authorities.

f) Implement specific measures required by Bhutan Environment and forest department.

3) In order to reduce adverse effects on public health resulting from the influx into the project area on construction workers, the Contractor will be obliged to undertake during the whole construction period the following preventive measures:

a) Ensure that all construction staff and workers, prior to being accepted to work on site, submit certificates of good health and, during the construction period, ensure that all employees are given a periodic physical examination (at least once a year and following any serious illness) by a qualified medical practitioner.

b) Ensure that workers suffering from noticeable contagious illnesses are removed from the site for treatment and are not permitted to return to the site without an updated medical certificate.

c) Carry out regular spraying of all parts of the site and site installations to control mosquito vector diseases, using approved insecticides.

d) Implement a control programme to ensure the maintenance of satisfactory sanitary conditions on the site and in the living areas, and report to the Engineer all cases of serious enteric and/or water-borne illness.

e) Install hand sanitizers and disinfect the site location on a regular basis. Ensure that all contractors' staff and labourers are instructed to maintain personal hygiene.

4) The Contractor will send representatives to constituted project environmental monitoring committees, as instructed by the Engineer, and will at all times comply with the requests of said committees with regard to the need for environmental or health protection measures. He will also maintain close contact with local authorities and government institutions in addressing issues arising from the construction activities. Such issues needing particular attention are the following:

a) Pollution caused by construction work.

b) Disputes related to the leasing of land for construction activities and/or site installations etc.

c) Disputes arising from traffic congestion and restrictions on the use of the main project access road and roads in the project area.

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d) All matters relating to road safety and measures to minimize the risk of traffic accidents.

5) The Contractor will submit to the Engineer monthly reports on environmental performance and control. These reports will give details of all environmental protection measures taken during the months, as well as:

a) Any environmental problems encountered during the month.

b) Details of health conditions, in particular any occurrence of contagious illness and any accidents.

c) Any notices received from government or state institutions relating to environmental matters, and the action taken by the Contractor as a result.

6) In view of the limited space available for the site accommodation facilities and in order to avoid problems of assimilation with the present population of the project region, the Contractor will be obliged to keep the number of workers imported from other areas to the minimum required for him to complete the Works on time and in accordance with the specifications. The Contractor will co-operate with the local authorities at all times to prevent migration to the area, of unauthorised persons not involved directly in the construction work. To this end, he will at all times strictly control the movement of persons into and out of the construction areas and camps.

2.19. PAYMENT FOR SITE INSTALLATION AND SERVICES

The initial mobilisation costs such as purchase and transport of Contractor's Equipment and materials to the Site, planning, designing, installing, operating, maintaining and removing of all Temporary Works, site installations, services and facilities specified in this Section, making submittals to the Engineer, recruiting and transferring staff, obtaining rights of way, statutory permits and clearances, clearing, grading and excavating in areas for temporary facilities, and any other costs involved in preparation for constructing Permanent Works will not be paid separately and the entire cost thereof shall be included in the Unit Prices for other items of the Works.

No separate measurement for payment or payment shall be made for complying with any environmental obligations required by Bhutanese laws and regulations, and/or as described in this Section, and all such costs incurred by the Contractor should be included in the Contractor's Unit Prices. keeping this statement.

Contractor if fails to comply with the environmental obligations, the Engineer shall get the required compliance done from third party at Contractor's risk and cost.

END OF SECTION A.2

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3. SAFETY PRECAUTIONS

3.1. SAFETY PROGRAMME AND ITS IMPLEMENTATION

1) Within 28 days from the date of issue of Notification of Award, the Contractor shall submit, in writing, his proposal for a comprehensive safety programme covering all aspects of the Works.

2) This safety programme shall detail policies, procedures, and plans, which the Contractor intends to implement to ensure the safety and health of his employees. It shall comply with the standards and regulations in force in Bhutan applicable to construction safety.

3) The Contractor shall designate a competent employee specially trained and experienced to act as Safety Officer, who will administer and be responsible for the implementation of the safety program. He shall carry out frequent and regular safety inspections of the working areas, materials, and equipment. The name and qualifications of the Safety Officer shall be submitted for approval to the Engineer prior to his appointment.

4) The Contractor shall be responsible for enforcement of the health and safety provisions for his subcontractors to be employed at the Site.

5) Prior to the start of any major construction activity or hazardous operation, the Contractor shall submit to the Engineer for approval, a specific plan for safety precautions covering such operation.

6) All accidental occurrence with serious accident potential such as major equipment failures, contact with high-voltage lines, exposure to hazardous materials, slides, cave-ins, etc., shall be immediately reported to the Engineer.

7) All serious and fatal injuries and diseases caused by the progress of work shall be immediately investigated by the Contractor and a comprehensive report shall be submitted to the Engineer.

8) In case of a fatal accident, only rescue and emergency teams and operations shall be permitted at the place of the occurrence until the Engineer gives permission to resume normal operations.

3.2. SAFETY STANDARDS

In addition to the requirements specified herein, the Contractor shall comply fully with all applicable national and state governments safety regulations and standards in force in Bhutan, as well as with the:

a) Employer safety manual

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b) Code of Practice for Construction of Tunnels, IS: 5878 (Part II-Sec.2).
c) Safety Code for Tunnelling Work IS: 4756.
d) Safety standards of the U.S. Bureau of Mines,
e) U.S. Army Corps of Engineers (USACE),
f) U.S. Bureau of Reclamation Construction Safety Standards.

3.3. PERSONAL SAFETY EQUIPMENT

3.3.1. GENERAL

1) The Contractor shall provide his and his subcontractor's personnel as well as the Engineer representatives and visitors with appropriate personal safety equipment. The use of such equipment shall be compulsory.

2) Every person entering the working area in open air or in underground shall wear a protective helmet. Every person entering into underground works shall have a battery operated electric lamp.

3) The safety-toe footwear with steel caps shall be worn by all employees engaged in work having an inherent danger to the feet. Light footwear such as sandals, canvas or tennis shoes shall not be permitted for construction work.

4) During the drilling works and in the areas where the employees are exposed to harmful noise levels, ear protectors shall be made available and required to wear.

5) Employees engaged in work having an inherent danger of eye or face injury shall be furnished and required to wear protection glasses, goggles or masks. Where irritant or toxic substances may come in contact with the skin or clothing, employees shall be wearing the protective clothing or shall be required to apply a protective ointment by a competent physician.

6) Employees working on steep slopes or otherwise subject to possible falls from levels not protected by fixed guardrails or safety nets, shall be secured by safety belts and lifelines.

3.3.2. REQUIREMENTS FOR UNDERGROUND WORKS

1) Emergency material shall be provided at each underground excavation heading. This equipment shall consist of the following, as a minimum:

a) 3 stretchers
b) 3 woollen blankets
c) 2 appliances for artificial breathing
d) 1 oxygen flask

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e) 3 explosion-proof lamps
f) wound dressing and disinfecting material
g) pain-killing injections
h) gas masks

2) At least two members of the Rescue Team as described hereinafter, properly instructed and trained in the rescue procedures, shall be in each crew working underground.

3.4. RESCUE TEAM

1) Prior to the commencement of construction, the Contractor shall organise and train a Rescue Team composed of his employees. This Rescue Team shall be capable to render help after accidents caused by fire, gas, explosion, avalanche, etc.

2) The Rescue Team shall be organised in such a way that sufficient number of members will be ready for action at any time until the Completion of Works.

3) The Rescue Team members shall be instructed and trained for their task by a qualified and experienced person. If required, the Contractor shall hire an outside specialist to perform such training. A refresher training for all members of the Rescue Team shall be conducted at least every six months.

4) Each Rescue Team member shall be skilled in giving the first aid, dealing with the appliances for artificial respiration, and fire fighting equipment and shall possess a good local knowledge. Adequate equipment for reaching even the remotest working area shall be at their disposal.

3.5. ILLUMINATION AND EARTHING

3.5.1. GENERAL

All working sites in the open, transit areas, excavation sites, access to tunnels, etc., shall be adequately illuminated during night work by electrical lights as specified in the Section "Site Installations and Services".

3.5.2. ILLUMINATION OF UNDERGROUND WORKS

1) Each working face shall be brightly illuminated.

2) The vaults along the entire length of the tunnel adits and shaft shall be illuminated with electrical light throughout the duration of construction works. The lamps shall be located as follows:

a) Every 25 m in unlined stretches,
b) Every 50 m in lined stretches.

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The lamps shall be installed in a particular area immediately after the rock supporting measures have been completed.

3) Electrical cables shall be well insulated, protected and firmly fixed to tunnel walls by means of adequate insulators. Lamps shall be well protected against damage.

4) Lighting by flame is expressly forbidden in the underground.

3.5.3. EARTHING, WET WORK AREAS, CONTROL OF ELECTRIC DISCHARGES

1) All equipment and appliances, which are exposed to lightning, shall be earthed electrically, and the effectiveness of such earthing shall be periodically checked by the Contractor's specialised personnel.

2) No equipment electrically powered by more than 24 Volts shall be operated by personnel standing in water.

3) Only air, battery-powered or hydraulic tools shall be permitted in the wet areas.

4) Where electrical blasting will be used, equipment shall be installed to control possible electric discharges in the ground due to storms, electrical motors, etc. As soon as such discharges are noted, electrical blasting operations shall be suspended, or the detonator type changed.

3.6. MAINTENANCE OF TRAFFIC AND SAFETY ON PUBLIC ROADS

1) The Contractor shall be responsible for the safety along the roads related to the Site, and he shall take all necessary precautions for the protection of the work and the safety of the public on the roads affected by his activities. Where the work will be carried out at the site of, or close to an existing road, the Contractor shall maintain the vehicular and pedestrian traffic safe at all times. If his operations can cause traffic hazards, he shall repair or fence or take such other measures for ensuring safety which are satisfactory to the Engineer.

2) Roads subject to interference by the work shall be kept open or suitable detours shall be provided and maintained by the Contractor, who shall provide, erect, and maintain all necessary barricades, suitable and sufficient flashlights, flagmen, danger signals, and signs.

3) Roads, which will be closed to traffic, shall be protected by effective barricades on which acceptable warning and detour signs shall be placed. All barricades shall be kept illuminated and all lights shall be kept on from sunset to sunrise.

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4) The Contractor shall submit his weekly activities schedule and the locations of his work along the existing public roads to the authorities concerned, and obtain all necessary approvals prior to commencement of the respective work.

5) At the road crossings or in heavy traffic locations, the Contractor shall carry out the work during the working hours as directed by the Engineer, and after the completion of the work he shall immediately make the necessary backfill and pavement at the crossings.

6) The Contractor shall provide temporary passes and bridges to give an access to the existing villages, houses, etc., to the satisfaction of the authorities concerned whenever he disturbs such existing way during the execution of the Works.

3.7. STORAGE AND TRANSPORT OF EXPLOSIVES

1) The Contractor shall at an appropriate time apply to the Client and concerned departments, police and military or other responsible authorities as applicable for all permits needed to allow him to transport, store and use the explosives required for the Works. The Contractor must allow in his work programme for the time needed to obtain said permits.

2) The Contractor is responsible for proper care and handling of detonators and explosives and he shall strictly comply with the rules and regulations in force in Bhutan regarding transport, storage, handling and use of explosives.

3) Explosive magazines shall be reinforced concrete buildings with walls and slabs of a minimum 250 mm thickness. Doors shall be made of double sheets having a minimum thickness of 5 mm each and shall be fitted with safety type locks.

4) Explosive magazines shall be kept at a safe distance from working areas and living quarters. They shall be surrounded with barbed wire, protected by safety locks, ventilated, and fitted with lightning arrestors. An air space shall be provided between the ceiling and the roof to prevent temperatures from reaching dangerous levels.

5) Blasting caps and detonators shall not be stored in the same magazines as explosives, but shall be located in separate magazines at least 15 m away if barricaded and 30 m if not barricaded.

6) Explosives shall be stored only in their original containers and with the top side up as designated on the container.

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7) Access to the magazines and permission to handle explosives shall be granted exclusively to trustworthy personnel, adequately instructed and experienced in the use and handling of explosives.

8) No explosives may be stored in the tunnels, galleries, caverns or shafts.

9) The Contractor shall provide adequate security measures necessary to prevent loss or theft of explosives. Storage of explosives and detonators outside of the magazines shall not be permitted.

10) The Contractor shall maintain a record of storage and withdrawal of all explosives. This record shall be made available to the Engineer on request. The Engineer shall be promptly notified of any loss or theft of explosives.

11) Between the magazines and the place of use, the explosives and detonators shall be transported separately in lockable metallic containers loaded on special wagons destined for the purpose of explosives transport only. These wagons shall be painted with striking colours for easy recognition. The inside of the containers shall be lined with wood in order to prevent a direct contact of the explosive or detonators with the metal.

3.8. BLASTING

3.8.1. GENERAL

1) All blasting shall be carried out in a workmanlike and safe manner by a competent, licensed and experienced blaster engineer or foreman. No blasting shall be done without his approval.

2) Blasting will be permitted only after adequate provisions have been made for the protection of persons, the Works, and public or private property. The Engineer's approval of any of the Contractor's blasting operations shall not relieve the Contractor of his sole responsibility for the safety of persons and property. The Contractor shall be liable for all claims resulting from personal injury and damage to property and equipment that may result from its blasting operations. Any damage done to the Works or property by blasting shall be repaired by the Contractor at his own cost.

3) Blasting in the open air shall be carried out only at certain hours of the day in accordance with a schedule mutually agreed upon by the Contractor and the Engineer. Barriers shall be erected and warning shall be given to the workers at the Site and to the public immediately before blasting, so that no person will enter the danger zone until blasting is finished. Any restriction imposed on the blasting schedule to ensure safety of structures, properties and lives shall not be accepted as a basis for a claim by the Contractor.

4) Upon completion of blasting, an "all clear" signal shall be given by the responsible blasting engineer after he has satisfied himself that all charges loaded have detonated and that no delay-explosions or misfiring are to be expected.

5) Such methods of blasting shall be employed that shock and vibration are minimised.

6) No blasts involving charges larger than 200 kg shall be carried without the written approval by the Engineer, who shall be notified at least one hour prior to the blast.

7) No blasting shall be permitted within 25 m of any concrete placed within the previous 7 days, except backfill concrete behind steel ribs. After 7 days, blasting may be performed only with the approval of the Engineer. Blasting will not be permitted within 10 m of structures or installations vulnerable to damage by blasting.

8) No charging and firing will be permitted during thunderstorms and other electrical disturbances.

9) Mats or rubber tires tied together with rope shall be used as protection from flying debris to cover the charges where blasting may expose persons or property to injury or damage.

3.8.2. UNDERWATER BLASTING

1) Only water-resistant blasting caps and detonating cord shall be used in underwater blasting operations.

2) Loading tubes and casings of dissimilar metals shall not be permitted because of possible electrical transient current from galvanic action.

3) When more than one charge is placed underwater, a float device shall be attached to an element of each charge in such manner that it will be released by the firing.

4) No drilling, digging or excavating shall be permitted until all misfires have detonated or the explosives are removed from the missed holes.

3.9. VENTILATION OF UNDERGROUND WORKS (IF APPLICABLE)

3.9.1. GENERAL

1) The Contractor shall design, furnish, install and operate ventilating systems for underground construction sites, and provide a tunnel atmosphere monitoring system. Details of the proposed systems shall be submitted to the Engineer for approval within 28 days after the day of receipt of the Notification of Award. This updated design shall include all calculations of fresh air supply volume, type of ventilation scheme, duct diameters,

materials and equipment and position of ventilators and dust arrestors. Description of the working cycle including number of persons employed, number and capacity of diesel-powered equipment working at one time at each tunnelling face shall also be included. The design shall be consistent with the proposal submitted by the Contractor with his Tender as well as with any subsequent amendments and additions agreed to by the Engineer and the Contractor.

2) All parts of the Works shall be maintained in a state which will not be injurious to the health of the personnel. The air in underground shall contain no less than 20% oxygen and shall not contain a concentration of harmful gases, vapours or dust greater than is safe for the health of workmen.

3) If required, the ventilating system shall be kept in operation also after break-through in tunnels, galleries and shafts in order to maintain the fresh air volume requirements stated hereafter.

4) Intermediate fans and boosters attached to the main duct line shall be provided as required to ensure satisfactory removal of contaminated air. All ventilation ducts shall be maintained in an airtight condition.

5) Ventilation ducts shall be firmly fixed to the vault in such position that a minimum clearance of 200 mm remains between the duct and the extremities of train or vehicular traffic employed in the underground.

6) The Contractor shall check the amount of fresh air at the heading face after each 200 m of heading progress, but at least once per month. The check of the air-tightness of joints and control of the air ducts for leaks shall be performed periodically. Any deficiency discovered or reported by the Engineer shall be immediately repaired by the Contractor.

7) Should the volume of fresh air at the heading face not reach the required amount and quality, the whole duct system shall be pressure-and-volume tested in portions not exceeding a few hundred meters. Measuring stations shall be located not closer than 10 times the duct diameter from any fan or other flow disturbance within the duct.

8) The underground ventilation system shall be continued till completion of all works and with written permission of the Engineer.

3.9.2. VENTILATING SYSTEM

1) The ventilating system shall be of such efficiency that the average air velocity in the largest excavated profile is not less than 0.3 m/s. In case the presence of methane gas is detected or suspected this value shall be increased to 0.5 m/s.

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2) Furthermore, the main ventilating system shall ensure that both of the following minimum fresh air volume requirements are satisfied at all times:

a) 3.0 m3/min for each person employed underground at one time

b) 6.0 m3/min for each metric horse power (PS) of diesel-powered equipment at work underground at one time. This value may be reduced to 3.0 m3/min providing the equipment is using diesel oil low in sulphur content (max. 0.2% of sulphur by volume).

These fresh air volumes shall be cumulative and the Contractor shall allow in his design calculations for the maximum number of persons and diesel-powered equipment working in the underground at any one time. Any estimated losses, e.g. due to the leaks in the ducts, shall be added to the figures stated above.

3) The ventilating system in the underground excavation performed by drilling and blasting shall consist of two parts:

a) Main ventilating system,

b) Secondary ventilating system.

4) The main ventilating system shall be designed to allow the flow to be reversed and shall be operated as follows:

a) Prior to the blasting, the system will be put in the exhaust mode of operation. Blasting fumes shall be extracted as close as possible to the excavation face. Exhaust air and blasting fumes shall be discharged in such a way that they can neither escape in any other working place nor be recirculated in the fresh air supply system.

b) Prior to the commencement of mucking and removal of material the system will be put in the forced mode of operation which will continue till termination of mucking.

5) The secondary ventilating equipment of the forced type shall be installed to provide adequate ventilation of the area between the heading face and the air intake/outlet of the main system. This system shall be switched on prior to the blasting and shall be operating until the main system has been put into forced mode of operation. The air intake shall be located at a sufficient distance from the heading face to ensure that blasting fumes do not permeate into this area and cause a recycling of blasting fumes. The outlet of this duct shall be located so close to the heading face that the driving of the blasting fumes and dust away from the face into main system is ensured. The minimum capacity shall be at least 70% of the main system capacity. The end diameter of the duct shall be such that the air discharge velocity is not less than 20 m/s.

6) Re-entry to the heading face and resuming of the work may not occur earlier than 15 minutes following each blast.

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3.10. CONTROL OF DUST, SILICA, AND NOXIOUS GASES IN UNDERGROUND WORKS (IF APPLICABLE)

3.10.1. DUST AND SILICA

1) To reduce the amount of dust, only wet drilling will be allowed and during mucking, muck tips shall be kept constantly damp by sprinkling with water. The use of high-pressure water jets for this purpose will not be permitted.

2) The Contractor shall measure the concentration of fine dust and content of silicon dioxide (SiO2) in all dust-producing underground operations by an approved method.

3) Air samples shall be taken within 10 days of commencing underground excavation, and at 90-day intervals thereafter. Further, within 30 days following major changes in tunnel excavation operation, or whenever required by the Engineer. Samples shall be taken from actual working areas. The sampling and testing shall be performed by a qualified person or laboratory to be proposed by the Contractor and approved by the Engineer. A copy of the test results shall be submitted to the Engineer within 2 weeks of the sampling date.

4) The concentration of fine dust (diameter less than 0.005 mm) may not in general exceed the value of 8.0 mg/m3 of air and in relation to the silicon dioxide content in the rock this value is lowered as follows:

Content of SiO_2 in fine	Concentration of fine dust
dust in percent by weight	in milligrams per m^3 of air
1 - 15%	8.0 mg/m^3
20%	6.0 mg/ m^3
30%	3.0 mg/ m^3
60%	2.0 mg/ m^3
80%	1.5 mg/ m^3
100%	1.3 mg/ m^3

5) Should the concentration of fine dust exceed the limits stated above, the Contractor shall undertake such necessary measures and install such additional equipment which will ensure that the dust concentrations are within the specified safe hygienic limits.

3.10.2. NOXIOUS GASES

1) Use of internal combustion engines, other than approved mobile diesel-powered equipment will not be permitted in underground construction sites.

2) The Contractor shall provide and maintain equipment for measuring the content of noxious gases and oxygen at each heading face throughout the duration of excavation works. Tests for determining concentrations of carbon monoxide, carbon dioxide, nitrogen dioxide, methane, other flammable gases, and oxygen shall be made before and after each blasting and at the beginning of each shift by qualified personnel. A record of readings shall be maintained and be available to the Engineer on request.

3) Gas concentrations in underground sites may not exceed the following limits:

0.005%	(fifty ppm) of carbon monoxide
0.5%	(five thousand ppm) of carbon dioxide
0.0005%	(five ppm) of nitrogen dioxide
0.001%	(ten ppm) of hydrogen sulphide
1.0%	(ten thousand ppm) of methane
0.01	milligrams per litre of nitrous oxide

4) Concentrations of other flammable gases shall not exceed 40% of the lower explosive limit at the heading face and 20% of the lower explosive limit in the general tunnel or shaft atmosphere.

5) If concentrations of noxious gases or other flammable gases exceed the permissible limits set forth above, all operations shall be interrupted immediately and personnel shall be removed to a safe area. All sources of ignition shall be extinguished or removed. All equipment, with the exception of ventilation equipment, shall be shut down.

6) The required measures will be mutually determined and agreed by the Engineer and the Contractor. In case of need, the Contractor shall engage the services of an independent consultant experienced in gaseous tunnelling. Re-entry and resuming of the work shall be prohibited until the Engineer has authorised re-entry in writing.

3.11. FIRE PRECAUTION

1) The Contractor shall deploy a fire brigade equipped for the fighting of any fires, which could break out on the construction sites, in temporary structures, stores, residential quarters, etc.

2) An adequate number of fire extinguishers shall at all times be available at each construction site and in each building in camps and in offices and they shall be kept in satisfactory working order.

3) Firefighting equipment shall be of the gas, dry powder or other suitable chemical or pumped water type. Their number, type and location will be subject to the approval of the Engineer.

3.12. DUST ABATEMENT

During the performance of the work and any operations appurtenant thereto, the Contractor shall carry out proper and efficient measures, such as sprinkling with water or other means, whenever necessary to reduce the dust nuisance, and to prevent dust which has originated from his operations from damaging crops, cultivated fields, and dwellings, or causing a nuisance to persons. The Contractor will be held liable for any damage resulting from dust originating from his operations.
If contractor fails to fulfil its obligations to control the dust menace, then Engineer shall take the suitable measures to control the dust nuisance at the cost of Contractor.

3.13. POLLUTION OF STREAMS AND RIVERS

1) The Contractor shall take all possible steps to prevent pollution of streams, rivers, and other water supplies, at or in the vicinity of the Site and shall comply with applicable laws, orders and regulations in force in Bhutan concerning the control and abatement of water pollution.
2) Under no circumstances shall the sewage from the camps, or other contaminated water, be released directly into river or other natural streams or any open areas without prior treatment.

3.14. MEASUREMENT AND PAYMENT

1) No extra measurement for payment or payment whatsoever will be made for the safety precautions required to be provided by the Contractor and the entire cost thereof shall be included in the Unit Prices for other items of the Works.
2) Any repair work or any indemnities required due to Contractor's non-compliance with the safety requirements shall be at the Contractor's expense. Nothing contained in these Specifications shall prevent Contractor from providing, at its own cost, such amount of rock reinforcement, steel ribs or other supports for ensuring safety of excavation performed under the Contract, as it may consider necessary, in excess of that specified by Engineer.

END OF SECTION A.3

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4. SURVEYING AND SETTING OUT WORKS

4.1. EXISTING SURVEY CONTROL POINTS

1) Basic survey network consisting of fixed triangulation polygon points and bench marks exists in the project area. In addition, these data have been supplemented by surveys carried out by the DGPC/Bhutan Survey. These data will be at the Contractor's disposal to serve as a base for the setting-out and checking work.

2) Prior to commencing any construction work, the Contractor shall undertake survey for the purpose of checking these reference data and in order to satisfy himself as to their accuracy. Should he have any objections to these data and the relevant drawings; he shall inform the Engineer in writing within two weeks of receiving them from the Engineer.

4.2. OBLIGATIONS OF THE CONTRACTOR

4.2.1. GENERAL

1) The Contractor shall perform all calculations, surveys and setting-out necessary to establish the accurate location of the structures as shown on the Construction Drawings and shall carry out all necessary surveys to verify the topographical data used by the Engineer for the project design and measuring purposes.

2) Within 21 days from the date of issue of Notification of Award, the Contractor shall submit his proposed survey plan to the Engineer. The proposed plan shall indicate the order of accuracy for all surveys.

3) In advance of any setting-out work associated with all principal project features, the Contractor shall submit to the Engineer for approval a description of the method and procedures he intends to use in establishing benchmarks and base lines.

4) If the Contractor chooses to use triangulation points or benchmarks other than those furnished by the Engineer, he shall do so at his own expense and risk.

5) The Contractor shall carry out topographical surveys of the original ground surface in each sector of the Works where surface excavation will be necessary, and produce sufficient and adequate cross-sections which will permit later to evaluate the volume of excavation for the measurement purposes and payment of excavation.

6) The Contractor shall entrust the surveying works only to surveyor who by their training and experience have sufficient qualifications and knowledge to ensure proper fulfilment of the survey tasks assigned to them. For the performance of the survey, the Contractor shall use a sufficient number of reliable and accurate instruments.

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4.2.2. BENCH MARKS AND TRIANGULATION STATIONS

1) Existing survey control point bench marks and base lines shall be verified with respect to permanent control points at site locations, corresponding bench marks and base lines established afresh as necessary to construct each portion of the Works.

2) Permanent survey control points shall be established prior to starting the work and such permanent points shall be preserved during construction.

3) If not already in existence, a minimum of 2 permanent bench marks shall be established for all adit portals and referenced to data established by survey control points. Benchmarks shall also be provided at intermediate locations between adit portals for checking and carrying purposes. The location of such points with horizontal and vertical data shall be recorded on Construction Drawings by the Contractor.

4) From the primary survey control points the construction surveys shall be performed as required to locate, layout and construct each portion of the Works.

5) Complete and adequate logs of all control and survey work shall be maintained as it progresses. Such logs shall be available for the Engineer's inspection at all times.

6) The Contractor shall protect, preserve and keep accessible the bench marks and triangulation stations of the basic survey and those provided by himself. Any damage or removal of benchmarks and stations, including such of other parties shall be prevented. Any accidental damage shall immediately be brought to the attention of the Engineer. It is expressly stated that the Contractor will be made responsible for the damage and its consequences.

7) Benchmarks shall be of stainless steel or cast iron. In softer soil, the steel bolt shall be embedded in a block of concrete of suitable size, and absolutely stable. Inscriptions shall be durable and clearly legible. Underground benchmarks shall be installed at suitable locations and adequately protected.

8) Subordinate points may be marked by steel pipes or pegs, subject to the approval of the Engineer. Every newly fixed point shall be checked, as far as possible through other elements than those, which served to establish the point.

4.2.3. ACCURACY OF SURVEYING

1) Horizontal distances shall normally be measured with optic or electronic distance measuring instruments. Chaining with metallic tape shall be restricted to measuring of short distances and will be rejected for use in survey of traverse nets.

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2) Elevations shall be determined by differential horizontal levelling.

3) Angles shall be measured by total station.

4) Traverse nets shall be executed with the precision and as per DGPC/Bhutan Survey practice and as per IS codes.

5) Levelling shall be checked by closing the loop to the initial benchmark.

4.2.4. AUXILIARY WORKS

1) The Contractor shall perform auxiliary works with regard to surveying which include, but not be limited to, the following:

a) Perform all necessary calculations with clear presentation of calculations and results in order to facilitate verification,

b) Expose covered bench marks,

c) Provide bench marks in lieu of and/or in addition to those in existence,

d) Remove machinery and obstructions from the required sight-lines,

e) Provide adequate ventilation in tunnels to ensure the necessary clear view,

f) Provide adequate lighting or shut off sources of interfering light to ensure the necessary clear view,

g) Provide adequate labour, and materials as deemed necessary and suitable by the Engineer for the control and auxiliary surveys,

h) Remove all obstructive accumulation of water,

i) Carry out additional topographical surveys in cases where the existing topographical data is, in the opinion of the Engineer, insufficient for accurate measurement of the Works,

j) Carry out all necessary topographical surveys for the incorporation of measuring equipment and instrumentation located in the Permanent Works,

k) Carry out all necessary topographical surveys for the observation of the behaviour of structures during construction.

2) All the above shall be done in close co-ordination with the Engineer.

4.2.5. DAMAGE TO CROPS AND VEGETATION

1) No trees or crops of economic value existing at the Site shall be damaged or removed by the Contractor during survey and cross-sectioning works prior to their enumeration and evaluation.

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2) Throughout the surveying and setting-out the Contractor shall work closely with the authorised local appraisers of crops and vegetation in question and shall provide them with facilities necessary for the expeditious performance of their duties.

3) As soon as a section of work has been defined and valued, the Contractor shall delineate the boundaries of the areas to be cleared by approved markings.

4.3. CHECKING OF CONTRACTOR'S WORK BY THE ENGINEER

4.3.1. REGULAR CHECKING

1) All elements of the Contractor's survey work associated with the setting-out of principal project features will be regularly checked by the Engineer during the course of the work, and the Contractor shall provide assistance at any time as required in the performance of such control work.

2) The Contractor may be required to provide the Engineer with any information, readings or computations for checking.

3) The regular checks will usually be made during work breaks, but in case of urgency, the Contractor shall restrict or stop the affected work.

4) Any checks by the Engineer shall not relieve the Contractor of his full responsibility for the accuracy of structures and parts of them with regard to their position and dimensions.

4.3.2. CONFIRMATION SURVEY OF THE TUNNEL AND DAM DRAINAGE GALLERIES ALIGNMENT (in rock)

(1) In addition to the regular check surveys described above, the Engineer, or an independent survey organisation nominated by the Engineer, will perform confirmation survey of the tunnel and dam drainage galleries in rock alignment in the course of excavation progress. Starting from the duly surveyed fix points at the portals, a traverse net (combination of traverse and gyroscopic measurements) and a levelling will be carried out in each case.

(2) For tunnels, the first confirmation survey is likely to be performed after the first 100 m of tunnel have been excavated. The following controls will be carried out after every 500 m of excavation. Each confirmation survey will require approximately 2-3 days.

(3) The Contractor will be notified in writing in advance about the date of such confirmation survey and of the appointment of an independent surveyor who will perform the survey. The Contractor shall co-operate with such surveyor and provide any assistance as required.

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(4) The Engineer and the Contractor, in co-operation with other contractors, will mutually arrange to carry out such confirmation survey at a time and in such a manner, so as to limit as far as possible any delay or inconvenience to underground work. But notwithstanding the above, the Engineer may arrange such superior control to be performed at any time and notify the Contractor accordingly.

(5) Such work will have to be temporarily halted which will, in the opinion of the Engineer, cause excessive vibration or noise such as drilling, mucking, hauling persons, materials or rock spoil in or out of the tunnel, installing permanent or temporary support or any similar work.

(6) The Engineer will normally give the Contractor written notice of such stoppage at least 48 hours in advance and will state the approximate time at which work must cease and the approximate duration of such stoppage. The Engineer will also indicate what work, if any, may continue. The Contractor must promptly acknowledge receipt of any such written notice and confirm this acknowledgement in writing.

(7) Irrespective of the times given by the Engineer, he shall not be bound to adhere strictly to these times but will attempt to do so in so far as it is feasible. While the Engineer will endeavour to co-operate with the Contractor in planning such temporary stoppages, the Engineer's decision in all cases will be final.

4.4. MEASUREMENT AND PAYMENT

4.4.1. SURVEY WORK PERFORMED BY THE CONTRACTOR

No extra measurement for payment or payment will be made for Contractor's survey and setting-out work including the assistance in check/confirmation surveys, and the entire cost thereof shall be included in the Unit Prices for relevant items of the Works.

4.4.2. TEMPORARY SUSPENSION OF WORKS IN UNDERGROUND

No extension of time for the Completion of Works will be granted to the Contractor due to temporary suspension of work required for the performance of the confirmation surveys of the surface and underground works by the Engineer. The Contractor shall take into account the number and time of these surveys indicated above in his construction time schedules and include all expenses, delays, disruptions, loss of production and inconvenience resulting from such temporary stoppage in the Unit Prices for other items of the Works.

END OF SECTION A.4

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5. QUALITY ASSURANCE

5.1. QUALITY ASSURANCE IN EXECUTION OF WORKS

1) The Contractor shall establish staff, equip and operate a comprehensive quality assurance set-up at the site during the full period of the Works. The principal responsibility and duty of this set-up shall be to ensure that all work carried out and materials produced or supplied by the Contractor comply fully with the Specifications.

2) With his tender, the Bidder shall submit his detailed proposal (in terms of experienced supervisory staff, trained workmen, procedures of work, equipment, obtaining support from outside agencies) for achieving quality in respect of the minimum following:

a) Underground and Surface excavation particularly quality control in blasting and minimisation of over breaks and damage to surrounding rock.

b) Maintaining clean working environment inside underground work with particular reference to lighting, ventilation and dewatering.

c) Rock support installations particularly the grouting of rock bolts / rock anchors / tendons in surface and underground works.

d) Workmanship in shotcrete placement.

e) Workmanship in concrete including RCC placement in surface and underground works.

f) Grouting activities particularly the mix designs and selection of mixes for particular application.

g) Final clean up.

The Bidder's proposal shall be specific enough to assure that all works are executed in a professional manner and Bidder has included in his bid the provision of employment of the best international practices of construction in the implementation of the work.

3) At the time of award of work, the Bidder's proposal at the time of tender proposal shall be confirmed again and shall be improved, if so required.

4) Immediately after the award of work, during mobilization phase, the Contractor shall take systematic steps to implement all the proposals given by him for achieving the desired quality in construction.

5) During course of execution, the quality of the work in progress shall be reviewed at least once in a month in the Quality Assurance meeting specifically called by the Engineer and participated by Contractors Project organisation. In case the Engineer is not satisfied with the resources employed vis-à-vis the commitments made in the proposal, the contractor shall take additional steps to supplement his efforts.

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5.2. CONTROL OF THE PROGRESS OF WORK

1) Close progress control, and the preparation of corresponding progress reports, shall be an important part of the Contractor's quality control responsibilities. The contractor must at all times provide the Engineer with up to date information on the progress of work and must without delay bring to the attention of the Engineer all delays or occurrences which could lead to delay or additional costs.

2) The Contractor shall submit detailed monthly progress reports to the Engineer, in which the contractual programme for the works is updated and information is given on the quantitative completion of civil works (in the form of tables indicating the quantities of completed work).

3) The monthly progress reports shall give full details of any delays to work in progress or planned delays in transport to/from the site, together with detailed proposals for overcoming or preventing delays, and for regaining any lost time.

4) The Contractor shall at any time, at the request of the Engineer, submit detailed reports on particular matters relating to the execution and progress of the works, if such reports are required in order to assess the quality or progress of specific activities or works.

5.3. CONTRACTOR'S QUALITY CONTROL STAFF

1) The Contractor shall assign one experienced engineer to site as full-time quality control manager, responsible with complying with all requirements of Technical Specifications.

2) The experience and qualifications of this engineer shall be given in the contractor's tender and shall be subject to the approval of the Engineer.

3) The positions, qualifications and duties, of the contractor's quality control staff shall be indicated in the QC organisation plan, and shall likewise be subject to approval by the Engineer. As a minimum, the contractor shall appoint one qualified and experienced geologist to be responsible for quality control of each of following the works as under:

a. Coffer Dams
b. Main Dam
c. Plunge Pool
d. Power Intake & Feeder Tunnel
e. Adit 1
f. Associated Infrastructure Works

5.4. CONTRACTOR'S LABORATORIES

1) The Contractor shall establish, equip and operate on site laboratories for the testing of the following principal construction materials:

a) RCC, Concrete, including also the testing of sand, aggregates, cement, water and admixtures.

b) Any site testing and/or calibration of monitoring instrument.

c) The laboratory shall be equipped with all the necessary equipment to carry out the tests indicated below :

i) Tests on aggregates as per IS: 2386 (Parts-I,II,III,IV)

- Sieve analysis
- Compressive strength
- Specific gravity
- Water absorption
- Flakiness and elongation indices
- Sand equivalent Soundness and organic matter
- Los Angeles abrasion

ii) Tests on cement

- Equivalent alkaline content (IS: 4032)
- Specific Blaine surface (IS: 4031 (6))
- Standard Mortar Compressive Strength
- Shrinkage (IS:4031(01))
- Heat of hydration (IS:4031(6))
- Setting time IS:4031(5)

iii) Tests on fresh concrete

- Consistency through slump test (IS:1199)
- Workability
- Heat of hydration using thermometers, cells and recording instruments

iv) Tests on hardened concrete

- Compressive strength on all classes of concrete (IS:516)
- Shrinkage IS: 4031 (10)

2) In some cases where special tests are required, they shall be made in other specialized laboratories after approval by the Engineer.

3) The numbers of samples to be tested, and the timing of testing, shall be as specified in the relevant sections of these specifications, or as may be instructed by the Engineer.

4) The staff of the Contractor's laboratory shall have proven experience in similar previous work and their qualifications shall be subject to approval by the Engineer-.

5) Complete records shall be kept of all laboratory tests carried out and shall be available at any time to the Engineer on request.

6) The Engineer shall be permitted at any time and without notice to observe tests being carried out in any of the Contractor's laboratories, to inspect equipment or to study results.

7) The site laboratory shall be properly air-conditioned and equipped with temperature are relative humidity recording instruments.

8) The site laboratories must be well-equipped with all general facilities which shall be required for collection, sampling, testing, quality control etc. of the construction material (viz. Sieve samplers, core boxes etc) should be of sizes/specification in prevalence in Bhutan/ as per relevant Bhutanese standard. However, if the design requirements necessitate, the non-standard sizes / specification may be used.

5.5. MATERIAL DELIVERED TO SITE

1) The Contractor's quality control staff shall keep full records of all materials delivered to site for use in the Works, and of all tests made on such materials either prior to or following delivery to site.

2) These records shall be available at all times to the Engineer, together with any factory testing certification.

5.6. MEASUREMENT FOR PAYMENT AND PAYMENT

1) No measurement for payment will be made for any of the Contractor's QC activities required in this Section. All costs of these activities will be included in the Unit Prices for work listed in the Schedule.

END OF SECTION A.5

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6. COMMISSIONING

6.1. GENERAL

(1) The Contractor will be responsible for the execution, installation, testing, and commissioning of both civil and hydro-mechanical works, ensuring proper sequencing and integration of all activities, and will require to cooperate with and assist the subcontractor/joint venture partner in the work.

(2) The periods for the installation and testing of these items are indicated in the Contractual Programme or otherwise intimated to him separately.

(3) During the installation, testing and commissioning of equipment the Contractor will allow full access to the staff of the subcontractor/joint venture partner of HM contractor, and for their equipment and materials, and must make full allowance in his work activities and programme for any delays, restrictions or changes of working methods which may result from this requirement.

(4) The Contractor will be expected to agree with the subcontractor/joint venture partner providing him with materials, consumables and electric power as these may be needed during the installation and testing of hydro-mechanical equipment, at costs to be agreed directly between them and at no cost to the Employer.

(5) The Contractor will be expected to make available to the sub-contractor/joint venture partner as available storage space for equipment items and plant during the installation of hydro-mechanical equipment, again at costs to be agreed directly between them and at no cost to the Employer.

6.2. HYDRO-MECHANICAL EQUIPMENT TO BE INSTALLED

1) The principal items of hydro-mechanical equipment which are to be installed in civil structures constructed in the contract shall include but not limited to the following:

a) Spillway Radial gate
b) Spillway Stoplogs
c) Steel liner in Spillway glacis, piers and breast wall in Spillway
d) Construction sluices wheel gates
e) Pipes and valves for temporary and permanent environmental flow release
f) Adit 1 gated plug
g) Intake structure (trashracks, trashrack cleaning machine – TRCM, service gates and hoists, maintenance gates and hoists)
h) Any other installation envisaged during construction.

2) In addition to above the contractor shall also have to coordinate his works with and make due allowances for the works being executed in the vicinity by other contractor.

6.3. TESTING OF EQUIPMENT

(1) The Contractor will work together as required with sub-contractors during the testing of all items of newly-installed hydro-mechanical equipment.

(2) Should the testing reveal any defects or inadequacies of the Works carried out by the Contractor, the latter will immediately act to remedy or make good these defects or inadequacies, to the satisfaction of the Engineer.

(3) The Contractor shall contribute any data or other information needed by the sub-contractor/joint venture partner or the Engineer for inclusion in testing report or commissioning certificates.

6.4. INSPECTION OF CIVIL STRUCTURE

1) On completion of civil works of all components, contractor shall submit (within7 days) a report for conditions covering the following aspects:

6.4.1. GENERAL REQUIREMENT FOR CONCRETE STRUCTURES

Visual Examination for

- -Width and pattern of cracks
- -Spalling, Swelling & Scaling of concrete surface
- -Honey combing, Cold joints, Exposed aggregates & Reinforcement
- -Water Leakage: Surface dampness, Seepage/leakage through joints or cracks
- -Adverse movements such as deflection, heaving, settlements etc.

6.4.2. REQUIREMENT FOR INDIVIDUAL STRUCTURES

i. CONCRETE DAM & SPILLWAY

a) Access of dam top is hindrance free, safe & well illuminated.

b) Bridge on spillway is functional.

c) All instruments / gauges have been installed / calibrated and their initial readings taken.

d) Curtain grouting and pressure relief holes in dam foundation have been completed. There should not be excessive seepage from pressure relief hole in galleries, when reservoir is filled up to FRL.

e) Various accesses to the foundation / drainage galleries etc. are clear and properly illuminated.

f)The de-watering pumps for drainage are functional.

g) There should be no excessive seepage/ leakage from dam block joints for all reservoir levels.

h) On filling of reservoir, the reading of the entire instruments shall be recorded carefully and analyzed for any unwarranted behavior of dam structure. The various parameters regarding behavior of dam should be within permissible limits.

i) The filling of reservoir shall be as per standard norms and guidelines.

j) All type of gates and hoist for spillway are properly tested and functional before filling of reservoir. There should not be excessive seepage/leakage through gate area. In case of excessive seepages/leakage adequate measures should be taken to ensure adequate sealing of gates before further filling of reservoir.

ii. INTAKE STRUCTURE

a) The intake structure is free from obstructions, debris and construction materials.

b) Trash racks are correctly installed, aligned and firmly anchored to the concrete structure.

c) All intake gates, stoplogs and hoists and other Hydro mechanical equipment are properly installed, and tested.

d) Proper physical check of all joints for water tightness.

iii. FEEDER TUNNELS & HEADRACE TUNNEL

a) Condition of sill beams shall be examined before lowering of gates so that necessary methods, materials and procedures are in place to cater for any exigency like damage to sill beam and underneath concrete.

b) Proper physical check of all joints for water tightness.

c) All pressure relief holes, if specified, have been completed and are clean, and seepage, if any, is not excessive.

d) Concrete Lining shall be checked for defects, and the same shall be rectified.

e) All Hydro mechanical equipment i.e. gates, NRVs, etc. are installed and tested.

6.5. MEASUREMENT FOR PAYMENT AND PAYMENT

1) There will be no measurement for payment for any of the activities related to equipment commissioning which are specified in this Section and all costs related thereto will be covered by the Unit Prices given in the Bill of Quantities.

END OF SECTION A.6

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1.1. SCOPE OF WORK

1) The Contractor shall provide all labour, material and equipment necessary to design, build, operate, maintain and remove the temporary dewatering facilities for protecting the Works under construction against flood flows in the rivers and creeks and to design, build, install, operate, maintain and dismantle the temporary dewatering facilities required to remove service water and natural surface flow or groundwater seepage from the working areas on surface as well as from underground.

2) The Contractor shall be responsible for maintaining work sites free of water at all times. Contractor shall make good any damage whatsoever caused by flooding of the work sites due to failure of equipment, improper maintenance of protective works and acts of negligence in his performance of the Work. The Contractor shall indemnify the Employer against claims arising out of any such failure, made by other contractors, land holders or other persons.

3) The contractor shall make the requisite arrangement for the construction power in accordance with the Special conditions of the contract and shall not be entitled to any claim or compensation due to failure or interruption of thereof.

4) The work shall be executed in accordance with the Contractor's design and specifications, and sequences as approved by the Engineer.

5) Temporary dewatering facilities shall be removed upon Completion of Works.

1.2. SUBMITTALS

1) Within 56 days after the date of issue of the letter of acceptance, the Contractor shall submit to the Engineer the details of planning of all diversion, protection and dewatering systems and the necessary flow measurements.

2) This design shall be consistent with the outline description submitted by the Contractor with his Tender, and shall include the following:

a) Design assumptions and calculations,

b) Layouts of drainage facilities,

c) Layout and capacity of pumps and pipes, sumps, drains, both open and covered, well points, etc., including efficiency and heads, piping arrangement and discharge points,

d) Details of standby dewatering arrangements,

e) Proposal for treating polluted water either by settling basins, filters, traps for separating silt or any other suitable method,

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f) Any other arrangements or installations the Contractor may propose for temporary protection of the Works and dewatering of the working areas both in the open air and underground.

3) At least 28 days prior to scheduled construction of the particular work the Contractor shall submit to the Engineer full details of equipment to be installed and all necessary construction details required for the dewatering purposes.

4) The Engineer reserves the right to require any additional information deemed necessary to be included in submitted documents.

1.3. EXECUTION

1.3.1. GENERAL

1) Dewatering systems (electrically operated) of adequate capacity shall be provided by the Contractor for carrying out dewatering of surface as well as the underground construction sites. The Contractor shall supply, install, maintain, and operate all dewatering pumps, pipes, supports, channels, troughs, electrical installations, and necessary accessories, and other consumables required to maintain the different work sites free of water during construction.

2) The Contractor shall provide standby power supply unit commensurate with the capacity of the pumps as to cope with the water inflow into construction sites during periods of breakdown and maintenance of his main power supply units.

3) Dewatering of the surface as well as the underground sites shall be undertaken by gravity whenever possible. Only where dewatering by gravity is not practical, pumping shall be resorted to after this mode has been approved by the Engineer.

4) The Contractor shall propose the permanent sumps locations for approval of the Engineer. The energy meters for the purpose of measuring energy consumed in dewatering for payment shall be installed at those locations.

5) Where, in the opinion of the Engineer existing or potential water inflows into excavations can be reduced or controlled by grouting, the Contractor shall perform grouting in accordance with the relevant Section of these Technical Specifications.

6) The pumped water carried in pipes or flumes shall be discharged at point sufficiently away from the edge of the excavation. Care shall be taken to ensure that there is no seepage or backflow to the working areas.

7) The Contractor shall ensure that all drainage water will be disposed of without causing interference to his own or other contractor's operations elsewhere at the Site and that no drainage water runs into adjacent works. Water discharged from work areas shall not be polluted or endanger the environment. Any polluted water coming from the working sites shall be suitably treated prior to its discharge from the Site. Particular attention shall be paid to possible pollution from oil or solvents coming into contact with the water prior to its discharge from the Site. Oil separators shall be provided within the drainage system as necessary.

8) The dewatering systems shall not adversely affect any of other project activities and structures or works of other agencies. Where more than one agency are working in the same or adjacent area, the Contractor who has already provided the drainage facility, shall extend this facility to other agencies also. In case of dispute the apportioning of such expenditure as applicable shall be decided by the Engineer, whose decision shall be final. In no case shall the Contractor stop the drainage activity.

9) In case the flow from the Contractor's site is passing through the site of other contractors or agencies, the drainage shall be attended by the Contractor in whose site the origin of the water is located.

10) If at any time during construction, in the opinion of Engineer, dewatering pumps in addition to the installed dewatering capacities are required in any working area; the Contractor shall provide and install such additional capacity of dewatering system as necessary.

1.3.2. DEWATERING OF SURFACE CONSTRUCTION SITES

1) The Contractor shall perform all works necessary to drain the surface construction sites of rain, groundwater and service water. The work shall include, but not be limited to the following:

a) Design and construction of drainage, ditches, pits, pump sumps and settlement ponds with oil separators,

b) Design, furnishing, operation and maintenance of dewatering equipment,

c) Relocation of dewatering facilities required for the performance of other works,

d) All auxiliary works required for safe and continuous dewatering of the construction sites.

2) The Contractor shall design and install complete facilities at the surface construction sites. All the components of the dewatering systems shall be installed and operated in accordance with the agreed method and the construction time schedule, or approved modification thereof.

3) Dewatering near the river or stream shall be done down to natural water level by gravity. Suitable drainage shall be made joining the course downstream of the construction site to provide required gradient to facilitate proper and efficient dewatering. Below the natural water table dewatering shall be done by pumping water collected in the sumps and discharging the same into the river course downstream of the construction site.

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4) The Contractor shall provide, install, maintain, and operate adequate pumping and other equipment, including standby units, to handle all water entering into any of surface construction sites. In addition, he shall provide sumps and pumps and/or well points in the immediate vicinity of the structure foundations using such water conductors as are necessary to conduct the water away from the excavation and concrete placement operations in an approved manner, so that such operation shall be kept free from standing or running water.

5) The Contractor shall provide the necessary power and energy for operating the pumps and well point system, if any. The standby power supply shall undergo weekly trial runs lasting at least 30 minutes.

6) The dewatering systems shall be designed and installed in such a way that modifications and extensions to the systems are possible while they are in full operation.

7) Drainage ditches shall be excavated along the top of excavated slopes and on the berm. Such ditches shall be kept well back from the excavation edges in order to prevent saturating the upper part of the slopes. The ditches shall have sufficient longitudinal gradient and shall be regularly cleaned by the Contractor out of all accumulated silt and other matter so that water may flow freely at all times.

8) The Contractor shall take measures to ensure that the foundation surfaces remain free of standing water and undamaged by the passage of construction traffic. All ditches shall be outside the foundation areas.

9) Where excavation is to be made below the groundwater table in loose material, the Contractor shall lower the water table sufficiently below any working surface in advance of the excavation by means of properly screened wells and pumps. Where excavation extends below the water table in rock, the Contractor shall drill holes 6 m deep below the final grade, no further 100 m apart, and measure the piezometric head in the hole for 2 days prior to blasting any rock. Excess hydrostatic pressure in the rock shall be relieved in approved manner to prevent upheaval of, or any other damage to the foundation.

10) Where concrete is to be placed, the water table shall be maintained below the lowest part of the finished excavation for minimum one day following the raising of structure above the natural groundwater table, and for such additional time as may be necessary to preclude damages to structure foundation.

11) Upon completion of dewatering, temporary pipes and pump sumps beneath permanent structures shall be closed off and completely filled with grout, mortar or concrete as required by the Engineer.

1.3.3. DEWATERING OF UNDERGROUND CONSTRUCTION SITES

1) The Contractor shall perform all work necessary to collect and drain service and infiltrating groundwater, convey it to main conduits, and lead it out from underground works such as tunnels, caverns, adits and shafts

etc.

2) The work shall include, but not be limited to, the following:

a) Design and construction of pits and trenches,

b) Design, supply, operation, and maintenance of dewatering equipment,

c) Relocation of dewatering facilities required for the performance of other tunneling work,

d) Design construction and operation of settlement ponds with oil separators at the portals,

e) All auxiliary work required for the safe and continuous dewatering of the underground sites.

3) Pilot holes will be drilled if required by the Engineer, to provide information on the inflow of water into the tunnel or shaft as the excavation proceeds. Where the indications are that flows are likely to be large, grouting to seal off the water flows and drilling of drainage holes may be ordered.

4) The Contractor shall design and provide a complete dewatering system for both the descending and the ascending headings. Dewatering of the ascending heading shall be by gravity alone. The Contractor shall design and construct corresponding drainage trenches in the tunnel inverts with or without lining as appropriate.

5) After break-through in the tunnel, the drainage water from the descending heading shall be taken over by the upgrade drainage system of the ascending heading (dewatering by gravity).

6) All excavated areas shall be drained of all service and groundwater. In order to keep the construction areas free from water, the dewatering systems must be able to operate at any time during the whole construction period in any part of the Works at the required capacity.

7) The Contractor shall provide adequate pumping capacity, including a sufficient number of standby pumping units, to handle all water entering into any portion of underground Works. These units shall be connected to the dewatering systems in such a way that proper and uninterrupted drainage will be guaranteed throughout the entire construction period.

8) The Contractor shall provide the necessary power and energy for operating the dewatering system. The standby power supply shall undergo weekly trial runs lasting at least 30 minutes.

9) All components of the systems shall always be maintained in ready-for-service condition and all access to pumps and other equipment shall be kept in good condition under the most adverse conditions.

10) The dewatering systems shall be designed and installed in such a way that modifications and extensions to the systems are possible while they are in full operation.

11) All components of the dewatering system shall be installed and operated in accordance with the agreed method and the construction time schedule, or approved modifications thereof.

12) After the excavated profile has been checked, the ground water which runs or drips into the excavated space shall be diverted into the drainage trench by means of water collectors, plastic foils, and pipes for collecting the seepage water from rock surfaces or steel lagging. Damp surfaces or seepage areas with low volume in flows can be sealed off with a quick-setting sealing compound.

13) Particular care shall be exercised where excavation passes through material which is liable to soften or swell when it comes into contact with water. In such locations the water entering the excavated space shall be collected as soon as possible and conveyed away in a pipe or other impervious channel in such a way that the water cannot come into contact with such material. Should the Contractor neglect to observe this requirement and a deterioration of the tunnel invert results from water being allowed to flow over or stand upon the sensitive or swelling material, the Engineer may order the removal of the affected material and it's replacement with concrete. The Engineer may order installation of additional rock supports in connection with such remedial work.

14) If any water from another portion of the tunnel or shaft flows into a lower section where concreting is being done, either for the invert or for drainage trench or any other concreting likely to be affected by water, all such water shall be diverted past this area in such a way that no damage occurs to the concrete.
The length of the affected sections over which water has to be diverted shall be ordered by the Engineer.

15) The Contractor shall perform regular checking and cleaning of the drainage trench and all dewatering equipment and accessories during the whole construction period.

16) The dewatering facilities shall be kept in operation according to the agreed schedule which shall be related to the progress of the work. No pumps may be stopped, no pipes, ducts, trenches, etc., shall be taken out of service without the permission of the Engineer.

17) Any openings such as pipes, boreholes, ducts, pump sumps etc., used for temporary drainage purposes in any part of the Works shall be completely sealed by filling with grout, mortar or concrete when no longer required, unless the contrary is directed by the Engineer in writing. The Contractor shall notify the Engineer in writing before any such openings are permanently closed.

1.4. MEASUREMENT AND PAYMENT

1.4.1. DEWATERING OF SURFACE CONSTRUCTION SITES

1) Measurement for payment or payment for the dewatering of surface construction sites will be based solely on the energy consumed in pumping water.

2) Payment will be made at the Unit Price per kilowatt-hour (kWh) entered in the Bill of Quantities, which shall include the entire cost of:

a) Supply, transportation, installation, operations including cost of electricity, maintenance, testing, and removal of pumps, pipelines with all accessories, and other dewatering equipment for pumping water, regardless of the amount of water,

b) Design of all dewatering systems,

c) All costs and labour for excavation, construction and protection of drainage ditches, wells, pits, pump sumps, and settlement ponds,

d) Multistage pumping,

e) Capturing and conveying the water into the drainage system,

f) Moving of the pumps and pipes as necessary between different locations,

g)All auxiliary work required.

3) The quoted Unit Price for dewatering will be payable to the Contractor for the measured actual energy consumed in dewatering. This Unit Price shall hold good for any quantity of dewatering required to be done by Contractor without any variation/deviation limit.

4) The Contractor shall ensure that dewatering pumps supplied by him perform in accordance with the manufacturer's specifications. In the event of any of dewatering pumps provided by Contractor consume energy in excess of the values specified by manufacturer, the same shall be repaired and replaced by Contractor at his own cost, without delay and to the entire satisfaction of Engineer.

5) Each pump installed shall undergo a trial testing at least once a week or as and when directed by the Engineer to demonstrate that it is actually discharging the water at its rated capacity and head. If significant deviations (more than 10% below) are discovered the Unit Price for pumping through that pump will be proportionally reduced for the period of the past 7 days, or until the time of the last pump testing, whichever may apply. Where several pumps are installed at the same site, the weighted average of the capacity of all installed pumps shall be calculated and the Unit Price proportionally reduced. The pump capacity will be measured at the outlet of the installed pipeline.

6) The meters and other electrical connections shall be installed by the Contractor at his own expense. Meters shall be tested by the electrical department of the Employer before installation. Approved test report of the meters shall be submitted to the Engineer before installation. In case the Employer does not have the facilities for such testing, the same shall be got done by the contractor at his own cost at a standard test house approved by Engineer or at the facilities of the State Electricity Department in the presence of the representative of the Engineer. In either case the test report shall be approved by the project electrical department of The Employer. Meters shall be calibrated and tested before installation and the test reports shall be submitted to the Engineer prior to installation.

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7) The Contractor shall not be entitled to any claim or compensation due to failure or interruptions in electric supply.

8) No extra measurement for payment or payment shall be made for dewatering surface construction sites by gravity and the entire cost thereof shall be deemed to be included in the Unit Prices for other items of the Works.

9) Payment for grouting and other seepage control and treatment work shall be paid as stipulated in the Section "Drilling, grouting and Pressure Relief Holes".

10) Payment for drainage trench excavated along the top of excavated slopes will be made at the appropriate Unit Prices for excavation, concrete, rock paving or others as the case may be. Drain ditches on the berms will not be measured for payment and the cost thereof shall be deemed to be included in the Unit Prices for surface excavation.

11) No extra measurement for payment or payment will be made for the following, and the cost thereof shall be deemed to be included in the Unit Prices for other items of the Works:

a) Excavation of drains and sumps required for dewatering purpose,

b) Piping arrangement, consumables, maintenance and repairs/replacement of dewatering system,

c) Caulking or plugging,

d) Construction, operation and maintenance of the settlement ponds, or other devices for treatment of polluted water,

e) Any dewatering done by pumping in contravention of the instructions given by the Engineer.

12) Any repair work or any liability, which result from non-compliance by the Contractor with any requirements of this Section shall be at the Contractor's full responsibility and at his expense.

1.4.2. DEWATERING OF UNDERGROUND CONSTRUCTION SITES

1) Measurement for payment for dewatering underground construction sites will only be of the energy consumed in pumping water.

2) Payment will be made at the Unit Price per kilowatt-hour (kWh) entered in the Bill of Quantities, which shall include the entire cost of:

a) Supply, transportation, installation, operations including cost of electricity, maintenance, testing, and removal of pumps, pipelines with all accessories, and other dewatering equipment for pumping water, regardless of the amount of water,

b) Design of all dewatering systems,

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c) All costs and labour for excavation, construction and protection of drainage ditches, wells, pits, pump sumps, and settlement ponds,

d) Multistage pumping,

e) Capturing and conveying the water into the drainage system,

f) Moving of the pumps and pipes as necessary between different locations,

g) All auxiliary work required.

3) The quoted Unit Price for dewatering will be payable to the Contractor for the measured actual energy consumed in dewatering. This Unit Price shall hold good for any quantity of dewatering required to be done by Contractor without any variation/deviation limit. The Contractor shall also keep a record of power supplied by the Employer to avoid any claim due to differential cost of power utilized for dewatering, i.e. supplied by the Employer and/or generated by the Contractor.

4) The Contractor shall ensure that dewatering pumps supplied by him perform in accordance with the manufacturer's specifications. In the event of any of dewatering pumps provided by Contractor consume energy in excess of the values specified by manufacturer, the same shall be repaired and replaced by Contractor at his own cost, without delay and to the entire satisfaction of Engineer.

5) Each pump installed shall undergo a trial testing at least once a week or as and when directed by the Engineer to demonstrate that it is actually discharging the water at its rated capacity and head. If significant deviations (more than 10% below) are discovered the Unit Price for pumping through that pump will be proportionally reduced for the period of the past 7 days, or until the time of the last pump testing, whichever may apply. Where several pumps are installed at the same site, the weighted average of the capacity of all installed pumps shall be calculated and the Unit Price proportionally reduced. The pump capacity will be measured at the outlet of the installed pipeline.

6) The meters and other electrical connections shall be installed by the Contractor at his own expense. Meters shall be tested by the electrical department of The Employer before installation. Approved test report of the meters shall be submitted to the Engineer before installation. In case The Employer does not have the facilities for such testing, the same shall be got done by the contractor at his own cost at a standard test house approved by Engineer or at the facilities of the State Electricity Deptt. in the presence of the representative of the Engineer. In either case the test report shall be approved by the project electrical department of The Employer. Meters shall be calibrated and tested before installation and the test reports shall be submitted to the Engineer prior to installation.

7) The Contractor shall not be entitled to any claim or compensation due to failure or interruptions in electric supply.

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8) No extra measurement for payment or payment will be made for dealing with water and dewatering of underground construction sites by gravity, and the entire cost thereof shall be deemed to be included in the Unit Prices for other items of the Works.

9) Payment for grouting and other treatment of seepage and fill grouting of drainage system will be made as stipulated in Section "Drilling, Grouting and Pressure Relief Holes".

10) No extra measurement for payment or payment will be made for the following, and the cost thereof shall be deemed to be included in the Unit Prices for other items of the Works:

a) Excavation of drains and sumps required for dewatering purpose,

b) Piping arrangement, consumables, maintenance and repairs/ replacement of dewatering system,

c) Caulking or plugging,

d) Construction, operation and maintenance of the settlement ponds, or other devices for treatment of polluted water,

e) Intermediate dewatering employing intermediate dewatering sumps/pits from first collection sump/pit to disposal end

f) Any dewatering done by pumping in contravention of the instructions given by the Engineer.

11) Any repair work or any indemnities which result from non-compliance by the contractor with any requirements of this section shall be at the contractor's full responsibility and at his expense.

12) No additional loads or related works, including any requirements for gravity-flow dewatering lines, shall be recognized or measured beyond those explicitly specified herein.

13) All lines shall be independently metered and subject to joint measurement and inspection by the Contractor and the Engineer.

END OF SECTION B.1

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2. SURFACE EXCAVATION

2.1. SCOPE OF WORK

1) This Section covers all surface excavation work to be performed under this Contract, which shall consist of removing all existing material of whatever nature to the lines and grades shown on the Construction Drawings or as otherwise directed by the Engineer. This work shall include the excavation under all conditions of saturation and involve drilling and blasting, loading, hauling and disposal of materials in designated spoil, stockpile areas or directly as construction materials.

2) The Contractor shall also be responsible for excavation which is not specifically required for the construction of Permanent Works, but incidental to the installation of temporary facilities such as site roads, office buildings, camp site, construction plants etc.

3) Slope protection and stabilization measures, which may be needed in conjunction with surface excavation work, are covered in section B17 of these Specifications.

4) The approval given by the Engineer to the Contractor's methods and equipment shall not relieve the Contractor of his responsibility for the proper and safe execution of surface excavations, or of liability for injuries to, or death of persons, or any obligations under this Contract.

2.2. SUBMITTALS

1) With his tender, the Contractor will be required to submit a detailed method statement and work programme for the excavation at sites of various components of the project i.e. Main Dam, Coffer Dams, Plunge Pool etc. This statement must indicate all proposed access and haul roads, stockpiles, spoil tips/ disposal areas for excess material etc. The method statement shall give details on the plant and equipment which the Contractor proposes to use for excavation and haulage, blasting methods, drainage and safety precautions, and procedures for the installation of rock supporting and stabilisation works.

2) At least 42 days prior to the commencement of any surface excavation, the Contractor shall submit to the Engineer an updated method statement and programme for the activities set out in (1) above, giving full details of the proposed excavation methods and sequences, including necessary site drainage and safety precautions. Any variations from the corresponding data submitted with the Contractor's tender will be explained and justified to the satisfaction of the Engineer. The data shall include the following:

a) Location and area of blasts.

b) Diameter, spacing, depth, pattern and orientation of blasting holes.

c) Type, strength, amount, column load and distribution of explosives to be used per hole, per delay and per blast.

d) The type of detonators, powder factor, sequence and pattern of delays to be used per blast.

e) Description and purpose of any special methods or equipment to be adopted by the Contractor.

3) The method statement shall include the excavation methodology by mechanised means and planning for its movement and access to various components of the Project.

4) The plans shall be in conformity with detailed requirements of codes read with Bhutanese laws and regulation for excavation sequencing, blasting and precautions to be taken in proximity of concrete and grouting operations, public roads, and for the safety of construction workers and members of the public.

5) Within 14 days of receipt of the overall updated excavation method statement and programme, Engineer will advice the Contractor in writing of his acceptance of, or comments on the submitted plans. The Engineer reserves the right to reject the proposed plan if in his opinion undesirable damage to permanent rock surfaces or existing structures would result from performing the blasting as proposed. If rejected, a new plan in whole or in part shall be submitted. Drilling and blasting shall only be carried out in areas for which the plan has been accepted by Engineer.

6) In addition to preparing a detailed blasting plan; the Contractor shall submit, not later than 36 hours in advance of each proposed blast, a detailed proposal showing the final details of the proposed blast. The Contractor shall not proceed with the blast until permission to load holes with explosives has been given by Engineer in writing.

7) At least 21 days prior to dumping or stockpiling any material, the Contractor shall submit the layout of spoil or stockpile areas, which will be within the areas designated on the Construction Drawings or as approved by the Engineer. All pertinent data of working methods and provisions for the security, stability and temporary and permanent drainage of the areas shall be included. Details of volumes, material types, heights and grades shall be provided.

8) Prior to starting any excavation in any particular area, the Contractor shall confirm in writing his agreement with the existing surveys and topographical data showing the original ground surface for the area in question, which will be used for measurement purposes. Should the Contractor have any doubts as to the correctness, or sufficiency, of such data, he shall carry out an independent survey on his own and submit his survey details to the Engineer for approval. In case of disagreement, the Engineer and Contractor shall mutually review the existing data and if required, a joint survey shall be carried out to reach to an agreement. The agreement concerning the original ground surface must be reached before commencing excavation work. Contractor's

failure to follow the procedure outlined above will forfeit his right to claim any other original ground surface than that established by the Engineer.

9) To enable the Engineer to verify all necessary elevations and cross-sections of the original ground surface, prepared by the Contractor, the latter shall notify the Engineer in writing, giving at least 7 days' notice before the commencement of any excavation. The Contractor shall clear, in advance, all vegetation that may interfere with this survey work.

10) The Contractor shall submit and agree with the Engineer upon a monitoring plan for the excavation to observe potential or actual movement of the slopes excavated in the rock and overburden. This plan shall also give details of the procedures and equipment to be employed by the Contractor to stabilise or protect as quickly as possible any areas in which it is determined that untoward movement or deformation is occurring or is apprehended.

11) Foundation excavation for dam involves removal of overburden consisting of alluvium, boulders and stones and bed rock up to the designated foundation level as shown in the drawings. Planning for such excavation has to be done by the contractor carefully including the stabilisation of slopes, berms & drainage arrangements.

2.3. LINES AND GRADES

1) The Contractor shall be responsible for setting-out all the structures and slopes as shown on the Construction Drawings, in accordance with the Section "Surveying and Setting-out Work". All extra work and over excavation caused by improper setting-out by the Contractor shall be corrected by himself immediately upon the request of the Engineer at his own cost.

2) The final excavation grades shall in general bed rock of required quality. However, where the final excavation grades are defined by line and grade, the Contractor shall take every precaution, and use the most appropriate method of excavation, to avoid the loosening of material or the breaking of rock beyond the lines and grades shown on the Construction Drawings.

3) The bottoms of all excavations shall be trimmed to line and grade as directed by the Engineer. The final 200 mm of any loose geological formation in excavations where concrete is to be placed, shall be excavated by hand, when directed, to avoid disturbance of the bottom.

4) If, for any reason, excavation is carried out beyond the lines and grades shown on the Drawings, the Contractor shall remove the excess material and take the necessary measures to restore the required lines and grades with approved backfill or concrete, as directed by the Engineer.

5) Should the Contractor wish to excavate beyond the limits given on the Drawings for his own convenience, he may do so only with the prior consent of the Engineer.

6) No rough excavation short of actual lines and grades as shown in the Construction Drawings shall be allowed to be taken up to enhance the progress or otherwise as this may trigger movements in the strata to be excavated.

2.4. SLOPES, SLIDES, GEOLOGICAL OVERBREAK AND UNSUITABLE FOUNDATIONS

1) If geological conditions during the performance of the work do not permit excavation of slopes as shown on the Construction Drawings, or where the material is unsuited to form a firm foundation for the structures, the Engineer will modify the drawings accordingly or issue direct order to change the slopes and grades.

2) Excavation beyond the lines and grades shown on the Construction Drawings, or as directed by the Engineer, is defined as over-break.

3) If over-break, slides or rock falls occur, which, in the opinion of the Engineer are due to improper working methods or negligence by the Contractor, and the effective excavated surfaces are beyond the excavation lines shown on the Construction Drawings, the Contractor shall remove all excessive material and, if required, place approved backfill in the excavated voids as directed by the Engineer.

4) Geologically accepted over-break in surface excavation is defined as that over-break which occurs while both of the following conditions are simultaneously fulfilled:

a) The Engineer is informed and given an opportunity for inspection while both the cause and the extent of the over-break are clearly visible.

b) The over-break did not occur while, in the opinion of the Engineer, the Contractor was using improper working methods or was otherwise negligent, and it could not have been prevented by prompt and appropriate installation of supports.

2.5. EXECUTION

2.5.1. GENERAL

1) The Contractor shall conduct all excavation procedures and operations so as to produce the required lines and grades.

2) The surface excavation shall be performed by any approved method using any excavating and hauling equipment suitable for the work in accordance with the submitted detailed plans and time schedule, or approved modifications thereof.

3) The surface excavation shall be performed with the provision of benches of sufficient width to accommodate catch water drains and movement of equipment. Adequate slope protection/ stabilization measure as shown on the Construction Drawings or as directed by the Engineer, shall be taken prior to the excavation to the next bench.

4) All excavated areas shall be drained to the satisfaction of Engineer. Any surface or subsurface water shall be satisfactorily controlled by methods acceptable to Engineer. When underwater excavation is to be performed, suitable equipment shall be used.

5) At all times during construction, Contractor shall adopt excavation procedures such that at no time shall the stability of any slope be impaired. Excavation shall always be started from top and worked down after putting designated supports. In no case should the excavation be carried out from the toe or any intermediate level. The acceptance by Engineer of excavation procedures or equipment shall in no way relieve Contractor of his sole responsibility for safeguarding the stability of all the rock faces and slopes excavated under this Contract.

6) The Contractor shall carry out periodic cleaning to ensure that no hazardous accumulations of loose material occur on the slopes or on any berm or ledges forming part of the excavation profile. The removal of mud and slush resulting from rain or flooding of the sites shall be performed by the Contractor when, in the opinion of the Engineer, it is considered necessary to ensure the safe and effective performance of the work.

7) Excavation for foundations of various components shall be performed under various conditions of saturation. Final surfaces shall be protected against damage by erosion and movement of construction equipment. Any damage caused shall be repaired by the Contractor at his cost.

8) Rock surfaces at sensitive excavations such as tunnel portals shall be carefully excavated and preserved during construction. Appropriate excavation method using mechanical means, smooth blasting techniques shall be generally used there. Line drilling may be applied at certain locations. Rock supports shall be installed where indicated on the Construction Drawings, or directed by the Engineer, to suit the actual geological conditions encountered.

9) The Contractor shall exercise particular care when excavating in the vicinity of existing structures or those under construction. He shall be liable for any damage to structures or equipment caused by his operations. Particle acceleration due to the blasting shall be monitored as specified hereinafter.

10) The Contractor shall protect the subsoil and particularly the ground water from contamination by fuel or oil from his equipment.

11) Water shall be sprinkled on work sites by the Contractor to ensure dust free atmosphere at no extra cost. If the contractor does not heed to the instructions in this regard, the Engineer shall be at liberty to get sprinkling done at the cost of contractor.

2.5.2. CLASSIFICATION OF EXCAVATION

1) Surface excavation is classified according to the method used to carry out the work, as follows:
   a) Common Excavation
   b) Rock Excavation
   c) Dental Excavation
   d) Minor Excavation
   e) Additional Excavation
   f) Borrow and Quarry Excavation

2) The dismantling of any concrete structure, exceeding thickness of 30 cm, shall be included in the item "Rock excavation".

3) Excavation of rock by ripping may be used at the Contractor's discretion, subject to the approval of the Engineer and provided that the work complies fully with the quality requirements of these specifications for rock excavation by blasting or mechanised means. Any such ripping work will be paid for as rock excavation. The ripping of the river borne material shall be treated as common excavation only.

2.5.3. COMMON EXCAVATION

1) Common excavation including riverbed overburden excavation comprises clearing and grubbing, stripping, and all kind of loose excavation other than solid mass of rock under all conditions of saturation.

2) Clearing shall consist of cutting and disposing of all shrubs, stumps, debris and any other vegetation and organic top soil, existing structures, foundations of structures (except concrete or masonry in mortar), fences and other materials on the surface of the ground within the areas to be cleared as indicated on the Construction Drawings, or as required by Engineer.

3) All inflammable material resulting from clearing shall be either burnt or disposed of by the Contractor in a manner acceptable to the Engineer. The Contractor shall be responsible for taking all safety measures required for burning of the materials, and he shall be responsible for any damage done by fire resulting from his work. The fire shall at no time be left un-attended, until it has been fully extinguished. The Contractor shall have suitable equipment and supplies for fighting fire during the burning of material and shall take all necessary precautions to prevent fire from spreading. None of the disposed material shall be piled in stream of river or in a location where in the opinion of Engineer it is liable to be washed away by floods.

4) Stripping consists of removing all rubbish, humus, vegetable material and all or part of the organic top soil in the areas and to the depth as indicated on the Construction Drawings or as directed by the Engineer.

5) Common excavation means general excavation of material such as organic topsoil, clay, silt, sand, gravel, and boulders of up to 2-cubic meter in volume and soft or disintegrated rock, which can be removed by common earth moving equipment without ripping or blasting.

6) Stripping and loose excavation shall be accomplished by proper excavation and hauling equipment suitable for the work which allows for an efficient work progress adopted to the soil conditions encountered.

7) The excavation in the dam area also involves excavation in river bed consisting of mainly river borne material, alluvium, sand, stone, gravels and boulders including large detached pieces of rock blocks lying in the overburden, which may require frequent blasting. Such overburden material will be removed till the rock surface is exposed upon which dam shall be founded.

8) When the bottom of the excavation as indicated on the Construction Drawings is not rock and the natural foundation material is loosened or disturbed, for any reason, the Contractor shall improve it by compaction or replace it with approved fill and compact as directed by Engineer.

9) The contractor shall submit a detailed plan accompanied by the drawings along with the tender document showing detail proposal of excavation, layout of haulage road, intermediate berms for excavation pit, dewatering arrangement, disposal proposal etc. The plan has to be accompanied by equipment and manpower planning and also detailed scheduling of different activities.

2.5.4. ROCK EXCAVATION

2.5.4.1. *GENERAL*

1) Rock excavation consists of the removal of rock by blasting or mechanised means includes all solid rock in place which cannot be removed until loosened by blasting, barring or wedging, removal of all boulders or detached pieces of solid rock larger than 2-cubic meter in volume, as well as any existing structural foundation made of concrete or masonry placed in mortar which cannot be removed during common excavation or by ripping.

2) Lines shown on the Construction Drawings such as "Rock line", "sound rock", "top of rock" etc., are approximate and for information only. They will not be used for measurement purpose.

3) All excavation shall be performed using methods and techniques that will produce smooth and sound rock surfaces with minimum over-break and fracturing beyond the lines and grades or limits of excavation shown on the Construction Drawings, or as required by Engineer, and will preserve the structural integrity of the excavated openings. All precautions shall be taken by the Contractor to achieve this result and also preserve, in a soundest possible and undisturbed condition all the materials beyond the limits of the excavation of lines and grades shown on the drawings. Particular care shall be exercised where vertical or near vertical faces are required.

4) Drilling and blasting shall be done in such a manner as to ensure that the rock will break along the desired lines and grades. Rock shattered by blasting operations outside the established limits of excavation shall be removed and replaced by concrete if necessary. Rock faces and slopes shall be scaled or cleaned of loose or overhanging rock immediately after excavation. Rock surfaces, both temporary and permanent, shall be regularly inspected by the Contractor and rectified whenever necessary.

5) The diameter and the spacing of the blast holes shall be constantly reviewed with respect to the actual conditions at the Site. The Contractor shall develop the blasting techniques as the work progresses to obtain the best possible excavation surface after blasting. The techniques used shall be at all times subject to the agreement of the Engineer, who may order blasting tests to be undertaken by the Contractor to substantiate his proposed methods of blasting. The Contractor shall engage a qualified professional blasting consultant to assist in establishing satisfactory techniques.

6) Rock excavation close to the final excavated surfaces shall be performed using controlled blasting methods such as "pre-splitting", "cushion blasting", and "smooth blasting" as defined hereinafter. Line drilling and broaching shall be used to limit the over break and damage of surrounding rock. Mechanical and or hand methods may be prescribed by the Engineer to minimize disturbance in sensitive areas.

7) The surface of rock excavation upon which RCC/concrete will be placed shall be prepared by picking, barring and wedging or other similar hand methods which will leave the rock in a sound condition as may reasonably be expected according to the rock quality. Rock surface shall then be thoroughly cleaned by high pressure compressed air and water jet or other suitable means before concrete is placed.

8) Shattering or splitting of rock, or the opening up of seams and joints in the rock, beyond the limits of excavation, shall be avoided. If in the opinion of Engineer such damage occurred due to Contractor's negligence, then additional rock support shall be installed and any resultant shattered material beyond such lines shall be removed and replaced with rock fill or concrete as directed by Engineer.

9) Immediately following the blasting, and at any time throughout the duration of the Contract, the Contractor shall scale and remove from the excavations all loose material, which appears to be unsafe or to endanger persons, work or property. The fact that such scaling and removal may enlarge the excavation beyond the

required excavation lines shall not relieve the Contractor from the necessity of performing such scaling and removal.

10) After scaling and prior to excavation of the next bench or round, the Contractor shall install rock stabilisation and reinforcement, and provide any surface treatment needed, as shown on the Construction Drawings or as directed by the Engineer.

11) All blasted rock shall be removed from the bench toe before the succeeding bench is excavated. The maximum bench height shall be as indicated on the Drawings and may be modified only with approval of Engineer. Rock excavation where the vertical height of benches is more than 10 m shall be done basically in a descending direction from horizontal berms by benching.

12) The excavation shall be made to sufficient depths to secure foundations of structures on sound rock free from weathered materials or other objectionable defects, as determined by the Engineer. The exploratory investigations of the foundations are not sufficiently complete to disclose all seams, defects, and other irregularities that may exist in the foundation rock. The lines of excavation shown on the Construction Drawings shall therefore not be interpreted as indicating the final or actual lines of excavation or that no defects exist. The excavations at all elevations shall be so shaped as to produce as uniform and regular a profile as is practicable using excavation methods described herein.

13) The final excavated surfaces shall have no abrupt changes in slope and sharp projections greater than 500 mm. Projections in excess of 500 mm shall be treated where necessary by supplementary excavation as determined by the Engineer, to produce the desired surface of contact between concrete and rock.

14) Whenever, in the opinion of the Engineer, further blasting may injure the rock upon or against which concrete is to be placed, or is otherwise undesirable, the use of explosives shall be limited to light charges or discontinued, and the excavation shall be completed by wedging, barring, line-drilling or other suitable methods approved by the Engineer.

15) Should the presence of rock appear to make excavation for the foundations of any structures unnecessary to the extent, which is shown on the Construction Drawings, the Contractor shall consult the Engineer before proceeding with such work. The Engineer will issue an order in writing on whether to proceed with the work as shown or to define how the work shall be modified.

16) When the excavation has been completed to the approximate grade, as shown on Construction Drawings or established by the Engineer, the surface shall be cleaned off by barring, wedging, picking or other approved methods, and with an air and/or water jet under pressure for purpose of inspection. If the foundation is found to be not satisfactory, as determined by the Engineer, supplementary excavation shall be made as directed, and the surface again cleaned for inspection. This procedure shall be repeated until a satisfactory

foundation level is obtained. Just prior to placing the concrete, a final cleanup of the rock surface shall be made. All loose, shattered, or disintegrated material shall be removed, and the final surface cleaned with jets of air and/or water under pressure.

17) Contractor shall regularly monitor and inspect all excavations made under this Contract, and shall forthwith promptly remove and dispose of any rock, which Contractor or Engineer deems loose, unsound or disintegrated, or in any other way unsafe.

2.5.4.2. *CONTROL PERIMETER BLASTING*

1) Bench or open-cut excavation of permanent rock slopes shall be carried out using the cushion blasting or pre-splitting techniques. However, depending upon the detailed geometry of rock slopes, other techniques, such as line drilling, may be used with written approval of Engineer. Production holes within 3 m of the perimeter row of holes shall be drilled at a reduced spacing and charged with a reduced load. Perimeter holes shall be drilled in such a manner to meet the following tolerances with respect to length, collar, locations and alignment:

a) The collar of perimeter holes shall be located within 75 mm of the perimeter line.

b) Perimeter holes shall not be longer than 6.0 m unless otherwise agreed by Engineer.

c) All perimeter holes shall be aligned so that each hole terminates within 200 mm of the line, to which the holes are being drilled.

d) Within 1 m of corners, the hole spacing shall be reduced by drilling intermediate holes so that satisfactory and high-quality excavation lines are maintained. The intermediate guide holes may or may not be loaded, depending on the results obtained and as required by Engineer.

2) Holes for perimeter blasting technique shall be at spacing of 450 mm, 600 mm or 750 mm. The selection of centre-to-centre spacing of holes for perimeter blasting shall be developed by trials. In initial stages of excavation, perimeter holes shall be drilled at 450 mm spacing and based on results this spacing may be varied.

3) Drill holes for controlled perimeter blasting shall be loaded in a manner and detonated in a sequence so as to ensure a minimum of damage to the rock beyond the excavation lines.

4) Contractor's controlled perimeter drilling and blasting techniques shall be considered acceptable and in conformity with these Specifications for controlling the completed rock surfaces if:

a) At least 50% of the drill hole traces of each round are visible in the final rock surface, distributed uniformly, after the scaling down of all loose and shattered rock that is liable to fall before or during rock reinforcement installation and if all drill hole traces are close to the lines shown in the Construction Drawings.

b) Engineer may modify the above criteria if, in his opinion, the achievement of such results is not reasonably possible because of adverse rock conditions.

2.5.4.3. *LINE DRILLING*

1) Line drilling shall be used where control perimeter blasting may cause excessive damage to the surrounding rock or where there are structures adjacent to the excavation.

2) Line-drilling is defined as a single row of unloaded holes drilled along the neat excavation line, spaced at 2 to 4 times the hole diameter centre to centre. These will form a surface of weakness to which the primary blast can break. Light blasting with well-distributed charges fired after the main excavation is removed or may be permitted in the holes. If, however, in the opinion of the Engineer, the blasting may injure the rock, the use of explosives shall be discontinued and the excavation shall be completed by broaching, wedging, or barring.

3) Line drilling is anticipated in the Abutment slope cuttings, if required as per site conditions, and around the portals.

2.5.5. DENTAL EXCAVATION

1) Dental excavation shall include the removal of unsuitable material from shear zones, clay seams, pockets, joints, or from spaces between boulders beyond the lines of excavation shown on the Construction Drawings or established in the field, which are too small to be excavated by common earth moving equipment.

2) Dental excavation, depending on its extent, will require the use of hand tools, or other small excavating equipment, as well as the use of a high velocity air-water jet. The methods employed shall be such as to avoid fracturing of the rock adjacent to the material being removed.

3) Dental excavation shall be performed where directed. The extent, to which such material shall be removed, including the depth, direction, and dimensions of the work, will be determined by the Engineer. In general, however, excavation into cracks or seams shall be to the depth that is a minimum of 3-times the seam width, and such excavation shall be backfilled with concrete or shotcrete. No blasting will be permitted.

2.5.6. MINOR EXCAVATION WORK

1) Minor excavation work consists of excavation, in all materials, of trenches or holes of less than, or equal to, 2 m width, and in other small or restricted areas, which will be carried out manually or using small equipment.

2) The Contractor shall excavate to the limits, lines and grades shown on the Construction Drawings.

3) Bracing, shoring or other methods of supporting the excavation shall be carried out as necessary.

4) Mechanical excavation of trenches, except those in rock, shall be stopped not less than 100 mm above final bottom level. The remainder of the excavation shall be removed, shaped, and graded manually.

5) In rock, the trenches shall be excavated to such depth that provides space for placing of compacted sand bedding at least 10 cm thick between the rock and the underside of any equipment or pipe.

2.5.7. ADDITIONAL EXCAVATION

1) The Contractor may be directed by the Engineer to perform excavation beyond the lines and grades of already completed work. Such excavation shall be defined as additional excavation.

2) Additional excavation may consist of any or all classes of excavation stipulated in this Section.

3) Excavation outside the excavation limits, which is required by the Contractor for his own convenience, may be performed only with agreement by the Engineer, who may direct the Contractor to refill it with concrete or rock fill in a satisfactory manner at no additional cost to The Employer.

2.5.8. BORROW AND QUARRY EXCAVATION

1) Materials required for the construction of Permanent Works which are not available from excavation will be obtained from the borrow areas and quarries the location of which are shown on the Drawings and/or described in the Information for Bidders, or from other areas as may be designated in the course of the work. For the sake of clarity, these terms have the following meaning:

- Borrow excavation will produce construction materials by loose excavation.
- Quarry excavation will produce construction materials by blasting.

2) The Engineer may request execution of exploratory core drillings as specified in the Section "Drilling and Grouting" prior or during the quarry operations.

3) Prior to commencing borrow and quarry excavation, the Contractor shall clear and strip the area and remove all material which is unsuitable for use in the construction of the Works. Topsoil shall be stripped from the excavated areas and stockpiled for future use apart from other excavated material.

4) The Contractor shall make such tests, use such equipment, and vary his excavating methods and blasting patterns as necessary to produce the required grading, uniformity or mixture of each material, and shall be fully responsible that those materials meet the specifications, and for adequacy and safety of the quarrying and borrowing operations.

5) Borrow excavation will produce material for cofferdams including clay core, concrete aggregates, base material for roads, riprap, rockfill, Gabions etc. If required to prevent excessive moisture content, the Contractor shall lower the water table in the borrow area by appropriate means, stockpile the excavated material to permit drying or perform such work as necessary to reduce the moisture content. Unsuitable material or material not required for permanent construction purposes found in the borrow area shall be left in place, or, with the approval of the Engineer, shall be excavated and disposed of in an approved spoil tip. The Contractor shall avoid contamination of construction material by such unsuitable material.

6) Borrow areas shall be kept graded and drained so that surface and ground water will not collect or stand there. Upon completion of the work, excavated surfaces shall be left with stable slopes not steeper than two horizontals to one vertical. Unless specifically waived by the Engineer, the slopes and bottoms of the borrow pits shall be evenly graded to present a neat and orderly appearance. Tracks or marks of heavy equipment or other disturbed earth shall be smoothed or filled to the surrounding level. The stockpiled topsoil shall be evenly spread over the subsoil exposed by the excavation.

7) Quarry excavation will produce material for Gabions, concrete aggregates, etc. Unsuitable material or material not required for permanent construction purposes found in the quarry shall be left in place or, with the approval of the Engineer, shall be excavated and disposed of in an approved spoil area. The Contractor shall avoid contamination of construction material by such unsuitable material.

8) During excavation at the quarry, berm approximately 3 m wide at 15 m vertical intervals shall be provided.

9) During quarrying operations, the Contractor shall take precautions in order not to interrupt the traffic along nearby roads and provide personnel and devices to warn the road users of blasting.

10) Upon the Completion of Works, rock faces, slopes and bottoms of quarries shall be scaled and cleaned of all loose and overhanging rock. Quarries shall be properly graded for self-drainage and finished with neatly trimmed slopes not steeper than one horizontal to two vertical, unless otherwise directed.

2.6. EXCAVATED MATERIALS

1) All suitable materials from the excavations shall be utilized to the fullest extent as practicable, as construction materials in Permanent Works on prior testing and approvals by Engineer

2) The Contractor's blasting and excavating techniques shall be such that, as far as practical, construction materials of satisfactory quality will be obtained. Wherever possible, such materials shall be excavated separately from materials needing to be disposed of to spoil tip.

3) Whenever possible, excavated material which is suitable for construction purposes shall be transported directly from the excavation area to the designated final locations for its use.

4) If the immediate placement in the final location is not possible, the materials shall be stockpiled. If the moisture content of excavated materials which would be suitable for embankments or backfill is too high after excavation, such material shall be drained and dried in the stockpile until the moisture content is sufficiently reduced to allow for placement.

5) The Contractor shall remove any cobbles, boulders or rock fragments found in otherwise approved materials which are greater or smaller than permitted for specific embankment zones and place them in other zones or dispose them of appropriately.

2.7. DISPOSAL OF EXCAVATED MATERIALS

1) Excavated materials, which are not suitable for, or are in excess of the construction requirements shall be disposed of in the spoil area shown on the Construction Drawings, or in areas designated as such by the Engineer in the course of the work. The Contractor shall be responsible for the stability of all fills, embankments and stockpiles created by the disposal of excavated materials.

2) The spoil tips shall be located where they will not interfere with the natural flow of streams or rivers, with construction operations in the borrow and quarry areas, with reservoir operation, with flow of water to or from outlet works, or with accessibility to the Site. Where required, the Contractor shall permanently divert (stage-wise if necessary) the present courses of the streams.

3) The excavated materials shall be transported to the disposal areas in such a way that these do not fall on the way. In case such materials fall despite taking reasonable care, such areas shall be promptly cleared by the Contractor to keep it in the state of cleanliness and tidiness.

4) No rock material may be dumped into any rivers or creeks. The earth or soil material may be dumped into natural flows only after written approval by the Engineer.

5) The surfaces of all disposed excavated materials which are to remain permanently exposed shall be finished to prescribed lines and to stable slopes approved by Engineer. Adequate diversion of water courses in such areas and drains shall be constructed to prevent the undesirable accumulation of water in or around the disposal or stockpile areas.

6) The Contractor shall be liable for any damage to Temporary or Permanent Works or to third parties and their property caused by inadequate drainage of the spoil or stockpile areas.

2.8. PREPARATION AND PROTECTION OF EXCAVATION SURFACES

1) Excavation surfaces against or upon which concrete, embankment fill, or backfill will be placed shall be prepared and protected as specified herein and in combination with specifications contained in the pertinent Sections of these Specifications or as shown on the Construction Drawings.

2) If, during excavation work, material beyond the limits of excavation shown on the Construction Drawings is loosened or disturbed, the Contractor shall re-compact the loosened material or remove it altogether and replace it with other compacted fill as directed.

3) If, during excavation in rock for concrete structures or linings, the rock beyond the limits of excavation shown on the Construction Drawings becomes broken or shattered, the Contractor shall remove all loose material and replace it with concrete or shotcrete as directed.

4) Foundation excavation shall be kept well drained and free of standing water. The Contractor shall provide all necessary drains, ditches and sumps, and use pumps when necessary; in order to ensure that foundation surfaces are not harmed by water. When foundations are damaged, the affected material shall be removed and replaced with approved backfill.

5) Shotcrete shall be applied to finished excavation surfaces where, in the opinion of the Engineer, it is deemed necessary to prevent air slaking, erosion or other deterioration of the surface. The protective coating shall be applied to excavated surfaces either with or without steel wire mesh reinforcement in accordance with the provisions of the Section "Shotcrete". Application of SFRS at any portion shall be as per site geology and as decided by the Engineer..

2.9. MONITORING AND PROTECTION FROM BLASTING

1) The Contractor shall adequately protect existing structures from the effects of blasting, both from impact with rock or debris and from excessive shock. Structures at risk shall be inspected both before and after blasting, and shall be monitored during the blasting operations by appropriate means, if so directed by the Engineer.

2) The Engineer may monitor part or all of the blasting operations utilizing velocity transducers, micrographs or other equipment. The Contractor shall cooperate with the Engineer in placing, operating and recording of monitoring equipment.

3) In case of concrete structures and cement grout maximum particle velocities that result from blasting operations shall not exceed the following limits:

a) For concrete and grout in place for more than 60 hours, the maximum particle velocities shall not exceed 5 cm/sec.

b) For concrete or grout in place for less than 60 hours, the maximum particle velocity shall not exceed 1 cm/sec.

c) For complete or partially complete portions of platforms in fill, peak particle velocity shall not exceed 5 cm/sec and the maximum particle acceleration shall not exceed 1.0 g.

4) Blasting within 25 m of concrete or grout will be permitted only after concrete or grout is 7 days old and only after submission by Contractor, and approval by the Engineer, of a plan showing the relative positions of structures or grouted area and the area to be blasted, Contractor's proposed drilling and blasting plan, together with outline of precautions being taken. All concrete and other completed work within 25 m of blasting shall be protected by limiting the size of blasts. Blasting will not be permitted within 10 m of structures or installations vulnerable to damage by blasting. Replacement or repair of work damaged by blasting shall be carried out by the Contractor at no expense to The Employer.

5) The blasting restrictions stated above are given as a guide only and may be revised by the Engineer on the basis of seismic measurements and observations during the progress of the work. If results of blast monitoring indicate that Contractor's blasting methods endanger excavation, grout or concrete work, Contractor shall be required to alter his blasting methods accordingly at no expense to The Employer.

2.10. MEASUREMENT AND PAYMENT

2.10.1. GENERAL

1) Measurement for payment for any class of excavation specified herein will be of the in-situ volume as measured from a survey performed by the Contractor and approved by the Engineer prior to any excavation work and the lines and grades shown on the Construction Drawings or established at the Site by the Engineer.

2) Payment will be made at the appropriate Unit Price per cubic meter entered in the Bill of Quantities, which shall include the entire cost of the following:

a) Provision of all labour, equipment and materials required for excavation, including any hand work necessary for trimming excavated surfaces; preparation, protection and maintaining excavated surfaces in satisfactory conditions until concrete or fill is placed; all additional excavation for Contractor's convenience; any temporary supports necessary to support the sides of the excavations.

b) Loading, hauling and dumping the excavated material on stockpiles, spoil tips or points of incorporation in Permanent Works up to 3km distance measured along the road i.e. nearest points along the road from the adit portal area up to the centre of disposal area; clearing of the spoil areas and formation of spoil tips as specified; clearing of the stockpile areas, formation and maintenance of stockpiles and spoil tips, drainage and dealing with water in stockpiles and spoil tips, re-handling of suitable materials including segregating, grading, draining and drying of materials suitable for use in concrete, embankment construction or as backfill.

c) All delays during excavation work resulting from installation of rock supports, stabilization and protection works required by the geotechnical conditions of the material encountered.

d) Complying with all requirements of statutory laws and regulations relating to blasting work and any restrictions resulting there from; obtaining all necessary permits and licenses for the purchase, use, storage and transport of explosives or any other material and equipment.

e) Surveying, setting-out, checking of excavated profile and alignment, and any subsequent rectification works resulting from undue or incorrect surveys, provision of suitable equipment for, and delays due to carrying out this work.

3) Extra payment will be made for handling the excavated material beyond 3km. Measurement for payment will be based on the hauled volume. The volume of the material will be measured during hauling operations by survey carried out y the contractor and approved by the Engineer, and will be calculated by applying the following bulking factors:

a) For common excavation material: 1.2
b) For excavated rock: 1.4

And using the formula

- Volume measured (and approved) / bulking factor

Payment for the resulting calculated volume will be made at the Unit Price per cubic meter. Kilometer (m^3.Km) entered in the Bill of Quantities. This volume shall be compared with that worked out on the basis of surveyed sections and the lesser of the two volumes shall be paid for hauling beyond 3 km.

4) Measurement for payment of additional volumes of excavation resulting from modification of slopes and grades shown on the Construction Drawings, which may be necessary in the course of the work and is not required by the contractor for his own convenience, will be of the in-situ volume as measured between the original and the modified lines and grades.

5) Payments will be made for protection works (like boulder wire-crates, random rubble masonry walls, etc.) for the dumped material in spoil tips.

2.10.2. GEOLOGICAL OVER-BREAK AND UNSUITABLE FOUNDATIONS

1) Measurement for payment for the removal of material arising from geological over-break accepted by the Engineer as occurring entirely for geological reasons, will only be made if the Contractor requests measurement to be agreed immediately after excavation, and only provided that the over-break can clearly be determined as being wholly due to adverse geological conditions.

2) Excavation and refill ordered in writing by the Engineer due to slides or over-break for geological reasons or unsuitable foundations will be measured for payment and paid for as follows:

a) Removal of material resulting from slides/ geological over-break accepted by the Engineer will be paid per cubic meter based on in-situ survey carried out by the contractor and approved by the engineer, at the Unit Price entered in the Bill of Quantities.

b) In-situ volumes of the additional excavation required in connection with geological over-break will be measured in cubic meters and payment will be made at the Unit Price for excavation of approved classification.

c) The concrete placed for refilling additional excavation in rock foundation will be measured in cubic meter of the in-situ compacted volume and payment will be made at the Unit Price per cubic meter for the concrete class as ordered by the Engineer.

2.10.3. COMMON EXCAVATION

1) No extra payment will be made for clearing, cutting, burning and disposing of trees and bushes, cost of which is deemed to be included in the unit prices.

2) Measurement for payment for common excavation (including clearing, stripping and loose excavation) will be of the in-situ solid volume of the material removed between the original ground surface levels and the lines and grades shown on the Construction Drawings or the surveyed and agreed surface levels for the classification "Rock Excavation".

3) Payment will be made at the Unit Price per cubic meter entered in the Bill of Quantities.

4) The removal of mud and slush resulting from rain or flooding of the sites will be, when ordered by the Engineer, considered as common excavation.

5) Breach of cofferdam during flood may require removal of material of cofferdam deposited in the dam area. This shall also be considered under common excavation.

2.10.4. ROCK EXCAVATION

1) Measurement for payment for rock excavation will be of the in-situ solid volume of the rock material removed between the actual jointly surveyed rock surface and the lines and grades shown on the Construction Drawings or as directed by the Engineer.

2) Payment will be made at the Unit Price per cubic meter, entered in the Bill of Quantities, which shall, in addition to work included and described under "General", include the entire cost of removal of rock material which cannot be removed by common excavation; protection of structures, properties, installations, trees, etc.; drilling holes for blasting and blasting, development and using controlled blasting methods, blasting tests, and any cost associated with establishing satisfactory blasting techniques.

3) In addition to material actually removed under this title the following shall also be classified as "Rock Excavation by Blasting", and shall be measured and paid for under this item:

a) Large boulders and detached pieces of rock that cannot be removed by ripping or by excavation machinery used for common excavation.

b) Rock removed by drilling, wedging or barring, or other approved methods in areas where blasting would be required but not possible or permitted for whatever reason.

2.10.5. CONTROL PERIMETER BLASTING

1) Separate measurement for payment and payment will be made for excavation performed at the final surfaces of excavation by controlled blasting methods. Measurement for payment will be of excavation area for which controlled blasting is required, calculated from the required lines and grades shown on Construction Drawings or as directed by the Engineer.

2) Payment will be made at the Unit Price per square meter entered in the Bill of Quantities.

2.10.6. LINE DRILLING

1) Measurement for payment for line drilling will be of the length of the holes actually drilled into the rock along the side of the excavation as directed by the Engineer.

2) Payment will be made at the Unit Price per meter of drilled hole entered in the Bill of Quantities, which shall include the entire cost of drilling the holes, light blasting, broaching, wedging, barring, or other methods used in conjunction with line-drilling.

2.10.7. DENTAL EXCAVATION

1) Measurement for payment for dental excavation in rock will be of the in-situ volume of material removed.

2) Payment will be made at the Unit Price per cubic meter entered in the Bill of Quantities, which shall include the use of any special equipment and hand work.

3) If measurement by volume proves impracticable, the surface area of seams and cracks to be cleaned may be equated, as the conditions dictate, to a volume mutually agreed upon by the Contractor and the Engineer.

2.10.8. MINOR EXCAVATION

1) Measurement for payment for excavation will be of the in-situ volume defined by the excavation lines as shown on the drawings, unless otherwise modified or directed by the Engineer

2) Payment for Excavation will be made at the same Unit Price per cubic meter as the item Common excavation entered in the Bill of Quantities.

2.10.9. ADDITIONAL EXCAVATION

Any additional excavation in areas where surface excavation has already been completed, which the Contractor may be directed by Engineer to carry out, will be measured and paid for at the same Unit Prices entered in the Bill of Quantities as for the original excavation. No increase in Unit Prices will be allowed for such additional excavation.

2.10.10. BORROW AND QUARRY AREA EXCAVATION

No separate measurement for payment or payment will be made for borrow areas excavation, for clearing, grubbing and stripping in, and for trimming, levelling and draining of the borrow areas. The entire cost thereof shall be included in the Unit Prices for supplying, placing, mixing, compaction, etc., of such materials as specified in the pertinent Sections of these Specifications.

2.10.11. EXCLUSIONS

1) All costs of dewatering and keeping the surface excavation sites dry will be as specified in the Section "Dewatering during Construction".

2) No extra measurement for payment or payment will be made for the following:

a) Extra work caused by the Contractor's negligence in setting-out the structures and slopes,

b) Surveys to verify the original ground surface, or for recording the top of the rock surface,

c) Provision and cleaning of drain ditches on the berms,

d) Removal of the materials resulting from the slides or overbreak caused by Contractor's inappropriate working methods and for the additional materials required to fill the voids so created,

e) Additional work of removing material, backfilling voids with approved material, and installing additional rock supports where overbreak due to adverse geological conditions coincides with that due to Contractor's poor working methods or negligence,

f) Excess excavation required for Contractor's convenience and the resulting additional backfilling with approved materials,

g) Additional work resulting from the Contractor changing slopes without prior approval by the Engineer. In such event, payment will be made only to the lines and grades shown on the Construction Drawings,

h) Excavation which is incidental to the installation of Temporary Works,

i) Shoring, bracing, and supporting of excavation surfaces except as specified in the Sections "Rock Supports" and "Slope Protection",

j) Clearing, grubbing and stripping in the borrow and quarry areas, and spoil and stockpile areas,

k) Draining, shaping, and trimming the dumped material in the spoil tips to the lines and grades as directed or approved by the Engineer,

l) Preparation and protection of foundation and slopes with the exception of concrete protective coating, which will be measured and paid for in accordance with the provisions of the Section "Shotcrete",

m) Stockpiling of construction materials from required excavation material, which cannot be incorporated directly into Permanent Works

n) Work or materials required when foundation surfaces have been allowed to become unsuitable due to the action of ground or surface water,

o) Extra work or material required for repairing damages to the final excavation surfaces caused by the erosion or travel of the construction equipment,

p) Monitoring of existing structures during blasting operations.

END OF SECTION B.2

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3. UNDERGROUND EXCAVATION

3.1. SCOPE OF WORK

1) This Section covers all excavation work for underground structures to be constructed under this Contract performed by conventional tunnelling methods using drilling and blasting, mechanical means or in exceptional cases by manual means. The work shall include all drilling and blasting, loading, transporting, and disposal of materials in spoil or stockpile areas, as well as the removal of all loose material and cleaning of excavated surfaces.

2) Excavation shall be made to the lines, grades and dimensions shown on the Construction Drawings or as otherwise directed by the Engineer.

3) The Contractor shall comply with all safety procedures and requirements as stipulated in the Section "Safety Precautions".

4) Rock supports, Shotcrete and dewatering are works covered in other Sections of these Specifications.

5) Devices for monitoring the excavation and rock-mechanics tests to be supplied and performed by the Contractor are specified in other Section of these Specifications.

6) The Contractor may be required to perform exploratory drilling, at any location and inclination, during excavation to ascertain the geological conditions.

7) The approval given by the Engineer to the Contractor's methods and equipment shall not relieve the Contractor of his full responsibility for a proper and safe execution of underground excavations, or of liability for injuries to, or death of persons, or any obligations under this Contract.

3.2. SUBMITTALS

1) At least 42 days prior to the commencement of excavation, the Contractor shall submit details of his excavating methods and sequences for all underground works, including equipment, ventilation, rock support, and safety.

2) The description of drilling and blasting procedures shall include the following:

a) Diameter, spacing, depth, pattern and orientation of blast holes,

b) Type, strength, amount, column load, and distribution of explosives to be used per hole, per delay, and per blast,

c) Type of detonators, and sequence and pattern of delays to be used per blast,

d) Description and purpose of any special method to be adopted by the Contractor,

e) Sequence of various activities of the excavation work in different headings with an indication of corresponding time requirements for each of the stipulated excavation classes.

3) At least 21 days prior to dumping or stockpiling any material, the Contractor shall submit the layout of spoil and stockpile areas, which will be within the areas designated on the Construction Drawings or as approved by the Engineer. All pertinent data of working methods and provisions for the security, stability, and temporary or permanent drainage of the areas shall be included. Details of volumes, material types, heights and grades shall be provided.

4) To enable the Engineer to verify all necessary setting-out and elevations carried out by the Contractor, the later shall notify the Engineer in writing, giving at least 7 days notice, of his intention to start excavation.

5) During the advance of underground excavations, the Contractor shall record and submit weekly to the Engineer 3 copies of the following:

a) Advance of each face and the chainage of face before the blasting of each round,

b) Type and number of drill holes, and length of each round,

c) Pattern of drill holes, their diameters and length,

d) Type, quality and location of explosives in each drill hole, and blasting scheme (direct or retarded),

e) Theoretical volume of solid material excavated according to typical sections, shown on the Construction Drawings,

f) Geology, competence of the rock formations, rock falls, zones of instability, and information obtained from any pilot holes,

g) Surface of shotcrete, and wire mesh installed,

h) Numbers, lengths, and types of rock bolts / rock anchors installed,

i) Amount, location, spacing, and type of steel ribs and lagging installed,

j) Water inflows at the face and the rate of discharge of water from the Dewatering systems, and the temperature of the water,

k) Occurrence of gas,

l) Personnel employed during various stages of the operation and their qualification,

m) Time required and detailed for each activity,

n) Unusual occurrences, all delays and the reasons for delays,

o) Volume of fresh air in the heading zone.

6) The Engineer reserves the right to require any additional information deemed necessary to be included in the documents to be submitted.

7) Minimum 30 days before start of excavation, the contractor shall furnish the detailed information in respect of pipes for pipe roofing, its installation methodology and name of specialized agency for approval of the Engineer.

3.3. DEFINITIONS

CONVENTIONAL EXCAVATION is the excavation performed by conventional tunnelling and shaft driving methods using drilling and blasting or by manual means.

FACE is the advance end or wall of a tunnel, or other excavation at which the work is progressing.

HEADING ZONE refers to tunnels (ascending and descending headings) with upward heading, excavated by conventional method (drilling and blasting) and is defined as the zone between newly established face and the distance equal to 1 m plus the length of the previous round behind that face, measured along the tunnel or shaft centreline.

REAR ZONE is the whole length of tunnel between the heading zone and the portal.

ROUND is defined as a single cycle of drilling, loading and blasting to excavate rock, scaling, mucking and moving construction equipment in and out.

HEADING AND BENCHING EXCAVATION is tunnel excavation carried out in two or more steps "Heading" is defined as the crown portion of underground tunnel excavation, which is undertaken as the first blast in each round; blast holes are generally horizontal for this purpose of excavation. "Benching" excavation is defined as the excavation of platform left after the 'Heading' excavation. Blast holes other than perimeter holes are generally vertical in such an excavation.

PILOT TUNNEL is defined as an initial excavation of limited cross section performed within the proposed tunnel limits, located as required anywhere within the proposed tunnel cross section.

FOREPOLING is defined as the placement of near horizontal steel bars / pipes / sections around the periphery of the heading to form a rock support cage, in areas of weak rock.

MULTIDRIFT / MULTISEGMENTAL EXCAVATION is defined as excavation of tunnel heading in segments. Various segments will be excavated one by one and supported involving segmental ribbing ultimately to form complete rib. Certain portion of excavation may not require drilling and blasting and at certain locations restricted blasting may be required.

3.4. EXCAVATION LINES

1) Typical cross sections, excavation lines, and dimensions of excavations and thickness of lining, where appropriate, are shown on the Construction Drawings.

2) The "A"-line (Minimum Excavation Line) shown on the Construction Drawings is the line within which no rock and no support, other than permanent support systems will be permitted to remain.

3) The "B"-line (Pay Line) shown on the Construction Drawings (which is 100 mm away from the A-line around in all underground excavations i.e. tunnels) is the line to which payment for the excavation will be made.

Measurement for payment of excavation will in all cases be made to the "B"-line regardless of whether the limits of the actual excavation fall inside or outside the "B"-line. In tunnels, the “B” line shall be all around the x-section including invert.

4) The Contractor is required to perform the excavation works in such a way that the final excavation surface is located between the "B" and "A"-lines and he shall take into account the imprecision of grade and alignment of the excavation by his excavating equipment, and guarantee that the theoretical thickness of the concrete lining is never reduced. All out-of-line excavations shall be rectified so that the "A"-line as defined above is maintained.

5) Immediately behind the face, the Contractor shall measure the excavated profile by means of a profile template or another method approved by the Engineer.

6) Excavation not shown on the Construction Drawings and not included in the Schedule, but which the Contractor considers necessary for his own purposes, such as excavation for passing and turning niches / train switches or stations, rail foundations, mucking pits, pump sumps, drain ditches other than those shown on the Construction Drawings, adits, spaces for supply facilities, may only be carried out with the prior approval of the Engineer. All such excavations shall be backfilled with Class M15/A40 concrete up to the "B"-line prior to commencement of the final tunnel lining.

7) The location of the tunnel portals shown on the Tender Drawings is tentative. The actual position will depend on the ground conditions and will be determined by the Engineer during the progress of the work.

3.5. OVERBREAK

1) Excavation beyond the "B"-line or the neat lines of excavation shown on the Construction Drawings is defined as Overbreak. In case cavity or chimney formation occurs during the excavation works, they shall be deemed to be covered by this definition of the "Overbreak".

2) Geologically accepted Overbreak in underground excavation is defined as a locally originated Overbreak which occurs while each of the following four conditions are simultaneously fulfilled:

a) Overbreak occurs only above the tunnel invert level, i.e. Overbreak at invert will not be recognized,

b) The Engineer is immediately informed and given an opportunity for inspection while both the cause and the extent of the Overbreak are clearly visible,

c) Overbreak was, in the opinion of the Engineer, not a result of Contractor's using improper or improperly applied working methods or his otherwise negligence, and could not have been prevented by prompt and appropriate installation of supports,

d) Overbreak extends beyond the "B"-line.

3) The Contractor shall survey and plot cross sections at sufficient intervals to allow for a reasonably accurate estimate of the volume of Overbreak, which he claims to be due to geological conditions.

4) All voids created by Overbreak extending beyond the "B"-line shall be filled up to the "B"-line with concrete or shotcrete as directed by Engineer. The class of concrete and time of placing of the concrete shall be as instructed by the Engineer.

5) If, for any reason other than accepted geological reasons, excavation is carried out beyond the "B" line or the neat line (for example due to the Contractor's careless blasting), the Contractor shall remove the excess material and backfill the voids as described above without any measurement thereof.

3.6. SUPPORTS FOR UNDERGROUND EXCAVATION

1) The provisional or permanent supports for the underground excavation shall principally consist of the SFRS (Steel Fiber Reinforced Shotcrete) as primary element, supplemented as needed by individual or pattern rock bolts. Structural steel supports shall be used only when required by the rock conditions as determined by the Engineer.

2) The Engineer, after having consulted with the Contractor, will determine the rock support system, which shall be used during the excavation advance. The decision of Engineer shall be final in this regard.

3) The Contractor shall employ and deploy supervising engineers, who by their schooling and knowledge are experienced in rock supporting work. These supervisors shall examine the rock conditions after each excavation advance and shall verify that the rock support system is installed as ordered. They shall carry sufficient rank to be able to order installation of additional supports or to stop further advance if, in their opinion, the conditions are unsafe. However, they shall have no right to cancel the type or amount of rock supports previously ordered by the Engineer. These supervisors shall be continuously present and inspect each face throughout the duration of underground excavation work.

4) The required supports shall be installed without delay during the process of excavation within the heading zone, without which further advance shall not be allowed. In the rear zone, additional supports shall be installed immediately after it is observed that the natural material or the supporting system previously installed is not sufficient to prevent further loosening of the material surrounding the excavation.

5) SFR Shotcrete, shall be applied to excavated surfaces in accordance with the provisions of the Section "Shotcrete". The Contractor shall take into account in his construction planning that placing of SFR Shotcrete support may be required immediately after blasting a round but before mucking-out is started.

6) Application of Plain Shotcrete with or without welded wire mesh at any portion shall be as per site geology & as decided by Engineer.

7) Rock bolts, rock anchors, wire mesh and structural steel supports shall be installed in accordance with the provisions of the Section "Rock Supports".

8) The use of timber will not be permitted for tunnel supports in any form, not even for temporary purpose.

9) The Contractor shall keep on the Site all necessary plant and equipment for installing rock bolts and SFR Shotcrete ready for operation in the heading zone during the whole excavation period.

10) Fore-poling/ Multi-drifting/ Multi-segmental excavation/ Pipe-roofing / Pre-grouting shall be done as per site geological conditions.

11) Even though it is the Engineer who determines the type and amount of rock supports to be installed (which might be complemented or objected by the Contractor), it is the Contractor who shall bear the whole responsibility for the proper and safe execution of the works, including the provision of extra supports and special protection for the personnel when the conditions so require.

3.7. CLASSIFICATION OF UNDERGROUND EXCAVATION

1) The underground excavation is divided into different classes to categorize the rock mass likely to be encountered during excavation work.

2) The class of excavation is defined in relation to the RMR encountered in the heading zone as per Bieniawski's RMR classification (1989) (Rock Mass Rating). The rock classification, upon excavation on the site, shall be approved by the Engineer.

3) The assignment of an individual excavation class shall always apply to the whole of the theoretical excavation cross section as defined by the minimum excavation line, even if the partial excavation method (e.g. top heading and benching) is being used.

4) The tentative rock support measures (Support Type) corresponding to underground excavation classes are listed here below, however the actual rock support measures shall be installed as shown in Construction Drawings:

Headrace Tunnel

RMR89	SUPPORT TYPE
>=81	B

61-80	C
51-60	D
35-50	E
Fault Zone	F

Tentative rock support measures (Support Type) for PHY_dam Lithological Unit along the Headrace Tunnel

RMR89	SUPPORT TYPE
>=86	A
66-85	B
51-65	C
36-50	D
25-35	E
Fault zone	F

Tentative rock support measures (Support Type) for Qz_hrt and Qz_ph Lithological Units along the Headrace Tunnel

Adits to HRT

RMR89	SUPPORT TYPE
>=81	B
56-80	C
41-55	D
31-40	E
Fault Zone / <=30	F

Tentative rock support measures (Support Type) for PHY_dam Lithological Unit along the Adits to HRT

RMR89	SUPPORT TYPE
>=86	A
66-85	B
51-65	C
36-50	D
25-35	E
Fault zone	F

Tentative rock support measures (Support Type) for Qz_hrt and Qz_ph Lithological Units along the Adits to HRT

Feeder Tunnels

RMR89	SUPPORT TYPE
>=81	B
61-80	C
41-60	D
21-40	E
Fault Zone	F

Tentative rock support measures (Support Type) for PHY_dam Lithological Unit along the Feeder Tunnels

Connection Tunnel to Dam crest

RMR89	SUPPORT TYPE
>=81	B
56-80	C
41-55	D
31-40	E
Fault Zone	F

Tentative rock support measures (Support Type) for PHY_dam Lithological Unit along the Connection Tunnel to Dam Crest

7) No classes will be attributed within the portion where multi-drift / multi-segmental excavation has been performed.

8) At certain locations, the tunneling may have to be carried out through slope wash material where the excavation shall be carried out by mechanised means without resorting to drill and blast. In such situations, no rock classification shall hold good.

3.8. EXECUTION

3.8.1. EXCAVATION PROCEDURES

1) Prior to the commencement of underground excavations for tunnels the Contractor shall construct a portal of sufficient rigidity in order to provide a good abutment for the forces created in the rock due to the first opening. The portal shall be of reinforced concrete or steel ribs-Shotcrete, rock bolts / rock anchors construction, depending on the rock conditions.

2) The tunnels (including adits) may be excavated by any of the following or combination thereof:

a) Full face excavation

b) Top heading and benching

c) Construction of pilot tunnel and its subsequent widening

d) Multi drifting / Multi segmental excavation

The contractor shall get prior approval of the Engineer before adopting any particular type of excavation method. Wherever required the contractor shall excavate the bench in such a manner so as to maintain support for the arch rib section of the steel sets installed during heading and to permit installation of steel support legs upto final invert as required by Engineer.

3) Fore poling, pre-grouting, Pipe Roofing and advance probing may also be required as directed by the Engineer.

4) The Contractor shall use drilling and blasting techniques which will produce a smooth final profile, a minimum of Overbreak and a minimum of fracturing of the rock beyond the required excavation lines. The techniques used shall be at all times subject to the Engineer's consent, who may order several blasting tests to be undertaken by the Contractor to substantiate his proposed methods of blasting.

5) Engineer may ask the contractor, for controlling overbreaks by improving blasting pattern for which services of any specialized agency shall be hired by the Contractor

6) When deemed necessary and directed by the Engineer, the Contractor shall carry out exploratory drillings, at any location and inclination, with core recovery as described in the relevant Section of this Technical Specifications.

7) The blasting pattern proposed to be adopted shall be submitted by the contractor well in advance to the Engineer for approval. No excavation shall be undertaken until the permission in writing has been given by the Engineer. However, during the progress of excavation the drilling and blasting pattern, specifically the number and depth of holes, quantity, quality, and distribution of explosives, shall be varied as necessary to suit the rock conditions encountered, taking into consideration the information obtained from the pilot holes and actual drilling work (velocity, colour of rinsing water, etc.), as well as of the previous blasting results.

8) Only wet drilling will be permitted in order to reduce dust in the underground excavations.

9) Perimeter drill holes shall be placed such that the over excavation beyond the "A"-line is minimised. The Contractor shall pay the utmost attention to obtain a smooth and uniform excavation surface.

10) Should the entire length of most of the perimeter drill holes not be visible after each round of blasting, the Contractor shall make an adequate adaptation in the blasting pattern used, and submit it to the Engineer for approval.

11) The depth of a new round shall never exceed that which was determined and approved prior to commencement of blasting. The Engineer may order a reduction of the adopted round depth if the actual rock condition requires it.

12) Blasting of a new round will not be permitted if insufficient personnel are available to perform the mucking and support work afterwards. In particular this applies to work before holidays, non-working weekends, etc.

13) Blasting that may damage the rock beyond the required excavation lines or the tunnel installations will not be permitted. Any damage to, or displacement of the supports, and any damage to any part of the Works caused by blasting or any other of the Contractor's operations shall be repaired by the Contractor in a manner satisfactory to the Engineer, at no cost to the Employer.

14) No new round shall be blasted until the support work required within or behind the heading zone has been installed.

15) Immediately following blasting, at frequent intervals during the progress of the work, and finally during clean-up prior to placing the final tunnel lining, all loosened material that is likely to fall shall be removed.

16) All rock material projecting inside the "A"-line shall be removed.

17) All loose rock shall be removed from the underground construction sites and disposed of in the approved spoil areas.

18) The Contractor shall constantly check the progress of excavation by means of Laser survey in order to avoid any substantial rectification of the already opened profile and eventual rearranging of the installed rock supports.

19) Where excessive inflows of water occur at the face, the Contractor shall take all appropriate measures to execute the excavation work safely and properly, including provision of extra supports and protection for workmen, and any special equipment necessary for working in waterlogged conditions.

3.8.2. BLASTING

All rock excavations shall be performed by controlled blasting techniques as described below.

1) Smooth blasting: consists of drilling a number of closely spaced holes along the final excavation perimeter, placing light charges in the holes and detonating the charges at the end of round. The outer line of drill holes for the main blast is set at an approved distance inside the final perimeter leaving an annulus of rock to be peeled off the damaged final excavation perimeter by the smooth blast. The smooth blast holes are drilled, charged and blasted in the same tunneling cycle as the main blast.

2) Pre-splitting: Consists of drilling a single row of closely spaced holes along the final excavation perimeter. These holes are lightly charged and detonated before the main blast; to produce a presplit crack which limits the propagation of cracks from the subsequent main blast, and in such a way reduces damage in the rock beyond it. The blasting of the main excavation zone requires a reduced explosive charge in the line of holes nearest to the presplit line, and a limit on the distance between the presplit line and the nearest line of main blast holes. The presplit holes shall be drilled deeper than the depth of the round.

3) Cushion blasting: A special case of blasting in which considerable air space or stemming surrounds charges in the holes and serves to reduce undesired blast effect on the final excavation perimeter.
Contractor's controlled blasting techniques shall be considered acceptable and in conformity with these Specifications for Controlling the completed rock surfaces if:

a) At least 50% of the drill hole traces of each round are visible in the final rock surface, distributed uniformly, after the scaling down of all loose and shattered rock that is liable to fall before or during rock reinforcement installation and if all drilling hole traces are between A & B lines.

b) Engineer may modify the above criteria if, in its opinion, the achievement of such results is not reasonably possible because of adverse rock conditions.

3.8.2.1. BLASTING PERSONNEL

1) The contractor shall engage a full time professional blasting expert to assist in establishing satisfactory blasting techniques subject to the approval of Engineer, at no additional cost to the Employer.

2) The contractor shall provide licensed Blaster and inspectors capable of inspecting freshly blasted faces, deal with misfires, evaluate air and dust conditions and direct scaling operations in accordance with the safety requirements as envisaged in "Safety Precautions". All blasting operations including handling of explosives shall be done by the licensed blasters only.

3.8.3. LINE DRILLING

1) Line drilling shall consist of a row of unloaded, closely spaced holes drilled along the neat line of the excavation. This operation is distinct from, and shall not be confused with, the peripheral or production holes of the regular blasting pattern.

2) Line-drilling is defined as a single row of unloaded holes drilled along the neat excavation line, spaced no more than two to four times the hole diameter on centres. These will form a surface of weakness to which the primary blast can break. Light blasting with well-distributed charges fired after the main excavation is removed may be permitted in the holes. If, however, in the opinion of the Engineer the blasting may injure the rock, the use of explosives shall be discontinued and the excavation shall be completed by broaching, wedging, or barring.

3) Line drilling is anticipated in some areas as specified in the construction drawings or as directed by Engineer.

3.8.4. DENTAL EXCAVATION

1) Dental excavation shall include the removal of unsuitable material from shear zones, clay seams, pockets, joints, caverns, or from spaces between boulders beyond the lines of excavation shown on the Construction Drawings or established in the field, which are too small to be excavated by common earth moving equipment.

2) Dental excavation, depending on its extent, will require the use of a back-hoe, hand tools, or other small excavating equipment, as well as the use of a high velocity air-water jet. The methods employed shall be such as to avoid fracturing of the rock adjacent to the material being removed.

3) Dental excavation shall be performed where directed. The extent, to which such material shall be removed, including the depth, direction and dimensions of the work, will be determined by the Engineer. In general, however, excavation into cracks or seams shall be to the depth that is a minimum of three times the seam width, and such excavation shall be backfilled with concrete or shotcrete. No blasting will be permitted.

3.8.5. CLEANING OF EXCAVATED SURFACES

1) Even prior to the removal of the bulk of the material loosened by blasting, the Contractor shall clean the newly exposed rock surface from rock fragments, dust and debris to permit, if required, the application of the first layer of shotcrete. Windows in this shotcrete layer shall be left open for geological mapping and inspection.

2) Cleaning shall be done by directing a jet of water or air at the rock surface. Compact, washable rock shall be cleaned with compressed air-water jets. Rock, which tends to a quick disintegration, or is interspersed with clay filled fissures, shall be cleaned with compressed air only. The cleaning shall be carried out to the satisfaction of the Engineer.

3) This cleaning is separate from cleanup of the excavated surfaces required immediately prior to placing of the final tunnel lining described in the Section "Concrete".

3.8.6. PROTECTION OF TUNNEL INVERT

Small grain or broken excavation material shall be used for invert protection, which shall be removed prior to placing of invert concrete or the final tunnel lining. No vehicular traffic shall be permitted over the tunnel invert after removal of the protective material.

3.8.7. EXCAVATION OF TUNNEL THROUGH SLOPE WASH MATERIAL

1) Initially concrete cut and cover shall be constructed up to a distance where the vertical cover from the tunnel overt is about 1D, where 'D' is the excavated dimension above the invert. The excavation slopes shall be as shown in the construction drawings or to suit the site conditions.
The tunneling shall commence in slope wash material only after completion of cut and cover part including the random filling over the cut and cover section as shown in the construction drawings.

2) No blasting shall be carried out in this stretch and excavation shall be carried out by hydraulic breakers or other such equipment except if expressly authorized by Engineer in writing.

3) Drainage holes if required shall be drilled along the periphery on the crown or as shown in the construction drawings.

4) Installation of pipe roofing (as explained elsewhere in this Section) to create protective umbrella under which excavation for the tunnel can be advanced in a safer manner.

5) Subsequent to the installation of pipe roofing, the mass shall be grouted with cement / colloidal silica as shown in the Construction Drawings at pressure of 0.5 MPa .

6) Once steps 3-5 have been carried out to the satisfaction of Engineer the heading shall be advanced for 0.5 to 1.0m either in multi drifting or complete heading depending upon the size of the tunnel and site conditions as directed by the Engineer.

7) Immediately after excavation of heading and placement of initial layer of shotcrete, ribs/lattice girders shall be installed and shotcreted. If required the face shall also need to be supported by means of shotcrete and 6.0m long self drilling type fiber glass rock anchors of 25 mm dia.

8) The surface lying above the tunnel in this reach shall be constantly monitored with survey targets etc.

3.9. EXCAVATED MATERIALS

3.9.1. USE OF EXCAVATED MATERIALS

1) All suitable materials from the excavations shall be utilized to the fullest extent practicable as construction materials in Permanent Works. The contractor shall be liable to make payment of royalties or other admissible taxes/duties, if any.

2) The Contractor's blasting and excavating techniques shall be such that as far as practicable, construction materials of satisfactory quality will be yielded. Wherever possible, suitable materials shall be excavated separately from materials to be wasted.

3) Whenever possible, the suitable materials shall be transported directly from the excavation to the designated final locations.

4) If the immediate placement in the final location is not possible, the materials shall be stockpiled. If the moisture content of excavated materials which would be suitable for embankments or backfill is too high after excavation, such material shall be drained and dried in the stockpile until the moisture content is sufficiently reduced to allow for placement.

5) The Contractor shall remove any cobbles, boulders or rock fragments found in otherwise approved materials which are greater or smaller than permitted for specific embankment zones and place them in other zones or dispose of them appropriately.

3.9.2. DISPOSAL OF EXCAVATED MATERIALS

1) All materials from underground excavation suitable for use as fill, concrete aggregates or for other purposes shall be stockpiled at the Site as directed or approved by the Engineer if the immediate placement in the final location in Permanent Works is not possible.

2) The spoil tips shall be located where they will not interfere with the natural flow of streams or rivers, with construction operations in the borrow and quarry areas, with flow of water to or from outlet works, or with accessibility to the Site. Where required, the Contractor shall permanently divert (stage-wise if necessary) the present courses of the streams.

3) Excavated materials which are not suitable for, or are in excess of the permanent construction requirements shall be disposed of in the spoil areas shown on the Construction Drawings, or in areas designated as such by the Engineer in the course of the work. The Contractor shall be responsible for the stability of all fills, embankments and stockpiles created by the disposal of excavated materials.

4) The Contractor shall shape, trim and stabilize the spoil tips and stockpiles to the lines and grades as directed or approved by the Engineer, and shall provide for adequate diversion of existing water courses and for proper drainage, as stipulated in the Section "Dewatering During Construction".

5) Excavated materials shall be transported to the disposal areas in such a way that spillage onto roads etc. is avoided. Any materials which despite the Contractor taking reasonable care does fall onto roads, etc. shall be promptly cleared and removed by the Contractor.

6) No rock material may be dumped into any rivers of creeks. Earth or soil material may only be dumped into natural watercourse with the agreement of the Engineer, and if prior written confirmation of this is obtained.

7) The Contractor shall be liable for any damage to Temporary or Permanent Works or to the property of third parties caused by poor drainage in the spoil or stockpile areas.

8) The contractor shall ensure and take necessary measures to effect dust abatement on the roads from excavation location till dumping yards. He shall employ water sprinklers on these roads for the same. Engineer shall deploy such sprinklers at the cost of contractor in case the same are not deployed by the contractor, so as to ensure dust free environment.

3.10. EVACUATION OF WATER

The Contractor shall carry out all work required to capture and drain service and infiltrated groundwater during the construction as stipulated in the Section "Dewatering During Construction".

3.11. ILLUMINATION

The Contractor shall install an adequate illumination system in the underground works as stipulated in the Section "Safety Precautions".

3.12. CONTROL OF GASES, VAPORS, FUMES, DUSTS, AND MISTS IN UNDERGROUND WORKS

3.12.1. DUST, SILICA AND NOXIOUS GASES

1) The Contractor shall install, operate and maintain a ventilation system in the underground works to enable the Works to be constructed in healthy, well-ventilated conditions. Dust shall be abstracted at or adjacent to the source.
2) To minimize the dust hazard arising from drilling operations in rock excavations, all holes shall be wet drilled unless otherwise approved. Water sprays or atomizers shall be used to prevent dust rising during drilling and mucking operations including keeping the floors of haulage ways damp.

3) The Contractor shall check at the work face and elsewhere for concentrations of noxious or other harmful gases (O2, CO, H2S, CH4 etc.) and silica before every shift and before and 45 minutes after each blasting operation and more regularly if necessary and when called upon to do so by the Engineer.
4) The Contractor will conduct spot monitoring using approved gas analyzers. For 8 hours continuous monitoring, the Contractor shall measure the concentration of fine dust and content of Respirable Crystalline Silica/silicon dioxide (SiO2) in all dust producing underground operations by an approved method or by subcontracting to a recognized third-party monitoring company.
5) The following standards shall be used for comparison with measured data for different means of monitoring for averaging time:

Sl.	Parameter	Unit	Maximum Concentration[1]	Means of Monitoring
1.	Oxygen (O_2)	%	19.5 – 22	Spot measurements[2]
2.	Carbon monoxide (CO)	ppm	100	Spot measurements
3.	Hydrogen Sulfide (H_2S)	ppm	20 [1926.800(j)(1)(v)(D)]	Spot measurements
4.	Explosive gas (CH_4)	%	20 LEL [1926.800(j)(1)(ix)]	Spot measurements
5.	Total Particulate	ppm	15 [Table 1 to §1926.55]	Spot measurements
6.	Total Dust	mg/m^3)	15 [Table 1 to §1926.55]	Spot measurements

1 Source: OSHA eCFR 1926.800, Safety and Health Regulations for Construction, Underground Construction, Caissons, Cofferdams, and Compressed Air, Underground Construction

2 Tests for oxygen content shall be made before monitoring other contaminants.

Sl.	Parameter	Unit	Average Concentration[3]	Means of Monitoring
1.	Oxygen (O_2)	%	19.5 – 20.5	8 hours continuous
2.	Carbon monoxide (CO)	ppm	50 [Table 1 to §1926.55]	8 hours continuous
3.	Hydrogen Sulfide (H_2S)	ppm	10 [1926.800(j)(1)(v)(B)]	8 hours continuous
4.	Nitrogen dioxide (NO_2)	ppm	5 [Table 1 to §1926.55]	8 hours continuous
5.	Explosive gas (CH_4)	%	10 LEL [1926.800(j)(1)(viii)]	8 hours continuous
6.	Respirable Crystalline Silica	mppcf	250 [Table 2 to §1926.55]	8 hours continuous

3 Source: OSHA eCFR 1926.55, Safety and Health Regulations for Construction, Occupational Health and Environmental Controls, Gases, vapors, fumes, dusts, and mists.

6) The Contractor shall at all times comply with both the 8 hours average and the maximum concentration levels.
7) The ventilation system used during construction shall ensure that at all times oxygen content shall be between 19.5-22% by volume is available in any underground works. Furthermore, the minimum fresh air requirements given herein refer to the required ventilation conditions and additional provision shall be made to account for any losses, e.g., due to leaks in the ducts, for which the Contractor shall make provision in the ventilation calculations.
8) Instruments to monitor all the harmful gases and dust shall at all times be available on the Site in good working order and condition. These shall be supplied and maintained by the Contractor, throughout the duration of the underground work. All equipment must be calibrated annually and the Contractor furnish proof of calibration to the Engineer for his verification. All calibrations shall be done by the manufacturer or an authorized dealer of the manufacturer or a laboratory and acceptable by the Engineer.

9) The Contractor shall be responsible for operating the ventilation system in the underground works until all construction work is completed, including all work to be carried out by other (sub)contractors.

3.12.2. HAZARDOUS GAS

A. GENERAL

1) The Contractor shall continuously monitor the underground works for the presence of explosive gases (e.g., methane) and when they occur, they shall be strictly controlled and on no occasion shall the concentration exceed 10% of the lower explosive limit (LEL) of that gas.
2) For this purpose, the Contractor shall supply, use and keep in good order sufficient equipment and apparatus to comply with the requirements specified hereunder. Where the term methane is used it shall be construed to mean any potentially explosive or hazardous gas.

B. METHANE DETECTION

3) The following minimum methane detection procedures are required:
   a) Monitoring for methane to be carried out at each probe hole, and in the case of upward inclined probe holes at the back of the hole. Particular attention shall be given for testing of methane when deep fractures are intersected by the probe hole.
   b) Testing for methane to be carried out continuously during drilling or boring operations.
   c) Continuous methane monitoring device(s) to be provided in ventilation columns with automatic alarm system.
   d) Regular methane inspections of headings and tunnels whether discontinued or in use for access to the rearward of the advancing face are to be carried out.

3.13. COMMUNICATION SYSTEM

The Contractor shall install and operate the communication system between each face and entrance to the tunnel or shaft as stipulated in the Section "Site Installations".

3.14. ATMOSPHERIC AND PERSONNEL EXPOSURE MONITORING

3.14.1. GENERAL

The Contractor shall perform monitoring for the duration of this contract and submit results to the Engineer. Monitoring activities shall include:

(a) atmospheric monitoring shall be conducted in tunnels before every shift and before and 45 minutes after each blasting operation.

(b) If the spot monitoring determination reveals worker exposure above the Personal Exposure Levels (PELs), the Contractor shall repeat such monitoring for each such worker at least every three (3) months

3.14.2. FREQUENCY, LOCATIONS AND STANDARDS

The items, frequency and number of locations of sampling or measurement shall be as below or as otherwise directed by the Engineer.

Parameter	Location	Means of Monitoring	Frequency
Atmospheric Monitoring in tunnels (O2, CO, H2S, CH4)	All underground (tunnel) worksites	Spot measurements for determining maximum levels/ concentrations in the tunnels	(a) Before every shift (b) Before and 45 minutes after each blasting operation
Personal Exposure Monitoring (Dust and Respirable Crystalline Silica)	All underground (tunnel) worksites	8-hour time-weighted average monitoring	Reveals worker exposure above the PELs, the Contractor shall repeat such monitoring for each such worker at least every three (3) months

Allowable Maximum concentration of gases in underground operation are presented below:

Sl.	Parameter	Unit	Maximum Concentration[1]	Means of Monitoring
1.	Oxygen (O2)	%	19.5 – 22	Spot measurements2
2.	Carbon monoxide (CO)	ppm	100	Spot measurements
3.	Hydrogen Sulfide (H2S)	ppm	20 [1926.800(j)(1)(v)(D)]	Spot measurements
4.	Explosive gas (CH4)	%	20 LEL [1926.800(j)(1)(ix)]	Spot measurements
5.	Total Particulate	ppm	15 [Table 1 to §1926.55]	Spot measurements
6.	Total Dust	mg/m^3)	15 [Table 1 to §1926.55]	Spot measurements

1 Source: OSHA eCFR 1926.800, Safety and Health Regulations for Construction, Underground Construction, Caissons, Cofferdams, and Compressed Air, Underground Construction

2 Tests for oxygen content shall be made before monitoring other contaminants.

8 hours average concentration of gases and personal exposure of silica in underground operation are provided below:

Sl.	Parameter	Unit	Average Concentration[3]	Means of Monitoring
	Oxygen (O2)	%	19.5 – 20.5	8 hours continuous
	Carbon monoxide (CO)	ppm	50 [Table 1 to §1926.55]	8 hours continuous
	Hydrogen Sulfide (H2S)	ppm	10 [1926.800(j)(1)(v)(B)]	8 hours continuous
	Nitrogen dioxide (NO2)	ppm	5 [Table 1 to §1926.55]	8 hours continuous
	Explosive gas (CH4)	%	10 LEL [1926.800(j)(1)(viii)]	8 hours continuous
	Respirable Crystalline Silica	mppcf	250 [Table 2 to §1926.55]	8 hours continuous

3 Source: OSHA eCFR 1926.55, Safety and Health Regulations for Construction, Occupational Health and Environmental Controls, Gases, vapors, fumes, dusts, and mists.

3.15. MEASUREMENT AND PAYMENT

3.15.1. GENERAL

1) Measurement for payment and payment for underground excavation shall be made only when the excavation along with the associated rock support as shown on drawings or as directed by the Engineer has been completed in all respects.

2) Measurement for payment and payment for underground excavation will be made according to the classification system specified above. Separate quantities and Unit Prices for the various excavation classes in different portions of the Works are provided in the Bill of Quantities.

3) The definitions of the excavation classes are only relevant for the measurement and payment of the excavation volumes. All rock supports will be measured for payment and paid for separately.

4) The estimated quantities for each excavation class given in the Bill of Quantities are not to be considered as an accurate indication of the quantity of work since the predicted and the actual length of each excavation class may differ due to geotechnical conditions encountered in the course of work. The Contractor shall not be entitled to any extra payment over and above the Unit Prices entered in the Schedule by reason of changes to the actual quantities of the various excavation classes.

5) Measurement for payment for underground excavation will be of the in-situ volume defined by the "B"-line as shown on the Drawings, or as specified in these specifications.

6) Payment will be made at the appropriate Unit Price per cubic meter entered in the Bill of Quantities, which shall include the entire cost of, but not be limited to, the following:

a) Provision of all labour, equipment and materials required for the excavation by tunnelling driving methods including drilling for pilot holes and holes for blasting; developing and improving controlled blasting methods, blasting tests and performance of blasting; cleaning, washing, protection, and maintaining excavated surfaces in satisfactory conditions, and protection of tunnel invert until the

concrete lining is placed; all enlargements and additional excavations required by the Contractor for his construction methods; all temporary supports required for the safety of working crews,

b) Provisions for, and operation of, the train as well as vehicular traffic; loading, hauling, and dumping the excavated material on stockpiles, spoil tips, or points of incorporation into the Permanent Works up to 3 km distance from the portal; clearing of the spoil areas and formation of spoil tips as specified; clearing of the stockpile areas, formation and maintenance of stockpiles, re-handling of suitable materials including segregating, grading, drainage and drying of materials suitable for use in embankment construction or as backfill,

c) Extra payment will be made for handling the excavated material beyond 3 km at the appropriate unit price as entered in the Bill of Quantities. Measurement for payment will be based on the hauled volume. The volume of the material will be based on survey carried out by the contractor and approved by the engineer, and will be calculated by applying the following bulking factors:

i) For excavated rock: 1.4
and using the formula:
ii) Volume measured (and approved) / bulking factor

Payment for the resulting calculated volume will be made at the Unit Price per cubic meter.kilometer (m^3.km) entered in the Bill of Quantities. This volume shall be compared with that worked out with surveyed sections and the lesser of the two will be paid.
The volume calculated through the bulking factor method shall be compared with the volume derived from surveyed cross-sections of the excavation; payment shall be based on the lesser of the two volumes.

d) All delays during excavation work resulting from installation of rock supports required by the geotechnical conditions of the material encountered, irrespective of the distance from the face,

e) Complying with all requirements of statutory laws and regulations relating to underground works and any restrictions resulting there from; obtaining all necessary permits and licences for the purchase, use, storage, and transport of explosives and other materials,

f) Surveying, setting-out, checking of excavated profile and alignment, and any subsequent rectification works resulting from undue or incorrect surveys; provision of suitable equipment for, and delays due, to carrying out this work,

g) Furnishing, installation, operation, maintenance, and removal of communication, illumination, and ventilating systems; safety precautions and measurement of dust, silica, and noxious and flammable gases,

h) Recording and preparation of reports related to excavation progress and procedures

i) All work involved with, and any partial or short interruptions or inconveniences caused by, the check surveys and performance of rock mechanics test, for which no separate payment is provided elsewhere in these Specifications.

j) Utilising the services of full time professional blasting Consultant.

7) Payment will be made for Protection works (like boulder-wire crates, stone masonry wall etc.) for the dumped material in spoil tips as per relevant section of Technical Specification.

3.15.2. EXCAVATION OF TUNNELS

1) Assignment of excavation classes for payment will be based on the rock class encountered in the heading zone during the excavation advance.

2) Volumes for payment for each excavation class will be obtained by multiplying the theoretical cross-sectional area defined by the "B"-line, by the length measured along the established centre line of the tunnel.

3) Payment will be made at the unit price per cubic meter for each excavation class as entered in the Bill of Quantities.

4) Length, type and diameter of installed rock bolts will not be considered as criteria for classification purposes.

5) Separate payment will be made where, due to geological reasons, excavation had to be performed by multi-drift/ multi-segmental method. Measurement for payment will be of the in-situ volume obtained by multiplying the theoretical cross-sectional area defined by the “B” line, by effective length as approved by the Engineer. Payment will be made at the Unit Price per cubic meter entered in the Bill of Quantities.

6) Separate payment will be made where the tunneling has been carried out through slope wash material. Measurement for payment will be of the in-situ volume obtained by multiplying the theoretical cross-sectional area defined by the “B” line, by effective length as approved by the Engineer. Payment will be made at the Unit Price per cubic meter entered in the Bill of Quantities. The measurement and payment for drainage/pipe roofing/shotcreting/self drilling fiber glass rock bolts etc. shall be regulated as per the relevant items of Bill of Quantities.

3.15.3. LINE DRILLING

1) Measurement for payment for line drilling will be of the length of the holes actually drilled into the rock along the side of the excavation as directed by the Engineer.

2) Payment will be made at the unit price per meter of the drill hole irrespective of the diameter, entered in the Bill of Quantities, which shall include the entire cost, as approved by the Engineer, of drilling the holes, light blasting, broaching, wedging, barring or other methods used in conjunction with line drilling.

3.15.4. DENTAL EXCAVATION

1) Measurement for payment for dental excavation will be of the in-situ volume of material removed.

2) Payment will be made at the Unit Price per cubic meter entered in the Bill of Quantities, which shall include the use of any special equipment and hand work, as approved by the engineer.

3) If measurement by volume proves impracticable, the surface area of seams, cracks and Caverns to be cleaned may be equated, as the conditions dictate, to a volume mutually agreed upon the Contractor and the Engineer.

3.15.5. REMOVAL OF OVERBREAK AND BACKFILLING

1) No payment will be made for the removal of material or for backfilling with cast-in-place concrete or shotcrete or grout, for excavation beyond the "B"-line except in case of an accepted geological overbreak.

2) Measurement for payment for the removal of material and backfilling of voids arising from overbreak accepted by the Engineer as occurring entirely for geological reasons, will only be made if the Contractor requests measurement directly after excavation, or as long as the overbreak can clearly be determined as being due to adverse geological conditions.

3) For approved overbreak due to geological conditions, all excavated material outside the "B"-line shall be measured. No payment will be made for excavation, but measurement for payment and payment will be made both for the removal of excavated material, including cleaning of surfaces, and for the additional concrete required for backfilling.

4) Payment for the removal of excavated material will be made at the Unit Price per cubic meter entered in the Bill of Quantities for loading, hauling and dumping of material and cleaning of the surface created by the overbreak.

5) Payment for backfilling of voids created by an approved geological overbreak with concrete, shotcrete or grout will be made at the applicable Unit Prices entered in the Bill of Quantities.

6) No measurement for payment or payment will be made for voids outside the "B"-line which are not accepted by the Engineer as being due to Geological overbreak.

3.15.6. EXCLUSIONS

1) All costs for Dewatering of underground sites and overcoming difficulties due to the ingress of water shall be covered by the applicable Unit Prices as specified in the Section "Dewatering during Construction".

2) Cost for Construction of drainage trenches proposed by the Contractor in the tunnel inverts is deemed to be included in the unit cost for underground excavation. No separate measurement for payment and payment will be made for it.

3) All cost for creating niches in the tunnels for turning/crossing of vehicles, installation of electrical equipments etc. is deemed to be included in the unit cost of underground excavation. No separate measurement for payment and payment will be made for it.

4) All costs for exploratory drillings will be covered by the applicable Unit Prices as specified in the Section "Drilling and Grouting".

5) All costs for supply and installation of rock supports will be covered by the applicable Unit Prices as specified in the Section "Rock Supports".

6) Rock supports required due to the Contractor's not adhering to approved drilling and blasting techniques will not be included for payment.

7) No extra payment will be made for the following:

.

a) Over-excavation, removal of material or backfilling with concrete, shotcrete or grout beyond the "B"-line, except that due to an accepted geological overbreak. This applies also to any rectification work resulting from incorrect surveys and/or blasting,

b) Additional work of removing material and backfilling voids with approved material where overbreak due to adverse geological conditions coincides with that due to Contractor's poor working methods or negligence,

c) The concrete and grout required to fill niches created by the contractor for its own convenience shall also be at the Contractor's expense,

d) Additional rock support measures required due to creation of niches within the niches and in the surrounding area shall be at Contractor’s expense.

e) Overbreak in additional excavation required by the Engineer,

f) Extra work or material required to repair damage to the tunnel invert caused by the construction equipment,

g) Clearing and grubbing in the spoil and stockpile areas,

h) Draining, shaping and trimming of the dumped material in spoil tips to the lines and grades as directed or approved by the Engineer.

i) Measures for dust abatement.

END OF SECTION B.3

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Dorjilung Hydro Power Limited

4. ROCK SUPPORT

4.1. SCOPE OF WORK

1) Works under this Section include all labour, materials, tests, equipment and services required to protect, stabilize or support rock faces, cuts, slopes and masses exposed in the course of surface and underground excavation works, as well as the anchoring of any concrete structures into surrounding or underlying rock.

2) This Section covers the following items:

a) Rock bolts, rock anchors, and grouted anchor bars
b) Post-tensioned rock bolt (tendons)
c) Wire mesh
d) Structural steel supports
e) Temporary supports
f) Pre-grouting, Forepoling and Pipe Roofing, Pre-Drainage Holes etc.

3) Steel Fibre Reinforced Shotcrete (SFRS), Shotcrete with/ without wire mesh, grouting and drainage work, which may also be required for rock support purposes, are specified in each relevant section of these Technical Specifications.

4) Principal works required are as follows:

a) Stabilizing of surface slopes and cuts:
b) Rock supports in tunnels
c) Anchorage of concrete structures.

4.2. GENERAL

1) The rock stabilizing and supporting measures to be undertaken during or after the excavation work for constructing the Works in a safe manner will be as determined or approved by the Engineer, based on the known or presumed behaviour of the rock or ground.

2) In case of emergency or unforeseen exigency, the Contractor is authorized and obliged to undertake independently such supporting measures, as deemed necessary without prior consent of the Engineer. In such cases the Contractor shall inform the Engineer immediately.

3) The Engineer retains the right to order the Contractor to change the method or system of rock supports being used, if he considers that the Contractor's method of work is unsafe.

4) In underground works the installation of the rock supports shall follow closely the excavation of heading and they shall be installed before the next round of excavation advance. The Contractor is responsible for the timely and proper installation of the rock supports and for checking and maintaining it until the final lining or structure is placed.

5) Rock stabilization measures required as the permanent feature of the Works shall be installed as shown on the Drawings or as directed by the Engineer.

6) Nothing contained in this Section shall be construed to relieve the Contractor from sole responsibility for the safety of the Works nor for liability for injuries to, or death of persons or damage to property, nor of any of his obligations under this Contract.

7) An adequate quantity of rock support materials and equipment, shall be stored by the Contractor at the construction sites and be kept ready for immediate use at any time during the whole construction period.

8) The quantities of all rock support items listed in the Bill of Quantities and the support systems shown on the Drawings are only tentative. The actual measures to be taken shall be dictated by the rock conditions encountered.

9) Grouting of rock bolts of various types and rock anchors is an important and critical requirement. Cement used in grout shall be OPC/PPC. Contractor shall ensure grout pumps of appropriate type are available at site in sufficient number to achieve the grouting of bolts in a proper manner.

10) Since installations of bolts require considerable skill, the contractor shall get professional advice from such specialized agencies/experts who shall assist him to achieve the required quality in carrying out the installation.

11) Works of pipe roofing shall be allowed to be executed only by an agency having both experience and technology for execution of these works.

4.3. SUBMITTALS

1) Within 28 days from the date of issue of Letter of Acceptance, but before procuring or shipping the materials to the Site, the Contractor shall submit to the Engineer following:

a) Full details of the type and quality of rock reinforcement which is proposed to be used together with manufacturer's instructions and certificates, methods of installations and testing (including details of testing equipment) and, for rock bolts and rock anchors, details of grouting system and anti-corrosion

measures. The Contractor may propose in addition alternative types of rock reinforcement to that described in this Section, but acceptance by the Engineer will be subject to full demonstration of its adequacy.

b) Complete details concerning type, and materials, together with manufacturer's instructions and certifications, methods of installation, corrosion protection, stressing equipment, grouting method and equipment, proposal for suitability and stressing tests and equipment.

c) Fabrication details of steel ribs, lagging and lattice girders.

2) Not later than 28 days prior to ordering any of the above materials, the Contractor shall submit to the Engineer for approval of his proposed materials delivery schedule. Any amendments to the delivery schedule, proposed by the Contractor as the work proceeds, will also have to be approved by the Engineer, and none of the above materials shall be called to the Site without Engineer's consent.

3) Contractor's shop drawings of structural steel supports and precast concrete lagging shall be submitted to the Engineer not later than 28 days prior to their installation.

4) A detailed test program for all rock reinforcing elements shall be submitted to the Engineer for his approval before the start of the work.

5) The test certificate for the wires/strands for each lot of tendons shall be submitted by the Contractor as obtained from the supplier to the Engineer for the approval prior to shipment.

6) The Contractor shall record the results of all tests performed on the rock bolts and post-tensioned rock bolt (tendons) prior, during and after the installation, register the readings taken at the load cells installed and submit these documents to the Engineer.

7) Minimum 48 days before start of use of resin capsules (if used), the contractor shall furnish the details of resin capsules, its installation methodology for approval of Engineer. If required, Engineer may ask the contractor for onsite trials of installation of grouted rock bolts before according approval.

8) Minimum 48 days before start of excavation, the contractor shall furnish the detailed information in respect of pipes for pipe roofing, its installation methodology and name of specialized agency for approval of Engineer.

4.4. ROCK BOLTS, SOIL NAILS, ROCK ANCHORS, GROUTED ANCHOR BARS

4.4.1. GENERAL

1) The Contractor shall furnish, install, test and maintain rock bolts, rock anchors, grouted anchor bars, post-tensioned rock bolts (tendons) as specified herein. They shall be installed in portions of the Works where anchorage of concrete structures to rock is required and where the stability of excavated or exposed rock faces and slopes has to be assured, either permanently or only temporarily during construction work.

2) Variations of typical design of excavation limits and rock support patterns and details, as shown on Drawings, has to be expected and allowed for, and could include modifications in the quantities, type, location, pattern, spacing and length of rock reinforcement and accessories. Such variations will be proposed or directed by the Engineer as the excavation proceeds, to suit field conditions.

3) For the sake of clarity, the terms used in this Section or any other section of this Technical Specifications are defined as follows, and may be applied in underground or in surface works:

REINFORCING ELEMENT is a general term for rock bolts, rock anchors, and grouted anchor bars, and post-tensioned rock bolts (tendons).

ROCK BOLT (consisting of a rod, a mechanical/cement grouted/Resin end anchorage and a plate and a nut) is a stressed (or tensioned) reinforcing element to be stressed immediately after installation by torquing or jacking, by means of an approved calibrated stressing device. Rock bolts shall be fully grouted (or ungrouted where load cells are provided on them). The rock bolt is synonym with active rock anchor.

SOIL NAILS: Soil nails are the reinforcement installed horizontally or sub horizontally so that it improves the sealing resistance of soil by acting in tension. Soil nails typically consist of fully threaded steel bar with broad pitched thread of 25-35 mm in diameter installed into drill holes having diameter 100-300 mm and at spacing of 1-2 m. Soil nails are installed in surface excavation. The diameter at the thread shall be greater than the nominal diameter of the bar to ensure higher load capacity at threads.

ROCK ANCHOR is an un-tensioned reinforcing element consisting of a fully threaded steel bar with broad pitched thread embedded in a cement mortar filled hole. The diameter at the thread shall be greater than the nominal diameter of the bar to ensure higher load capacity at threads. The rock anchor shall have a plate and a nut. Extension pieces may need to be provided on rock anchors for anchorage of concrete structures. The rock anchor is synonymous with "passive rock anchor".

GROUTED ANCHOR BAR is a reinforcing element consisting of a reinforcing bar embedded in a cement mortar-filled hole. It shall extend into structural concrete to provide anchorage of concrete structures.

PIPE ROOFING refers to the installation of seamless hollow pipe on top of the tunnel at advanced face with umbrella alignment followed by grouting.

INDIVIDUAL BOLTING refers to the installation of reinforcing elements in localized areas of instability or weakness, as may be determined during excavation. It is synonymous with "spot bolting".

PATTERN BOLTING refers to the installation of reinforcing elements in a regular pattern over the excavation surface.

4) The following types of rock bolts shall be used:
   a) Expansion-shell rock bolts.
   b) Resin grouted/ cements grouted rock bolts.
   c) Post-tensioned rock bolts (tendons).

5) The following types of rock anchors shall be used:
   a) Rock anchors
   b) Grouted anchor bars
   c) Self Drilling Hollow Core Anchors.
   d) Water Expandable Friction Anchors

6) The type, length, diameter, inclination and pattern of the reinforcing elements shall be as determined or approved by the Engineer, except as stipulated in Clause 4.2 (2) here above. The reinforcing elements for above bolts/anchors shall be manufactured from reinforcing bar with yield strength not less than 550 N/mm^2. The reinforcing bar shall comply with IS 1786. Each bolt shall be fully threaded steel bar with broad pitched thread. The diameter at the thread shall be greater than the nominal diameter of the bar to ensure higher load capacity at threads. Rock bolts shall be of various lengths and diameters as specified in Drawings.

7) Reinforcing elements shall be furnished complete with all accessories and other materials necessary for their installation, fixing, stressing and grouting.

8) Bearing plates shall be flat or dished steel plates of following minimum dimensions:

36mm dia.	1 no. plate of 200x200x16mm
32mm dia.	1 no. plate of 200x200x12mm
25mm dia.	1 no. plate of 150x150x10 mm

The plate shall conform to IS 2062 for Structural Steel. The nuts shall be heavy hexagonal type.

9) The threads on the projecting ends of bolts/anchor shall be protected and lubricated with rust preventive compound.

10) If directed or approved by the Engineer, the Contractor shall supply and install flat steel plates or rolled steel sections to connect together two or more rock reinforcing elements. The steel plates and sections shall conform to IS: 2062. Couplers may be required for the bolts. When coupler is used, the threading in the bar shall not reduce the effective diameter of bar. Coupler itself should be able to transfer at least 125 % of the yield load of the bar.

11) When the reinforcing elements are used in conjunction with wire mesh, the mesh shall be connected firmly to the bolts as shown on the Drawings or as directed by the Engineer.

12) If directed by the Engineer, rock bolts shall be provided with devices for load measuring. In this case they shall not be grouted.

13) If directed by Engineer, rock bolts and its related coupler, plates and nuts shall be hot dip galvanized. In such cases the threads of couplers, plates and nuts shall be reamed by the supplier to ensure proper they fit properly on the rock bolt.

4.4.2. TESTING AND MONITORING OF REINFORCING ELEMENTS

1) The Contractor shall furnish at least 2 sets of testing equipment including hydraulic jacks, fixing device, hydraulic pump with manometer, and all necessary accessories. The testing equipment shall be capable of stressing the largest diameter rock bolt to the yield stress of the bolt.

2) Prior to the installation of reinforcing elements in the Works, a series of pull-out tests shall be carried out in different rock types designated by the Engineer and which will be representative of the rock expected to be encountered during the excavation, to prove the suitability of the reinforcing elements. During the pullout test both, the load applied and movement undergone shall be measured. At least 5 tests shall be required for each combination of the type of the reinforcing element/installation condition to be able to assess the suitability of the element. The pull-out tests shall be carried out sufficiently in advance of the installation of the reinforcing elements in the Works so that, in the event that the elements do not meet the requirements, the Contractor shall have time to furnish and test elements of a different type. The Contractor shall maintain detailed records of the pull-out tests, the results of which will be used to establish relation between rock quality and type of reinforcing element and tensioning.

3) During progress of the Works the Contractor shall, in general, perform pull-out tests, in the presence of the Engineer on at least 2 per 100 reinforcing elements installed. The Engineer will determine the elements to be tested depending on rock type and conditions of installation. In case of failure, additional testing shall be performed on selected reinforcing elements installed in the vicinity of the failed one. All tested anchors shall be replaced as directed by the Engineer.

4) Rock bolts shall be tested before grouting. Other type of reinforcing elements shall be tested after the mortar has achieved its design strength. Water expandable friction anchors shall be tested after installation.

5) As a part of monitoring program during the progress of the work, and when directed by the Engineer, rock bolts shall be fitted with mechanical read out load cells. Approved load cells which allow to measure the increase or decrease in load in the bolt to an accuracy of 2% shall be supplied by the Contractor, who shall measure the deformation undergone and record the loads registered on each load cell installed twice a month and submit the results to the Engineer within 48 hours of taking such readings. Such load cells shall be installed on the ungrouted rock bolts only.

4.4.3. DRILLING HOLES AND PREPARATION FOR INSTALLATION

1) Holes for rock bolts and rock anchors shall be drilled as specified herein and in accordance with the applicable provisions of the Section "Drilling, Grouting and Pressure relief holes".

2) Diameter of hole drilled for installation of rock bolt/anchor shall be as under or as recommended by manufacturer and approved by Engineer:

36 mm dia.	at least 45 mm dia.
32 mm dia.	at least 40 mm dia.
25 mm dia.	at least 32 mm dia

3) The length of drill hole shall be such as to receive the specified reinforcing element and to provide for its satisfactory anchorage, and sufficient provision of the threaded portion out of hole to fix plate, nut, and coupling for any kind of extension piece. The holes shall extend 150 to 200 mm beyond the length of the rock bolt or anchor.

4) After drilling, each hole in sound, washable rock shall be washed out with clean water and cleaned by blowing out all drill cuttings and debris with compressed air. The holes in rock, which tends to swell or is interspersed with clay filled fissures, shall be cleaned with compressed air only. The compressed air shall not contain any oil or other material preventing the bond.

5) Spacers (centralizer) shall be used for 32 mm dia. and 36 mm dia. rock bolts for length greater than 4 m for equal grout annulus all around the bolt/anchor.

6) Prior to installing the reinforcing element, the rock surface shall be treated with an initial layer of shotcrete. In case of rock bolt, if the surface is not perpendicular to the hole axis, bevel washer shall be placed between the bearing plate and the nut, or dished bearing plate and hemispherical washer used, to ensure uniform bearing.

7) If a reinforcing element is not installed immediately after drilling the hole, the hole shall be washed and cleaned as stipulated above immediately prior to installing the element.

4.4.4. INSTALLATION OF ROCK BOLTS

4.4.4.1. EXPANSION SHELL ROCK BOLTS

1) Expansion-shell rock bolts shall be as per ASTM F432 or equivalent Indian Standard. They shall be supplied complete with all accessories required for installation, stressing and grouting. Expansion shell rock bolts shall meet the following requirements:

a. The bar of the expansion shell rock bolt shall be at least Fe500D CRS Grade as per IS1786, with elongation at yield ≥ 5% and at rupture ≥ 13%. The bar must have cold rolled threads on both sides for mounting expansion shell and nut.

b. Bolt must be able to provide immediate point loading of at least 8 Tons immediately after installation and prior to grouting.

c. Expansion Shell Rock Bolt must have polyethylene corrugated sleeves with inner centralizer over the bar. Corrugated sleeve must be connected to weld on sleeve of dome shaped grouting adapter with grouting hole. Domed plate over the weld on sleeve shall include bore for discharge of excess grout, indicating that the bored hole in which anchor is installed is fully grouted.

d. As directed by the Engineer expansion shell rock bolts may be hot dip galvanized and/or epoxy coated as per the project requirement. Hot Dip Galvanization shall done in accordance to DIN EN ISO 1461. Epoxy coating shall be done in accordance to BS EN 13438 and BS EN ISO 2049.

2) The method and equipment used for installation, to effectively seat, and to stress the expansion-shell rock bolts shall be in accordance with the manufacturer's instructions and subject to the approval of the Engineer.

3) The rock bolts shall be stressed, immediately after installation in the hole, by torquing or jacking, by means of an approved and regularly calibrated stressing device, to an extent specified by the manufacturer or directed by the Engineer on the basis of values established during pull-out tests.

4) Expansion shell rock bolts shall generally be tensioned at the following maximum values, however, final values as mentioned in Construction Drawings shall be followed.

Rock Bolt size	reinforcing elements conforming to IS 1786	reinforcing elements conforming to EN 10138-4 or equivalent international standard
36 mm dia rock bolt	30 t	55 t
32 mm dia rock bolt	24 t	45 t
25 mm dia rock bolt	15 t	25 t

5) After initial installation, the Contractor shall ensure that the rock bolts continue to act as effective supports by periodically testing the rock bolts and, if necessary, re-tightening to the directed torque or tension.

6) Grouting of the expansion-shell rock bolts shall be performed without destressing the bolt. Grouting shall be performed as soon as practicable after, but in any case within 21 days, of rock bolt installation. The bearing plate shall be caulked around its perimeter and grout shall be introduced into the hole through a plastic tube fixed to the shaft and extended to outside through a hole provided in the bearing plate, at a pressure sufficient to fill completely the space around each bolt for the full length without any air-pockets remaining inside the hole. A grout return tube through another hole in the plate shall be provided to ensure full column grouting.

7) Cracks and fissures adjacent to the rock bolt, which the grout is found to be flowing from, during the grouting operation, shall be plugged or caulked at the excavation surfaces.

4.4.4.2. RESIN GROUTED/ CEMENT GROUTED ROCK BOLTS

1) Material for reinforcing elements of Rock bolts shall conform to IS 1786 (Fe 500 min) and corresponding to grade Fe500 or equivalent international standard as indicated in the drawing. They shall be supplied complete with all accessories required for installation, stressing and grouting. Each bolt shall fully threaded steel bar with broad pitched thread. The diameter at the thread shall be greater than the nominal diameter of the bar to ensure higher load capacity at threads.

The reactable resin mixture as approved by the Engineer shall be contained in an easily ruptured plastic cartridge having one pocket for the resin components and a separate pocket for the curing agent, also known as the hardener or catalyst. A bolt is inserted and a rotary tool is then coupled to the free end of the bolt, turning the bolt, breaking the package and mixing the resin reactants. The mixing time shall be determined at site based on the recommendation of manufacturer and as per site trials as approved by the Engineer. This mixing distributes the curing agent and starts resin cure. When the resin is fully cured and the bolt is anchored fast. The remaining length shall be grouted with Normal Portland cement. Grout mix shall have sand to cement ratio of 1:1 by weight, or as specified by the Engineer. Admixtures shall be approved by the Engineer.

2) The method and equipment used for installation, to effectively seat, and to stress the rock bolts shall be in accordance with the manufacturer's instructions and subject to the approval of the Engineer.

3) The rock bolts shall be stressed, immediately after installation in the hole, by torquing or jacking, by means of an approved and regularly calibrated stressing device, to an extent specified by the manufacturer or directed by the Engineer on the basis of values established during pull-out tests.

4) Rock bolts shall generally be tensioned at the following maximum values, however, final values as mentioned in Construction Drawings shall be followed.

Rock Bolt size	Reinforcing elements conforming to IS 1786	reinforcing elements conforming to EN 10138-4 or equivalent international standard
36 mm dia rock bolt	30 t	55 t
32 mm dia rock bolt	24 t	45 t
25 mm dia rock bolt	15 t	25 t

5) After initial installation, the Contractor shall ensure that the rock bolts continue to act as effective supports by periodically testing the rock bolts and, if necessary, re-tightening to the directed torque or tension.

6) Grouting of the rock bolts shall be performed without destressing the bolt. Grouting shall be performed as soon as practicable after, but in any case within 21 days, of rock bolt installation. The bearing plate shall be caulked around its perimeter and grout shall be introduced into the hole through a plastic tube fixed to the shaft and extended to outside through a hole provided in the bearing plate, at a pressure sufficient to fill completely the space around each bolt for the full length without any air-pockets remaining inside the hole. A grout return tube through another hole in the plate shall be provided to ensure full column grouting.

7) Cracks and fissures adjacent to the rock bolt, which the grout is found to be flowing from, during the grouting operation, shall be plugged or caulked at the excavation surface.

4.4.5. INSTALLATION OF ROCK ANCHORS

4.4.5.1. ROCK ANCHORS

1) The rock anchors will not be stressed. The rods shall be fully grouted with cement mortar grout.

2) The rod shall be manufactured from high yield strength deformed reinforcing bars conforming to IS: 1786 (Fe 500) and EN 10138-4 (Pre-stressing Steel Bar of Grade 950/1050) or equivalent international standard as indicated in the drawing. The diameter of the bars shall generally be 25/32/36 mm, and the length and position shall be as shown on the Drawings or as directed by the Engineer. Each anchor shall fully threaded steel bar with broad pitched thread. The diameter at the thread shall be greater than the nominal diameter of the bar to ensure higher load capacity at threads. For the Contractor's convenience the bars may be installed in shorter pieces as approved by the Engineer. Threaded couplers for the coupling of the single elements shall be able to transfer at least 125% of the yield load of the bar.

3) The surface of the rock anchors shall be clean of rust, scale, dirt or other foreign matter.

4) Holes drilled for rock anchors shall be kept plugged until just prior to commencement of grouting and installing operations. Before grouting, each hole shall be thoroughly flushed with water and cleaned with compressed air.

5) Water shall be removed from the hole before grouting. If the hole cannot be kept dry during grouting, the grout shall be introduced into the end of the hole through a pipe, which shall be gradually withdrawn as the hole is filled.

6) Portland cement shall be used for the grout mixture. Grout shall have a water to cement ratio of between 0.4 and 0.6 by weight, and a sand to cement ratio of 2:1 by weight (If added), or as specified by the Engineer. Admixtures shall be approved by the Engineer.

7) The anchor bar shall be forced into the mortar/grout-filled hole before the initial set of the grout. The bar shall be vibrated or tapped in order to ensure good contact between the steel surface and the grout.

8) Anchor bars shall be protected after installations in such a manner as to prevent any movement until the grout has hardened. The Contractor shall replace any bars found to be loose after the grout has set.

9) The depth of holes indicated on the Drawings or as directed by the Engineer shall be measured from the effective excavation surface.

4.4.5.2. WATER EXPANDABLE FRICTION ANCHORS

(1) Water expandable friction anchors shall be of a reputed make. These shall be of lengths varying between 3m – 6 m and installed as a temporary support at the locations determined by Engineer in the underground excavations. These anchors shall be used generally at places where in the opinion of the

Engineer, the strata is such that an immediate temporary support is required and it is not possible to provide other types of rock support within a reasonable time.

(2) The anchor consists of a 41 mm diameter, steel tube of 2 mm thickness which is folded during manufacturing to create a 25-28 mm diameter unit to be inserted in a hole of 32-39 mm diameter. The anchors shall be provided with a domed shaped face plate, as per the manufacturer's recommendations. The material of steel tube shall conform to EN 10025-S355JR or equivalent.

(3) The anchor shall have a minimum breaking load of 100 KN and a minimum elongation of 15%. The anchor shall be activated by injection of high water pressure at 30 MPa which inflates the folded tube into intimate contact with the wall of borehole.

(4) Water expandable friction anchors shall be supplied, installed and tested as per recommended procedure of the manufacturer. Additional testing, if required, shall be carried out as determined by the Engineer depending on site conditions.

4.4.5.3. SELF DRILLING HOLLOW CORE ANCHOR

1) The anchor shall be a fully threaded steel bar which can be drilled and grouted without the use of a casing. The bar shall have a hollow bore for flushing or simultaneously drilling and grouting.

2) Self drilling anchors shall be fabricated from Grade J55 steel conforming to EN 10083-1 type of steel or equivalent. The threads shall be of type R32 ISO 10208

3) The anchor shall be of 25/32 mm outer diameter with anchor coupling, nut, anchor plate and drill bit.

4) The anchor shall be capable of taking minimum ultimate load of 210 KN, and minimum yield load of 160 KN.

5) The minimum average tensile strength shall be 690 N/mm^2 and minimum average yield strength 530 N/mm^2.

6) The anchors shall be hot dipped galvanized for corrosion protection

7) The anchor to be used shall be grouted as directed by the Engineer.

4.4.5.4. GROUTED ANCHOR BARS

1) The grouted anchor bars will not be stressed. The rods shall be fully grouted with cement mortar grout. Hooks or L-shaped extensions will be welded to the grouted anchor bars and are covered under the Section "Reinforcing Steel".

2) The rod shall be manufactured from high yield strength deformed reinforcing bars conforming to IS: 1786 Grade Fe 500. The diameter of the bars shall generally be 25/32/36 mm, and the length and position shall be as shown on the Drawings or as directed by the Engineer.

3) The surface of the anchor bars shall be clean of rust, scale, dirt or other foreign matter.

4) Holes drilled for anchor bars shall be kept plugged until just prior to commencement of grouting operations. Before grouting, each hole shall be thoroughly flushed with water and cleaned with compressed air.

5) Water shall be removed from the hole before grouting. If the hole cannot be kept dry during grouting, the grout shall be introduced into the end of the hole through a pipe, which shall be gradually withdrawn as the hole is filled.

6) Portland cement shall be used for the grout mixture. Grout shall have water to cement ratio of between 0.4 and 0.6 by weight, and sand to cement ratio of 2:1 by weight, or as specified by the Engineer. Admixtures shall be approved by the Engineer.

7) The anchor bar shall be forced into the grout-filled hole before the initial set of the grout. The bar shall be vibrated or tapped in order to ensure good contact between the steel surface and the grout.

8) Bar ends to be embedded in the concrete structure shall be provided with hooks or L-shaped extensions welded to the bar to provide a good anchorage. In order to facilitate the inserting of the bars into the holes, the hooks can be welded to the anchor bar after installing. The welding and the overlap of the bar end with the hook(s) shall be as approved by the Engineer.

9) Anchors bars shall be protected after installations in such a manner as to prevent any movement until the grout has hardened. The Contractor shall replace any bars found to be loose after the grout has set.

10) The depth of holes indicated on the Drawings or as directed by the Engineer shall be measured from the effective excavation surface. Should the anchor bars be connected to the reinforcement steel of the

concrete structure to be anchored, longer bars shall be provided in case of over excavation, to maintain the required position in the structure.

4.4.5.5. ROCK BOLT / ROCK ANCHOR EXTENSIONS INTO CONCRETE

1) Threaded portion of Rock Bolts and Rock Anchor, where required to be extended into structural concrete, shall be protected during excavation and shotcreting operations and shall protrude sufficiently beyond the shotcrete. The extension shall consist of an L-shaped reinforcing bar of similar size (as that of the bolt/anchor) and shall be welded to the bolt. The welding and the overlap of the bolt with extension piece shall be as approved by Engineer.

4.5. SOIL NAILING

1. General

1) This Part specifies the requirements for the supply of materials and the construction of Soil Nail Structures. These consist of galvanized steel bars that are installed in drilled holes, grouted, fitted with galvanized plates and nuts and covered in a concrete facing

2) This technique consists of improving the soil slopes sometimes near vertical cuts by the inclusion of 150 mm iron nails. Due to the 'check dam' action, erosion of soil is prevented during rains and the danger of seeds and nutrients being washed away along with top soil is stopped. Thus, vegetation takes roots quickly and grows to cover the entire slope. Soil nailing offers a neat and economic solution to the problem of providing support to slopes/excavation, in particular for very compact granular soils

3) The Contractor shall comply with the requirements of this Part and the Soil Nail Structure Design / drawings, whichever is the higher standard

4) The contractor must follow the IS 14680 (1999): Landslide Control - Guidelines [CED 56: Hill Area Development Engineering] for Soil Nailing construction

2. Quality Requirement

The Contractor shall prepare and implement a Quality Plan that includes, at a minimum, the following documentation

a) Excavation:

i. Method and sequence for excavation of soil

ii. Method to protect the exposed soil surface from water and protection from drying out prior to nail and wall installation

b) Drilling and Nail Installation

i. Procedure for drilling of holes (including method of drilling, proposed use of temporary casing in unstable ground and method to remove drill casings without lowering the grout to soil bond strength);

ii. Procedure for inspection of the holes and reporting their condition;

iii. Procedure for removal or treatment of loose or softened soil;

iv. Procedure for installation of nails

c) Grouting:

i. Complete and comprehensive details of the grout proportions, additives, mixing and pumping equipment

ii. Details of the experience of the personnel supervising grouting activities

iii. Procedure for grouting, included proposed grouting pressure and method for ensuring that the grout completely fills the hole to the line of the excavated surface (particularly when temporary sleeves are used)

3. Material

a) Unless specified otherwise in any drawings, nails shall be hot dipped galvanised 500N deformed high strength steel reinforcing bar. Each nail shall be fully threaded steel bar with broad pitched thread. The diameter at the thread shall be greater than the nominal diameter of the bar to ensure higher load capacity at threads. Nails shall be formed in one length with no joints and shall not be welded. Nails shall be free of corrosion, damage and surface abrasions

b) Centralisers shall be fabricated from plastic, stainless steel, or other material non-detrimental to the nail. The bearing plate shall be fabricated from mild steel and not smaller than 200 mm x 200 mm x 20 mm thick. All metal components shall be hot-dipped galvanized in accordance with AS 4680 to produce a minimum coating thickness of 50 µm. Threads of the nails and nuts shall be cleaned by centrifuging, brushing or similar process after galvanizing in accordance with AS 1214. Care shall be taken during transportation handling storage and installation of the nails to prevent damage to the galvanizing.

4. Grout

i) Grout shall comply with the requirements specified below :

a) Minimum compressive strength at 7 days - 25 MPa

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b) Water cement ratio - Not exceeding 0.45

c) Consistency: Free from lumps and undispersed cement

d) Bleeding: Not to exceed 4% of the initial volume. All bleed water shall be reabsorbed after 24 hours

e) Volume change after 24 hours: within the range 0% to +5%

ii) Documented evidence that the proposed grout mix complies with the specified requirements shall be submitted at least 7 days prior to grouting operations commencing

iii) The Grout equipment shall :

(a) produce a grout that is free of lumps and undispersed cement

(b) include a positive displacement grout pump

(c) be equipped with a pump pressure gauge that can measure at least twice the intended grout pressure

(d) have a minimum of bends, valves and changes in diameter in the piping

(e) be sized to enable the grout to be pumped in one continuous operation; and

(f) include a mixer capable of continuously agitating the grout

5. Installation

a) General

i) The Contractor shall provide at least 14 days notice of the day that installation will commence, and 24 hours notice of the time that drilling of each soil nail will commence

b) Drilling and Insertion of Nails

i) Water shall not be used to remove drill cuttings. After drilling and prior to the nail being installed, the Contractor shall inspect the holes and provide a report confirming that:

a. the holes are in a condition suitable for installation of the nails;

b. the holes are located within the tolerance specified in the drawing

c. the nails are not corroded or damaged

ii) The soil nail shall be inserted and grouted on the same day as the completion of the drilling. Centralisers shall be used to ensure a minimum of 50 mm of grout cover over the nail. The centralisers shall:

(a) be placed at the top and bottom ends of the nail, with each not further than 0.3m from the top and bottom of the hole

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(b) be placed at sufficient locations not exceeding 2.5m, to keep the nail centralised and to maintain the minimum grout cover at all points along the nail

(c) not scrape away or otherwise disturb the soils at the surface of the drilled hole during installation of the nail; and

(d) be fixed to the nail and not move relative to the nail during installation or grouting

iii) The soil nail shall be installed in one operation and at a controlled rate to avoid damage to the nail and the drill hole. The nail shall be inserted into the hole to the required depth without difficulty. If the nail cannot be completely inserted, the Contractor shall remove the nail and clean or redrill the hole to permit insertion.

6. Tensioning the Nail

(a) Plates and nuts shall be attached as per Drawings. If precast panels are used, bearing plates shall be set normal to the nail by the use of non-shrink epoxy mortar (Epirez 633 or similar approved) and heavy duty grease shall be applied to the exposed section of the nail immediately prior to tensioning.

(b) Unless specified otherwise on the drawings, the nut shall be tightened with 150 Nm of torque after the grout and any sprayed concrete have obtained 50% of their 7-day compressive strength and the epoxy grout has cured.

4.6. POST-TENSIONED ROCK BOLTS (TENDONS)

4.6.1. GENERAL

Post-tensioned rock bolts (tendons) are tensioned reinforcing elements of higher capacity than the other reinforcing elements, consisting of high strength steel tendon fitted with a stressing anchorage (fixed length) at the inner end, a means permitting force to be transferred, and a head on the rock surface at the outer end. The post tensioned rock bolts shall be Double Corrosion Protection (DCP) in accordance to BS 8081:2015.

2) The Contractor shall furnish and install post-tensioned rock bolts of 2500 kN ultimate strength and 1250 kN working load in area and to the extent shown on the Drawings or as directed by the Engineer. The work shall be executed in stages, in step with the progress of the excavation, or after the excavation has proceeded downwards.

3) Installation of post-tensioned rock bolts includes excavation for concrete bases, placing of concrete bases, drilling and testing of holes, furnishing of rock bolts with all accessories, load cells, permanent corrosion protection of all elements of the rock bolt, primary grouting, stressing, testing, re-stressing, secondary grouting and finishing, and all other auxiliary and supporting works.

4) The anchor materials and parts, tensioning, installation and grouting procedure shall conform to the applicable Indian Standards (IS 10270) for temporary applications, and to the relevant International Standards (BS 8081:2015) Double Corrosion Protection (DCP) for permanent applications and shall be approved by the Engineer before incorporating into the work.

5) The entire work of drilling and grouting of drill holes for rock bolts, fabrication, installation and testing shall be carried out under the guidance and supervision of qualified professionals experienced in this specific field, and under strict quality control.

6) The entire work of drilling, grouting, fabrication, installation and testing of Post tensioned rock bolts (tendons) shall be carried out by a specialized agency having experience, equipment and technology for execution of these works and under strict quality control.

4.6.2. DEFINITIONS

The following terms are used in the text to conform to the International Standards:

Lock-off load is the load transferred to the head immediately after lock-off, before long-term losses start to occur.

Proof Load is the maximum test load to which a rock bolt is subjected.

Datum load is the level of load from which the rock bolt head displacement is measured during a stress test. In general, a value of 10% test load is adopted.

Suitability test is a load test to confirm that a particular rock bolt design will be adequate in particular ground conditions.

Acceptance test is the load test to confirm that the rock bolt conforms to the acceptance criteria. Each working rock bolt will undergo the Acceptance Test.

4.6.3. SUITABILITY TEST

The following terms are used in the text to conform to the international standards:

Lock-off load is the load transferred to the head immediately after lock-off, before long-term losses start to occur.

Proof Load is the maximum test load to which a rock bolt is subjected.

Datum load is the level of load from which the rock bolt head displacement is measured during a stress test. In general, a value of 10% test load is adopted.

1) The rock bolts for Suitability Tests (or test rock bolts) will be executed in accordance with the requirements of the relevant Indian Standards and where not covered by these standards to the applicable International Standards or as directed by the Engineer in order to find out suitable procedure for drill hole rock treatment prior to rock bolt installation and to determine the following:

a) To ascertain external rock bolt resistance in the actual ground conditions, in particular bond between grout and rock

b) To derive the optimum bond length and verify the adequacy of the fixed length of rock bolts as specified in the relevant Drawings in relation to their working capacities, ground conditions and locations so as to ensure a minimum factor of safety equal or bigger than that of the tendons, as specified by the manufacturer

c) To check the adequacy of the foreseen working procedures (drilling, consolidation grouting and rock reinforcing work) and design details of working rock bolts

d) To determine the apparent tendon free length

e) To establish acceptance criteria including creep criteria for testing of working rock bolts

f) To find out requirements to eventually consolidate entire rock below the head by pre-grouting the area before the rock bolts are homed in the drill hole.

2) Test rock bolts shall be installed and tested in some typical geological conditions expected in excavation prior to commencement of any installations of the permanent rock bolts. The Suitability Test rock bolts shall be used only for testing and not as a part of the permanent rock bolting system.

3) An accurate drilling and grouting record shall be kept for each test to allow a comparison of the test rock bolts with the permanent rock bolts (which have not undergone any tests). If too large deviations occur during the installation of rock bolts, the Engineer may order a new series of tests to be performed in different conditions.

4) The number of test rock bolts shall correspond to 2% of total rock bolts to be installed, but minimum 3 pieces shall be supplied for testing purposes and not used again.

5) The measuring equipment shall be able to measure displacement of 0.01 mm when creep is being measured.

6) The measurement of loads in rock bolts shall be by hydraulic or electrical load measuring device able to measure to an accuracy of better than 2% of the maximum applied load during each test. Any load measuring device used for load loss tests shall be able to measure loads to 0.5 % of the maximum applied load.

7) All Suitability Tests shall be carried out in the presence of the Engineer.

8) All the working rock bolts shall be subjected to Acceptance Test in accordance to BS 8081:2015 prior to their lock- off.

4.6.4. DRILLING HOLES AND WATER PRESSURE TESTING

Holes shall be drilled as specified herein and in accordance with applicable provisions of the Section "Drilling, Grouting and Pressure Relief Holes" at the locations and to the depths and inclination shown on the Drawings or as directed by the Engineer. The drilling method shall be suited to the type of ground and the necessary drill hole diameter.

2) Diameter of the holes shall be such as required by the manufacturer, or as directed by the Engineer. Depth of the hole shall exceed the total rock bolt length (including the fixed length) by 500 mm or by such additional amount as required in case drill cuttings cannot be removed from the bottom of the hole.

3) Holes shall be either drilled by rotary method with water flush or pneumatic percussion method with air and/or water flush or any other type such that the disturbances to the adjoining rock are minimal. Use of bentonite, rod grease or other lubricants on drill rods will not be permitted.

4) Drilling of the holes shall conform to the least of the following tolerances:
   a) Initial alignment when setting up the drilling rig shall not deviate by more than 2° from the specified axis of the drill hole.
   b) Deviation of the hole during drilling shall be limited to 1/30 of the overall hole length.

5) Core drilling shall be performed for exploratory purposes where required by the Engineer, and cores shall be stored in suitable core boxes and kept in a secure place.

6) The sequence of drilling of holes shall be approved by the Engineer before starting the work.

7) During the drilling operations, all changes in rock type should be recorded together with notes on drilling rates, flushing losses or gains, and stoppages.

8) After completion of the drilling in rock the entire length of the hole shall be washed out with clean water, as approved by the Engineer.

9) Each drill hole in rock shall be checked for water-tightness by means of water-pressure tests before the anchor is installed. After drilling of hole, tests shall be carried out on a length equal to fixed length plus 2 m and if water loss is found to be more than 3 Lugeon, consolidation grouting through the hole shall be carried out. The hole shall be re-drilled, water test repeated and the whole procedure repeated till a Lugeon value of less than 3 is obtained. The Contractor shall make a complete record of the water-pressure testing. This procedure is subject to approval by the Engineer.

10) The drill hole shall also be grouted and re-drilled if groundwater is entering the drill hole, or if during execution of the water-pressure tests water entry into neighboring drill holes can be observed.

11) Consolidation grouting shall be carried out with neat cement and water grout, the water cement ratio which shall be in the range of 0.4 to 0.6 by weight. Admixtures, if required, for improving workability or durability, to reduce bleeding or shrinkage or increasing rate of strength development and to ensure smooth flow properties and compactness of the grout, shall be tested and have to be approved by the Engineer prior to their use.

12) Upon completion, the drill hole shall be tightly plugged in suitable manner to prevent contamination by foreign matter. The hole shall be washed clean prior to inserting the rock bolt. In loose material the walls of the drill hole shall be supported by casing until the rock bolt has been installed. In earth or rock liable to swell the rock bolt shall be installed and grouted immediately.

13) Any hole that becomes clogged or otherwise obstructed before the completion of rock bolting operation shall be cleaned or re-drilled. If not possible another hole shall be provided by the Contractor.

4.6.5. MATERIAL AND CORROSION PROTECTION

(1) Permanent Anchors (strands) for permanent applications shall be approved by DIBt/ETA for atleast 100 years of design life in conformance to BS 8081 / EN 1537 for Double Corrosion Protection (DCP).

(2) The Double Corrosion Protection (DCP) Strand Anchor shall be composed of a number of Pre-stressing Steel strands of 15.7 mm dia and Grade 1860 shall be made consisting of seven cold drawn smooth individual

wires and conforming to IS 14268 or ASTM A416/A416M-12. Strands shall be delivered in coils of suitable diameter to prevent kink, properly protected against abrasion and corrosion protection by a factory applied method conforming to ASTM A416/A416M-12.

(3) Pre-stressing strands used are to be provided with PE sheathings in the area of the free anchor length at the applicant's factory, with the void between the strand and the sheathing being completely filled with suitable corrosion inhibitor complying with provisions of BS 8081 / EN 1537.

(4) DCP Strand Anchor complying with provisions of BS 8081 / EN 1537 shall have following corrosion protection as per below:

	No of Strands	Corrosion Protection System in the	
		Free Tendon Length L_{fs}	Bond Length L_{tb}
Double Corrosion Protection (DCP) Strand Anchor	1– 22	Plastic Sheathing around each individual strand, filled with corrosion protection compound at the factory; overall strand bundle within a corrugated plastic duct to be injected with inner cement grout in the borehole	Corrugated plastic sheathing, filled with inner cement grout either at the factory or in the borehole.

Anchor Head:

The pre-stressing strands must be anchored with wedges in the wedge plate as per below specifications:

Wedges- The pre-stressing strands must be anchored one by one in wedge plates using two- part wedges (round wedges). Suitable wedge must be used for 15.7 mm pre-stressing strands (nominal cross section 150 mm^2). Wedges must be manufactured in control factory production and evidence for the material and wedging properties must be produced with inspection certificate in accordance with DIN EN 10204. Wedges may be approved by Deutsches Institut für Bautechnik (DIBt) or other equivalent organization as per BS 8081/EN 1537 and comply with the requirements.

Wedge Plate- Wedge Plate must be provided with an external thread for verification purpose. The wedge plates rest with their entire surface on the anchor plates. Wedge plate must be manufactured in control factory production and evidence for the material and wedging properties must be produced with inspection certificate in accordance with DIN EN 10204. Wedge plates may be approved by DIBt or other equivalent organization as per BS 8081/EN 1537 and comply with the requirements.

Protection caps- The protection cap made of steel (Grade S235JR) with an inserted sealing washer made of perbunan is screwed on to the anchor plate and the void of which must be filled with corrosion protection

compound. Protection caps may be approved by DIBt or other equivalent organization as per BS 8081/EN 1537 and comply with the requirements.

Steel transition tube (steel tube)- The pipe socket must consist of steel (Grade S235JR) and have dimensions conforming to the number of strands as per BS 8081 / EN 1537. The trumpets are connected to the anchor plate on the air side end, and on the earth side end they overlap the corrugated sheathing. The overlap with the corrugated sheathing must be sealed by means of roll rings (closed cell- chloroprene rubber) arranged in pair. Steel transition tube may be approved by DIBt or other equivalent organization as per BS 8081/EN 1537 and comply with the requirements.

Anchor plate- Anchor plates with direct support on concrete or on steel transition structures, the anchor plates must be verified in accordance with applicable technical building regulations. Anchor plate may be approved by DIBt or other equivalent organization as per BS 8081/EN 1537 and comply with the requirements

Smooth and Corrugated Sheathing**-** Both smooth and corrugated sheathing to be used in anchor free length and full length respectively must be of PVC-U as specified by DIN EN ISO 1163-1, of polyethylene with a molding compound pursuant to DIN EN ISO- 1872-1 – PE, E, 45 T 022- or of polypropylene with a molding compound as defined by DIN EN ISO 1873-1- PP- B, EAGC, 10-16-003 or by DIN EN ISO 1873-1- PP- H, E, 06-35-012/022. Only sheathing without trapped air bubbles and with uniform pigmentation may be used. Unspliced tubes must be used as sheathing. It is necessary to ensure that only straight pipes are used. Sheathing of the individual strands in the free steel length Lfs must be made of polyethylene with the aforementioned molding compound and of dimension 19.7x1.25mm diameter (for strands 15.7mm diameter) must be used. The basic dimension of sheathing must be corresponding to no of strands in the post tensioned anchor system.

Tests should be carried out to ensure all materials used in the assembly of DCP Strand Anchors must be approved by DIBt or any other equivalent organization as per BS 8081/EN 1537 and comply with the requirements.

INSTALLATION AND ROCK BOLT GROUTING

1) A reinforced concrete pad shall be constructed on the prepared excavated ground in accordance with provision of the Section "Concrete". Concrete shall be of Class (M30/A20). No stressing of the rock bolt may be performed until the cube compressible strength of the base concrete has reached 20N/mm^2. Such admixtures shall be added in concrete, which allow the required strength to be developed within 72 hours

2) The tendon shall be slowly inserted into the hole in such a manner as to prevent damage and tangling of the individual wires/strands. At the bottom of tendon sleeve or nose cone shall be used to minimise the risk of tendon or borehole damage during homing. Special care shall be taken to ensure that existing corrosion protection (epoxy coating) remains undamaged during insertion into the hole.

3) After being inserted, the rock bolt shall be fixed in position so that no displacement can occur during the grouting work. The tendon shall be centred in the hole by spacers so that adequate covering with the grouting material is ensured as directed by the Engineer.

4) Immediately following installation of the rock bolt into the hole, the primary grouting of the anchorage zone and outside of sheathing shall be carried out. The grouting equipment must permit grout pressure up to 20 bars.

5) Grout shall have a water to cement ratio of 0.25-0.28. An admixture containing an efficient water reducing agent, a shrinkage compensating component and thixotropizing agent shall be used. The grout mix shall have strength development of min 25 MPa at 24 hours. Doses of the admixture shall be as per the manufacturer's recommendation to achieve the required properties.

6) Proper grout pipes shall be used to ensure grouting from bottom to top and achieve complete filling with neat cement grout. This requirement applies to all rock bolt grouting operations including end cap filling.

7) As soon as possible, after stressing or re-stressing have been completed and rock bolt has been accepted by the Engineer, the secondary grouting inside and outside of the sheathing shall be performed to encase completely the strands/wires for the full length of the hole and to fill all voids.

8) The recess left in the concrete pad for accommodating the head shall be filled with concrete if not otherwise directed by the Engineer.

4.6.6. STRESSING OF ROCK-BOLTS AND ACCEPTANCE TESTS

Stressing of the rock bolts shall be performed only when the grout has achieved minimum cube strength of 30 N/mm2 and only after the end anchorage/fixed length has acquired the required strength. The minimum time between grouting
of anchorage zone or concreting the pad, and stressing shall be established during the Suitability Tests or as specified by the Engineer.

2) The stressing shall follow a program submitted by the Contractor which shall include the sequence in which the rock bolts are to be stressed up to the test loads, the lock-off loads (Lock-off load = Design or Working load + Allowance of 10% for long term losses), any eventual stressing modifications to be made subsequently and tests to be carried out, and shall be approved by the Engineer.

3) All rock bolts shall be checked by means of an Acceptance Test (or simple stressing test) and at least 5% of the total number of rock bolts installed shall undergo the comprehensive stressing tests stipulated in the International Standards to the satisfaction of the Engineer.

4) During the Acceptance Test, behaviour of the rock bolt at the test load and the deformation shall be observed for a period of time in accordance with procedures established by the Suitability Tests. After reaching the test load the rock bolt shall be detensioned to zero or datum load (i.e. about 10% of test load) and thereafter stressed to lock-off load and further by the amount necessary to compensate for seating loss. Seating losses shall be restricted to 6 mm.

5) During the comprehensive stressing test, the rock bolt shall be tensioned in steps. Behaviour of the rock bolts shall be observed during the intermediate steps, the unloading periods and at the test load. The load shall be maintained at each step for a period of time in accordance with procedures established by the Suitability Tests. The load/deformation curve shall be recorded for loading and unloading. After reaching the test load, the rock bolt shall be detensioned to zero or datum load (i.e. about 10% of test load). Thereafter, the rock bolt shall be restressed to lock-off load and stressed further by the amount necessary to compensate for seating loss. Seating losses shall be restricted to 6 mm.

6) The Contractor shall record and compare, jointly with the Engineer, with the acceptance criteria all the important conditions and observations during the stressing procedure, the loads applied and the elongation of the tendon with each load increment. The values measured during the simple and comprehensive stressing tests shall be plotted and all records and graphs submitted to the Engineer.

7) The test load to which rock bolts shall be subjected during various tests shall be 80% of the guaranteed ultimate tensile strength (GUTS) of the tendon, if not otherwise specified by the Engineer. Lock-off load shall be 60% of GUTS of the tendon, if not otherwise specified by the Engineer.

8) Stressing shall be made by applying a single jack to all strands/wires. Jack shall be actuated by a hydraulic pack. In all stressing operations all wires/strands of a tendon shall be stressed simultaneously.

9) The measuring equipment shall be able to measure displacement of 0.01 mm when creep is being measured.

10) The measurement of loads in rock bolts shall be by hydraulic or electrical load measuring device able to measure to an accuracy of better than 2% of the maximum applied load during each test. Any load measuring device used for load loss tests shall be able to measure loads to 0.5 % of the maximum applied load.

11) All Acceptance Tests shall be carried out in the presence of the Engineer. Rock bolts which do not fulfil the acceptance criteria will be rejected the Engineer and replaced by the Contractor.

12) After the rock bolt has been tensioned, the stressing shall not be relaxed for any purpose, unless directed by the Engineer.

4.6.7. MONITORING

All rock bolts which have been stressed according to the Acceptance Test (simple stressing test) shall be load checked by lift-off test immediately after stressing and again 3 5 days later. Rock bolt shall be accepted only if the residual rock bolt load is more than 98% of the lock-off load, if the loss is more the rock bolt will be restressed and an additional load check shall be performed again after 3 5 days.

2) All rock bolts which will be tested according to the comprehensive stressing test shall be short term monitored during the time of installation of the working rock bolts by means of measuring the residual load with a hydraulic load cell so as to ensure that the residual rock bolt load is more than 98% of the lock-off load. If the loss is more, the rock bolt shall be re-stressed as described. The measuring Intervals as per international practice shall be as follows:

First week after stressing	Daily
Up to 3 weeks after stressing	Each 3rd day
Up to 6 weeks after stressing	Weekly
After 6 weeks to six months	Each 2nd week

or till the rock bolt is accepted by the Engineer.

3) Acceptance shall be subject to the condition that the loss in stress is less than 2% of the lock-off load.

4.7. MESH REINFORCEMENT

4.7.1. CHAIN LINK FABRIC

1) Chain link fabric shall be installed on surface excavations generally without shotcrete, to protect surfaces from which loose pieces of rock or boulders may fall.

2) Chain link fabric shall conform to the requirements of IS 2721 for Zinc-coated Steel Chain-Link Fence Fabric. The fabric shall have a mesh size of approximately 50x50 mm and a wire diameter of 3.15 mm.

3) The fabric shall be clean of mud, grease, oil or other foreign matter in case shotcrete is to be applied.

4) The fabric shall be placed against excavated surfaces and fastened to rock reinforcement, if present, with extra steel plates of minimum size 100x100x5 mm and nuts. The fabric shall be securely fastened to the rock at intermediate points between the rock reinforcement with steel pins. Sufficient pins shall be provided to ensure that the fabric is held tightly to the rock surface.

5) The installation of chain link fabric as reinforcement of shotcrete shall generally not be permitted. When the excavated surface is so uneven and rough that placing of welded wire fabric is impractical, use of chain link as reinforcement to shotcrete may be permitted by Engineer.

4.7.2. WELDED WIRE MESH

1) Wire mesh shall consist of welded wires in a fabric. Wire mesh shall be installed in surface excavation as reinforcement for plain shotcrete usually in combination with rock reinforcement. It may also be used with steel ribs, when it shall be laid over the outer flange of the rib and pinned or fixed to the excavated surface between the ribs where necessary.

2) Wire mesh shall conform to the requirements of IS 4948 (Welded Steel Wire Fabric for general use). The wire mesh shall have a square mesh of 100x100mm spacing with wire of 8Swg made of wires having yield strength not less than 275N/mm^2..

3) Where possible, the wire mesh shall be placed at the same time as the rock reinforcement is installed. It shall not be placed between the rock surface and bearing plates, but shall be placed over the heads of rock reinforcement, and fastened to them by separate plates and nuts. It shall be ensured that the fabric is drawn close to the excavated surface so that when SFR shotcrete is applied subsequently, the mesh neither sag nor vibrate excessively and impair the effectiveness of the shotcrete. In underground excavation, application of Plain Shotcrete with or without welded wire mesh at any portion shall be as per site geology & as decided by Engineer.

4) Welded wire mesh shall be fixed to rock with suitable mesh anchor (in addition to rock reinforcement nearby, if any) of minimum 5KN capacity at minimum spacing of 1m x 1m. Usage of wooden pegs or pins for fastening of the wire mesh to the rock surface will not be permitted.

5) Wire mesh shall be firmly stretched between the rock reinforcement and other fastening attachments.

6) Overlap of wire mesh shall be at least 3 times the mesh spacing with the clearance between parallel bars but not less than 300 mm.

4.8. STRUCTURAL STEEL SUPPORTS

4.8.1. GENERAL

1) The Contractor shall install the structural steel supports consisting of lattice girder and/or steel ribs with or without lagging (steel or concrete) in underground excavation to the shape as shown on the Drawings.

2) Structural steel supports shall be installed in conjunction with rock reinforcement and shotcrete as immediate support after excavation in the heading zone when the material encountered in the process of excavation requires such measures.

3) Steel ribs shall be furnished complete with bracing, bolts, nuts, washers, plates, tie rods, and other accessories necessary for installation of the supports. Wall plates and horizontal or bent steel bracing in the invert may be required.

4) Spacing of structural steel supports may vary as per site geology.

5) Lagging shall be furnished separately from steel ribs.

4.8.2. MATERIALS

4.8.2.1. STEEL RIBS

1) All steel sections and plates used for ribs and accessories shall conform to IS: 2062 "Structural Steel".

2) Steel for bolts, nuts and washers shall conform to IS 2062. "Specification for High Tensile Strength Structural Steel".

3) Material used in splices shall conform to the specification of the material being spliced.

4) All steel and fabrication thereof shall conform to the requirements of IS 800 "Code of Practice for use of structural steel in General Building Construction".

5) All welding, welding electrodes and workmanship shall conform to IS 814 and IS 816.

6) Latest revisions of the IS Codes where referred shall be applicable for this Contract.

7) Spacing of steel ribs may vary as per site geology. Steel ribs may be fully encased in Shotcrete/SFRS/Concrete in very poor class of rock as per site geology.

8) Steel ribs with or without invert bracing in very poor rock classes shall be as per site geology.

4.8.2.2. LAGGING

1) Lagging with backfilling are the longitudinal supporting members placed behind the steel ribs where necessary to support the walls and crown of the excavation.

2) Two different types of steel lagging are envisaged:

a) 2 to 3 mm thick to be used behind the steel ribs in profiles already excavated

b) 4 to 5 mm thick when they are to be pressed or hammered ahead of the heading face for protection.

3) Pre-cast reinforced concrete panels of 7.5 cm (minimum) thickness may be used as lagging instead of the steel profiles. Type of lagging used must be approved by the Engineer before the Contractor starts with the manufacture thereof. Concrete grade used shall be M25/A40 and reinforcement at the rate of 60 kg/m^3 minimum shall be provided.

4.8.2.3. LATTICE GIRDERS

1) Lattice girders shall be installed where shown on the drawings

2) Lattice girders shall consist of 3 nos., 25 mm or greater dia, as indicated in the drawings or as otherwise required by the Engineer. reinforcing bars forming an equilateral triangle of 100 mm or greater depth, laced together by 12 mm dia. reinforcing bars, or of 4 nos., 25 mm dia. reinforcing bars, as indicated in the drawings or as otherwise required by the Engineer, forming a square section of 140 mm depth.. The lattice girders shall be installed in similar manner as steel ribs. The accessories of lattice girders, like plates, bolts, nuts washers welding electrodes etc. shall be similar as indicated in 4.8.2.1. Lattice girders shall be fully encased in shotcrete/ SFRS.

4.8.3. EXECUTION

1) Steel ribs shall be cold bent within 1% of the theoretical excavation profile. Reshaping of the bent ribs at the place of installation may only be undertaken with Engineer's consent and only if the material properties would not be impaired. All structural steel used for ribs shall be true to dimension, square, plumb and level.

Joints and intersecting members shall be accurately fitted with adequate fastenings. All work is subject to acceptance by Engineer prior to installation.

2) The Engineer may, based on his judgment, instruct the Contractor to install structural steel support in the underground excavations, and the Contractor has to comply with this instruction with the minimal possible delay.

Whenever the Contractor encounters conditions to install structural steel support in the underground excavation, he has to notify to the Engineer immediately, who shall approve the installation.

The Contractor may, for his own purposes and at his own expense and risk, install structural steel support. However, this installation shall also be subject to the approval of the Engineer.

3) Excavation of tunnels/ adit shall be completed as close as possible to the "A"-line before installation of steel ribs. Steel ribs shall be placed at spacing as shown on the Drawings or as determined by the Engineer.

4) Concrete blocks or steel profiles provided as footings for horseshoe or D-shaped steel ribs, shall be founded on firm rock. Use of timber, as foot blocks shall be strictly prohibited. The footplates shall be of sufficient size and rigidity. If required, the legs of the ribs shall be anchored to the rock by the rock anchors. Where invert bracing is required, it shall be bolted securely to the lower legs of the steel rib in such a way that buckling is not induced in the steel rib by a presence of such bracing.

5) Immediately after placing the ribs in a correct position, they shall be interconnected and braced by means of steel rods or beams in order to prevent any displacement and to maintain spacing. Use of timber spreaders shall be strictly prohibited.

6) The space remaining between the outer flange of the steel ribs and the rock surface shall be backfilled immediately after the rib has been placed, with SFR shotcrete over the entire circumference of the steel rib in order to provide uniform load distribution. In over-excavated sections, the bulk of the void space may be filled with concrete blocks or rock pieces, followed by the SFR shotcrete. SFR shotcrete may also be required to be applied between the steel ribs and encasing them to form an arched bracing in the direction of tunnel centerline.

7) The Contractor shall survey and record the position of all steel ribs installed in order to facilitate drilling operations. Their position and chainage shall be marked on the finished concrete lining surface.

8) Blocking and wedges used to set the steel ribs may be timber, steel, or concrete blocks. If timber is used, it shall be placed as individual blocks with sufficient space to permit the blocks to be encased in the SFR shotcrete or concrete lining by at least the width of the wood block.

9) Any steel ribs which have been improperly placed or which have become misalign or damaged due to negligence of Contractor shall be adjusted, repaired or replaced by the Contractor as directed by the Engineer.

10) Lagging shall be placed behind the steel ribs where necessary to support the roof or the sides of the underground excavations. Where conditions require, it may, supported on the last steel rib erected, be pushed by pressing and/or hammering into the ground ahead and provide a temporary overhead protection while installing the next steel rib.

11) The space between the rock surface and the lagging shall be backfilled with cast-in-place concrete or plain shotcrete.

12) Backfilling between rock and lagging with rock spalls, bracing with timber and timber lagging shall be strictly prohibited.

13) Should Engineer consider additional support to be required because of buckling of steel ribs which have already been installed, or for any reason whatsoever, the Contractor shall install additional steel ribs or carry out any other repair or remedial work which Engineer requires.

4.9. TEMPORARY SUPPORTS

1) Temporary supports may be used to support sections of excavation not completed to final lines and grades or to facilitate installation of the permanent support.

2) All such temporary supports, lagging, or blocking which do not comply with requirements for primary support shall be removed by the Contractor prior to placement of the permanent support.

3) Timber may be used in temporary supports if specifically approved by the Engineer.

4.10. ADDITIONAL SUPPORT MEASURES REQUIRED IN POOR REACHES OF UNDERGROUND EXCAVATIONS

1) In general all poor reaches shall be supported by regular supporting measures (rock reinforcement, shotcrete [SFRS or Plain Shotcrete (with/without welded wire mesh as per site geology)], lattice girders, steel

ribs, etc.). However, certain ground conditions may require additional support measures as well. For such situations the additional support measures as described below shall be implemented at site as per directions of Engineer

4.10.1. PROBE HOLE

Probe holes of 50 mm dia. shall be undertaken with core recovery or otherwise as desired by Engineer. The probe holes shall be drilled up to approximately 10-15 m long for every 50 m length of excavation. Probe holes monitoring shall give an indication of rock type, rock mass and water inflows and provides important information on the upcoming tunnelling.

4.10.2. PRE-GROUTING

4.10.2.1. PRE-GROUTING WITH GROUT

1) Pre-grouting shall consist of drilling of 45 mm dia. holes (up to 10 m long) at an inclination of 5 to 10 degrees outgoing along the periphery at a spacing of 1.5 to 3 m. These holes shall be grouted using a neat cement grout mix

2) The maximum w/c ratio may vary between 0.4 : 1 to 1 : 1. Bentonite shall be added as necessary and as directed by the Engineer. Grouting parameters shall be adopted to suit ground conditions as determined by Engineer.

3) Suitable dispersing agent with dosage 1.5-2% of cement weight shall be used wherein ultrafine cement grout is resorted in pre-grouting, for which no additional payment shall be made. However, trial mixes should be carried out for grout optimization & its effect.

4) Grout pump should be of duplex-piston type capable of producing controlled pressure of 10 MPa. All pipes/hoses/other connections should be compatible to withstand maximum pressure of the grouting equipment.

5) Grout Mixer shall be a high shear colloidal mixer with minimum rotor speed of 1500 rpm.

4.10.2.2. PRE-GROUTING WITH COLLOIDAL SILICA

1) In case of very poor geological conditions and heavy ingress of water, pre-grouting with colloidal silica shall be carried out at a high pressure (>5 MPa) as directed by Engineer.

2) Pre-grouting with colloidal silica consist of drilling of 57 mm dia., 15-30 m long (with overlapping of 5 m) at an inclination of 10 to 12 degree outgoing all along the periphery and at the face (if required) at the spacing of 2 to 3 m.

3) Appropriate steel pipes/sleeves may also be required if necessary. Colloidal silica shall be of reputed make and duly approved by Engineer having viscosity of 5m Pa-s and particle size of 0.016 µm.

4) If required, pre-grouting with micro fine cement shall be carried out prior to pre-grouting with colloidal silica with the approval of Engineer.

5) Mixing capacity of grout pump shall have provision of colloidal mixture with RPM not less than 1500 RPM in case of ultra-fine or micro fine cement. In this case pre-grouting with micro fine cement grout will fill the joints with large apertures. Thereafter pregrouting with low viscous colloidal silica grout fill the finer joints and the joints filled with clay and silts.

4.10.3. FOREPOLING

1) Forepoling shall consist of installing 32 mm dia. reinforcing bars (up to 15-20 m long) at a close interval of 200 to 300 mm along the periphery of the tunnel inclined 5 to 10 degrees outwards from the periphery by hammering or by drilling and grouting.

2) In case, Drilling is required for installation of fore poles, the holes shall be fully grouted as per section 4.4.5 "Rock Anchor Installation".

3) The contractor shall deploy an expert or an expert agency for handling/executing pre-grouting/ fore poling so as to avoid cavity formation.

4.10.4. PIPE ROOFING

1) When ground conditions in tunneling are such that face cannot be supported by regular support like SFR shotcrete, rock bolts, steel ribs, pre-grouting and / or fore poling, the special technique of pipe roofing shall be required to be implemented as directed by Engineer.

2) As an option, the pipe roofing works may be carried out either by a specialized agency or by the Contractor's own in-house team, provided that the Contractor demonstrates adequate experience, qualifications, and resources to the satisfaction of the Engineer.

3) Depending upon the ground conditions, drainage in advance of rock mass ahead of the face with long drainage holes may be required.

4) Pipe roofing consists of high tensile seamless/electro resistive welding (ERW) pipe casing (maximum 21 m long) driven into the medium using a Symmetrix drilling system (or equivalent), using sacrificial drill bits or using retractable drill bit and lost pilot bit. The pipe diameter shall be of 89 mm with thickness as 10-12 mm. Alternate perforated pipes and plane pipes each of 3 m length are connected to each other using squeezed coupling or nipple coupling only, to create a positive connection. The pipes are spaced at 300 to 500 mm center to center along the periphery of the tunnel. The pipes are inclined 5 degrees outward from the periphery. The perforated pipes are then grouted in stages of 3 to 6 m using packer in each stage, using cement grout (w/c ratio varying between 0.8 to 0.4), at a pressure of 5kg/cm^2.

5) The entire system is required to form an umbrella ahead of face so that further excavation can be carried out in safer manner.

4.10.5. ROCK DOWELS GFRP TYPE

1) GFRP forepoling bars shall be manufactured from Glass Fiber Reinforced Polymer elements complying with ASTM D7957 or equivalent international standards, unless otherwise approved by the Engineer.

2) Bars shall be full-length solid GFRP rods, factory-made, with continuous helical thread and a nominal diameter as indicated on the Drawings or directed by the Engineer.

3) All GFRP bars shall be corrosion-resistant, non-conductive, and capable of sustaining the design bond strength when installed and fully grouted in place.

4) The surface of the bars shall be free from dust, grease, laitance, moisture or any foreign matter that may impair bonding with the grout.

5) Holes drilled for GFRP installation shall be kept plugged until the commencement of grouting; prior to grouting, each hole shall be flushed with clean water and blown with compressed air.

6) Grouting shall be carried out using a cementitious grout with water-to-cement ratio between 0.4 and 0.6,

or as approved by the Engineer; micro-cement may be used if specified.

7) Grout shall be introduced under controlled low pressure from the bottom of the hole, using a tremie pipe withdrawn progressively to ensure complete filling and avoid air pockets.

8) GFRP bars shall be inserted into the freshly placed grout before initial set; the Contractor shall ensure full encapsulation and uniform bonding along the entire bar length.

9) Installed bars shall be adequately supported to prevent displacement or vibration until the grout has fully hardened; any bar found loose after setting shall be replaced at the Contractor's cost.

10) The length, inclination, spacing and orientation of the GFRP bars shall be as shown on the Drawings; in case of over-excavation, the Contractor shall provide longer bars to maintain the required embedment.

4.10.6. PRE-DRAINAGE HOLES

1) Pre drainage holes are provided prior to the excavation in the poor reaches of rock, where there is heavy ingress of water. Pre drainage holes are provided as shown in the "Drawing(s)" or as directed by Engineer.

4.11. MEASUREMENT AND PAYMENT

4.11.1. GENERAL

1) The estimated quantities given in the Bill of Quantities for each type of rock supports specified in this Section are not to be considered as an accurate indication of the quantity of work, since actual amount of supports installed will be determined by the geotechnical conditions encountered in the course of work. The Contractor shall not be entitled to any extra payment over and above the Unit Prices entered in the Bill of Quantities by reason of changes to the actual quantity of each support type installed.

2) The prices entered in the Bill of Quantities shall be applied regardless if the work is performed on the surface or underground, regardless of the excavation method used, conventional full-face or partial excavation (e.g. top heading and benching) or mechanical excavation by raise-boring whether the rock supports are placed within the heading or in the rear zone. For the definitions of the various zones mentioned above see the Section "Underground Excavation".

3) Extensions/hooks provided on reinforcing elements shall be paid separately at unit rates indicated in Bill of Quantities.

4.11.2. ROCK BOLTS, SOIL NAIL, ROCK ANCHORS AND GROUTED ANCHOR BARS

4.11.2.1. TESTING AND MONITORING OF REINFORCING ELEMENTS

1) Payment will be made for the supply and installation of all rock reinforcing elements used in pull-out tests provided always that the rock reinforcement tested comply with these Specifications. Measurement for payment and payment will be as for rock reinforcement used for the Permanent Works.

2) Measurement for payment for supplying and installing load cells where directed by the Engineer will be as provided in the relevant section of these specifications.

3) Measurement for payment for testing of rock reinforcing elements will be made of the no. of tests performed on rock reinforcing elements installed as specified herein above or as required by Engineer. The payment will be made at the Unit Price entered in the Bill of Quantities for performing rock reinforcing elements tests complete in all respects and as specified herein above.

4.11.2.2. SOIL NAILING

Measurement for payment for soil nails will be of the total length of soil nails installed and approved by the Engineer.

2) Payment will be made at the appropriate Unit Price per linear meter entered in the Bill of Quantities, which shall include the entire cost of:

a) Purchase and delivery to the Site with all necessary accessories
b) Storage and protection at the Site
c) Drilling of the holes
d) Installation of the soil nails with all accessories
e) Furnishing of grout materials and grouting
f) Measurement for payment and payment for shotcrete shall be made in accordance with the provision of the section B-5 "Shotcrete."

4.11.2.3. EXPANSION SHELL ROCK BOLTS

1) Measurement for payment for supply and installation of expansion shell rock bolts will be of the length of expansion cell rock bolts of various lengths and diameters provided in the Bill of Quantities.

2) Payment will be made at the appropriate Unit Price per linear meter entered in the Bill of Quantities, which shall include the entire cost of:

a) Purchase and delivery to the Site with all necessary accessories
b) Storage and protection at the Site
c) Drilling of the holes
d) Installation of the rock bolts with all accessories
e) Stressing
f) Furnishing of grout materials and grouting.

3) This payment will be made only for expansion shell rock bolts installed in the works and approved by the Engineer.

4.11.2.4. RESIN GROUTED/ CEMENT GROUTED ROCK BOLTS

1) Measurement for payment for supply and installation of resin type rock bolts will be of the length of rock bolts of various length, grade and diameters provided in the Bill of Quantities.

2) Payment will be made at the appropriate Unit Price per linear meter entered in the Bill of Quantities, which shall include the entire cost of:

a) Purchase and delivery to the Site with all necessary accessories including resin capsules/cement capsule.
b) Storage and protection at the Site.
c) Drilling of the holes
d) Providing and installation of quickset resin cartridges
e) Installation of the rock bolts with all accessories
f) Stressing
g) Supplying of grout materials and grouting.

3) This payment will be made only for resin/cement grouted type rock bolts installed in the works and approved by the Engineer.

4.11.2.5. ROCK ANCHORS

1) Measurement for payment for rock anchors will be of the total length of installed and approved by the Engineer.

2) Payment will be made at the Unit Price per linear meter entered in the Bill of Quantities, which shall include the entire cost of:

a) Equipment and materials for erection of working platforms
b) Drilling of the holes

c) Washing and water-pressure testing (as required)

d) Furnishing and installing of steel bars, couplers, plates and nuts

e) Furnishing of grout materials and grouting.

3) Additional payment will be made for drilling with core recovery when such drilling has been ordered by the Engineer for exploratory purposes. The Unit Price for core recovery drilling will be paid per linear meter of drill hole as entered in the Bill of Quantities, and shall include the entire cost of equipment and labour necessary to obtain, store and protect the cores.

4) Additional payment will be made for consolidation grouting and re-drilling of a hole when such treatment has been ordered by the Engineer. Payment will be made as per the Section "Drilling and Grouting".

4.11.2.6. WATER EXPANDABLE FRICTION ANCHORS

(1) Measurement for payment for water expandable friction anchors will be of the total length installed and approved by the Engineer.

(2) Payment will be made at the Unit Price per linear meter entered in the Bill of Quantities, which shall include the entire cost of:

a) Drilling of the holes

b) Washing and cleaning of the holes

c) Furnishing and installing water expandable friction anchors as per the guidelines of the manufacturer and as directed by the Engineer.

4.11.2.7. SELF-DRILLING HOLLOW CORE ANCHORS

1) Measurement for payment for Self-Drilling Anchor will be of the total length installed and approved by the Engineer.

2) Payment will be made separately for each bar diameter at the Unit Price per linear meter entered in the Bill of Quantities, which shall include the entire cost of:

a) Furnishing and installation of Self Drilling Anchor with all accessories of the holes

b) Stressing and load/ pull out testing

c) Furnishing of grout materials and testing.

4.11.2.8. GROUTED ANCHOR BARS

1) Measurement for payment for grouted anchor bars will be of the total length of the bars installed and approved by the Engineer.

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2) Payment will be made at the Unit Price per meter entered in the Bill of Quantities, which shall include the entire cost of:

a) Drilling of the holes

b) Washing and cleaning of the holes

c) Furnishing, cutting, and installing reinforcing steel bars

d) Furnishing of cement mortar and filling the drill holes

4.11.2.9. ROCK BOLT / ROCK ANCHOR EXTENSIONS INTO CONCRETE

When a rock bolt/rock anchor is extended into concrete through welding, such extension shall be paid as weight of extension piece in Kg. Welded L-shaped piece of the grouted anchor bar shall also be measured and paid per kg weight installed.

4.11.2.10. PROTECTIVE COATINGS (GALVANIZATION AND EPOXY)

1) Measurement for payment for hot-dip galvanization or epoxy coating of rock bolts will be of the total theoretical weight (in kilograms) of the steel bars and related accessories (plates, nuts, and couplers) actually treated and installed as directed and approved by the Engineer.

2) Additional payment for protective coatings will be made at the Unit Price per kilogram (kg) entered in the Bill of Quantities, which shall include the entire cost of furnishing of all materials, specialized processing (hot-dip galvanizing or epoxy coating), thread reaming, logistics, quality testing, and field repairs required to provide the coating in full compliance with the specified standards.

3) Payment for these items will be made only when such treatments have been specifically ordered by the Engineer. No separate payment will be made for coatings applied by the Contractor for his own convenience or without prior written instruction.

4.11.2.11. MISCELLANEOUS STEEL PROFILES USED IN CONJUNCTION WITH ROCK REINFORCEMENT AND OTHER ROCK SUPPORTS

(1) Measurement for payment for miscellaneous steel profiles such as steel plates and all accessories will be of the weight of steel actually installed.

(2) Payment will be made at the Unit Price per metric ton entered in the Bill of Quantities, which shall include the entire cost of supply and installations.

4.11.2.12. EXCLUSIONS

No extra payment will be made for the following:

a) Loose and rejected elements, elements which fall out during trimming, slashing or widening, elements which are otherwise damaged or displaced as a result of Contractor's operations. The Contractor shall replace such elements at his own expense. If the rock condition in the underground excavation requires an immediate installation of the elements in the heading face, which will be destroyed later as the excavation advances, deviation from this rule may be granted after a mutual agreement between the Engineer and the Contractor.

b) Reinforcing elements which had to be installed as a consequence of Contractor's non-compliance with the approved drilling and blasting methods as specified in the Section "Underground Excavation".

c) No extra payment will be made for installation of temporary rock reinforcing elements (to be removed subsequently for widening, etc.) in temporary excavations (e.g. pilot shafts, multi drifts, etc.).

d) The threaded part of the rock bolt/ rock anchor protruding outside the hole shall not be measured for payment. The cost of the same shall be deemed to be included in the unit cost of the rock bolt/rock anchor.

e) Unit Prices for rock reinforcing elements in underground excavations shall apply regardless of the location or accessibility.

4.11.3. POST-TENSIONED ROCK BOLTS (TENDONS)

4.11.3.1. SUPPLY AND INSTALLATION OF ROCK BOLTS (TENDONS)

1) Measurement for payment for the supply and installation of post-tensioned rock bolts will be of the total length in linear meters of rock bolts installed, measured from the outer face of head to far end of the strands/wires. Payment will be made at the Unit Price per linear meter entered in the BOQ, which shall include the entire cost of drilling of the holes, supply of the rock bolts complete with all accessories including tendon head, storage and protection at Site, corrosion protection, installation, furnishing of grout materials and grouting, stressing, testing, re-stressing and monitoring. Equipment and materials used for enabling works like erection of working platforms shall be included in the Unit Price in linear meters of the rock bolts entered in the BOQ.

4.11.3.2. TEST ROCK BOLTS

1) Payment will be made for the supply and installation of post-tensioned rock bolts used in Suitability Tests. Measurement for payment and payment will be as for the post-tensioned rock bolts.

2) No extra payment will be made for the testing equipment for performing the Suitability Tests and simple and comprehensive stressing tests nor for plotting and submitting the stressing records. Load cells used for comprehensive monitoring shall however be paid under section B18 "monitoring instruments".

4.11.4. MESH REINFORCEMENT

4.11.4.1. CHAIN LINK FABRIC

1) Measurement for payment for chain link fabric will be of the net area (without overlaps) actually installed.

2) Payment will be made at the Unit Price per square meter entered in the Bill of Quantities, which shall include the entire cost of supply and installation of chain link fabric including overlaps, and the provision of all necessary accessories for fixing, such as steel pins and extra plates and nuts for fastening to rock reinforcement.

4.11.4.2. WELDED WIRE MESH

1) Measurement for payment for wire mesh will be of the net area (without overlaps) actually installed.

2) Payment will be made at the Unit Price per square meter entered in the Bill of Quantities, which shall include the entire cost of supply and installation of wire mesh, including overlaps, and the provision of all necessary accessories for fixing, such as steel pins and extra plates and nuts for fastening to rock reinforcement.

4.11.5. STRUCTURAL STEEL SUPPORTS

4.11.5.1. STEEL RIBS AND LATTICE GIRDER

1) Measurement for payment for supply and installation of lattice girder and steel ribs will be of the weight of lattice girder and steel ribs installed and approved by the Engineer.

2) Payment will be made at the Unit Price per metric ton entered in the Bill of Quantities, which shall include the entire cost of:

a) Supply, fabrication, bending of the ribs and lattice girders and delivery to the Site with all necessary accessories required for installation
b) Storage and protection at the Site
c) Transport to the place of erection and erection

d) Installation of all foot plates, wall plates, ties, bolts, nuts, washer, joint plates, cross-bracing and all other accessories, including all permanent or temporary welding

e) Backfilling with shotcrete, concrete blocks, or any other material approved by the Engineer, including cement and additives, except in accepted geological over break in which case the backfilling will be paid separately as stipulated in the Section "Underground Excavation"

f) Surveying and marking the position and chainage of lattice girder, ribs on the concrete lining.

3) For measurement and payment purposes, the weight of the lattice girder and steel ribs will be based on the unit weight of the steel profiles per linear meter, as stated on the certified copies of manufacturer's reports which the Contractor have submitted to the Engineer, or, in absence of such reports, as per IS Code standard weight and no pay for any variation beyond IS Code will be made.

4.11.5.2. LAGGING

1) Separate Unit Prices are provided in the Bill of Quantities for steel lagging and concrete lagging.

2) Measurement for payment and payment for steel lagging will be of the weight of lagging.

3) Payment for supply and installation of steel lagging will be of the weight of lagging actually installed and approved by the Engineer. Payment will be made at the Unit Price per metric ton entered in the Bill of Quantities, which shall include the entire cost of:

a) Supply, manufacture and delivery to the Site with all necessary accessories required for installation

b) Storage and protection at the Site

c) Transport to the place of installation and installation of lagging

d) Over-excavation beyond the Payline (B-Line) required for placing of lagging

e) Backfilling with concrete, grout, or SFR shotcrete, including cement and additives, except in accepted geological over break in which case it will be paid separately as stipulated in the Section "Underground Excavation".

4) For the measurement and payment purposes, the weight of the steel lagging will be based on the unit weight of the steel profile per linear meter, as stated on the certified copies of manufacturer's reports which the Contractor has submitted to the Engineer, or, in absence of such reports, by Standard IS Code weight.

5) Measurement and payment for furnishing and installation of precast concrete lagging will be of the volume of lagging actually installed and approved by the Engineer. Payment will be made at the Unit Price per cubic meter entered in the Bill of Quantities, which shall include the entire cost of:

a) Design and manufacture of concrete lagging including supply of cement aggregate, additives, steel reinforcement and formwork complete

b) Storage, transport to the place of installation and installation of lagging

c) Over excavation beyond the payline ("B"-line) required for placing of lagging

d) Backfilling with concrete, grout, or SFR shotcrete, including cement and additives, except in accepted geological over break in which case it will be paid separately as stipulated in the Section "Underground Excavation".

4.11.5.3. EXCLUSIONS

1) Rock reinforcement installed to hold the installed lattice girder/ steel ribs in position will be measured and paid under relevant items in the Bill of Quantities.

2) Shotcrete applied between, or encasing the lattice girder/ steel ribs will be measured for payment and paid for as stipulated in the Section "Shotcrete".

3) No extra payment will be made for the following:

a) Structural steel supports, which have to be replaced, repaired or re-erected as a result of Contractor's operation. The Contractor shall rectify or replace such steel ribs and lagging at his own expense

b) Structural steel supports which have to be installed as a consequence of the Contractor's non-compliance with the approved drilling and blasting methods as specified in the Section "Underground Excavation"

c) Weight difference in case the Contractor prefers installation of heavier or stronger steel supports or for additional ribs due to closer spacing than those ordered by the Engineer

d) Transport from the underground working zone back to the storage site, of any unused structural steel supports and further storage to and/or removal from the Site

e) Unused concrete/steel laggings.

f) Developing expert personnel or expert agency for a particular support element or grouting.

4.11.6. TEMPORARY SUPPORTS

No extra payment will be made for furnishing, erection, and removing of temporary supports of any kind and the entire cost thereof shall be included in the Unit Prices for other items of the Works.

4.11.7. PRE-GROUTING

1) Measurement for drilling of holes of 45/57 mm diameter will be the total length of the hole in meters.

2) Measurement for grouting will be the number of completed grouted holes, with each hole considered as one operation.

3) Cost of grouting material (except colloidal silica) shall be as provided in the relevant chapter of these Technical Specifications.

4) Measurement for colloidal silica used for pre-grouting will be by weight. Payment will be made at the Unit Price per metric ton entered in the Bill of Quantities, which shall include the entire cost of supply, delivery, transportation, storage, mixing, and all requirements specified.

5) No additional payment will be made for the use of dispersing agents when applied with ultrafine cement grout.

4.11.8. FORE POLING

1) Measurement for installation of fore poles (drilling/driving) will be the total length installed in meters. Payment will be made at the Unit Price per meter entered in the Bill of Quantities, which shall include the entire cost of materials, supply of fore poles, labour, equipment, and installation complete in all respects, except grouting.

2) Measurement for grouting of fore poles will be the number of grouted fore poles, with each fore pole considered as one operation. Payment will be made at the Unit Price per number entered in the Bill of Quantities, which shall include the entire cost of labour, equipment, mixing, connecting to the hole (where required), injecting grout, hole closure, and cleaning.

3) Cost of grouting material shall be as provided in the relevant chapter of these Technical Specifications.

4.11.9. ROCK DOWELS GFRP TYPE

1) Measurement for installation of Rock Dowels GFRP Type (drilling/driving) will be the total length installed in meters. Payment will be made at the Unit Price per meter entered in the Bill of Quantities, which shall include the entire cost of materials, supply of fore poles, labour, equipment, and installation complete in all respects, except grouting.

2) Measurement for grouting of Rock Dowels GFRP Type will be the number of grouted dowels, with each dowel considered as one operation. Payment will be made at the Unit Price per number entered in the Bill of Quantities, which shall include the entire cost of labour, equipment, mixing, connecting to the hole (where required), injecting grout, hole closure, and cleaning.

3) Cost of grouting material shall be as provided in the relevant chapter of these Technical Specifications.

4.11.10. PIPE ROOFING

1) Measurement for payment for pipe roofing will be of the total weight of the pipes installed.

2) Payment will be made at the Unit Price per kilogram entered in the Bill of Quantities, which shall include the entire cost of:

a) Drilling of the holes
b) Washing and cleaning of the holes
c) Supply and installing of pipes and bits
d) Grouting operation except the cost of grouting material.

3) Cost of grouting material shall be as provided in the relevant chapter of these Technical Specifications.

4.11.11. PROBE HOLES

Measurement for payment and payment for probe hole drilling shall be made in accordance with the provisions of the section B-7 "DRILLING, GROUTING AND PRESSURE RELIEF HOLES".

4.11.12. PRE-DRAINAGE HOLES

1) Measurement for drilling of pre-drainage holes will be the total length drilled in meters.
2) Payment will be made at the Unit Price per meter entered in the Bill of Quantities.

END OF SECTION B.4

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5. SHOTCRETE

5.1. SCOPE OF WORK

1) The work under this Section includes all labour, materials, equipment and services required for the execution of Shotcrete work to be carried out by the Contractor under this Contract. Shotcrete shall be applied to excavated surfaces both in underground and surface excavations, where shown on the Construction Drawings or as directed or approved by the Engineer.
2) The Contractor shall design the mix, furnish materials, place, cure and test shotcrete as necessary to provide temporary or permanent protection and/or support of excavated surfaces either in surface or underground excavations.
3) The Contractor shall furnish all materials, labour and equipment for preparing test panels, both for trial mixes and during the course of the work, and for testing cores from panels or from in-situ shotcrete.
4) When the shotcrete is applied as a temporary rock supporting or protection measure, the number and thickness of layers to be applied shall be governed by the prevailing rock conditions and will be determined by the Engineer.
5) When the shotcrete is intended to remain as a permanent lining or protection of rock surfaces, the thickness of such lining shall be as shown on the Drawings or as directed by the Engineer.
6) Shotcrete shall be placed with or without steel wire mesh reinforcement, as directed, and may be used in conjunction with rock bolts, steel ribs and other rock supporting measures.
7) The Contractor shall maintain adequate stockpiles of materials for shotcrete for immediate use in cases of emergency. Any damage or delay resulting from shortage of such materials shall be the Contractor's entire responsibility.
8) Methods and workmanship in the application of shotcrete shall be in accordance with IS: 9012 or BS EN 14487-1:2022 (Sprayed concrete Definitions, specifications and conformity).

5.2. DEFINITIONS

1) Shotcrete is defined as a mixture of cement, aggregate, water, with or without steel fibre of high steel quality along with admixtures and accelerators (alkali free) in correct proportions, with maximum size of aggregates less than 10 mm, projected at high velocity from a spray nozzle on to a surface to form a layer of pneumatically applied concrete on that surface. Mixes with aggregate size less than 4.75 mm will be used mainly as a thin protection against loosening of rock surfaces immediately after excavation. Mixes with aggregate size greater than 4.75 mm will be used in subsequent layers and mainly to fill the cavities caused by overbreak or weathering and for protection of rock surfaces after excavation. Shotcrete can be either wet or dry mix.
2) Dry-Mix Process: The cement, aggregates and accelerator batched by weight, are thoroughly mixed dry (with enough moisture to prevent dusting) and fed into a purpose-made machine wherein the mixture is

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pressurised, metered into a dry air stream and conveyed through hoses or pipes to a nozzle in which water as a spray is introduced to hydrate the mix which is projected without interruption into place.

3) Wet-Mix Process: All materials including cement, aggregates weight batched and mixed together with water, but without accelerators, to produce mortar or concrete. The mixture is then conveyed by positive displacement or compressed air to a nozzle where air and accelerators are injected to increase velocity, and projected without interruption into place.
4) Flash coat is a term used for sprayed concrete applied as a thin layer protecting, priming or finishing the surface.
5) Layer is a term used for a discrete thickness of shotcrete built up from a number of passes of the nozzle and allowed to set.
6) Rebound is a term used for all material, which, having passed through the nozzle does not adhere to the target surface.

5.3. SUBMITTALS

1) At least 30 days from the date of issue of Notification to Commence, the following submittals shall be made for approval:
    a) Details, including numbers and type of equipment proposed for mixing and applying the shotcrete.
    b) Qualifications and experience of the proposed personnel (foremen, nozzlemen and delivery equipment operators) and the specialist for the steel fibre shotcrete for approval of Engineer.
    c) Manufacturers' certificates giving full details of any proposed admixture, and the Contractor's proposal regarding the use of such admixtures, including certification of harmlessness to operators,
    d) The Contractor's proposed mix proportions prior to the commencement of testing and work,
    e) Details of methods to be employed for controlling the thickness of the layers of shotcrete applied (e.g. plug gauges or boreholes).
    f) Technical details of steel fibre, micro silica/silica fumes and suitable admixtures.
2) The selection of method, i.e. dry-mix or wet-mix process as defined above is Contractor's option for surface work. If the Contractor intends to apply the dry-mix process, he shall submit to the Engineer all relevant documents and references to prove that such method will in no way impair the quality and efficiency of the work, will not cause any increase in cost and will have no negative impact to the environment. However, in underground works only wet shotcrete shall be permitted.

5.4. MATERIALS

5.4.1. GENERAL

1) Cement used in shotcrete shall conform to IS: 9012, OPC cement should be preferred.
2) The cement shall be purchased by the contractor at his own cost, while the source will be identified by the Employe/Owner as specified in General Condition and Particular Condition of the Contract.
3) Cement, aggregates, water, admixtures, shall conform to the requirements of the Section "Concrete", except as specifically amended hereafter. The reinforcement of shotcrete can be done with welded wire fabric and/or steel fibres, as indicated in the Drawings.
4) The water content of aggregate at the time of incorporating into the mix shall be less than 2% by weight of oven dry aggregate.
5) Air used to apply shotcrete shall be clean and free of oil and other contamination.

5.4.2. AGGREGATES

1) Aggregate gradation used in shotcrete shall conform to those established by the preconstruction trial mix tests. The gradation shall not be changed without the prior approval of the Engineer.
2) The following aggregate gradation shall be taken as a guide for mix design purposes, but may be modified, subject to the results of the trial mix tests specified hereinafter:

Square Mesh Sieve Opening (mm)	% Passing (by weight)
9.500	90-100
4.750	73-100
2.36	37-72
1.18	51-36
0.60	22-50
0.30	11-26
0.150	4-12
0.075	2

3) Should the nature of the aggregates used during the course of the work change (e.g. source, rock type, shape) from that used in the trial mix tests, the Contractor shall produce new trial mixes, using the new aggregates.

4) In principle the shotcrete shall be applied in layer thickness that shall not exceed 50 mm.

5.4.3. ADMIXTURES

Admixtures shall be used to develop fast setting and high early strength of shotcrete, to ensure good workability, low pumping pressure, adequate slump retention and low rebound, as approved by the Engineer, conforming to requirements of relevant standards. Only proven admixtures which meet the requirements of the specifications on field trials and long-term satisfactory performance on other projects already constructed

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shall be approved. The admixture used shall have acceptable service records of at least five years use in this type of application and the suitability and the required amounts thereof shall be established during preconstruction tests. It shall not contain water-soluble chlorides or materials corrosive to steel, and shall not entail other detrimental effects, such as cracking and spalling of applied shotcrete. The consumption of admixtures shall be recorded daily. The average content may reach 4.5%, however the maximum content shall not exceed 6% of the weight of cement.

1) **Super plasticisers:** Shall meet the requirements of ASTM C 494 type F shall be compatible with cement & accelerator. Super plasticisers shall be added at the batching plant to keep the shotcrete mix workable during transportation and to ensure good pump ability at an acceptable low water cement ratio. The Super plasticisers shall be free of chlorides.
2) **Accelerators:** Accelerator (alkali free) shall be added to the mix to speed-up the setting rate of the cement. The accelerator shall be added at the nozzle.
   Testing of accelerators in accordance with this specification with regard to setting time and early strength gain shall be in accordance with the following:

a)	Initial set of cement/admixture paste	3 min
	Final set of cement/admixture paste	12 min
b)	3-hour strength of shotcrete	0.7 N/mm^2
	8-hour strength of shotcrete	4.0 N/mm^2
	24-hour strength of shotcrete	10.0 N/mm^2

5.4.4. STEEL FIBRES AND MICRO SILICA

1) Steel fibres for shotcrete reinforcement shall be made up of high-quality steel comprising of loose cold drawn wire fibre with hooked ends glued in bundles conforming to EN 14889-1 Fibres for concrete – Part 1: Steel fibres – Definitions, specifications and conformity.
2) Fibres shall have aspect ratio i.e. length/dia. ratio shall be 65 and tensile strength 1000 N/mm2. Tolerance shall be according with ASTM A820.
3) Fibres shall be with CE marking, system 1.
4) Fibre length: 35-60 mm.
5) Micro silica shall have chemical and physical properties conforming to IS: 15388.
6) Micro silica and other admixtures shall be of reputed brand as recommended by the manufacturer and approved by the Engineer.

5.5. MIX DESIGN AND QUALITY REQUIREMENTS

5.5.1. Normal Shotcrete

1) Shotcrete mix shall be designed by the Contractor such that they achieve the strengths specified. The mixes shall be approved by the Engineer.

2) The cube compressive strength at 28 days for structural or permanent shotcrete shall be 35 N/mm^2 and compressive cylinder strength shall be 28 N/mm^2. The compressive strength after 7 days shall reach 70% of the specified strength at 28 days.
3) To determine that the shotcrete meets the requirements to the compressive strength, the in-situ strength requirements given below shall be met, which are based on a 50 mm diameter by 100 mm long core and include a 0.85 reduction factor to allow for effects of in-situ coring.

Minimum compressive strength (MPa)	
Strength class	C28/35
Core	24

4) Mixes shall be such that the aggregate gradation and cement content after placing are as those obtained from samples taken from test panels produced using approved trial mixes. All constituents shall be uniformly dispersed throughout the mix. The minimum cement content shall be 450 kg/m^3.
5) The water content of the mixes shall be limited to prevent sloughing. The water-cement ratio of fresh shotcrete in place shall be between 0.32 and 0.40.
6) The Engineer reserves the right at any time during the progress of the work to instruct the Contractor to vary the proportions of the constituents of the shotcrete or order further trial applications to ensure that adequate strengths are maintained.
7) Plain shotcrete may be placed with or without wire mesh as per drawings or as directed by Engineer.

5.5.2. Steel Fibre Reinforced Shotcrete (SFRS)

1) SFRS mix shall be designed by the Contractor such that they achieve the strengths specified based on trials undertaken at site with the help of specialist to be engaged by the contractor. The quantity of steel fibre shall likely be 25-30 kg/cum of shotcrete for E700 and 35-40 kg/cum for E1000 class of Steel fibre Reinforced Shotcrete which is to be firmed up based upon trial mix as approved by the Engineer.
2) The cube compressive strength at 28 days for structural or permanent shotcrete shall be 40 N/mm^2 and compressive cylinder strength shall be 32 N/mm^2 or 35 N/mm^2 and compressive cylinder strength shall be 28 N/mm^2 as indicated in the drawings. The compressive strength after 7 days shall reach 70% of the specified strength at 28 days.

3) To determine that the shotcrete meets the requirements to the compressive strength, the insitu strength requirements given below shall be met, which are based on a 50 mm diameter by 100 mm long core and include a 0.85 reduction factor to allow for effects of insitu coring.

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Minimum compressive strength (MPa)	
Strength class	C32/40
Core	27

4) Mixes shall be such that the aggregate gradation and cement content after placing are as those obtained from samples taken from test panels produced using approved trial mixes. All constituents shall be uniformly dispersed throughout the mix, and the assumed cement content shall be 500 kg/m^3.
5) The water content of the mixes shall be limited to prevent sloughing. The water-cement ratio of fresh shotcrete in place shall be between 0.32 and 0.40.
6) Steel Fibres shall not be used as first component in the mixer; however, steel fibres can be introduced together with sand and aggregates or can be added in freshly mixed concrete.
7) Fibres which tend to form fibre balls during batching and mixing shall not be used.
8) The Engineer reserves the right at any time during the progress of the work to instruct the Contractor to vary the proportions of the constituents of the shotcrete or order further trial applications to ensure that adequate strengths are maintained.
9) Micro silica shall be added approximately 8 to 12% by weight of cement.

5.6. TESTING

1) For the purpose of approving mix design by Engineer, Contractor shall prepare initially not less than a set of three test panels for each mix for testing at least 56 days before any shotcreting work is started. For any subsequent change in additive or equipment the Engineer may order fresh testing. All tests shall be done as per IS: 516 and IS: 9012.
2) For the purpose of routine quality control, the number of panels to be supplied shall generally consist of 3 for every 50 m^3 of shotcrete to be placed.
3) The set of three test panels for mix design approval and for routine quality control shall consist of one shot downward onto a horizontal surface, one shot onto an inclined or vertical surface and one shot overhead onto a horizontal surface.
4) Test panels for shotcrete quality control and to determine the suitability of additives shall be made as specified herein and in accordance with the requirement of Engineer.
5) The Contractor shall furnish all plant, materials and assistance necessary and carry out all work to obtain representative tests panels of shotcrete.
6) Test panels shall be obtained by securely attaching an approved 1m x 1m by 80 mm deep steel box to an area of rock similar to that to be shotcreted or an approved alternative surface arrangement, wetting the box and applying shotcrete to the area contained by the box in the manner specified herein and using the same mixing and placing equipment to be used for the works. The test panels shall be constructed alongside the area of placement and at the same angle and shall be sprayed by each nozzleman in

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rotation so that the tests shall represent the quality of the sprayed concrete being placed by each nozzleman. The test panels shall be stored and cured alongside and under similar conditions to the sprayed concrete placed in the Works.

7) All test panels shall be of a minimum thickness of 100 mm, and shall be made in the presence of Engineer. The panels shall be left undisturbed at the point of placement until the final set has taken place.

8) Test panels and specimens shall be transported by the Contractor to the site laboratory immediately after final set has taken place, not sooner than two hours and not later than eight hours after manufacture, and in such a manner as to prevent them from being damaged in any way.

9) Compressive strength tests shall be performed on drilled cores from the sprayed concrete structure or from the sprayed test panels. Six cores of a minimum diameter of 50 mm shall be cut from each test panel at right angles to the plane of the panel approximately 48 hours after the panel has been sprayed. The cores for the 28 days compression test shall be sampled from the panel after 21 days in order to decrease damages during coring operation. The panel shall be stored in the site laboratory to avoid the direct exposure to the sun. Cores shall not be taken within 10 cm of the edges of the panel. Their minimum diameter shall be 50 mm and the height/diameter ratio shell be in the range of 1.0 to 2.0. Test results from cores with height/diameter ratio different from 2.0 shall be converted to equivalent cylinder strength using the values given in table below.

Conversion factors to equivalent cube and cylinder strengths

Height/diameter ratio of core	Cube factor	Cylinder factor
2.00	1.15	1.00
1.75	1.12	0.97
1.50	1.10	0.95
1.25	1.07	0.93
1.10	1.03	0.89
1.00	1.00	0.87
0.75	0.88	0.76

10) The crushing strength of the shotcrete shall be determined by testing 75 mm cubes drawn from the test panels immediately before testing and shall be capped and tested in accordance with IS:456

11) Cubes test results will be statistically analysed in accordance with the recommendations of IS: 516. Test result shall be consistent with the average 28 days compressive strength required to limit the probability of test falling below the specified crushing strength to one out of every five tests with a coefficient of variation of 15% for tests for mix design approval and 20% for tests for quality control. The average of any six consecutive tests shall not be less than the specified crushing strength.

12) Core test results will be statistically analysed in accordance with the recommendations of IS: 456. Test results shall meet all the acceptance criteria specified in IS: 456. All cores shall be suitably labelled to identify them with the panels from which they have been taken, and the location in the Works to which they relate.

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13) In the event that test specimens fail to meet the specified requirements, Engineer may order Contractor to take in place 80 mm diameter core specimens of placed shotcrete associated with such specimens. If tests performed on cored specimens indicate that the shotcrete fails to meet the specified requirements of in situ strengths then Contractor shall carry out such remedial works as Engineer may require, including placement of additional shotcrete, and if deemed necessary repair and/or removal and replacement of shotcrete.
14) Tests for steel fibre reinforced shotcrete shall be as per European standards (EN)or equivalent IS.
15) The minimum performance class should be E700 (700 joules of minimum energy absorption when testing shotcrete according to EN 14487-5 1 part 5: Determination of energy absorption capacity of fibre reinforced slab specimens). Performance class E 1000 (1000 joules minimum) may also be required for difficult ground/rock condition.
16) Preconstruction tests shall be performed. Tests shall be carried out on a sufficient quantity of sprayed concrete in order to reach a uniform flow. It shall be demonstrated that the requirements can be met before start of execution. The preconstruction tests shall be performed with the same personnel, materials equipment and spray method which will be used during production. Conformity for energy absorption capacity is obtained when at least two of three test panels have an energy absorption capacity not lower than the specified energy absorption capacity according to the specified class given and the mean value higher to the specified class given.
17) Performance and control criteria should be specified following the EN 14487-1, taking account the requirement of the project.
18) When additional requirements for the residual strength is required, test should be done on three-point bending test. This three-point bending test is carried out on the test specimen described in EN 14488-5.
19) Should any of the cores reveal defects such as a lack of compaction, dry patches, voids or sand pockets, the Contractor shall take further tests or cores from the remainder of the panel(s) or reject the procedure used and remake a test panel with a modified procedure.
20) When required, the Contractor shall make 25 mm diameter probe holes to determine the thickness of the shotcrete (or alternatively, place plug gauges where required). When required, the Contractor shall cut sets of minimum 50 mm diameter cores from the finished shotcrete, which shall be tested using the same procedure as on cores taken from the test panels.

5.7. EQUIPMENT

1) Only modern, properly operating mixing, delivery, and placing equipment approved by the Engineer shall be used for the performance of the work.
2) The compressor shall provide a supply of air adequate to maintain sufficient nozzle velocity for all parts of the work while simultaneously operating a blowpipe for clearing away rebound when required.
3) The delivery equipment shall be a pneumatic feed type or, for the wet-mix process, positive displacement type. The equipment shall be capable of delivering a continuous smooth stream of uniformly mixed material at the proper velocity from the discharge nozzle at all heights of the work.

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4) The delivery equipment shall be thoroughly cleaned at the end of each shift. Equipment parts, especially the nozzle liner and water ring, shall be regularly inspected and replaced as required.
5) The discharge nozzle, for the dry-mix process, shall be equipped with a manually operated water injection system (water ring) for directing an even distribution of water to the aggregate- cement mixture. The water valve shall be capable of ready adjustment to vary the quantity of water and shall be convenient for the nozzle man.
6) Water pressure shall be maintained at a uniform level which shall be at least 1 bar above operating pressure and sufficient to ensure adequate hydration at all times.
7) The nozzle shall be capable of delivering a conical uniform discharge stream. Distortion of this stream shall be remedied by examination of the nozzle and any malfunction rectified by replacement of defective parts before further work is carried out.

5.8. PROFICIENCY OF WORKMEN

1) Nozzlemen shall have had previous experience in the application of coarse aggregate shotcrete or shall work under the immediate supervision of a foreman or instructor with adequate experience in, and full knowledge of, spraying techniques and shall have at least five years of spraying experience including two years as a nozzleman. Each crew shall demonstrate acceptable proficiency in the application of shotcrete to vertical and overhead test panels before beginning production work. Only approved work crews shall perform the work.
2) The acceptable shotcrete shall consist of a dense uniform concrete without major rebound inclusions and without discernible weakness of bond between layers. The nozzlemen shall shoot shotcrete with a uniform consistency and at the wettest consistency short of the sag point. The nozzle shall be held at a predetermined distance and position so that the stream of flowing material shall impinge as nearly as possible at right angles to the surface to be covered.

5.9. SURFACE PREPARATION

1) When shotcrete is to be applied to excavated surface immediately after blasting, the surfaces shall be prepared by a minimum of scaling followed by washing with clean water. All surfaces shall be wet & clean and already shotcreted surface on which another shotcrete layer is to be placed, free of rebound, at the time of application of shotcrete. The surface shall be kept moist until shotcrete is applied.

2) Where water flows from the rock against which shotcrete is to be placed and that water cannot be sealed off by shotcreting alone, the water shall be excluded from the area by caulking or diverted by pipes, pans or other approved means in such a manner that the shotcrete will be unaffected by action of the water

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through percolation, by hydrostatic pressure or erosion. No plugging or damage shall be made during spraying to drain holes, water collecting gutters or pipes.

3) A layer of shotcrete, which is to be covered, immediately by a succeeding layer shall first be allowed to take its initial set. A layer of shotcrete, which is to be covered by a succeeding layer after its final set has taken place, shall have all laitance, loose material, dirt or other deleterious material and rebound removed by sweeping with brooms, sluicing or other means acceptable to the Engineer.

4) Shotcrete surfaces shall be kept moist until either the succeeding layer of shotcrete is applied or alternatively the curing requirement set out in this Section has been observed.

5) At any time during surface preparation, the Engineer may order Contractor to apply shotcrete to isolated areas before proceeding with surface preparation due to safety reasons in case of emergency.

5.10. MIXING AND PLACING

1) Shotcrete materials shall be accurately weigh-batched before mixing. Aggregates shall be thoroughly mixed without the addition of water before being deposited in the placing equipment. Mixes, which are not applied within 60 minutes of adding cement, shall be discarded. Rapid hardening additive shall be accurately proportioned.

2) The minimum thickness of shotcrete in any one layer shall be 25 mm. The maximum thickness of shotcrete applied in any one layer at any location shall be 50 mm.

3) The Engineer will examine rock faces following blasting and scaling in underground excavation. On the basis of such examination, the Engineer may require immediate shotcreting of surfaces, in which case shotcrete shall be applied within 4 hours of blasting and before drilling the next round. Shotcrete equipment shall be available before blasting where poor rock conditions are anticipated so that shotcrete can be applied with minimum delay.

4) Shotcrete, other than that placed immediately after blasting, shall not be placed in any area until all blasting within 20 m of the area has been completed, unless otherwise approved by the Engineer.

5) Shotcrete in open area works shall not be carried out when shotcrete cannot be placed effectively because of adverse weather conditions unless adequate cover is provided over the working area until the shotcrete has been cured sufficiently to prevent damage.

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6) The Contractor shall develop operating procedures and operations to give:
   a) minimum rebound,
   b) Smooth finished surface,
   c) no hollow areas in the shotcrete,
   d) minimum of shrinkage cracks,
   e) good adherence of the shotcrete to rock or other surface.

7) The flow of the material at the nozzle shall be continuous and uniform and the rate of application over any given area shall also be uniform. Slugs, sand spots, wet areas or other defects shall be cut out and corrected as specified herein.

8) An approved method of establishing layer thickness, such as the use of plug gauges or boreholes, shall be employed.

9) In shotcreting vertical or steeply inclined surfaces, other than roofs of underground excavations, application shall begin at the lowest point and the shotcrete layer shall be built up in horizontal strips until the entire surface is covered.

10) Where drain holes have been drilled and instruments have been installed into rock on which shotcrete is to be placed, the Contractor shall take all necessary precautions to prevent such holes from being plugged or instruments from being damaged.
11) When shotcreting is to be performed near existing structures, Contractor shall ensure that no damage results to the structure and shall protect the surfaces of structures before and during shotcreting.

12) Application of shotcrete in any area shall be considered complete when the shotcrete has been built up to the thickness specified. The thickness of shotcrete specified on Drawings shall be the minimum thickness measured anywhere in the treated area.

13) Where shotcrete is placed over wire mesh and supporting bolts, it shall be covered with shotcrete to a depth of at least 25 mm. Where rock bolt extensions are to be added to existing rock bolts, the exposed ends of the rock bolt threads shall be suitably protected before shotcreting. The steelwork and reinforcement shall be cleaned of loose rust, oil, scale, paint and any coating or previously deposited rebound material which might prevent a proper bond prior to the application of shotcrete. Welded wire mesh shall be installed where required, as specified in the Drawings.

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5.11. REBOUND

1) Rebound shall be kept to a minimum and continuously monitored. Special care shall be taken that rebound does not build up at the junction of walls and floors both underground and on the surface.

2) Rebound shall be removed and disposed of before any adjacent area is shotcreted. Rebound shall not be reused.

3) Contractor shall make every effort to keep rebound to a minimum. If, in the opinion of the Engineer, rebound is excessive, he may require the Contractor to revise the mix design or the application procedures or take other measures deemed necessary to reduce the rebound.

5.12. PROTECTION, CURING, AND FINISHING

1) Suitable screening of the nozzle and of the application surface shall be provided during periods of windy or draughty conditions.

2) Freshly laid shotcrete shall be protected from rain or water until the surface is of sufficient hardness to prevent damage.

3) When dry specks first appear at the surface of any shotcrete layer, it shall be wetted with a water jet at least once in every 4 hours or otherwise cured to the satisfaction of the Engineer for a minimum period of 7 days. Membrane curing shall not be used when a further layer of shotcrete or other bonded finish is to be applied.

4) In underground excavations and surface excavations the shotcrete shall be water cured.

5) The surface of the shotcrete shall be left as shot without any finishing. As an exception, the surface of the annulus of reinforced shotcrete placed at the internal surface of the tunnel concrete lining shall be smoothened.

5.13. REPAIR

1) Before a succeeding layer of shotcrete is placed, the preceding layer shall be checked for drumminess.

2) The Contractor shall repair all drummy, sandy, cracked or spalled areas and any other areas where, in the opinion of the Engineer, the shotcrete is faulty, by removing the shotcrete to a sound area of rock or shotcrete, carrying out surface preparation as specified herein and replacing that area to the satisfaction of the Engineer.

5.14. TOLERANCES

In exceptional circumstances and only under the approval of the Engineer, the following tolerances may be accepted:

1) For shotcrete on natural surfaces or surfaces with an undefined shape, the thickness at any point shall not be less than 80% of the specified nominal thickness and also the average thickness of shotcrete shall not be less than specified nominal thickness.

2) The thickness over the individual protruding rock pieces may not be less than two-thirds (2/3) of the specified nominal thickness.

5.15. MEASUREMENT AND PAYMENT

5.15.1. General

1) Measurement for payment for shotcrete will be of the volume of shotcrete placed. The volume will be calculated from the payment area of shotcrete multiplied by the specified thickness as shown on the Drawings or as directed by the Engineer. When significant overbreak due to geological conditions is observed, the shotcrete used to reshape the design conditions of the excavation shall be paid separately as instructed by the Engineer.

2) The payment area for surface excavation works is defined as the projected area over the plane parallel to the plane of average excavation.

3) The payment area for underground excavation works is defined as follows:
   a) When excavated profile does not extend beyond "B" Line as defined in the Section "Underground Excavation", the payment area will be the radial projection of irregular area covered by shotcrete on to the excavation pay-line (i.e. B-line perimeter multiplied by length along the underground opening),

   b) When excavated profile extends in the portions of geologically accepted overbreak as defined in the Section "Underground Excavation", an imaginary line parallel to B-line will be drawn in such a way that it depicts average line of the actual excavation. In case perimeter of such an imaginary line is less than or equal to the perimeter of a line parallel to and 300 mm beyond B-line, the payment area will be calculated by considering perimeter of pay-line (B-line) only, as described in (a) above. However, in case perimeter of such an imaginary line is more than the perimeter of a line parallel to and 300 mm beyond B-Line, the payment area will be calculated by multiplying the perimeter of such an imaginary line with length along the underground opening.

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4) Payment will be made at the Unit Price per cubic meter entered in the Bill of Quantities which shall include the entire cost of, but not be limited to, the following:
   a) All labour, plant and materials including cement and admixtures.
   b) Transportation and storage of cement from Owner's stockyard/store up to silos close to the batching and mixing plant.
   c) Batching and mixing of all materials, water supply, preparation and cleaning of surfaces,
   d) Placing of plug gauges for control of layer's thickness,
   e) Shotcrete material wasted in rebound,
   f) Temporary protection, curing and testing,
   g) All activities related with performance of material testing.

5) The Contractor shall not be entitled to any extra payment over and above the Unit Prices entered in the Bill of Quantities for application of shotcrete within heading zone or bottom range zone as defined in the Section "Underground Excavation".

6) The in-situ volume of shotcrete placed in underground works shall be deducted from the volume of structural concrete lining and backfill concrete behind steel lining /ribs to be measured for payment as stipulated in the Section B-9 "Concrete".

7) Shotcrete placed by Contractor in excess of thickness shown on the Drawings or as specified by the Engineer will not be measured for payment.

5.15.2. Materials

1) No separate payment will be made for the nominal cement content as indicated in this Section i.e. 450 Kg/m^3 for normal and 500 Kg/m^3 for SFRS.

2) In case the required minimum specified compressive strength of the shotcrete/SFRS cannot be reached, or is attained with the specified cement content, variation of cement content will be assessed separately and paid to the Contractor or recovered from the Contractor as the case may be and as specified herein.

3) Measurement for payment for variations of Portland cement content used for shotcrete will be of the quantities, by weight in kg, of cement approved and computed on the basis of the number of cubic meters of shotcrete measured and approved for payment. The amount of cement required per cubic meter of shotcrete will be as established at trial mix stage or the approved modifications thereof as established by the Engineer in the course of shotcrete work.

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4) Payment will be made at the Unit Prices entered in the Bill of Quantities, which shall include the extra cost of provision, delivery, transportation, etc. from owner's stockyard/store to Contractor stockyard/store/worksite, storage and mixing, and complying with all requirements specified.

5) No separate payment will be made for the accelerators and the cost thereof shall be included in the Unit Price for shotcrete.

6) Cost of Superplasticizers used shall be separately paid at the Unit Price per kg as in case of Concrete.

7) Steel fibres and micro silica in fibre reinforce shotcrete shall be paid at the Unit Price per kg entered in the Bill of Quantities.

END OF SECTION B.5

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6.1. SCOPE OF WORK

1) This section covers all labour, materials, equipment and services required in the construction of the Coffer Dam Embankments.

2) It does not refer to work on roads or other minor embankment works.

3) The embankment works shall be executed generally in accordance with the Drawings and this Technical Specification or as the Engineer may direct.

4) Specific sub-sections of this chapter illustrate zoning, grading and compaction criteria to be applied for the coffer dam embankments.

5) In addition to any limitations on the gradings of the fill material or any compaction requirements which may be determined by site testing and experiments, the Engineer reserves the right to modify, during the progress of the work, any other features which he considers necessary for the proper performance of the completed works.

6) The approval given by the Engineer to the Contractor's plants and equipment or their operation, or of any construction methods shall not relieve the Contractor of his full responsibility for the proper and safe execution of embankment works or any obligations under this Contract.

6.2. SUBMITTAL

6.2.1. SUBMITTALS BEFORE CONSTRUCTION

1) At least 60 days prior to the commencement of the embankment construction the Contractor shall submit to the Engineer for approval the proposed quarry working method and results of trials and tests carried out at the quarry site.

2) During the progress of trial embankments and tests, the Contractor shall submit to the Engineer copies of all records and results of tests.

3) At least 30 days before starting the construction of dam embankment the Contractor shall submit for the Engineer's approval, a detailed construction programme and method statement for the coffer dams embankment works.

4) Within 30 days from the date of issue of Notice to Commence and prior to the delivery of the compaction plant to the Site, the Contractor shall provide the Engineer with all the manufacturer's data, drawings, and

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computations to verify compliance with the specified compaction requirements. The characteristics and efficiency of this equipment shall be subject to the approval of the Engineer.

6.2.2. SUBMITTALS DURING CONSTRUCTION

1) To enable the Engineer to verify the condition of the prepared foundation surface, the Contractor shall notify the Engineer in writing, giving at least 7 days notice before the commencement of placing any embankment fill.

2) At least 7 days prior the commencement of placing of any filter layer the Contractor shall submit for Engineer's approval details of proposed filter design, materials source and methods of placing and compacting.

6.2.3. PROGRAMMES AND RECORDS

In addition to the contractual requirement for the construction programme, the Contractor shall prepare and submit the following programmes and records at the times stated in a form which shall be agreed and approved by the Engineer:

1. Before the start of foundation excavation: submission of a bar chart programme showing the period required to excavate the volume calculated between quoted significant chainages and elevations with the assumed monthly rates of production.

2. Before the start of embankment fill production: submission of a bar chart programme showing the period of production of construction material based on the assumed monthly rates of production of each type of material and the volumes and characteristics of each portion of material to be stored in stockpiles.

3. Before the start of embankment fill placing: submission of a bar chart programme showing the period of the volume to be placed in each zone of fill above foundation level between quoted significant chainages and for increments in elevation of not more than 2.00 metres with the assumed monthly rates of production.

4. During the progress of the work: submission of a daily record showing the volumes excavated, the volumes of production of each type of material, and the volumes placed in each zone of fill for the previous day together with equivalent cumulative values for the month.

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5. Not later than 3 days after the end of each month: submission of drawings of construction in progress with several typical cross sections and a plan of the upper surface of each embankment section showing the fill levels reached at the end of the previous month.

6.3. MATERIALS

6.3.1. GENERAL

1) The construction materials shall be taken from the rock quarries shown on the Drawings or from other approved sources as directed by the Engineer.

2) Materials originating from excavation for Permanent or Temporary Works may also be used as fill materials, but only when such materials have been approved for such use and only within specified zones.

3) The rockfill embankment is divided into zones with material classifications defined on the drawings.

6.3.2. ROCKFILL MATERIAL

1) The construction materials shall be taken from the Quartzite and Phyllite rock quarries, borrow areas or from other approved sources. Materials originating from excavation for Permanent or Temporary Works may also be used as fill materials, but only when such materials have been approved for such use.

2) The principal material to be used in the construction of the coffer dams shall comprise sound rock fragments (rockfill) obtained by blasting or processing rock from quarries, or by selection from excavated materials arising from other parts of the Works.

3) The required grading of rockfill shall be obtained by selective and suitable exploitation of the quarry.

4) The rockfill embankment is divided into zones with material classifications defined on the Drawings.

5) When required, screening shall be by any suitable method (e.g. "grizzly" or bar screens) including, if necessary, vibrating screens and washing facilities.

6) Rejection by the Engineer may be made at the source, on the transporting vehicle, or in place.

7) Final acceptance of rockfill will be made only after the materials have been dumped, spread and compacted in place.

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8) The Contractor shall co-operate with the Engineer to ensure that only acceptable rockfill materials be hauled from the source to the work site.

9) The type of material and requirements for the various zones of the coffer dams are described in the Tender Drawings and here below.

6.3.3. EMBANKMENT ZONES

1) The zones designated here are a preliminary indication and will be specified in the construction design and Drawings. During the construction, to better utilise available materials, further changes may be implemented and included in the revised drawings, which shall be issued prior to the implementation of any changes.

2) The different characteristics and functions of the various zones for the main embankment are defined by the corresponding numbers shown on the Drawings.

3) The grading curves of the different zones, together with their compaction requirements (i.e. layer thickness, water content, etc.) are a preliminary indication and will be specified in the construction design and drawings, after further analysis carried out during construction through relevant in situ tests.

6.3.3.1. UPSTREAM COFFER DAM

Zone 1A: Silty Sand (SM) and silt/fat clay (CH)

It constitutes the upstream part of the pre-cofferdam, aimed at improving overall impermeability.

Zone 1B: Well graded sand (SW)/Gravel (GW)

It constitutes the core of the upstream pre-cofferdam where diaphragm wall cut-off is carried out (specifications for diaphragm wall cut-off are included in Section B08).

The main features are preliminary set as follows:

- D100 (mm) 20
- Ltk (mm) 300
- 10 t Passes no. 4

Zone 2B (Phyllite): Transition between Membrane > 3A

The Membrane base, with a thickness of about 1.5 m, provides the transition from the main embankment to the membrane, aimed at protecting the membrane from abrasion and puncturing. It shall comprise phyllite from the quarry or from selected excavated material of maximum size 80 mm.

The main features are preliminary set as follows:

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- D100 (mm) 80
- Water (l/m3) 100-150
- 10 t Passes no. 4
- Width (m) 1.5

Zone 3A (Quartzite): Drainage Filter Transition between zone 2B and downstream RCC steps > 3B

This zone is a transition between the upstream zone 2B and zone 3B, and between downstream RCC steps and zone 3B, and consists of selected quarry Quartzite rock with maximum size of 500 mm. The zone will be placed in 500 mm thick layers and compacted with 4 passes of 15 ton vibratory roller, watered with 150 l/m3. The width of this zone is about 1.5 m. The main features are preliminary set as follows:

- D100 (mm) 500
- Ltk (mm) 500
- Water (l/m3) 150
- 15 t Passes no. 4
- Width (m) 1.5

Zone 3B (Quartzite): Main Rockfill

The remaining portion of the embankment consists of quarry Quartzite particles up to 1.000 mm. This zone will be placed in 1.000 mm thick layers and compacted with 6 passes of 15 ton vibratory roller, watered with 150 l/m3. The main features are preliminary set as follows:

- D100 (mm) 1000
- Ltk (mm) 1000
- Water (l/m3) 150
- 15 t Passes no. 6

Zone 4: Rip-Rap Material

The rip-rap protection layer consists of quarry rock (Quartzite or equivalent approved material) with particle sizes up to 1000 mm, placed on the upstream surface of the pre-cofferdam to ensure stability and prevent erosion of the underlying clay layer. The material shall be placed in a single layer with controlled placement to achieve proper interlocking. No mechanical compaction is required; however, stones shall be arranged to ensure stability. Minor adjustment and filling of voids with smaller stones may be required.

The main features are preliminarily set as follows:

- D100 (mm) 1000
- Ltk (mm) 1000

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6.3.3.2. DOWNSTREAM COFFER DAM

Zone 2B (Phyllite): transition between 1B > 3B

It serves as base layer for the membrane, as well as a transition between the membrane and zone 3A. The main features are the same of those indicated above for the same zone of the Upstream Coffer dam.

Zone 3A (Quartzite): Transition between zone 2B > 3B

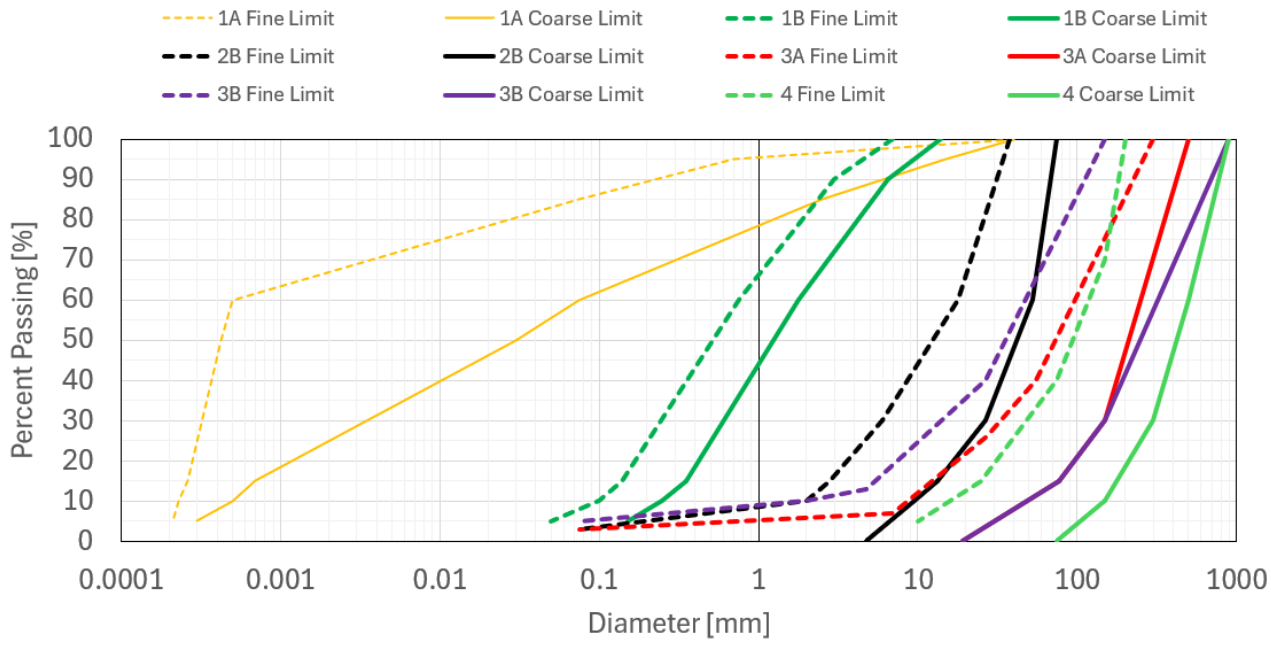
This zone is a transition between the superficial zone 2B and zone 3B. The main features are the same of those indicated above for the same zone of the Upstream Coffer dam.

Zone 3B (Quartzite): Main Rockfill

The remaining portion of the D/S embankment consists of quarry Quartzite particles, with the same characteristics of zone 3B indicated above for the Upstream Coffer Dam.

6.3.3.3. GRADING LIMITS

The preliminary grading limits of the materials to be used for the construction of the cofferdams zones in loose materials are indicated in the grading curves provided below. Such curves shall be considered as general guidance. The final grading curves will be indicated in the construction drawings or specified by the Engineer, which shall take precedence over the aforementioned reference curves.



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6.3.4. DOWNSTREAM FACE PROTECTION (U/S COFFER DAM)

The downstream face of the upstream cofferdam shall be protected by a revetment system composed of RCC carapace composed of stacked slabs each 0.50 m thick and 5.0 m long. Side walls shall be provided to channel any overtopping flows, with a design height of approximately 3.0 m.

At the downstream toe of the cofferdam, an RCC block shall be constructed to enhance the stability of the downstream slope.

For the specifications related to RCC works reference shall be made to the relevant section of these Technical Specifications, namely Section B20.

6.3.5. GEOMEMBRANE

The PVC geomembrane is foreseen to be placed along the wet face of the U/S and D/S Coffer Dams and shall form a continuous impermeable barrier extending from the pre-cofferdam crest and the main coffer dam crest in accordance with the Drawings and Engineer's instructions.

The works include all ancillary materials, preparation of surfaces, protection layers, anchorage systems, and all operations necessary to ensure long-term watertight performance.

All works related to installation of geomembrane shall be carried out in accordance with good engineering practice and to the satisfaction of the Engineer.

6.3.5.1. MATERIALS

a) GEOMEMBRANE

Unless otherwise specified, the PVC geomembrane shall meet the following minimum requirements:

- Thickness ≥ 2 mm
- Tensile strength compliant with ASTM D6693 or equivalent
- Elongation at break ≥ 600%
- Puncture resistance compliant with ASTM D4833
- Permeability effectively impermeable

The geomembrane shall be supplied in rolls, free of defects, holes, or contamination.

b) PROTECTION LAYERS

Geotextiles or protective cushioning layers shall be provided below the geomembrane where in contact with rockfill to prevent puncture or abrasion.

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Nonwoven needle-punched geotextile is recommended to meet the above purpose, with a minimum mass per unit area of (or as specified in Drawings):

- 500 g/m² for membrane lying directly on concrete curbs (Upstream Cofferdam)
- 1000 g/m^2 for membrane lying directly on rockfill material (Downstream Cofferdam)

c) ANCHORAGE MATERIALS

Anchorage components, including clamps, anchor trenches, or mechanical fastening systems, shall be corrosion-resistant and compatible with the geomembrane.

6.3.5.2. CONCRETE CURBS

1) Concrete curbs shall:
   - Provide a regular and stable support surface for the geomembrane installation;
   - Ensure proper alignment and continuity of the upstream face of the coffer dam;
   - Prevent localized stress concentrations and potential damage to the geomembrane;
   - Facilitate drainage and avoid water accumulation beneath the membrane, where applicable.

2) Concrete shall comply with the requirements specified in Section B09 – Concrete.

3) Curbs shall be constructed with the dimensions and spacing shown on the drawings. The top surface shall be smooth, continuous, and free from abrupt irregularities. Edges shall be rounded or chamfered (minimum 20 mm) to prevent damage to the geomembrane. Alignment tolerances shall ensure compatibility with the geomembrane installation requirements.

4) The surface of the curbs shall be finished to a dense, closed texture, free of honeycombing, laitance, sharp protrusions, or loose material. Any defects shall be repaired prior to geomembrane installation. The surface shall be clean and dry before placement of the geomembrane or any intermediate layer (e.g., geotextile).

5) Curbs shall be inspected for geometry, surface finish, and defects prior to geomembrane installation. Any non-conforming areas shall be repaired or reworked to the satisfaction of the Engineer.

6.3.5.3. INSTALLATION

Geomembrane placement shall be performed by qualified personnel experienced in hydraulic liner systems.

The liner shall be positioned to minimize wrinkles and stress concentrations and shall follow the vertical alignment indicated in the Drawings.

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Panel overlaps shall be welded using thermal fusion methods. Welding shall be continuous and uniform, producing watertight seams. Installation shall proceed under suitable weather conditions. Placement during excessive wind, rain, or extreme temperatures shall not be permitted.

6.3.5.4. SEAMING AND TESTING

All field seams shall be welded and tested using non-destructive methods such as air pressure testing, vacuum testing, or spark testing, as applicable.
Destructive seam testing shall be performed at a frequency agreed with the Engineer. Any defective seams shall be repaired and retested.

6.3.5.5. ANCHORAGE AND TERMINATION

The geomembrane shall be securely anchored in designated trenches or fixing systems near the cofferdam crests and head of cut-off walls. Terminations must ensure continuity, mechanical stability, and watertightness, with no unsupported sections remaining after installation.

Connection to the diaphragm cut-off wall shall be achieved as follows:

- The diaphragm wall head shall be cleaned of laitance and debris, and a uniform layer of plastic sealant applied to provide a flexible, watertight interface before casting the plinth.
- A Besaplast FM 350 waterstop (or equivalent) shall be installed within the plinth, with its lower bulb embedded at the sealant/diaphragm interface and its upper part extending to the plinth surface.
- Concrete shall be cast against the diaphragm head without displacing the waterstop.
- The geomembrane shall be laid over the plinth and mechanically anchored, ensuring a continuous hydraulic barrier between the face liner and the internal waterstop system.

6.3.5.6. QUALITY CONTROL

The Contractor shall implement a quality control program including:

- material certification verification
- inspection of surface preparation
- seam testing
- installation records

All results shall be submitted to the Engineer.

6.3.6. QUARRY OPERATIONS

1) The rockfill for the major part of the Coffer dam embankments shall be obtained by operating the quarries.

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2) The operation of quarries shall generally be in accordance with requirements included in Section B02 and particularly the specification in respect of blasting in that Section.

3) Before commencement of embankment construction, the Contractor shall carry out trials as specified at the designated quarry sites to ascertain the optimum methods for production of the rockfill materials.

4) The aim of the trials and tests shall be to establish an efficient system by which to produce fill material within the specification requirements with the minimum of additional treatment or screening and to minimize wastage.

5) As a result of such tests and trials the Contractor shall propose for the Engineer's approval a quarry working method. If approved, subject to any modifications required by the Engineer, this method shall become the standard operating procedure for the quarry and shall only be varied or changed by agreement with the Engineer.

6) The Contractor shall provide and maintain facilities at the quarry to enable the selection of any special grading of fill material for particular zones of the dam as specified herein and on the Drawings or as subsequently instructed by the Engineer. On completion of the Works the Contractor shall ensure that the quarry is left in a safe and tidy condition to the satisfaction of the Engineer.

6.3.7. ORGANIC MATTER

No organic matter shall be included in the Coffer dams construction and the Engineer reserves the right to reject complete loads of fill where the organic content is high or mixed with the fill so as to preclude satisfactory removal.

6.3.8. STOCKPILING OF EMBANKMENT MATERIALS

1) The Contractor shall stockpile embankment materials, graded or not, in such a manner as to fulfil the construction programme without delay.

2) The period, volume, location, etc. of the stockpiling, shall be in accordance with the requirements of relevant section of the Technical Specification and shall be entirely the Contractor's responsibility.

6.4. TRIAL EMBANKMENT

1) After the completion of the quarry exploitation trials and at least 2 months before the commencement of placing any of the embankment zones previously described, the Contractor shall carry out tests and trials to optimise the selection, placing and compaction of materials in the embankments.

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2) These trials shall continue during the initial stages of construction of the Coffer dams.

3) Such tests and trials shall be as specified by the Engineer, generally in accordance with quality control tests described in these specifications and will be supervised by the Engineer, to whom copies of all records and results shall be submitted.

4) Such tests and trials shall be sufficient to clearly demonstrate suitable methods by which to obtain the specified requirements for the finished works.

5) The trial embankments shall be constructed by the equipment and methods described in the following sub sections for "Placing" and "Compaction".

6) The trial embankments shall be of sufficient size to simulate all the operations for the permanent works and to optimize the placing and compaction techniques.

7) Not less than 2 embankments each of at least 200 m3, excluding ramps, shall be constructed.

8) The materials and plant to be used in the trial embankments shall be similar to those proposed for the permanent works.

9) The construction of the trial embankments shall be used to determine the optimum method of compaction using the specified equipment for each zone of the embankments.

10) In collaboration with the Engineer, the Contractor shall determine the pattern and the number of roller passes required to achieve the specified requirements of each zone.

11) Up to 8 passes of the specified compaction plant shall be used. These methods shall then be adopted on all subsequent embankment work unless otherwise approved by the Engineer.

12) Subsequent work and tests on samples may be used to determine modifications to the compaction methods but any changes shall be submitted for the Engineer's approval.

6.5. FOUNDATION PREPARATION

6.5.1. GENERAL

1) The foundation for the Coffer dam embankments shall be excavated generally in accordance with the requirements of the Section B02 of the Technical Specifications.

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2) All overhanging rock shall be detached by barring or wedging and all loose or semi detached blocks shall be removed from the foundation surfaces.

3) The exposed rock surface in the foundations shall be cleaned by means of water and/or air jetting and shall then be inspected by the Engineer.

4) Where residual soil material is exposed in the foundations, the surface will be compacted according to the Engineer's instructions and filter layer shall be placed over the area as directed by the Engineer.

5) Where erodible material might be exposed in the foundations, the surface will be compacted according to the Engineer's instructions and specially selected and graded material shall be placed over the area as directed by the Engineer to provide a specifically designed filter as directed by the Engineer.

6) To assess the quality of foundations the Engineer may require sampling and testing to be carried out on the material exposed in the foundations and the Contractor shall provide all facilities to assist the execution of such sampling and testing.

7) In particular cases, e.g. faults, the removal of soft or decomposed material and surface protection by shotcrete may be directed by the Engineer.

8) Preparation of foundations shall include the provision of adequate drainage and dewatering to ensure sufficiently dry working conditions for the operations in progress.

9) The placing of fill to form the embankments may proceed only with the approval of the Engineer, which will be based on the condition of the foundation determined by inspection after the completion of all foundation preparation works. The Contractor shall be responsible for maintaining the foundation surfaces in the approved condition until they have been covered by fill material.

6.5.2. PROCEDURES FOR CHECKING EMBANKMENT EXCAVATIONS

1) The following procedure for checking each section of the dam excavation at site will be carried out as soon as a significant area of the foundation (1,000-2,000 m^2) is excavated.

Geometry:

- As-built topographical survey is made by the Contractor following embankment excavation.
- The excavation geometry resulting from the as-built topographical survey is plotted together with the design geometry on plan and profile.

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- The Designer's Representative may optimize the foundation levels shown on the drawings in accordance with the actual characteristics of the foundation and paying due attention to the structural requirement of the Dam.

Rock Mechanics:

- This section applies when rock is found along embankment foundation
- Contractor and/or Designer's geologists will perform the geological mapping and geomechanical preliminary assessment of the excavation following dam excavation.
- If the geomechanical parametres significantly differ from the design parametres, the matter shall be studied by the Designer and, if and where needed, investigation and/or re-profiling and/or specific treatment of excavation prescribed.
- The Contractor shall allow safe access and cleaning to the portion of excavation to be inspected.
- At the end of the process a provisional "release" for the examined foundation area will be issued by the Designer on the inspected excavation. The final "release" of the examined foundation area will be issued after the final inspection carried out when the instructed foundation treatment has been completed.

6.5.3. CLEANING, PREPARATION AND PROTECTION OF EXCAVATION OF THE EMBANKMENT

1) Material shall not be placed in any part of the embankment until the foundation for that part has been dewatered, cleaned, suitably prepared, mapped and approved by the Designer.

2) Prior to placement of fill the area shall be dewatered, major geological features mapped, and lineament and major fracture zones treated as specified. All portions of exploratory trenches and pits below the final excavation line shall be backfilled with embankment material and compacted as specified.

3) In the foundation areas where sound rock is not present, the foundation shall be compacted with 2 passes of 15 t vibrating roller and protected by 1 layer of transition rockfill (thickness up to 80 cm) compacted by 4 passes of 15 t vibrating roller.

4) Design modification in the plinth alignment and of the foundation excavation may be made, based on the principal findings of the site investigations and excavation works.

5) The Contactor shall plan his excavation and embankment fill operations in such a manner that the fill in the central section may proceed unaffected from the abutment excavations, avoiding that fill will be contaminated by the overburden stripping.

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6.6. PLACING

6.6.1. GENERAL

1) Placing of embankment materials shall be carried out according to the lines, slopes and level as shown on the Drawings or as directed by the Engineer. The setting out of the zone limits shall be performed by the Contractor and these limits shall be strictly observed. The Engineer reserves the right to modify these limits as well as make any other changes in the dam section as he may decide upon to optimize and/or expedite construction.

2) The fill material shall be placed and spread to provide layers which when compacted shall have a thickness of not more than the limits established by the results of the trial embankments or those established by the Engineer.

3) The optimum thickness of layers to provide the required degree of compaction and the specified density of compacted fill shall be determined by the site tests and trials.

4) The placing of embankment materials over the foundation surface shall only proceed upon the receipt of permission from the Engineer following an inspection of the area concerned.

5) The placing methods shall be continuously reviewed by discussion between the Engineer and Contractor, with the Engineer reserving the right to subsequently modify any arrangements where this is considered necessary to optimise and/or expedite construction.

6) The quality control tests which shall be carried out in situ during construction of the embankment are indicated in the relevant subsection.

7) The materials shall be placed in such a manner that the top surface of any section under construction shall remain approximately level.

8) The embankments shall be generally raised uniformly in horizontal layers, with variations in level within and between zones permitted only where essential for the progress of the work and approved by the Engineer.

9) Rockfill shall always be placed on top of previously compacted material clear of the outer edge of the slope. Spreading shall be generally at right angles to the axis of the dam to move the larger pieces of material to the exposed faces of the downstream slope.

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10) The rockfill shall be roughly classified by the spreading, and oversize particles shall be moved to the downstream limit of the fill.

11) Coarse rockfill shall be dumped and the blocks placed individually.

12) If, during or after placing, material in any zone has become contaminated with material from another zone or with topsoil or other unacceptable material from the passage of construction machinery or by any other means, the contaminated material shall be entirely removed, and the Contractor shall not be entitled to any additional payment for this remedial work.

6.6.2. WATER CONTENT

1) The water content at which the rockfill or the earth shall be placed must be such as to give optimum workability and ensure no further deformation as a result of future wetting during operation.

2) The optimal amount of water to be added will be decided on the basis of the site tests and trials. Preliminary indication are given in the relevant sections.

6.6.3. TEMPORARY RAMPS WITHIN EMBANKMENTS

1) Where ramps are constructed within the embankments, all material within the ramps shall be placed in accordance with the requirements of these Specifications for each type of fill and tolerances in dividing lines and differential heights of the various fills shall be in accordance with the specified dimensions.

2) The side slopes of the ramps shall not be steeper than 1 vertical to 1.3 horizontal in rockfill. As the remainder of the embankment fill adjacent to ramps is placed, fill material in the side slopes of the ramps shall be cut-back a minimum of 0.6 m to remove any loosened or segregated material and the resulting material combined with new material before re-compaction of the relevant zone.

3) Where temporary ramps are constructed on or in the downstream face of the dam, upon completion of the embankments these shall be removed, leaving the downstream face in uniform appearance and to the design lines.

6.7. COMPACTION

6.7.1. COMPACTION EQUIPMENT

1) Compaction of rockfill embankments shall be by vibratory compactors which shall have the static weight of at least 150 kN.

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2) At least 70 percent of the weight shall be transmitted to the ground through a single smooth steel drum when the roller is standing in a level position hitched to the towing vehicle.

3) The drum shall be equipped with suitable cleaning devices to keep it free from any accumulation of material.

4) The frequency of vibration during operation shall be between 1,100 and 1,500 rpm, and the dynamic force shall be not less than 2 times the static weight at 1,400 rpm. The roller shall be towed or self propelled at speeds not to exceed 5 kilometers per hour.

5) Towed type rollers shall be towed by a crawler tractor with a minimum drawbar rating sufficient for efficient speeds of operation.

6) The vibrating roller shall be equipped with a compaction meter, i.e. an instrument which indicates, from roller behavior, when the required degree of compaction has been achieved. The instrument shall record and print continuously the condition of the compacted fill.

7) The compaction equipment shall be maintained in first class condition at all times and, upon direction of the Engineer, any adjustments necessary to obtain the required compaction shall be made immediately.

6.7.2. METHODS

1) The methods and number of passes of compaction equipment shall be as determined by the tests carried out in the Trial Embankments and shall be modified as necessary as the work proceeds to ensure the achievement of the specified requirements. Indications given in the previous sections are preliminary only.

2) Except as otherwise approved by the Engineer, the compaction units shall travel in a direction parallel to the axis of the structures.

3) During placing, spreading and compacting operations, the turning of equipment shall be made carefully to ensure uniform compaction. The layers shall be compacted in strips, with adjacent strips overlapping by not less than the layer thickness.

4) Compaction in any area shall be achieved completely by a single type compaction unit.

5) Portions of rockfill which, in the opinion of the Engineer, cannot be adequately compacted with rollers due to inaccessibility, and the areas of fill adjacent to concrete structures (e.g. downstream RCC block of Upstream Coffer dam) shall be placed in layers not exceeding 30 cm and compacted to the specified density by means of approved power tampers. In these zones a maximum stone size of 20 cm shall be allowed.

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6.7.3. TRIMMING OF EMBANKMENT SLOPES

1) Coarse rockfill and rock particles larger than the maximum size shall be pushed towards and placed in the embankment downstream slopes during spreading. Simultaneously with the rising of the coffer dam shoulders the coffer dam slopes shall be trimmed by back-cut of placed material to the line and slope as specified, by regulating the coarse rockfill in the slope and filling openings between the coarse particles with smaller stones in such a way, that the trimmed slope has a stable and relatively plain surface with irregularities of less than 300 mm.

2) The trimming of the slope shall be done by appropriate equipment and by hand.

6.8. TESTS AND QUALITY CONTROL

1) During the construction of the trial embankments and the cofferdam embankment, tests shall be carried out to measure the achievement of the specified requirements for all zones of the embankments.

2) All tests will be specified by the Engineer in advance with sufficient time for the Contractor to organize the appropriate equipment and personnel.
3) The standard tests to be performed shall be as follows:
    - specific weight — measurement of the density of the intact rock in the laboratory. 5 Samples per test.
    - point load — measurement of the point load resistance of the intact rock in the laboratory. 10 Samples per test.
    - unconfined — measurement of the unconfined compression strength compression (U.C.S.) of rockfill samples by standard method in the laboratory. 3 Samples per test.
    - grading — the grading of rockfill samples in the laboratory and production of grading curves.
    - settlement — measurement of settlement of layers in situ by topographic levels over a defined grid for each pass of compaction plant. Each test comprises a set of measurements for each layer and a report on results.
    - field density — excavation to the complete depth of the in situ layers of rockfill, the measurement of the void volume by water contained by plastic sheet lining and the measurement of the weight of the removed rockfill.
    - transmissibility — during the excavation for density test, the measurement of the rate of discharge of water from the void through the rockfill. Following

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the density test the further excavation below the layer boundary with the previous layer, the measurement of the additional void volume and the measurement of the rate of discharge of water from the increased void. Comparison of the discharges to determine any effect of layer surface blinding.

4) Special additional tests such as great triaxial tests and in situ tilting tests may be directed by the Engineer and these will be arranged by the Contractor or through a specialist sub contractor, subject to the approval of the Engineer, to whom the Contractor shall provide all assistance and cooperation.

5) The purpose of the tilting tests is to determine the shear strength of the rockfill at a field scale.

6) The test shall be carried out according to the Engineer's instructions and following the procedures described below:
    i. During construction of the embankments (either trial or final) a box shall be incorporated therein with minimum dimensions of 1.5 x 3 m and 2 m in height.
    ii. The box shall be particularly strong to withstand the compaction loads. The box shall be closed at the bottom and open at the top and it shall be made up of two parts, one above the other held together by means of a removable bolted steel strap.
    iii. The box shall be equipped with lifting equipment, which is operated manually by a hydraulic jack. Lifting will act on one of the shorter sides whilst the other is fixed to the ground with a hinged support.
    iv. The box shall be filled with the rockfill to be tested. In this operation the same placing and compacting techniques used for the other zones of the embankment shall be adopted as far as practicable.
    v. Once the box is full, excavation shall be carried out around it and the bolted steel strap (see point b.) removed.
    vi. By means of the lifting equipment (see point iii.) the box shall be slowly tilted and the following information recorded on a special form supplied by the Engineer:
        - lifting force;
        - tilting angle;
        - deformations in the direction parallel to the plane of the box (recorded by t least 2 No. mechanical extensometers);

7) The above readings will be carried out once the following tilting angles are reached: 10, 20, 30, 35, 40 degrees and proceeding at 2 degree intervals until the upper half of the box completely slips.
    i. The box configuration at each angle indicated shall be photographed.

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ii. The material still in place inside the lower half shall be removed and the relative grading curve determined.

8) The frequency of the tests for each embankment shall be as follows:

TYPE OF TEST	NUMBER OF TESTS	
	Trial Embankment	Coffer Dams
Specific Weight	10	40
Point Load	10	40
UCS	10	40
Grading	5	40
Settlement	5	On Engineer request but not more than 50 tests
Density	5	40
Transmissibility	5	15

9) In addition to these specific tests records shall be kept of the following factors for each zone:
- spreading method
- layer thickness
- weight of compaction plant
- vibration frequency of compaction plant and compaction meter print-outs
- number of passes of compaction plant

10) These factors shall be varied during the construction of the trial embankments and the standard tests conducted on samples from various combinations to ascertain the optimum method and the sensitivity of the results to variation of the factors.

6.9. TOLERANCES

1) The following tolerances to dimensions of the embankment shall be observed in respect of the finished works:
- Crest level ± 5 cm

Horizontal tolerances

a) the dam shall be placed to an accuracy of not less than 0.3 m

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b) at the time of placing the downstream face of the dam embankment shall have the following horizontal tolerance limits: ± 0.3 m

Vertical tolerances

c) Vertical tolerances on the sloped fill are equal to the horizontal tolerances defined above divided by 1.3

6.10. MEASUREMENT AND PAYMENT

6.10.1. TRIAL EMBANKMENT AND TESTS

1) No separate measurement or payment will be made for the trial embankments and standard tests.

2) The unit rates for the embankment fill materials shall include for all works on the trial embankments as specified, together with the regular measurement recording and standard testing as specified and the reinstatement of embankments after testing.

6.10.2. FOUNDATIONS

1) The preparation of foundations to the embankments shall be measured as the net area of surface prepared as specified and the payment under this item will be made at the Unit Price per square meter entered in the Bill of Quantities which shall include all the works necessary.

2) For the foundations at the cut off, RCC blocks and other structures, the preparation as specified shall be measured by the net area of finished surface.

3) Any additional concrete or shotcrete shall be measured and paid for as similar work covered in Section B09.

6.10.3. EXCAVATED MATERIALS

1) Where suitable material is obtained from excavations on the Works its use as fill will be measured separately by volume of such material placed and compacted in the embankment.

2) The payment for this item will be made at the Unit Price per cubic meter entered in the Bill of Quantities which shall include costs of excavations (where necessary) loading and transporting the material from the relevant excavation or disposal area and for its placing, spreading and compaction in the embankment as specified.

3) Any work of stockpiling of this material shall also be included for in the unit rates of the placed material.

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6.10.4. EMBANKMENTS

1) The measurement of quantities of fill in the embankments shall be based on the agreed survey of the foundation area after its preparation to receive fill. The measurement of the embankments will be made to the specified lines.

2) The payment for embankment material shall be made on the basis of the net volume of compacted material in the embankments, placed in layers of thickness as specified, spread, water added when necessary and compacted to the required performance criteria, according to the Unit Prices per cubic meter entered in the Bill of Quantities for the category of fill embankment indicated in par. 6.3.3.

3) The rates shall be deemed to include the entire cost of, but not limited to, the following:
   i. the excavation at the specified quarries including blasting and any selection at the quarry face, stockpiling, crushing, screening, washing in order to obtain the required grading, together with all loading and transporting of the material to the embankments, and the disposal of waste, placing, spreading and compacting the material as specified herein and directed by the Engineer;

   ii. surveying, setting out, checking of embankment profile and alignment, and any subsequent rectification works resulting from undue or incorrect survey; provision of suitable equipment for, and delays due to carrying out this work.

6.10.5. GEOMEMBRANE

1) The geomembrane waterproofing system shall be measured for payment by the square meter (m^2) of geomembrane supplied, installed, welded, anchored, protected, tested, and accepted by the Engineer. The measured area shall be calculated based on the theoretical surface indicated in the approved Drawings, without allowance for overlaps, wrinkles, cutting waste, or additional material used by the Contractor.

2) Payment at the unit rate shall constitute full compensation for all labor, materials, equipment, tools, protection layers, anchorage systems, surface preparation, welding, testing, quality control, temporary works, and all operations necessary for the complete installation of the geomembrane system, including all items and activities required to ensure a complete, fully functional and properly performing system.

3) The unit rate shall include, but not be limited to:
   - supply and delivery of geomembrane materials;
   - protective geotextiles or cushioning layers;
   - surface preparation;
   - panel layout and placement;

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- welding and seam testing;
- anchorage and terminations;
- repairs and adjustments;
- protection during rockfill placement;
- quality control and documentation.

4) No separate payment shall be made for incidental or supplementary works required to achieve compliance with the Specifications.

5) Concrete curbs works shall be measured under the relevant items defined in Section B.09 – Concrete.

6.10.6. RCC WORKS

All costs for RCC are excluded from this Section and shall be measured and paid for in accordance with the provisions of the Section B.20.

6.10.7. CUT-OFF WORKS

All costs for Cut-Off works are excluded from this Section and shall be measured and paid for in accordance with the provisions of the Section B.08.

6.10.8. EXCLUSIONS

1) No extra measurement for payment or payment will be made for the following:
   i. extra work caused by Contractor's negligence
   ii. all costs of dewatering and keeping the foundation surface dry, which are covered in Section B.01
   iii. surveys to verify the foundation area
   iv. extra work or material required to repair damages to the final embankment surface caused by erosion or travel of the construction equipment
   v. Damage and repair to the concrete/RCC structures caused by Contractor's operations.
   vi. For PVC Membrane, all overlaps, trimming losses, repairs or replacements due to installation damage, additional anchorage or corrective works arising from the Contractor's methods, standby time, temporary works, repeated testing due to non-compliance, and any incidental operations required to meet the Specifications shall be deemed included in the unit rate and shall not be measured or paid separately.

2) Any additional work in areas where surface embankment has already been completed, which the Contractor may be directed by the Engineer to carry out, will be measured and paid for at the same Unit price entered

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in the Bill of Quantities as for the original item. No increase in Unit Price for such additional work will be allowed.

3) Any alteration or adjustment to the construction methods to be adopted following the results of site tests or trials, will not allow increasing the unit rates and price for the works unless it has been demonstrated that the relevant materials or conditions are significantly different from those that could have been foreseen at tender stage by an experienced Contractor (as defined in Conditions of Contract).

END OF SECTION B.6

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7.1. SCOPE OF WORK

1) The work under this Section includes all labour, materials, equipment, operations and services required for the execution of drill holes, water-pressure test, performance of grouting in the holes from surface and from the underground construction sites (i.e. area of diversion tunnel plugs and dam galleries extended into the rock mass abutments), at locations shown on the Drawings or as directed by the Engineer.

2) Drilling from the surface shall include the following:
   a) Drilling of exploratory holes (including drilling of RCC dam for investigation purposes),
   b) Drilling for grout curtain below the foundation of Dam and other appurtenant structures,
   c) Drilling for consolidation grouting in the rock formation of dam, Drainage tunnel portals and other areas,
   d) Drilling of check holes to determine the effectiveness of grouting,
   e) Drilling of drainage holes,
   f) Drilling for installation of instrumentation (if required).

3) Drilling from the underground shall include the following:
   a) Drilling of exploratory holes (including drilling of RCC dam for investigation purposes),
   b) Drilling for consolidation grouting of zones of sheared and disturbed material and/or of zones of high-water inflow,
   c) Drilling of pressure relief holes,
   d) Drilling for installation of instrumentation,
   e) Drilling of water-pressure test holes,
   f) Drilling for contact grouting,
   g) Drilling for consolidation grouting of rock surrounding the excavated tunnels.
   h) Drilling from grouting gallery/drainage tunnel for the dam grout curtain,
   i) Drilling for crack grouting,
   j) Drilling for curtain grouting in diversion tunnel plugs.

4) Grouting operations shall include the following:
   a) Contact grouting at pressure of up to 5 bar to fill voids between concrete and rock, between backfill concrete and steel lining, and in the concrete plugs in the tunnels,
   b) Consolidation grouting of rock foundation of dam and concrete structures, and of the rock surrounding the tunnels, which shall commence after placing of the concrete lining and completion of contact grouting,

c) Curtain grouting to a sufficient depth below the dam and from appurtenant structures in order to create a high-density zone with a low permeability; curtain grouting shall be executed from the surface and from specially constructed grouting galleries.

d) Fill grouting, at pressures of up to 5 bar, of conduits, exploratory drill holes and drain holes.

e) Crack grouting, at pressures of up to 5 bar, to seal the open cracks and joints in the tunnel concrete lining.

f) Pre-grouting of the rock mass, where required, to reduce permeability and improve ground conditions prior to excavation or construction activities. Pre-grouting shall be carried out ahead of tunnel excavation or foundation works, using suitable grout mixes and pressures as approved by the Engineer, in order to limit water inflows, stabilize discontinuities, and ensure safe and dry working conditions.

5) Water pressure tests shall be carried out by the Contractor in grout, exploratory and check holes/control holes as per Drawings and as directed by the Engineer.

6) The location, orientation and depth of the drill holes for the contact, consolidation and curtain grouting are tentatively indicated on the Drawings for the purpose of tender preparation. The final number, length, location and inclination of the drill holes as well as the composition and consistency of the grout mixes, grouting pressure, pumping rates and sequence in which the holes are to be drilled and grouted shall be governed by actual conditions encountered on site and shall be at all times subject to the approval by the Engineer.

7) The whole temporary drainage system, if any, in the underground shall be filled with grout.

8) The extent of crack grouting will be determined by Engineer.

9) Drilling for installation of rock bolts, grouted anchors bars and prestressed anchors shall be performed in accordance with the provisions set forth in the Section "Rock Supports".

7.2. SUBMITTALS

7.2.1. DRILLING

1) Prior to the start of drilling (and/or grouting work) in any one working area, the Contractor shall provide notice of and make available to the Engineer a drilling and/or grouting plan (a method statement of the works to be done), with 56 days time for review. Once work has commenced and as the local sub-surface conditions are disclosed, the drilling and/or grouting plan may have to be

modified accordingly on the basis of consultation with and direction by the Engineer. The Contractor shall be prepared and equipped for variations in the drilling and grouting work.

2) The Contractor shall make drilling logs and other pertinent information available to the Engineer on completion of each work phase and as needed during the work.

3) The Contractor shall give notice of and make available to the Engineer reports giving the results of each water-pressure test performed within one working day of the end of the shift in which the tests were carried out. The reports shall contain complete records of the execution of the test as described in this Section.

4) The Contractor shall provide to the Engineer (prior to scheduled use in the field) documentation of the effects on the grouting mixture of any additive proposed for use in the drilling water, and no additives shall be used without prior approval by the Engineer.

5) Within 24 hours of completion of any drilling with core recovery, the Contractor shall submit, in duplicate, a technical log of the drill hole in a form approved by the Engineer. The log shall be in accordance with IS: 4464 and shall include the following data:
   a) Date of beginning and end of drilling,
   b) Drill hole number,
   c) Location, collar elevation, coordinates, inclination, direction, and length of drill hole,
   d) Type and diameter of drilling bit and core barrel used, make of drilling rig and length and diameter of casing, if used,
   e) Elevation of ground water levels encountered, including dates and times of measurement,
   f) Results of leakage tests and other drill hole tests, if any,
   g) A record of the driller's observations on progress of drilling, rate of penetration, speed and uniformity of rotation of bit, action of the drill rig such as jerky, smooth, rough, steady, etc.,
   h) Length of each core run and the length, or percentage, or both of the core recovered and location and cause of core losses,
   i) Any changes in the character of the drilling water or mud, and in case the drilling water was lost (partly or totally), the elevation or depth when this happened,
   j) A simple driller's interpretation and description of the nature of the formation encountered as the drilling progress,
   k) Location and nature of cavities, seams, cracks, soft or broken rock, whether filled or open, and any other observation which could give information in connection with the purpose of exploratory drilling,
   l) Names of driller and inspectors.

6) Geological logging shall be performed by the Engineer. When required by the Engineer the Contractor shall provide assistance during core logging, and in particular with handling of core boxes and cleaning of cores.

7) Color photographs of the core boxes from each drill hole shall be taken by the Contractor and shall be submitted to the Engineer within 10 days from the completion of the drill hole.

8) The Contractor shall submit and keep on site reports in duplicate giving the results of each water-pressure test performed, within 24 hours of the end of the shift in which the tests were carried out. The reports shall contain the following:
   a) Location and number of drill hole,
   b) Date and time of test performance,
   c) Type of test,
   d) Pressure readings and water levels before and after testing,
   e) Packer rod characteristics and depth of packer(s),
   f) Total injected water volume and rate per minute and per linear meter of hole for various pressures applied. A plot showing water take versus increasing and decreasing pressure shall be prepared and both data and plot shall be submitted.
      The Contractor shall execute necessary tests to allow evaluation of head losses along the piping system and / or provide devices to measure the applied pressure directly in the zone being water-tested.
   g) Description of all surface water leaks indicating the distance and approximate quantity.

9) If the Contractor intends to use a water-soluble additive to drilling water, he shall submit a notification and a sample of the additive to the Engineer for approval at least 15 days prior to being used.

10) The drilling in overburden for the grout curtain below cofferdams, if and where required, shall be performed as per this section and that in the rock shall be performed as specified herein.

7.2.2. GROUTING

1) At least 56 days prior to the start of the grouting works, the Contractor shall submit for approval fully detailed proposals and a detailed layout of his proposed arrangements for grouting, including specifications of all equipment, tools and all grouting materials to be used, and qualification and experience of the proposed personnel, and extent of technical support from external agencies.

2) An overall grouting program shall be drawn up jointly between the Contractor and the Engineer. Grouting mixes, pressures, pumping rates, and sequencing will be selected, subject to modifications,

to meet local conditions encountered during the performance of the work. Grouting works shall be planned in such a manner that they can be carried out according to the approved plan concurrently with other activities. Modifications to the grouting program shall be implemented as directed by the Engineer.

3) Prior to each phase of grouting, the Contractor shall submit for approval a detailed program for the particular grouting works along with information relating to the methods he proposes to use and details of grout mixes. No grouting work shall be executed without prior written approval by the Engineer.

4) During the performance of the grouting works, the Contractor shall keep complete daily records of all grouting operations. These grouting records shall be compiled on an approved form and shall be submitted weekly to the Engineer. Results of water pressure tests and grout takes shall be presented in tabular form as well as graphically. The records shall contain all the information as per guidelines of IS:6066, and shall include the following:
   a) Number and location of the drill holes,
   b) Results of water-pressure tests,
   c) Grouting method,
   d) Date and time of commencement of grouting and of each change in grouting operations,
   e) Rate of pumping,
   f) Grouting pressures and gauge reference number,
   g) Water-cement ratio and its variations,
   h) Separate quantities of cement, sand, bentonite, fly ash, admixtures and chemicals used,
   i) Connections, if any, with other holes and cracks, as well as any surface leakage of water or grout; crack location, how it was caulked and the success of caulking shall be described and approximate station and offset of each surface leak shall be recorded where it occurs in the dam foundation,
   j) Number of holes and depth of holes left for re-drilling,
   k) Time of completion,
   l) Name of the foreman in charge.
   m) Marsh cone.
   n) Density.
   o) Temperature of the grout.
   p) Bleeding.

5) Grouting volumes, pressure, time of grouting and all sensitive data shall be recorded in real-time during the execution of the grouting with Jean Lutz or equivalent recorder apparatus.

6) The Engineer reserves the right to require any additional information deemed necessary to be included in the documents to be submitted.

7.3. DEFINITIONS

These definitions are applicable for drilling and grouting in rock only.

- **Grouting** is defined as injecting a mixture of cement and water with the addition of admixtures, sand, bentonite, and fly ash, if required, or similar approved mixture under pressure into overburden or rock mass or between rock/concrete contacts through a system of boreholes by means of a pump designed for such a purpose. Cement grouts are subdivided into stable and unstable mixtures:
  - **Unstable mixtures** are simple suspensions of cement in water. These suspensions are only homogeneous as long as they are in movement and the sedimentation starts as soon as the movement is stopped.
  - **Stable mixtures** are colloidal suspension dissolved in water whose grain size is so small that no appreciable sedimentation occurs during the grouting operation. These suspensions are obtained by high-speed mixing of cement with addition of bentonite and/or admixtures

- **Zone** is part of the impervious curtain grouting or consolidation grouting where all the drill holes have the same depth or the same inclination or where a level for the depths of holes is specified. In a zone, Engineer may adjust the drill holes as required by the topographical and geological conditions to ensure a continuous grouting curtain.

- **Stage** is a section of a drill hole in which grouting or water pressure testing is performed.

- **Packer Grouting** consists of drilling a hole to its full depth in a single operation, cleaning and washing, water pressure testing if required and grouting the hole in successive stages in any desired sequence of section which are isolated by use of packers from the ungrouted sections. This method shall generally be used.

- **Stage Grouting** consists of drilling and grouting a hole by stages. First a hole is drilled to a limited depth, cleaned, subjected to water pressure tests if required and then grouted. Just after the initial set of grout, the hole is cleaned by washing or by other appropriate means. Then the hole is drilled to another limited depth, cleaned, subjected to water pressure tests if required and grouted and so continued in successive stages until satisfactorily grouted to its full depth. This method is to be used only when directed by Engineer.

- **Full depth Grouting** means that each hole is drilled to the full desired depth, washed, pressure tested and grouted in one operation. This method is usually limited to short holes 5 m or less or holes up to 10 m that have only small cracks and joints and there is no risk of surface leakage.

- **Split spacing** consists of progressively closing curtain or consolidation grouting by drilling and grouting holes midway between holes which have previously been drilled and grouted. The spacing between primary and secondary holes may vary from one zone to another depending upon geological conditions encountered.

- **Consolidation Grouting** is the drilling of shallow holes generally up to 10 m long and grouting of the rock in foundation and in rock surrounding concrete lining of tunnels and shafts.

- **Pre-grouting** is the drilling of shallow holes and grouting of the rock in foundation of the dam, dam abutments, intake and in rock surrounding the tunnels, caverns and shafts to improve the stability of poor and unstable ground or rock, before the execution of excavation.

- **Curtain Grouting** is the grouting executed to form a continuous impervious wall. In principle, this curtain shall consist of a single or multiple rows of holes divided into zones of variable depths, inclinations and spacing.

- **Contact Grouting** is drilling and grouting at low pressures required to fill the voids between concrete and rock surface or between concrete and steel lining.

- **Open End Washing** is the process of cleaning drill cuttings and sludge from a drill hole by injecting water or water and air at the bottom of the hole and returning the fluid and suspended matter to the top of the hole.

- **Grouting pressure** shall mean the pressure of grout injection as measured at the nearest pressure gauge near collar of hole while the grout is being pumped into the hole.

- **Effective pressure** shall mean the actual pressure of grout at the packer end, taking into consideration the difference of elevation between the packer end and the nearest pressure gauge or the water table.

- **Successful Connection** means the completion of all operations necessary to achieve a proper seating of a packer assembly that can sustain the required pressure without leakage or loss of pressure during pressure water testing or grouting to refusal.

- **Grout take or Grout absorption** is the quantity of materials injected in a hole expressed in units of kg of dry cement/ bentonite and of sand per meter of length of the hole (the inclusion or exclusion of the volume of the hole shall be clearly reported)

- **Water Cement ratio** is the ratio of the mass of water to the mass of cement.

- **Drain hole** means the drilling of a hole in the rock to a specified depth and inclination for the purposes of draining water from the rock and preventing the build-up of water pressure in the rock.

- **Piezometer hole** means a hole in the rock/overburden in which a piezometer standpipe or standpipes are installed to monitor groundwater levels.

- **Instrumentation drill hole** A hole drilled for the purpose of placing instruments in the structure or rock.

- **Lugeon** is the measure of permeability of the rock. One Lugeon unit signifies a leakage of one litre per minute per metre length of hole per 10 bars of pressure.

- **Refusal** is reached when the flow rate of grout pumped into a hole at the maximum specified pressure is equal to or less than one litre per minute per metre length of hole or as specified by the Engineer

- **Upstage grouting** shall mean the process of drilling a hole to full depth initially and grouting from the bottom of the hole upward at different depths by means of a packer set at different depths. Upstage grouting shall be performed by attaching a packer to the end of the grout supply pipe, lowering the grout supply pipe into the hole to the top of the lowest section to be grouted, expanding the packer, grouting at the required pressure, allowing the packer to remain in place until there is no back pressure, withdrawing the grout supply pipe to the top of the next higher section to be grouted and thus successively grouting the hole in sections at the specified pressures until the entire hole is completely grouted.

- **Downstage grouting** shall mean the process of drilling a hole to a limited depth, grouting to that depth, either washing out the grout hole after the injected grout has attained its initial set or redrilling through holes that are not flushed out, drilling the hole to a further depth after at least 24 hours of grouting the previous portion and then grouting the next stage. Thus, the hole is successively drilled and grouted until the required depth is completely grouted to the satisfaction of the Engineer.
  Downstage grouting can further be sub-divided into:
  - Grouting of all stages with the packer at the surface. This shall include any hole which is completely grouted from base to surface in a single operation.

- Grouting the stages with the packer at the bottom of the previous stage.

- **Multi-Packer Sleeved Pipe** (MPSP) is a multi-stage grouting system based on tube a manchette (TAM) system and inflatable fabric bags positioned at regular intervals to isolate stages to be grouted.

- **GIN (Grouting Intensity Number**) refers to both the product of final grouting pressure (P) x grout volume injected (V) and the methodology of grout injection as described in technical literature (e.g. Grouting design and control using the GIN principle, 1993 G. Lombardi, D. Deere)

7.4. EQUIPMENT

7.4.1. DRILLING EQUIPMENT

1) All drilling equipment used shall be of a type, capacity and mechanical condition capable of performing the drilling required under this Contract, and shall be subject to the approval of Engineer.

2) The Contractor shall have sufficient drilling rigs at the Site for the timely completion of the Works. The drilling rigs shall be in good operating condition and adequate for the satisfactory progress of the work. Combustion engines for operation of drilling equipment will not be permitted for underground work and within dam body galleries.

3) Drilling equipment shall be capable of drilling at any angle, upward or downward, and shall have the following capacity:
   a) Exploratory holes up to 300m,
   b) Curtain grouting up to 200 m,
   c) Consolidation grouting up to 20 m,
   d) Contact grouting up to 5 m.

4) Standard drilling equipment of the rotary and percussion type shall be used to perform the drilling as specified herein or as required by the Engineer. Percussion drilling equipment shall be equipped with a water swivel for continuous flushing of the holes during drilling.

5) The Engineer may require some of the grout holes and pressure relief holes to be drilled using rotary type drills with core recovery. The rotary type machines shall be capable of drilling minimum NX / NQ size holes utilizing double tube/ triple tube core barrels equivalent and capable of recovering soft or friable materials with maximum possible core recovery. The equipment and crew shall be made available at site when Engineer requires exploratory holes to be drilled. All such cores shall be properly stored in wooden boxes and logged for inspection as per the Indian Standard.

6) The drilling units shall be mobile and of size suitable to the dimensions of the galleries.

7) The contractor shall keep at the Site an ample supply of different types and sizes of drilling bits to allow optimal drilling in the different materials to be encountered in the course of work, and sufficient rods and casings of various diameters to allow proper telescoping and to ensure the stability of drill holes.

8) The Contractor shall provide measuring equipment for checking the actual inclination and alignment of drillholes.

9) The Contractor shall have sufficient drilling equipment to retrieve 150 mm RCC cores according to the program reported in section B22.

7.4.2. GROUTING EQUIPMENT

1) Only modern, properly operating grouting equipment approved by the Engineer and operated by trained and experienced crew shall be used for the performance of the work. This shall be specifically observed when dealing with chemical products.

2) The grouting equipment required to carry out the work shall include mixers, grout pumps, packers, pipes, grout lines, fittings, pressure gauges, telephones, lighting circuits, trolley grout platforms and miscellaneous supplies. Sufficient grouting equipment shall be provided to meet the construction schedule and each plant shall be capable of satisfactorily supplying, mixing, stirring, pumping and injecting grout mixes of various viscosities as specified herein. The equipment shall be maintained in good operating condition at all times and any grout hole that is lost or damaged due to mechanical failure of equipment or inadequate delivery of grout shall be replaced by another grout hole by Contractor at no additional cost to the Employer.

3) The grouting equipment for mixing and placing the grout shall be such as to provide a continuous circulation of grout throughout the system and to permit accurate volume and pressure control. It shall be capable of effectively mixing and stirring the grout and forcing it into the hole in a continuous uninterrupted flow at any desired pressure up to the maximum required grouting pressure for a flow rate of 150 litre/min.

4) Grouting pumps shall be of the double acting piston-type, progressive cavity type or other type of pump approved by the Engineer and shall be capable of pumping at least 150 litres/min of grout at a maximum discharge pressure of 5000 KPa (5 N/mm^2). The pumps shall be capable to pump thick sand-cement grouts.

Pumps shall be equipped with precise pressure and capacity control valves which allow the setting of both, the maximum pressure and the flow, independently. They shall automatically stop whenever the preset pressure is reached, and shall maintain that pressure within the fluctuation indicated in the Engineer prescription.

For works, not in relation to consolidation grouting and grout curtain works, requiring a very small volume of grout, the Contractor may use hand operated grout pumps capable to achieve a pressure up to 10 bar, after having proposed it to the Engineer approval,.

5) Grout mixers shall have a minimum capacity of 0.2 m^3 and shall be colloidal high-speed impeller type. Facilities shall be provided at the mixer for the accurate measurement of grout materials so that mix proportions can be carefully controlled.

   Mixers shall be provided with equipment for measuring weight and volume of mix components with an accuracy of ± 3%

6) Sump or holding tanks having a minimum capacity of 0.5 m^3 shall be mechanically operated and designed to keep the mixed grout agitated and in suspension. All grout should be discharged from the mixer into the agitator and from the agitator into the pump panel through a 2.36 mm screen to remove lumps and large particles.

7) Water meters shall be calibrated in liters and tenths of liters without by-pass so that water can be measured directly in the mixer. A strainer with cleaning valve shall be provided in the water supply line, upstream of the meter to prevent sand and abrasive particles from entering the meters.

8) Pressure gauges of the approved make shall be of such calibration to cover a range of pressures from 0 to 0.5 N/mm^2 (500 KPa) and from 0 to 6 N/mm^2 (6000 KPa). An adequate number of spare gauges shall be provided at each grout plant. Contractor shall provide a standard master gauge against which all other gauges shall be checked periodically for accuracy and satisfactory operation. All the pressure gauges shall be numbered for identification and shall have an accuracy of ± 3%

9) Packers shall be capable of effectively sealing the grout holes at the specified elevation and shall be capable of withstanding without leakage pressures up to the maximum grouting pressure. The type of packer to be used shall be of the pneumatically expanded rubber sleeve type. Double packer assemblies separated by up to 3 m of perforated pipe shall also be provided.

10) A double line circulating system shall be used and the inside diameter of all lines, walls and connections shall be not less than 25 mm. Hoses and supply lines shall be capable of withstanding pressure 50% greater than those specified for grouting and shall be protected from damage or breakage.

A return line shall be provided for flushing hoses, to control the rate of pumping and for emergency pressure relief. These shall be connected to the pump side of the recorder gauges at the collar of the grout hole and shall discharge into the holding tanks or to waste containers only.
The length of grouting hose from the grout pumps to the hole to be grouted must be such that it does not affect negatively the properties of grout mix.

11) Grouting headers shall be provided for feeding grout into the holes. The header shall include a supply connection, a connection with a valve to the hole, and a return line with valve. Two number of approved make pressure gauges for the appropriate pressure range shall be installed. One shall be installed to indicate the pressure of the supply at the pump and the other to measure the back pressure at the hole.

12) Contractor shall furnish, install, maintain and operate satisfactory communication system between grout plants and the holes being grouted regardless of grout area locations.

13) Contractor shall supply sufficient operating personnel, supervisors, labour, spare tools, to carry out each phase of the work properly and expeditiously.

14) The grouting units shall be mobile and of size suitable to the dimensions of the galleries/drifts.

15) Computerized systems (such as Lutin supplied by Jean Lutz or similar approved) will be used for real-time measurement and storage of grouting parameters (pressure, flow, volume, ratio between flow and pressure, etc.). These systems shall be of a robust design capable of operating under all conditions that will exist during grouting operations. One such system is required per injection point with one spare. All equipment shall be satisfactorily maintained to ensure continuous and efficient performance during all grouting and water testing operations.

7.4.3. WATER PRESSURE TESTING EQUIPMENT

1) The washing and water pressure testing equipment shall include pumps, piping, pressure gauges, valves, seal assemblies and all other accessories, necessary to perform the Work.

2) The Contractor shall provide a sufficient number of complete sets of pressure testing equipment (with spares) to allow simultaneous testing at the various drilling and/or grouting locations.

3) The pumps furnished shall be of the gear, centrifugal, or other acceptable types, with a minimum output of not less than 0.25 m^3/min at 1.5 N/mm^2 (1500 KPa) gauge pressure and shall be capable of maintaining constant pressure of at least 3 N/mm^2 (3000 Kpa)

4) The Contractor shall supply water storage tanks sufficient for the pumps in addition to flow meters and pressure gauges for calibration and checking.

5) Water-meters and pressure gauges shall be calibrated and certified by an independent laboratory prior to installation at the Site and shall be subject to periodic verification. One pressure gauge and one water-meter shall, after independent checking, remain at the disposal of the Engineer for further checking purposes. The pressure gauge shall be placed preferably within the test chamber or at the depth of the stage, in order to avoid all approximations related to the estimation of the water-losses through pipes and device. In case pressure gauges are installed at the collar of the drill hole, with the approval of Engineer, the Contractor must establish, by way of tests, correction graphs for pressure losses occurring in the pipes.

Water pressure shall be measured by means of a pressure gauge with an accuracy from 1 to 2 bar and a range of 30 bar. Discharge shall be measured with an accuracy of 2 %. The water meter shall measure the discharge from 1 litre/min. Watermeters as well as all pipes, hoses and couplings shall be designed to resist a pressure of at least 60 bar

7.4.4. EMBEDDED PIPES AND FITTINGS FOR GROUTING

1) Standard mild steel pipes and fittings for grouting shall be set in the rock and concrete as the Engineer may direct, or where shown on the Drawings. The pipes and fittings embedded in concrete shall be cleaned thoroughly of all dirt, grease, grout and mortar immediately before embedding and shall be firmly held in position and protected from damage or displacement while the concrete is being placed. A standard coupling and nipple wrapped to facilitate eventual removal shall be attached to the grout pipe where embedded in concrete. No portion of the pipe shall be allowed to remain within 50 mm of the concrete surface and the resulting recess, after removal of the pipe or fitting, shall be filled with dry-pack mortar.

2) Care shall be taken to avoid premature blockage of pipes. Any pipe that becomes blocked before completion of operations shall be cleaned out in a satisfactory manner or replaced by the Contractor.

7.5. SITE LABORATORY

1) The Contractor shall have a laboratory specially equipped for studies and tests relative to drilling and grouting works available on the Site. The laboratory shall be manned by experienced laboratory assistant(s) familiar with conventional grout tests.

2) In addition to the usual general laboratory equipment such as scales, oven, permeability meter and the like, it shall be equipped with:
   a) A multi speed laboratory mixer
   b) A Marsh test cone
   c) A mould for pressure testing the above cubes, variable from 0 to 2 tons
   d) A set of sieves for grain size analysis of fines
   e) Conventional laboratory glassware, including 1 litre beakers and test tubes
   f) Thermometers and aerometer, and Atterberg limit measuring cups
   g) A Baroid scale type mud density meter

3) The Engineer shall be given free access to the laboratory and shall be entitled to carry out any studies and measurements he deems necessary.

4) The Contractor shall prepare and test the trial mixes as directed by the Engineer at least 28 days before commencement of any grouting. Materials for use in grout mixes shall be tested for compliance with the applicable requirements stipulated in "Materials" of this Section. Tests shall be performed on the grout mixes proposed for use in the Works, to establish the consistencies in mixes, practical mixing ratios, initial and final setting times, and such other properties as may affect the quality of the grout.

5) During the actual grouting operations, the Contractor shall carry out tests on grout mixes at the same time as grouting, and shall plot values of viscosity, sedimentation limits, compressive strength, and maximum viscosity possible for the grouting on a diagram. The frequency of testing will be once for each grouting job site or until acceptance criteria have been met. However, if a significant change in the cement source occurs, sampling and testing must be repeated and the new mix approved by the Engineer.

7.6. GROUTING MATERIALS

1) Water used for all drilling, washing and water testing and as an ingredient of grout mixtures shall be fresh, clean and free from deleterious amounts of silt, organic matter, alkali, acids, salts, oil and other impurities. Water shall comply with ASTM C 1602-M, shall not contain particles larger than 80 microns, shall not contain more than 2,000 ppm of suspended colloidal solids and shall not be aggressive. The chloride content shall be less than 50 mg/l and the sulphate content less than 100 mg/l. The quality of the water shall not affect the required properties of the bentonite.
   The temperature of water used for the preparation of grout shall be in the range of 5 to 30 °C at the collar.

2) Cement used in the grout mixes shall be OPC/PPC, conforming to IS:269 & IS:1489 Part-1 respectively. The fineness shall be such that 100.0 percent passes the 74 micron IS sieve and that the Blaine fineness is not less than 2250 cm^2/gm. The cement shall be free from lumps.

3) Whenever sand is added to the grout mix, it shall consist of clean, hard and durable particles free from lumps or clay and objectionable foreign matter. Sand shall conform to the following grading requirement:

Sieve size (mm)	Percentage passing by weight
2.360	100
1.800	95-100
0.600	60-85
0.300	30-50
0.150	10-30
0.075	0-10

4) Bentonite may be required in grout mixes. The bentonite used shall be conforming to IS: 12584. It shall be supplied from an approved source. Test certificates of the properties of the bentonite supplied shall be made available to the Engineer on request. When mixed with water the bentonite shall not contain any particle larger than 75 microns and shall not contain any substance detrimental to the setting and hardening of the bentonite/cement.
The bentonite/water slurry base shall be prepared in advance using cement-free water in a high turbulence (colloidal) mixer and kept agitated in a large container for at least 24 hours. Mixers used for grout shall not be permitted to mix the bentonite/water slurry.

5) Approved admixtures shall be used by Contractor in the grout mix to optimise the strength, viscosity, density, decantation, setting time and shrinkage. The admixtures shall be commercially available retarding or accelerating agents or grout plasticizer for water reduction and expansion during the plastic stage. Only admixtures proved by testing prior to the start of grouting may be used, when approved by the Engineer. Manufacturer's certificates or guarantees will not be accepted as relieving the Contractor of his responsibility for the suitability of any admixture.

6) The Ultra fine cement is micro cement with excellent penetration characteristic ideal for extremely demanding injections. The cement is finally ground to a specific particle size distribution, and a combination of special grinding process and special clinker produce a product.

7) The ultra fine cement is having high Blaine value. The Blaine should be > 900 m^2/kg with maximum particle size of 15 micron (100% passing) to avoid premature blockage of the fine openings caused by jamming of the coarsest particles.

8) The Contractor shall handle, store and protect all cement and additives in such a manner that these materials will not be subject to deterioration or contamination. Deteriorated or contaminated materials shall not be used in the Works.

7.7. GROUT MIXES

7.7.1. SELECTION OF GROUT MIXES

The type of grout and products for each mixture will be determined by the Contractor according to design requirements and the purpose of the work. The proportions of various constituents in the grout mixtures shall be selected based on careful laboratory tests carried out by the Contractor to obtain the most favourable water/cement ratio (for instance, 0.7/1.0 by weight for OPC cement), selecting the super plasticiser type and its dosing (for instance 0.5-1.5 %) and shall be approved by the Engineer in order to obtain the following target parameters:

- bleeding 5 % maximum in 2 hours
- viscosity 35 sec maximum in Marsh Cone 4.8 mm
- strength > 15 MPa at 28 days measured on 50 mm cubes or as specified by Engineer.

Grout mixes shall be specified by the Contractor at least 2 months before starting the drilling and grouting works of each section of works.

Any grout which does not contain a retarder and has not been used within one hour of the time of mixing shall be discarded and disposed of in a manner approved by the Engineer.

7.7.2. STABLE CEMENT GROUTS

Stable mixtures shall consist of cement, with addition of bentonite and/or admixtures as required. The water-cement ratio (W/C) may vary according to the laboratory results and the grouting requirements.

1) Stable cement grouts shall be laboratory tested prior to use.
   The following graphs, in particular, shall be drawn:
   a) Equiviscosity curves,
   b) Bleed limit curves,
   c) Curves of equal mechanical strength,
   d) Curve of maximum possible viscosity for grouting.

2) These figures shall be obtained with a mixer which reproduces the high turbulence of the site mixers and with the same materials (cement, bentonite, admixture, water) as will be used on the site.

3) Bentonite/cement mixes for grouting shall not bleed more than 5%, expressed in terms of the volume of water visible above the grout after setting and the total volume prior to setting, as measured in a 1 litre, 6 cm diameter test tube.

4) Viscosity shall be measured with a Marsh cone or equivalent method.

5) Unconfined compressive strength after 7 and 28 days shall be measured on 5 cm cubes stored in water.

6) The time to initial set shall not be longer than 24 hours.

7.7.3. PREPARATION

1) The Bentonite/cement grout shall be made by first mixing a bentonite/water parent slurry in a high turbulence mixer and storing it, once adjusted to the defined W/B ratio, for approximately 24 hours in a large tank where it shall be kept in gentle movement, after which a quantity of this parent slurry shall be taken and mixed with additional water and cement in a high-turbulence mixer.

2) The final mixing of the parent slurry with cement shall last at least two minutes after addition of all ingredients.

3) The same mixing drum shall under no circumstances be used for mixing both Bentonite/cement grouts and bentonite/water slurries. Bentonite shall not be suspended in water which contains even the slightest amount of cement.

4) The Contractor shall provide detailed information regarding the material and batching, mixing and grouting plant he proposes using in his submission for the Engineer's approval.

7.7.4. MICRO FINE / ULTRA FINE CEMENT GROUT

1) Micro fine / ultra fine cement grout is a suspension composed of water and very fine grains of cement and/or other binder material and/or addition (like bentonite for instance). To be qualified as ultra fine cement grout, the suspension shall not contain more than 2% of the grains in weight having a diameter greater than 12 microns. The Ultra fine cement grout is stronger and less permeable than existing

cementitious grouts, has a high compressive strength and extremely small particle size (only a few microns, in contrast to typical particle sizes of 60 to 70 microns in conventional cements).

2) Ultra fine cement grout should have following properties:

a)	W/C ratio	1
b)	Initial setting time	60 to 120 minutes
c)	Final setting time	120 to 150 minutes
d)	Maximum bleeding	2%
e)	Flow cone time	32 to 34 sec
f)	28 days Compressive strength	>40 MPa
g)	D100	15µm (100% passing)
h)	D98	12µm (98% passing)
i)	D50	3.5µm (50% passing)

7.7.5. COLLOIDAL SILICA

Colloidal silica used for grouting shall be of reputed make and duly approved by Engineer having viscosity of 5MPa-s and particle size of 0.016 µm. Low viscous colloidal silica grout fill finer joints and the joints filled with clay and silts.

7.8. EXECUTION

7.8.1. GENERAL

1) The extent of proposed drilling and grouting programme is tentative. Engineer reserves the right to increase or decrease any part of the drilling and grouting programme should conditions indicate that this is required.

2) The Contractor shall provide sufficient pump capacity and storage to ensure a continuous supply of water to all grouting operation at all times at each grouting location. Minimum water pressure in the supply lines shall be 0.35 N/mm^2. Sufficient compressed air shall be supplied by the Contractor to perform the work with all equipment using compressed air operating at full capacity, the minimum delivery pressure in the air supply lines shall be 0.70 N/mm^2 at all times.

3) In general, for pre-grouting operations, Grout pump should be of duplex-piston type capable of producing controlled pressure of 10MPa. All pipes/hoses/other connections should be compatible to withstand maximum pressure of the grouting equipment. Grout Mixer shall be a high shear colloidal mixer with minimum rotor speed of 1500rpm.

Suitable dispersing agent with dosage 1.5-2% of cement weight shall be used wherein ultrafine cement grout is resorted in pre-grouting, for which no additional payment shall be made. However, trial mixes should be carried out for grout optimisation & its effect.

4) In order to ensure efficient and satisfactory performance, Contractor shall employ competent and experienced drilling and grouting supervisors who shall execute directions of Engineer and supervise the work to be done.

5) During drilling, grouting, washing and pressure testing operations, the Contractor shall keep concrete and rock surfaces free and clean of oil, grease, drill cuttings, grout, cement, excess of water or any kind of waste. At all times during the progress of the work covered by this section Contractor shall protect all open drill holes from becoming plugged or filled with oil, grease, drill cuttings, grout or waste. Contractor shall clean up; and remove all waste upon completion of the work in each area before he vacates that area.

6) Modifications to drilling and grouting techniques may be required as the knowledge and experience of rock and foundation conditions are gained. The Contractor will be required to alter his operations properly to meet such modifications as per instructions of the Engineer. Necessity may also arise for drilling holes at certain places in a telescopic manner.

7) Both percussion and rotary core drilling will be required (grouting and pressure relief) from surface as well as dam galleries at various angles including vertically upwards.

8) All drill holes shall be thoroughly washed and cleaned by allowing drilling water to run until the return from the hole is reasonably clean as explained in IS: 6066.

9) All drill holes shall be protected from being clogged. Clogged holes shall be redrilled and cleaned at Contractor's cost.

10) Unless indicated otherwise, the drill holes shall not deviate from their designed alignment by more than 2% of their designed length.

11) Drilling through overburden shall be done by ODEX or other suitable method approved by the Engineer. Consequently, grouting shall be done by method "grouting through tubes with sleeves" as described in IS:4999 or any other equivalent method approved by Engineer. Execution and controls shall be as per IS:4999 for overburden grouting.

7.8.2. DRILLING

7.8.2.1. GENERAL

1) The holes shall be drilled at locations, in the sequence, orientation, inclination and to the depths shown on the Drawings or as required by Engineer.

2) Most of the holes for consolidation and contact grouting and pressure relief will be drilled with drill of the percussion type which shall be equipped for constant water flushing at the far end of the drilling rod.
Unless otherwise directed by the Engineer, drain or pressure relief holes shall be drilled by percussion drilling and flushed clean.

All drill holes for curtain grouting shall be rotary drilled holes unless otherwise directed by the Engineer. Where shown on the drawings, sleeves will be provided in the concrete for grout holes. Rotary drills with diamond tipped coring bits of the same diameters as the grout holes shall be available to penetrate any reinforcement which cannot be avoided by sleeved holes.
Should steel reinforcement be encountered during the drilling of any hole in concrete, where required by the Engineer, drilling shall be discontinued immediately and a new hole shall be drilled alongside. Such discontinued holes shall be stemmed.

3) The use of rod dope, grease or other lubricants on drill rods shall not be permitted. No drilling water additives of any kind shall be used without the written permission of Engineer.

4) Holes drilled for contact/ consolidation/ curtain grouting in various structures shall be of 45 mm dia., unless otherwise directed by the Engineer.

5) Holes for pressure relief (in dam foundation and dam body) shall be percussion drilled of 200 mm diameter unless otherwise specified by the Engineer.

6) Holes for pressure relief (in excavation slopes) shall be percussion drilled of 76 mm diameter unless otherwise specified by the Engineer.

7) All holes shall be established to within 250 mm of the specified location. All orientation shall be within 1 degree of the orientation specified. If for any reason the drill hole deviates in inclination or orientation in such a way that it does not satisfy the purpose for which it was intended, the Contractor shall correct the deviation or shall drill another hole to the satisfaction of Engineer.

8) Whenever the drill water is lost or artesian flow is encountered drilling operations may be stopped by Engineer who may require the hole to be grouted before drilling operations are resumed. The Contractor is required to record the location, the flow and pressure of any artesian conditions encountered in any drill hole.

9) On completion of drilling of any grout, exploratory, check and pressure relief holes, the drilled hole shall be washed with high pressure water to remove all drill cuttings, sediments, sludge and other loose or foreign materials until the return water is clear,
The Contractor shall immediately cap the holes with proper removable plugs (wooden or plastic) and shall protect them from entry of dirt or other foreign material. Any grout or pressure relief hole that gets obstructed prior to grouting or installation of elbow shall be cleaned out or another hole shall be drilled by the Contractor.

10) Pressure relief holes shall be installed with perforated PVC pipe or PVC slotted liner where shown on the Drawings or directed by the Engineer. The diameter of PVC slotted liner, pattern and size of its slots shall be as shown in the drawings or as directed by the Engineer. A preliminary diameter of PVC slotted pipes of 36 mm shall be considered, unless otherwise specified in the Drawings or directed by the Engineer.

11) Grout or pressure relief holes shall not be drilled within 12 m of another hole which is being grouted or which has been grouted within the previous 24 hours.

12) No hole shall be drilled through concrete before 5 days after the placement of the concrete.

7.8.2.2. EXPLORATORY DRILLING / HOLES FOR INSTRUMENTATION / CHECK HOLES ETC.

1) The Contractor shall perform exploratory drilling holes through overburden, concrete, rock and hardened grout at any inclination as directed by Engineer. The amount and the requirement for exploratory drilling will be determined by Engineer.

2) The use of mud or any other drilling fluids besides water is not permitted when coring.

3) Whenever the Engineer asks for the core recovery, the Contractor shall collect the cores and the cores shall be placed in wooden boxes in the correct sequence and designated accurately by permanently labelled wooden blocks recording the measured distances in the hole. No box shall contain cores from more than one hole. Designation marks, hole numbers and depth values shall be inscribed in the boxes, the cover securely fastened to the core boxes, and the boxes delivered at an area near the site as designated by the Engineer.

Before the cores are sampled and as soon as possible after cores have been correctly packed in the core boxes and marked up, the Contractor shall photograph the core boxes in colour.
The core box shall be arranged so that all details of the core and markings inside the core box will be clearly visible and easily readable in the photograph, which shall also include colour charts, a linear scale and a title board. To facilitate the clarity, the cores shall be wetted just before being photographed. The Contractor shall submit the photographs in digital form to the Engineer.

4) Maximum core recovery will be required and if the blocking of the core is indicated by the drill behaviour, the core shall be removed immediately from the hole, regardless of the length of run, which has been made.

5) Exploratory holes shall be water pressure tested and grouted under pressure if required by Engineer.

6) The Contractor shall give the Engineer all the necessary assistance and facilities to perform in situ tests or examination using bore hole camera or geophysical tests in the selected exploratory holes if required by Engineer.

7.8.2.3. DRILLING FOR CRACK GROUTING IN CONCRETE LINED GALLERIES

1) The contractor shall drill holes for the crack grouting and sealing of open cold joints, construction joints and cracks in the concrete lining as directed by the Engineer and as stipulated in Section 'Concrete'.

2) The drilling shall consist of a series of 38mm dia. drill holes executed within or along the cracks which have been determined by Engineer to receive such treatments. Rotary drilling shall be used unless otherwise approved by the Engineer.

7.8.3. WASHING AND WATER PRESSURE TESTING

1) Immediately before grouting or pressure testing, the hole shall be thoroughly washed with water as explained in IS: 6066 or any other standard practice as approved by the Engineer.

2) In conjunction with the drilling and grouting operations, the Contractor shall make water tests in grout holes and check holes at any time and at such depths as are required by the Engineer to determine the permeability of the rock and the effectiveness of the grouting operations. The Contractor shall set packers in the drill holes at locations determined by the Engineer, supply all

necessary equipment, gauges etc., inject water at pressures determined by the Engineer and record the rate of water acceptance.
Unless otherwise directed by the Engineer abbreviated water tests shall be conducted in designated holes immediately before grouting.

3) Abbreviated water tests shall be conducted in grout holes in each stage above the water table to wet up the surrounding rock. A simple water pressure test involves isolating a segment of a hole generally 3 to 5 m in length by means of a single or double packers and pumping in water at constant pressure for a period of 10 minutes. The tests shall be carried out as per IS: 6066 or any other standard procedure or code of practice approved by the Engineer.

4) All cored grout holes shall have a comprehensive water test per stage drilled. The Engineer may, at his discretion, instruct comprehensive water tests on other types of holes.

5) Water shall be pumped into the hole in 5 incremental stages up to the pressure specified by the Engineer and then reduced in the same stages. The pressure shall be maintained constant for 10 minutes at the end of each pressure increment or decrement and the rate of flow shall be measured and recorded at minimum 1-minute intervals. The pressure and flow shall be carefully recorded with digital apparatus and made immediately available to the Engineer.

7.8.4. GROUTING

7.8.4.1. GENERAL GROUTING PROCEDURE

1) Grout holes shall not be grouted except with permission from the Engineer, until the concrete/shotcrete within a radius of 12 m from the grout hole has been completed and cured for five days.

2) Full depth grouting shall be limited to 5 m depth of hole in rock, however with latest information about rock geology, experience and pre-grouting results the Engineer may allow full depth grouting up to 10 m depth.

3) For deeper grout holes, more than 5 m length the grouting shall be performed in stages of not more than 5 m length of grout holes as directed by the Engineer.

4) Once the grouting of a stage of a hole has been commenced it should be continued without interruption until completion. In general, a stage may be considered complete when absorption of grout at the desired limited pressure is less than 1 lit./meters/min over a period of 5 minutes.

5) As far as practical, a continuous flow of grout should be maintained at the desired pressure and the grouting equipment shall be operated to ensure continuous and efficient performance throughout the grouting operation. The Contractor shall respond quickly and effectively to manipulate the desired changes in the grout mix consistency, rate and pressure of injection, etc., as directed by the Engineer during the grouting operation.

6) When grouting is interrupted due to plant break down, about 500-1000 liters of clean water should be run into the hole and allowed to stand.

7) Should any hole connect to another during injection, the grout should be allowed to escape from the coupled hole until it is of the same consistency as that being injected; the coupled hole should then be capped and the combined holes brought up to pressure. After the first hole has been grouted, all the other holes are successively connected to the grouting header to subject them to the full pressure.

8) Grouting shall be stopped whenever pressure gauges register a sudden drop of pressure or the rate of grout absorption increases abruptly or there is any indication of upheaval, disturbance or leakage. Additional holes may have to be drilled and grouted in the vicinity or sealing cracks which might have been left due to premature blocking of holes by interruption of grouting operation.

9) The true pressure at any depth should take into account the pressure head caused by weight of the grout in the hole as explained in IS: 6066

10) The control of pressure shall be exercised according to the guidelines of IS: 6066.

11) Compositions of all grout mixes shall be approved by the Engineer.

12) All grout holes shall be backfilled with grout mix 0.7 water: 1 cement with 3% bentonite or by mix as approved by Engineer after the grouting. A minimum 25 mm diameter delivery pipe is lowered to the bottom of the hole. Grout is pumped in the delivery pipe until it flows from the hole, then the delivery pipe is slowly withdrawn while pumping continues. If settlement of grout occurs after initial set, the holes shall be again backfilled by grout.

13) The Contractor shall caulk, dry pack or seal any surface leaks in rock or concrete before continuing grouting operation.

14) In areas of higher grout consumption sand may be required to be incorporated in the mix, the proportions of the sand permitted shall normally not exceed 2 parts of sand for 1 part of cement with approved plasticizer.

15) The grout mixes, which cannot be injected within 1 hours of mixing, shall not be used for grouting.

7.8.4.2. CONTACT GROUTING IN UNDERGROUND STRUCTURES

1) Low pressure contact grouting shall be carried out between concrete lining and rock over the entire length of concrete lined section.

2) Contact grouting shall normally be performed from sleeve pipes provided in the concrete for grout holes. Rotary drills with diamond tipped coring bits of the same diameters as the grout holes shall be available to penetrate any reinforcement which cannot be avoided by sleeved holes, previous authorization of Engineer.
Contact grouting holes and shall be carried out in advance of consolidation grouting operations.

3) Washing and water pressure testing will not be required prior to contact grouting, unless otherwise instructed by the Engineer.

4) In any section of the underground structure, the concrete lining within 50 m of that section shall have been in place for at least 21 days before grouting commences.

5) Contact grouting shall be carried out at low pressure and shall continue until all voids are filled, unless otherwise directed by the Engineer. Vent pipes for the release of air and water during grouting shall be provided in locations directed or approved by the Engineer.

6) After the grouting of any hole is completed, the pressure shall be maintained by means of a stopcock or other suitable device until the grout has set.

Check grouting shall be carried out as directed by the Engineer, to verify that voids have been completely filled with grout. Grouting will be regarded as being satisfactory if the pressure can be maintained for at least 5 minutes without further grout take.

7.8.4.3. GROUTING OF THE CONCRETE PLUGS

1) Once the concrete plugs of the diversion tunnels and construction sluices have been completed and sufficiently hardened, contact grouting between the plugs and the surrounding concrete shall be

performed where necessary. Grout shall be forced through previously installed feeder pipes and to grout outlets placed between the plug and the surrounding concrete faces and in vertical construction joints between the plug sections.

2) All grouts shall consist of neat cement/water mix. The addition of bentonite, admixture or other chemical substances will be considered case by case at the laboratory following the Engineer instruction. Water at a temperature not exceeding 30 °C shall be used in the mix to prevent quick setting of the grout.

3) The grout shall be pumped into the bottom headers of the pipe system and the vent or highest headers shall be left open until the joint is filled with grout of proper consistency for retention in the joint. Thereupon the system shall be closed and the required pressure applied and held until the grout has set sufficiently to be retained in place.

4) Nipples, valves or collars in the exposed faces shall be removed and the holes filled with dry pack mortar.

7.8.4.4. CONCRETE-STEEL CONTACT GROUTING

1) Low pressure contact grouting shall be carried out to fill all voids between the steel lining and backfill concrete/ backfill concrete and surrounding rock. The maximum grouting pressure shall be 3 bar or as directed by Engineer. A special air chamber and safety valve shall be incorporated into the grouting system to smooth out pressure fluctuations and limit maximum pressure.

2) Holes shall be drilled 300 mm into the rock or concrete from pre tapped holes provided in the steel liner by the hydro mechanical contractor. The contractor shall provide threaded pipes to protect the tread of the grouting hole during the drilling and grouting operation.

3) Caution shall be exercised by the Contractor during the grouting operations to prevent any damages to already applied corrosion protection of the steel lining.

4) After completion of grouting, the contractor shall clean the threaded holes and screw the plugs into position. The plugs will be welded permanently into the steel lining and the stub heads ground off flush by the lining supplier. When this work is complete the contractor shall thoroughly clean the whole steel lining surface of all grout remnants and other debris, and shall assist the lining supplier in restoration of the pre-applied corrosion protection.

5) After conclusion of the grouting, the Engineer and contractor will inspect together the effectiveness of the grouting. Should a hollow sound indicate voids, the lining supplier will open additional holes through which the contractor will inject grout until all voids are completely filled. The Contractor shall extend all assistance to the lining supplier.

6) Grouting between the steel lining and the backfill concrete shall not commence until the backfill concrete within 30 m of the section being grouted has been in place for at least 28 days.

7) Works shall be required to be executed in close coordination with HM contractor.

7.8.4.5. CONSOLIDATION GROUTING AND PRE-GROUTING

1) Consolidation grouting shall be performed underneath or around structures from the surface at the Dam foundation, rock galleries and in any other zone within the construction sites where conditions so dictate and as the Engineer may direct.

2) Consolidation grouting shall normally be performed in a single stage through a nipple or packer installed at the collar of the hole within the concrete lining, but if geological conditions so dictate multiple-stage grouting either in ascending or descending arrangement shall be performed in the deeper holes.

3) Consolidation grouting at an open-air structure shall first commence 7 days after concrete placement. Grouting for rock consolidation in any section of the completed underground structure shall not start earlier than 21 days after completion of contact grouting within 50 m of that section.

4) Consolidation grouting shall extend over the full length of the dam foundation or as directed by the Engineer. It shall be performed to a depth of approximately 10 m at a spacing of 3 m or as directed by the Engineer. The grout pressure shall not exceed 10 bar unless otherwise instructed by the Engineer.

5) In rock galleries depth of consolidation grouting shall be approximately 10 m or as directed by the Engineer. Grouting shall be done in a continuous operation avoiding disturbance of zones grouted within the previous 24 hours. The grout pressure shall not exceed 10 bar unless otherwise instructed by the Engineer. Consolidation grouting may also be required during the excavation works in order to consolidate the heading face or seal off the inflow of groundwater.

6) Immediately before grouting, the grout holes shall, rock characteristics permitting, be thoroughly washed out under pressure until the returning water is clear, and pressure tested.

7) Grout holes adjacent to a grout hook-up shall be left open during grouting operations to facilitate the escape of air and water from pockets in surrounding rock. Where, during grouting of any hole, grout is found to be flowing from adjacent holes or cracks of any kind, such openings shall be capped temporarily by plugging or caulking.

8) When performing the multiple-stage grouting in descending arrangement, the grout that is within the hole shall be removed from each stage except the deepest one, by washing, or by the use of a chopping or a "fishtail" bit before the grout sets.

9) In the event of a sudden drop in pressure or a sudden increase in grout take, grouting operations shall be temporarily halted until the crack or opening causing the loss is located and caulked. During this time the drill hole shall be continuously washed to avoid a premature grout set which would inhibit grouting when resumed. If such a pressure drop or increase in grout take can be related to hydro fracturing, grout pressure shall be reduced.

10) If surface grout leaks cannot be located and successfully caulked, or the cause for the pressure loss cannot be determined, within 1 hour, the washing of the drill hole will be stopped and the grout in the rock formation shall be allowed to set for 24 hours. After setting, the drill hole shall be hooked onto again and grouted. If the hole, or stage, does not accept grout the hole shall be redrilled or a replacement hole shall be as directed by the Engineer.

11) If, during grouting, there is a communication between the holes the Contractor shall either set packers in the communicating holes, which shall be bled of, accumulated air frequently and continue grouting one hole after another, or he may pressure grout the communicating holes simultaneously.

12) Grouting injection will be deemed to be completed when the take has become less than indicatively 2 litre/metre/minute at the specified grouting pressure and mixture. The grouting methodology (e.g. refusal or GIN) and relevant limit values will be established by the Engineer based of the actual geological and geotechnical conditions and results of grout test panels.

    Additional consolidation grouting holes may be prescribed by the Engineer based on the results of grout injections in a certain zone.

13) After completion of grouting, the packers shall remain in the hole and the pressure shall be maintained until the grout has attained its initial set.

14) Testing of efficacy of grouting: The contractor is required to do the testing for the efficacy of the consolidation grouting by way of water pressure tests. The water pressure test shall be carried out both for pre and post grouting stage to assess the effectiveness of grouting operations. Based on the information of water pressure testing, the Engineer shall determine whether the grouting in each section of works under consideration is completed in a satisfactory manner, or whether additional grouting in separate drill hole is required. The termination of grouting work in any sequence in any section of the Works will be as determined by the Engineer.

15) Pre-grouting consists of drilling 45 mm diameter holes up to 10 m long (57mm diameter when with use of colloidal silica, up to 15-30 m long). In general, for pre-grouting operations, grout pump should be of duplex-piston type capable of producing controlled pressure of 10 MPa. All pipes/hoses/other connections should be compatible to withstand maximum pressure of the grouting equipment. Grout mixer shall be a high shear colloidal mixer with minimum rotor speed of 1500rpm.

    Pre-grouting with colloidal silica shall be carried out at a high pressure (>5 MPa) as directed by Engineer. Colloidal silica shall be of reputed make and duly approved by Engineer having viscosity of 5m Pa-s and particle size of 0.016 µm.

    Suitable dispersing agent with dosage 1.5-2% of cement weight shall be used wherein ultrafine cement grout is resorted in pre-grouting, for which no additional payment shall be made. However, trial mixes should be carried out for grout optimisation & its effect.

7.8.4.6. CURTAIN GROUTING

1) Curtain grouting shall be performed as indicated in the Drawings and or directed by the Engineer, mainly from the galleries in the dam body and their extension in the rock mass and Diversion Tunnel Plugs. Hole depths, inclinations, sequence of grouting, method of grouting, whether single or multi-stage, in ascending or descending arrangement shall be as directed by the Engineer based on information from exploratory drilling or current operations. The holes shall be drilled and grouted by the split-spacing method. In principle, all curtain grouting holes require multi-stage grouting.

    Unless otherwise instructed by the Engineer, every 4th primary hole in the grout curtain shall be cored and comprehensively water tested. Rotary core drilling will be carried out by means of a diamond or a tungsten tipped bit using a double tube or triple tube core barrel from which 100% core recovery is expected. The diameter of grouting holes shall be 45 mm for curtain grouting and exploration work, unless otherwise directed by the Engineer.

Drilling for grout curtain holes shall be carried out with water circulation. If water loss is experienced, drilling shall cease and the hole shall be grouted to refusal, irrespective of depth reached, before resuming the drilling operation.

Where support to the sides of the hole is necessary the Contractor shall supply and install drillhole casing to a depth approved by the Engineer. The casing shall be of sufficient diameter to permit a drillhole of the specified size to be drilled within it.

2) In normal sequence of grouting all primary holes shall be completed in the area being treated prior to commencement of secondary holes, with secondary holes competed in advance of tertiary. Grouting operation shall be ascending from bottom to top of hole. In case of collapse of the hole or total loss of the drilling fluid, grouting shall generally be performed in descending arrangement.

3) When performing the multiple-stage grouting in descending arrangement, the grout that is within the hole shall be removed from each stage except the deepest one, by washing, or by the use of a chopping or a "fishtail" bit before it takes a hard set.

4) Stage length shall be a maximum of 5 m unless differently instructed by the Engineer.
During the grouting stage where there is an interface with the dam concrete the packer shall be placed 1 m into the mass concrete to ensure that contact grouting is accomplished.

5) Unless otherwise determined by the Engineer grouting associated with the dam works will follow the GIN (Grouting Intensity Number) method, i.e., it will be governed by a relationship between the grout take V and the pressure P to be reached. Grouting will be stopped when the product P x V reaches a specified GIN boundary curve function, defined by three values: Grouting Intensity Number (product of the injection pressure, P and the cumulative volume, V), maximum grout pressure (P_{max}), maximum cumulative volume of grout taken (V_{max}). These values shall be determined by ground conditions by undertaking grouting trials in advance of the main grouting works in the most representative geological units. The purpose of the trials is to establish the appropriate depth and spacing of hole, grouting methods (GIN value, maximum pressure) and grout mixes.

6) Where open features and / or voids are present, grouting using GIN method shall be used as a second stage treatment, only after the voids or open features have been first treated with mortar or other agreed method.

7) In general, the pressures shall be as high as practicable but shall be limited so as not to cause fracturing / displacement of rock, concrete. The Contractor shall regulate, measure and supervise the grouting operations continuously so that the pressures are at all times in accordance with the

Engineer's instructions or approvals. Grout pressure shall not be released nor packers moved until the grout in each successive stage has achieved an initial set.

8) Completion criteria

Once the value of P x V reaches the boundary curve the flow rate will be reduced as the cumulative volume increases so that the product of P x V remains constant at or below the limiting GIN value. This operation is to be carried out using approved computed controlled, piloted grout pumps at all stages of an injection, using continuous real time feedback of data on the pressure, cumulative volume and flow rate to the grouting computer. The computer shall then respond to the incoming data and automatically slow down the rate of the pumping to allow the value of P x V to track the GIN boundary curve until one of the following criteria is reached:

- Maximum pressure, no further injection is possible without exceeding the allowable pressure
- Maximum volume, the cumulative volume of grout injected has reached the target limit
- Minimum flow rate, the injection rate falls to a level which is impractical or poses considerable risk of blockage to the pump/injection lines, taken as 1 litre/min/metre over a 5-minute period.

9) Closure Criteria

Closure criteria are the criteria by which grouting in any given panel or area is considered completed. During the grouting process, the take of subsequent hole series should progressively diminish while the final pressures increase in inverse proportion. This is related to the fact that the wider open joints will be grouted to a greater distance than the thinner ones.

The appropriate closure criteria shall be defined upon the execution of trial grouting.

In general, a portion of the curtain will be considered completed if, in the relevant GIN chart (P and V axis), the final injection points fall on the leftmost side of the maximum grout pressure line (P_{max}). On the contrary additional holes may be generated.

10) The curtain grouting shall be performed from one or several grout stations. If several such stations are used, each shall be equipped complete, with mixers, agitator sumps, pumps, gauges and measuring devices, and shall have a sufficient supply of grouting materials.

11) In case when the required pressure is not reached even when injecting maximum volume, the Engineer will decide whether the grouting will be interrupted, or the grout mixture is to be changed, or accelerator added.

12) Where grout is found to be flowing from adjacent holes or cracks of any kind, such openings shall be capped temporarily by plugging or caulking. If this does not bring satisfactory results, further grouting shall be interrupted and the injected material allowed hardening.

13) After the conclusion of the grouting program, the Contractor shall drill check holes at the spacing of 30m or as decided by Engineer, at the full depth of the grout curtain. Check holes may also be drilled in areas of complex hydrogeology, which require particular treatment. These holes shall be grout injected following the same methodology of grout holes. Based on the water pressure test results obtained in the check holes, the Engineer may order additional grout holes or a new line of grout holes to be executed.

14) The general target of permeability of the grouted dam foundation rock is 3 Lugeons. Any sections of the grout curtain which fails to achieve the design permeability criteria shall have additional drilling and grouting undertaken on it over a 10 m wide section either side of the failed test, and then be re-tested as above.

15) Where grouting holes have been drilled through mass concrete and require backfilling these shall be filled with an approved grout mix achieving the equivalent concrete strength. The backfilling of holes shall be undertaken via gravity grouting using a tremie from the base of the hole.

7.8.4.7. PROTECTION OF DRAINAGE SYSTEM DURING GROUTING

The Contractor's grouting plan shall be such as to afford maximum protection against blockage of temporary and permanent drains. If necessary, the Contractor shall maintain a flow of water through the drains likely to be affected during grouting operations. Should leakage of grout into drains occur, the Contractor shall remove grout from the affected drains.

7.8.4.8. FILL GROUTING/ CLOSURE OF HOLES AND CLEAN-UP

1) Upon completion of grouting work each hole shall be backfilled with a thick grout mix or dry pack mortar as directed by Engineer.

2) Filling of upward inclined holes shall be by pressure injection unless a thixotropic grout is used. Filling of downward inclined holes shall be through tremie pipes pushed down to the bottom of the holes and withdrawn slowly as filling proceeds after first blowing all water out of the holes The end of each hole shall be filled to a depth equal to the lining thickness with dry pack mortar which is well rammed in and finished flush with the face of the concrete, or in the case of embedded steel, not more than 5 mm below the steel/concrete interface. If any hole shows signs of weeping water after being stemmed the hole shall be drilled out, regrouted and re-stemmed without any additional payment

3) After completion of the grouting works the internal surface of the concrete or steel lining shall be cleaned and restored to its original condition.

7.8.4.9. CRACK GROUTING IN CONCRETE LINED GALLERIES

1) Crack grouting shall be performed, if required, in the concrete lining of the stretch of dam body galleries extended in the rock mass.

2) Crack grouting shall be performed to seal the cold joints, construction joints, shrinkage cracks, honey combs, poorly closed grout holes etc., in the structural concrete as directed by the Engineer and as stipulated in section B.9 "Concrete".

3) Crack grouting shall consist of injecting a stable, cement-water mix through holes specially drilled into cracks or joints. Prevention measures shall be taken by plugging the joint with wooden wedges, cardboard, cement gypsum mortar or other suitable means to prevent the grout from flowing out of the joint.

4) Chemical injections may be required for crack grouting, as instructed by the Engineer. When chemicals are required, they shall be accompanied by the manufacturer's certificates that they have been commercially used with satisfactory service in similar type of work. The storage, handling and usage shall be according to the manufacturer's instructions. The use of toxic chemicals shall not be permitted.

7.8.4.10. GROUTING OF OVERBURDEN BELOW COFFERDAM

1) The riverbed overburden below the pre-cofferdam, which mainly consists of gravel, boulder and porous material, may be grouted if shown in the drawing or required by the Engineer

2) Drilling (150 mm min dia) shall be done by ODEX method as described in IS:4999 or by equivalent method as approved by the Engineer.

3) Grouting shall be done through tubes and sleeves system as described in IS:4999. Alternative equivalent or superior method according to established procedure as approved by the Engineer may also be used for grouting.

4) Specialized agency / subcontractor shall be deployed by the contractor for drilling & grouting of overburden below coffer dam and as approved by the Engineer.

7.9. MEASUREMENT AND PAYMENT

7.9.1. GENERAL

1) The estimates of the quantities for drilling, water pressure testing, sampling, and grouting given in the Bill of Quantities are to be considered merely as a guide serving the Contractor to prepare his Tender and not as an accurate indication of the quantity of the work.

2) The quantities for each of the pay items will be varied to suit the conditions disclosed in the course of the work, and the Contractor shall not be entitled to any extra payment over and above the Unit Prices entered in the Bill of Quantities by reason of changes of the amount and length of holes to be grouted and amount of material absorbed, by reason of the location of the grouting required by the Engineer, or by reason of the timing of the grouting in relation to excavation, concreting or other works.

3) The measurement and payment for drilling shall be as per the unit rate for respective diameter and method of drilling as entered in the Bill of Quantities.

4) Measurement for payment and payment for grouting will be made separately for 'placing grout' and for 'grouting materials'.

5) Unit Prices for placing grout shall include, but not limited to, the entire cost of labour, equipment, processing, mixing, hooking-up to the hole (where appropriate), injecting grout, hole closures and clearing up, and shall be independent of the volume or weight of materials injected. Where multiple-stage grouting is employed, this item shall also include cleaning grout from the holes at the completion of a grouting stage. Each stage of grouting shall constitute one operation.

6) Unit Prices for grouting materials shall include, but not be limited to, the entire cost of supply, handling, transportation, storage, and testing.

7.9.2. DRILLING

7.9.2.1. DRILLING FOR CURTAIN GROUTING

1) Measurement for payment for rotary drilling of 45 mm diameter grouting holes in rock/ concrete will be of the length of holes actually drilled in positions as directed by the Engineer. Payment will be made at the Unit Price per linear meter entered in the Bill of Quantities, which shall include the entire cost of labour, equipment and materials for drilling and washing out of the holes and for temporary casing, if required. The Unit Price shall apply irrespective of the location, inclination or direction of the hole.

2) When drilling of the hole is carried out successively for multiple-stage grouting, the measurement for payment will only be of the total length of the hole drilled actually in the rock or concrete. Any re-drilling required because of the Contractor's failure to clean the grout out of the hole before it has set shall be performed at the expense of the Contractor.

3) Measurement for payment for any required re-drilling where the grout has been allowed to set at the direction of the Engineer will be of the actual length of re-drilled hole. Payment for this length in linear meters will be made in the form of an additional payment over and above that made for the original drilling at the rate of 50% of the appropriate Unit Price.

7.9.2.2. DRILLING FOR CONTACT/CONSOLIDATION GROUTING OR PRE-GROUTING

1) Measurement for payment for rotary drilling of 45 mm dia. through any material for contact/consolidation grouting and percussion drilling of 45 and 57 mm diameter holes through any material for pre-grouting, carried out either during the excavation or after placing of the concrete, will be of the length of holes drilled in positions shown on the Drawings or established at the Site by the Engineer. Payment will be made at the Unit Price per linear meter entered in the Schedule, which shall include the entire cost of labour, equipment, and materials for drilling and washing out of the holes, maintaining the holes free from obstructions until grouted, reaming or re-drilling the holes after completion of grouting and filling with dry-pack mortar.

2) Where drilling is required after placing of the structural concrete lining, measurement of the length of hole drilled shall include the theoretical thickness of the lining irrespective of whether the hole was actually drilled through the lining or formed by other means.

3) When drilling of the hole is carried out successively for multiple-stage grouting, the measurement for payment will only be of the total length of the hole drilled actually in the rock or concrete. Any re-drilling required because of the Contractor's failure to clean the grout out of the hole before it has set shall be performed at the expense of the Contractor.

4) Measurement for payment for any required re-drilling where the grout has been allowed to set at the direction of the Engineer will be of the actual length of re-drilled hole. Payment for this length in linear meters will be made in the form of an additional payment over and above that made for the original drilling at the rate of 50% of the appropriate Unit Price.

7.9.2.3. DRILLING OF PRESSURE RELIEF HOLES

1) Separate measurement and payment will be made for the following:
   a) Drilling and washing out of the dam and foundation drainage hole
   b) Drilling and washing out of the excavation slopes drainage hole
   c) Supply and installation of slotted PVC pipes/ liner
   d) Supply and installation of drain holes outlet devices. Details of outlet devices are shown on the Drawings.

2) Measurement for payment for percussion drilling of dam and foundation drainage holes of 200 mm diameter and percussion drilling of excavation slopes drainage holes of 45 mm dia. will be of the length of holes actually drilled in positions as directed by the Engineer. Payment will be made at the Unit Price per linear meter entered in the Bill of Quantities, which shall include the entire cost of labour, equipment and materials for drilling and washing out of the holes and for temporary casing, if required. The Unit Price shall apply irrespective of the location, inclination or direction of the hole.

3) Measurements for payment of PVC pipe/ liner installed in the drainage holes as directed by the Engineer will be of the length of pipe so installed. Payment will be made at the Unit Price per linear meter entered in the Bill of Quantities, which shall include the entire cost of supply and installation of perforated or non- perforated pipes, as well as all necessary couplings.

4) Measurement for payment for the supply and installation of drain holes outlet devices will be of the number of outlets installed. Payment will be made at the Unit Price per piece entered in the Bill of Quantities, which shall include the supply and installation of all required accessories and sealing with mortar.

5) Where re-drilling of the previously drilled drainage holes is required after an additional grouting, measurement for payment will be of the actual length of re-drilled hole. Payment for this length in linear meters will be made in the form of an additional payment over and above that made for the original drilling at the rate of 50% of the appropriate Unit Price.

7.9.2.4. DRILLING OF EXPLORATORY HOLES, CHECK HOLES, AND HOLES FOR INSTRUMENTATION

1) Separate measurement for payment and payment will be made for the following:
   a) Drilling of holes 45 mm minimum diameter with and without core recovery,
   b) Drilling of holes 76 mm minimum diameter with and without core recovery,
   c) Drilling of holes 98 mm minimum diameter with and without core recovery,
   d) Drilling of holes 115 mm minimum diameter with and without core recovery

e) Drilling of holes 150 mm minimum diameter with core recovery (RCC dam coring)

f) Drilling of holes 400 mm minimum diameter without core recovery (invert pendula, diameter shall be confirmed in Drawings)

g) Extra over for drilling with triple tube core barrels.

2) Measurement for payment for drilling of exploratory holes will be of the length of holes of different diameters drilled in positions as directed by the Engineer, for any inclination. Payment will be made at the appropriate Unit Price per linear meter of drill holes of different diameters entered in the Bill of Quantities, which shall include the entire cost of labour, equipment and materials required for rotary drilling of holes.

3) Measurement for payment for core recovery when ordered by the Engineer will be of the length of the cored hole. Payment will be made at the Unit Price per linear meter entered in the Bill of Quantities, which shall include the entire cost of labour, equipment and materials required for the core recovery, provision of core boxes, preservation and storage of cores, preparation of technical logs of the drill holes, provision of colour photographs of the boxes cores, and any assistance provided by the Contractor to the Engineer during the geological logging and handling of core boxes.

The Unit Prices for drilling from the underground shall apply irrespective of the location inclination or direction of the drilling.

7.9.2.5. DRILLING FOR CONTACT GROUTING IN UNDERGROUND STRUCTURES, INCLUDING DIVERSION TUNNEL PLUGS AND FEEDER TUNNEL

1) Measurement for payment for drilling the holes for contact grouting between the concrete and rock in the concrete-lined and steel lined-sections of underground structures will be of the length of holes drilled in positions shown on the Drawings or established at the Site by the Engineer, irrespective of the location or inclination of the hole. Payment will be made at the Unit Price per linear meter entered in the Bill of Quantities, which shall include the entire cost of labour, equipment and materials required for setting-up drilling equipment, drilling and washing out the holes, reaming or redrilling the holes after completion of grouting, and filling with dry-pack mortar.

2) Measurement for payment for drilling the holes for contact grouting between the steel/ concrete lagging and rock, or in any other zone will be of the length of holes drilled in accordance with Engineer's instructions, regardless of the location, inclination, direction or diameter of the hole. Payment will be made at the Unit Price per linear meter entered in the Bill of Quantities, which shall include the entire cost of labour, equipment and materials required for setting up drilling equipment; drilling and washing out of holes, reaming or re-drilling the holes after completion of grouting, and filling with dry-pack mortar.

7.9.2.6. DRILLING FOR CRACK GROUTING

No separate measurement for payment or payment will be made for drilling holes for crack grouting and sealing of cracks in the structural concrete lining and the cost thereof shall be included in the corresponding unit prices for the concrete lining in question.

7.9.2.7. WATER PRESSURE TESTING

1) Measurement for payment for water-pressure tests will be of the number of tests satisfactorily performed, irrespective of size, length, or inclination of hole or whether carried out in holes drilled from the surface or underground.

2) Payment will be made at the Unit Price per test entered in the Bill of Quantities, which shall include the entire cost of labour, equipment, and materials used for carrying out the water-pressure test, the provision of test records and reports to the Engineer, and all costs associated with interruptions to the drilling caused by the intermittent nature of the testing work.

7.9.2.8. EMBEDDED PIPES AND FITTINGS FOR GROUTING

1) Separate measurement for payment and payment will be made for standard mild steel pipes and fittings in rock and concrete.

2) Measurement for payment for such embedded steel pipes and fittings left permanently in place will be by weight, regardless of pipe diameter. Payment will only be made for pipes whose installation has been expressly ordered or approved by the Engineer or when shown on the Drawings. Payment will be made at the Unit Price per kilogram entered in the Bill of Quantities, which shall include the entire cost of supply, installation, and protection against blockage of pipes and fittings.

7.9.2.9. EXCLUSIONS – DRILLING

1) All costs for drilling the holes for rock reinforcement (viz. rock bolts, rock anchors and grouted anchor bar, drain holes, etc.), pregrouting, forepolling, pipe roofing and pre drainage holes are excluded from this Section and will be measured and paid for in accordance with provisions of the Section B.4 "Rock Supports".

2) No extra measurement for payment or payment will be made for the following:
   a) Drilling through steel ribs, steel/ concrete lagging, reinforcing steel or steel lining, Installation and removal of grout stub pipes,

b) Reaming or re-drilling any holes through the concrete lining for the purpose of placing, and for supplying and placing, the dry-pack mortar,

c) Holes which have been blocked and cannot be used because of cave-ins, lost drill rods or packers, or striking other obstructions (e.g. reinforcement bars), and drilling the new holes to replace them.

7.9.3. PLACING GROUT

7.9.3.1. CONTACT GROUTING IN CONCRETE UNDERGROUND STRUCTURES

1) Measurement and payment for placing grout will be made as number of operations, and payment will be made at Unit Price per grouting operation (Nos. of grouting operation is equal to nos. of holes up to 5m length) entered in the Bill of Quantities.

2) When contact grouting has been ordered by the Engineer, measurement and payment for placing grout will be made as number of operations, and payment will be made at Unit Price per Grouting Operation entered in the Bill of Quantities.

7.9.3.2. FILL GROUTING

1) Measurement for payment for filling the temporary drainage system in tunnel, or elsewhere, with grout will be of the length in which fill grouting has been completed to the satisfaction of the Engineer. Payment will be made at the Unit Price per linear meter entered in the Bill of Quantities, which shall include the provision of any standpipes, blockouts or extra drilling work required.

2) Measurement for payment for fill grouting of exploratory or control holes where directed by the Engineer will be of the length of holes so grouted. Payment will be made at the Unit Price per linear meter entered in the Bill of Quantities.

3) Unit rate of fill grouting shall include cost of grouting material and entire cost of grouting operations.

7.9.3.3. CONTACT/CONSOLIDATION GROUTING AND PRE-GROUTING

1) Separate measurement for payment and payment will be made for placing grout in holes:
   a) In single - stage grouting,
   b) In multiple - stage grouting,

2) Measurement for payment for placing grout in a single stage will be of the number of holes injected with grout. Payment will be made at the Unit Price per hole entered in the Bill of Quantities.

3) When multiple-stage grouting in holes, as directed by the Engineer, has been performed, measurement for payment and payment will be made for holes grouted. Measurement for payment will be of the number of stages in each hole injected with grout. Payment will be made at the appropriate Unit Price per stage entered in the Bill of Quantities.

7.9.3.4. CURTAIN GROUTING

1) Measurement and payment for placing grout will be paid as number of operations. Each grouting operation shall consist of a stage, normally 5 meters in length. The payment will be made at Unit Price per Grouting Operation entered in the Bill of Quantities.

7.9.3.5. CRACK GROUTING

No separate measurement for payment or payment will be made for crack grouting and the cost thereof shall be included in the Unit Prices for structural concrete lining.

7.9.4. GROUTING MATERIALS

7.9.4.1. CEMENT

1) Measurement for payment and payment for cement used for grouting (except for contact grouting in concrete lined tunnels and fill grouting) will be of the quantity, by weight.

2) Payment will be made at the Unit Price per metric ton entered in the Bill of Quantities, which shall include the entire cost of provision, delivery, transportation, storage and mixing, and complying with all requirements specified.

7.9.4.2. SAND AND BENTONITE

1) Measurement for payment for sand and bentonite will be of the weight of materials with average natural water content, obtained from the mixing plant records or by other means approved by the Engineer.

2) Payment will be made at the appropriate Unit Price per metric ton entered in the Bill of Quantities for each material which shall include the entire cost of provision, delivery, transportation, storage and mixing and complying with all requirements specified.

7.9.4.3. ADMIXTURES

1) Measurement for payment for admixtures (will be of the weight or volume of the agreed dosages established at trial mix stages or the approved modifications thereof.

2) Payment will be made at the Unit Price per kilogram entered in the Bill of Quantities, which shall include the entire cost of supply, handling, storage, and dispersing.

7.9.4.4. MICRO FINE/ ULTRA FINE CEMENT

1) Measurement for payment and payment for micro fine/ ultra fine cement used for grouting will be of the quantity, by weight.

2) Payment will be made at the Unit Price per Kg entered in the Bill of Quantities, which shall include the entire cost of provision, delivery, transportation, storage and mixing, and complying with all requirements specified.

7.9.4.5. COLLOIDAL SILICA OR OTHER CHEMICALS

1) Measurement for payment and payment for Colloidal silica or other chemical compound used for grouting will be of the quantity, by weight.

2) Payment of colloidal silica or other chemical compound, if used, will be made at the Unit Price per kilogram entered in the Bill of Quantities, which shall include the entire cost of provision, delivery, transportation, storage and mixing, and complying with all requirements specified.

7.9.5. GROUTING OF OVERBURDEN BELOW COFFERDAMS

1) Measurement for payment and payment for drilling and grouting in overburden below cofferdam shall be the length of hole drilled in overburden and grouted using pipe and sleeve method. Payment shall be made at the unit price per linear meter entered in the schedule, which shall include the entire cost of labour, equipment, casing, drill bits, bentonite sheath grouting, provision of tube and sleeve and carrying out grouting operation in stages.

2) The cost of cement, bentonite and sand shall be paid separately.

7.9.6. EXCLUSIONS – GROUTING

1) All costs for grouting of the rock bolts, grouted anchor bar post-tensioned rock anchors are excluded from this Section and will be measured and paid for in accordance with the provisions of the Section "Rock Supports".

2) No extra measurement for payment or payment will be made for following:
   a) Preparation and testing of trial mixes,
   b) Grouting materials used in contact grouting in the crown of the concrete lined hydraulic tunnel.
   c) Grouting materials used in mixture which has been prepared more than one hour prior to injecting or which have been lost due to improper handling or rejected due to improper mixing,
   d) Supply and injection of water,
   e) Plugging and caulking leaks during grouting,
   f) Protection of drainage system, if any, during grouting,
   g) Communication facilities required during grouting,
   h) Fill grouting/Closure of the holes as specified and clean-up,
   i) Preparation and submission of records and reports on grouting operations.

END OF SECTION B.7

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8.1. PLASTIC CONCRETE CUT-OFF WALL

8.1.1. SCOPE OF WORK

1) The Works provided for in this specification consist of furnishing all plants and equipment, labour, material and services necessary for constructing a plastic- concrete cut-off wall through the alluvial deposits, to the dimensions specified herein and/or as indicated on the drawings. The wall will extend from the level of the working platform on the top of the upstream pre-cofferdam to the alluvium/bedrock contact with required socketing into the bedrock as per approved design/drawings. The depth of this bedrock contact is variable, but the maximum depth of the cut-off is anticipated to be approx. 50 m below the embankment-foundation contact level, for Upstream Cofferdam, and approx. 25-30 m, for Downstream Cofferdam.

2) The Contractor shall further set-up, equip, operate and maintain a field laboratory for sampling, testing, mix design and quality control for all work related to the cut-off wall construction.

3) Geometrical features of the cut-off walls are the following:
   - Upstream Cofferdam length = 120 m; area = 5'200 m^2
   - Downstream Cofferdam length = 125 m; area = 3'500 m^2

   The minimum width of the plastic concrete panels will be 1'000 mm.

4) The equipment, working procedures and accuracy must be such that the panel thickness is nowhere less than 1000 mm and the minimum width of the contact surface between adjacent panels is never less than 200 mm on the bottom of the cut-off wall.

8.1.2. STANDARDS

1) Unless otherwise specified, the standards and recommendations of the Indian Standards Code of Practice shall be followed in respect of all materials, equipment and performances. Indian Standard IS 456: 2000 is specifically mentioned.

2) In case of differences between the Indian Standards and the Specification given herein, this Specification shall take precedence.

3) In case there are procedures or methods etc. for which an Indian Standard has not yet been issued, other generally well-known Standards shall be accepted as substitutes, such as the German Industrial Standards (DIN), British Standards (BS), American Society of Testing and Materials (ASTM) or the American Petroleum Institute (API), Japanese and in this order of preference.

8.1.3. GEOLOGICAL AND GEOTECHNICAL CONDITIONS

For the design and construction of the cut-off wall the Contractor has to take into account the geological- & geotechnical conditions in the Coffer Dams foundation.

It can be highlighted the potential presence of boulders which are isolated but can also accumulate to a boulder stratum.
The compressive strength of the competent rock is expected to be between 20 MPa and 60 MPa.

8.1.4. SUBMITTAL

1) Submittals listed herein are related to items which require the consent of the Engineer and are to be made by the Contractor before the appropriate work may proceed.

2) Contractor shall submit detailed plans and descriptions of all the following matters related to the construction of the cut-off wall:
   - Names and experience records of specialist staff who will work on the wall.
   - Plant and equipment to be used: full description (type and capacity) and drawings for the following items:
     - Trench excavation plant
     - Site installation plan
     - Bentonite slurry plant
     - Desanding plant
     - Batching and mixing plants
     - Equipment for transport and placing of concrete
   - Sampling and testing of materials: List and details of equipment for sampling and testing, detailed programme of mix-design for plastic-concrete and selection criteria, detailed programme for quality control of bentonite, bentonite suspension, plastic-concrete mix and hardened plastic-concrete. Qualifications and experience of the Contractor's proposed personnel.
   - List and details of equipment and methods to be used to check and verify the depth, width, verticality, continuity, and progress of concrete placement.
   - Testing programme to determine slurry loss, penetration and filtration.
   - The method of treatment and disposal of spoil and contaminated bentonite slurry.
   - Programme of work and detailed working procedures and sequences (method statements, QA/QC plan, ITP etc.,).

3) Within 28 days from the date of issue of Notice to Commence, but before mobilizing the equipment to the Site, the Contractor shall update the data listed above, and any subsequent amendments and additions to them shall have to be agreed to by the Engineer and the Contractor,

4) At least 56 days in advance of the start of placing of any plastic or conventional concrete for the cut-off, the Contractor shall submit to the Engineer the following:
   - Test results on aggregates, and results of mix-designs and trial mixes for plastic concrete, which the Contractor proposes to use for the construction of the wall.
   - - Notification of the source, characteristics, method of delivery and storage of cement, bentonite, aggregates and admixtures.

5) The Contractor shall request certificates from the suppliers for each consignment of materials to be incorporated in the Works and submit them to the Engineer for approval. These certificates state the grade and quality of the materials in the consignment and the results of all tests carried out thereon.

6) The Contractor shall submit to the Engineer for approval a weekly work programme and plan indicating detailed location of excavation work, excavation rates, details of concrete placement and comparisons between volume to be excavated and concrete placed in each section to be completed. This weekly programme shall be submitted to the Engineer not later than Wednesday of the previous week.

7) Before commencement of any plastic concrete placing in any section or panel of the cut-off trench, the Contractor shall prepare a checklist describing all significant preparations for the specified work, such as cleaning of the bottom of the excavation, the density of the slurry, depth of the trench and submit this list to the Engineer who, after approving it, will instruct the Contractor in writing to commence placing of plastic concrete in that section or panel.

8) During trench excavation and concrete placement, the Contractor shall prepare daily reports in which he shall record construction progress, samples taken, tests performed, and difficulties encountered. These reports should be always made available to the Engineer and must contain at least the following information:
   - Commencement and termination of each excavation section.
   - Checks performed during excavation to ensure verticality, width, and continuity of the wall.
   - Details of any unusual obstructions encountered (e.g. boulders in excess of 0.5 m) and the time spent dealing with and removing them.
   - Quantities and quality of bentonite and water used to produce the suspension of slurry, and major losses of slurry, if any.
   - Quantities, quality, and mix proportions of cement, water, bentonite, admixtures and aggregates used to produce plastic concrete.

- Date and time of start and completion of panel concreting.
- Location, length and width of panels, and their depth.
- Sampling and testing performed and summary of results; materials rejected.
- Numbers of personnel employed during the various stages of the wall construction and names of the responsible inspectors and foremen: details of time spent on site.
- Equipment used.
- Directives received from the Engineer, and requests made.
- Any special material or procedures employed.
- Any other observations.

8.1.5. MATERIALS

8.1.5.1. BENTONITE

1) Pulverized bentonite shall be used to produce the slurry suspension. The proportions of the slurry shall be altered to meet construction conditions by adding appropriate admixtures at the discretion of the Contractor who in any case shall be responsible for the proper consistency of the slurry and for the stability of the trench excavation.

2) The bentonite used to produce the slurry shall be in accordance with the latest edition of the American Petroleum Institute Standard 13A .

3) For any one ton of bentonite used, the moisture content shall not deviate by more than ±2%; the apparent viscosity by more than ±2cP and the gel strength measured at 10 minutes by more than ±0.023 N/m2.

4) The Contractor shall test one sample of bentonite slurry per panel under the same conditions as those under which testing was carried out by the supplier or manufacturer, at the date work on the panel is commenced.

5) Composition: The bentonite shall be the high swelling sodium base bentonite consisting mainly of the clay mineral montmorillonite. No more than 10% of the particles shall be larger than 74 microns and the liquid limit shall not be less than 400%. The marsh viscosity with 5% material shall not be less than 40 seconds.

6) Purity:
   - Montmorillonite content: 90% min.
   - Native sediments: Nil

- Chemical composition: Sodium montmorillonite: 60% minimum; Calcium and magnesium montmorillonite: 40% max.

8.1.5.2. WATER

Clean water shall be used to produce bentonite slurry. The Contractor shall use a source that shall comply with the tests specified. The quality of the water used for the Works shall comply with IS:456 or equivalent.

8.1.5.3. CEMENT

Portland pozzolana cement and other cementing agents, such as ground granulated blast-furnace slag or fly ash may be used. The properties of cement shall comply with the Standards described for concrete. Portland pozzolana cement shall comply with IS:1489, ground granulated blast-furnace slag with IS:455, and fly ash with IS:3812. All fly ash used shall be provided from a single source. The cement has to be stored in watertight buildings, bins or silos.

8.1.5.4. ADMIXTURES

If the design of the slurry and/or the plastic concrete includes admixtures, these admixtures shall have been successfully used on previous cut-off walls contracts, or their effects shall be demonstrated in trial mixes prior to the commencement of the Works. Admixtures shall comply with IS:9103.

8.1.5.5. AGGREGATES

Coarse aggregate shall consist of sound naturally rounded well-graded gravels when they are available in the locality or of crushed sound rock suitable for making concrete, as specified in project specification for concrete works. They must comply with BS 882. Fine aggregate shall be sand which is conform with Grading M of IS:383.

8.1.5.6. BENTONITE SUSPENSION (SUPPORTING SLURRY)

1) The slurry used to maintain the stability of the trench/panel excavation shall satisfy the following requirements
   - Continuous support of the excavation.
   - Solid particles are kept in suspension.
   - The slurry can be easily displaced during concreting,
   - The slurry shall not cause pollution of the ground, or of surface or groundwater before, during or after use.

2) The constituents of the slurry suspension shall be mixed thoroughly to produce a homogeneous mix. The temperature of the water used in mixing of the supporting slurry at the time of commencing concrete placement shall not be less than 5°C.

8.1.5.7. PLASTIC CONCRETE

The plastic-concrete mixture shall consist of Portland cement, water, coarse and fine aggregate, bentonite and approved admixtures. Some portion of the Portland cement may be substituted by ground granulated blast-furnace slag or fly ash, or Composite Cement, if the Contractor can demonstrate by comprehensive mixing trials that the hardened mixture will have the required properties.

8.1.5.8. CONCRETE

Concrete for the guide wall and head of the cut-off wall shall be manufactured according to the specification given in the section B09 of the Technical Specification.

8.1.6. MIX DESIGN

1) The Contractor shall prepare and submit a detailed mix designing programme for plastic concrete to be used for the cut-off wall construction. The plastic concrete shall have the following main properties:

- Maximum grain size	12mm
- Unconfined compressive strength (28 days)	2 ± 0.5 MPa
- Confined compressive strength (σc = 0.4 MPa)	> 2.5 MPa
- Strain at failure (Triaxial test)	~ 5%
- Permeability	< 1x10-8 m/s (at lab testing)

2) The Contractor shall perform all required tests on this concrete which shall include, but not be limited to the following:
   - Density of mix
   - Viscosity, consistency
   - Setting time
   - Triaxial stress-strain behaviour
   - Permeability
   - Erosion resistance
   - Slump
   - Slump flow

3) The Contractor shall prepare reports containing all test results, a detailed evaluation of them and a proposal of the mix which it is intended to use for construction.

8.1.7. QUALITY CONTROL

1) The Contractor shall perform with regular frequency quality control tests of the bentonite suspension and the concrete mixes as per Inspection & Testing Plan (ITP).

2) Quality tests of the bentonite suspension are given in Annexure II.

3) The tests for quality control of plastic-concrete are listed in Table 1, together with the tentative acceptance criteria. These acceptance criteria may be somewhat adjusted based on the results of the mixes the Contractor proposes to use. The Contractor shall vary the proportions of the mix to achieve the desired strength and deformation properties of the plastic concrete.

Table 1: Quality control tests for plastic-concrete

Types of tests	**Testing frequency**	**Testing method**	**Acceptance criteria**
Aggregate grain size	Once per 300 m^3	IS: 2386(Part I)	Design
Slump	Once per 60 m^3	IS:1199	24 ± 2cm
Slump flow	Every Truck	IS:1199	400 – 600mm
Air Content	Once per 60 m^3	IS:1199	<1.7%
Temperature	Every Truck	Thermometer	5° - 35°
Unconfined compressive strength (28 days)	3 cylinders/ 60 m^3	150 Φ x 300 mm high	2 ± 0.5 MPa
Confined strength (28 days): σc = 0.4 MPa	3 cylinders/ 60 m^3	Triaxial test	>2.5 MPa
Strain at failure in triaxial test	Once per 300 m^3	Triaxial test	~5%
Strain at failure in unconfined test	Once per 300 m^3	IS:4332-Part 5	0.375%-1.25%
Young's modulus	Once per 300 m^3	Triaxial test	200 - 400 MPa
Permeability	Once per 200 m^3	Triaxial test	< $1x10^{-8}$ m/s

4) Ordinary reinforced concrete which will be used for the cap at the head of the cut- off wall shall be tested according to the project specification.

8.1.8. EQUIPMENT

8.1.8.1. EQUIPMENT FOR EXCAVATION

1) The Contractor shall consider in his bid that the equipment for excavation must be suitable for gravely and sandy soils, permeable and semi permeable, with pebbles, and in which there are embedded individual blocks and large boulders of generally sound, hard rock and being capable to excavate into the underlying bedrock vertically and horizontally, as required by this Specification.

2) The equipment for excavation of the slurry trench must be suitable to reach the specified depth and maintain a minimum width of 1000 mm at any location of the Cut-off Wall (including the joints between individual panels). The equipment shall also be able to clean the contact with the bedrock at the bottom of the cut-off trench. In addition, any chiseling of large boulders shall be considered.

3) The equipment must be able to achieve an excavation finish which ensures a continuous wall and tight joints between the panels. Only equipment and procedures will be accepted which the Contractor can demonstrate to the satisfaction of the Engineer have proven satisfactory in previous projects of similar magnitude and alluvial material of similar characteristics, in particular containing boulders and blocks.

4) Whatever equipment the Contractor intends to use, he must demonstrate that it can at all times satisfy all requirements given in these Specification.

8.1.8.2. EQUIPMENT FOR MIXING AND PLACEMENT OF THE SLURRY

1) For mixing and placement of the slurry the Contractor shall provide a plant comprising a mixing facility of the type Venturi-flash or equivalent capable of producing a colloidal suspension of bentonite in water, a mechanically agitated sump, pumps, valves, hoses, supply lines, and small tools, all as may be required for a continuous supply of slurry to the trench. The slurry sumps are used to give the slurry sufficient hydration time and serve as reserve in the case of losses of slurry across permeable zones in the trench walls. Final, full details of the equipment for mixing and placing of slurry shall be submitted to the Engineer for approval, within 28 days of Notice to Commence.

2) All slurry must be mixed in the plant, and mixing in the trench will not be permitted.

8.1.8.3. EQUIPMENT FOR CLEANING THE TRENCH BOTTOM AND REGENERATING THE SLURRY

The Contractor shall provide equipment which enables the extraction of slurry, sediments and rock debris from the bottom of the cut-off trench and for the cleaning (regeneration) of the slurry, by removing from it excess

sediments and residues from drilling and excavation work, so that a pure bentonite slurry can be obtained for reuse.

8.1.8.4. EQUIPMENT FOR PLACING THE CONCRETE (BACKFILLING OF THE TRENCH)

The Contractor shall employ suitable equipment, such as tubes, hoses, pipes, for placing the plastic-concrete into the trench by the tremie pipe method. In particular, the Contractor shall avoid contamination of the concrete by slurry or the inclusion of slurry pockets into the placed concrete.

8.1.8.5. EQUIPMENT FOR TESTING AND QUALITY CONTROL

1) The Contractor shall provide equipment suitable for carrying out material tests on the slurry and on the plastic-concrete. These tests shall be performed according to approved well-known standards, such as ASTM, API, DIN, BS, and others.

2) The Contractor must make available suitable tools, devices and instruments for verifying at any time the depth, width and verticality of the cut-off trench and the progress of concrete placement. These shall include a state-of-the-art sonar sounding device.

3) All readings and results of testing and quality control must be presented in clear and comprehensive form and must be submitted on a continuous basis to the Engineer.

8.1.9. EXECUTION

8.1.9.1. GENERAL

1) The Contractor shall use appropriate methods and procedures for the construction of the plastic-concrete cut-off wall. This work includes but is not limited to the following activities:
   - Excavation:

     The excavation of the cut-off trench, or sections of the trench, to a minimum width of 1000 mm across the valley along the cofferdam. The wall shall begin at the elevation 782 m asl for upstream cofferdam and from the toe plinth for the downstream cofferdam, and location shown on the Contract Drawings or in subsequent Construction Drawings and shall extend down through the underlying alluvial materials until 1 m below the bedrock line, including socketing into the bedrock as required by the Contract Drawings.
   - Stabilization:

     The walls of the cut-off trench must be stable during all execution work and until backfilling of the trench with plastic-concrete has been completed in all respects.
   - Depth control:

The progress of excavation must be continuously checked, and the control measures taken must be able to verify that trench excavation has reached the alluvium/bedrock contact surface and required embedment in bedrock across the full valley width.

- Cleaning:

Prior to placing concrete, the bottom of the cut-off trench, left and right joints (Secondary panels) must be cleaned in order to remove sediments, residues from drilling and all other unacceptable material from the bedrock surface.

- Avoidance of slurry contamination:

Placing plastic concrete into the trench shall proceed in such a way that contamination of the concrete by slurry or deformation of the trench walls are prevented.

- Wall head:

The top of the cut-off wall will be provided with a head of shuttered reinforced concrete.

2) The Contractor shall provide adequate and safe access roads to the storage areas or silos of the materials needed for the construction of the cut-off wall. The width of the working platform for cut-off construction shall provide sufficient working space and for all excavation and concreting plants, and for the transport of materials.

3) All spoil material from the cut-off excavation and all surplus bentonite supporting slurry shall be properly disposed of at an authorized location. The high pH value of the bentonite slurry may place constraints on spoil disposal. Disposal of all materials shall be carried out in compliance with all relevant Indian laws and regulations.

8.1.9.2. EXCAVATION

GENERAL

The excavation of the cut-off trench will only be started after placing of the backfill which will support the plinth. Near the trench, the surface of this till shall be protected from damage by equipment and traffic by a layer at least 500 mm thick of sand/gravel. This layer will be removed when the construction of the wall is completed and before the plinth/slab is constructed. Excavation of the cut-off trench for the upstream cofferdam shall be made from the platform, which is presently shown at EL 782 m asl on the tender drawing, corresponding to the top level of the upstream pre-cofferdam or from an elevation subsequently determined by the Engineer. For downstream cofferdam, it shall be made following the toe plinth at variable elevations.

SETTING OUT

1) Setting out of the line of the cut-off wall shall be the responsibility of the Contractor, based on information provided by the Engineer. Before start of construction of the cut-off wall, the Contractor shall mark the

alignment of the wall with suitable identifiable pins or markers. The Contractor shall provide and maintain coordinated setting out points throughout the duration of the Works.

2) Setting out of the wall shall be to a centerline positioned with a tolerance of ± 50 mm, whereas the maximum horizontal deviation of the constructed panel from the centerline shall be ± 15 mm at the top level of the cut-off wall.

GUIDE WALLS

1) A suitable guide wall shall be used in conjunction with the method of excavation to ensure stability of the strata near ground level until concrete has been placed. During construction the level of support slurry in the excavation shall be maintained within the guide wall or stable ground, so that it is not less than 1500 mm above the level of external groundwater at all times. The wall shall extend at least 800 mm below ground level or the surface of the working platform, or to any other such depth as will maintain stability of the upper soils during the panel excavation and as may be approved.

2) The finished inner faces of the guide walls shall be vertical with a tolerance of I in 200. The minimum clear distance between the inner faces of the guide walls shall be the specified cut-off-wall thickness plus 50 mm.

MATERIAL TO BE EXCAVATED

Based on the results of his own site investigation activities (additional boreholes), the contractor shall revisit the actual conditions of the ground and his selection of the most appropriate equipment. The Contractor has to be aware that the excavated material corresponds to sand and sandy gravel, as well as boulders, individual large blocks of sound hard rock and bedrock. Depending on the amount of fines which may be present in certain pockets the ground may be permeable or semi-permeable.

ROCK SURFACE

1) The rock surface on the tender / Construction Drawings is based on the results of the site investigations described in the Information for bidders and earlier geological reports on the Project. It is, therefore, only approximate and the elevations etc. shown between drillholes have been estimated by interpolation. The Contractor has to expect and allow for variations in the position of the alluvium/rock contact surface as shown in the Drawings. Therefore, prior to excavation work the Contractor shall make additional drillholes, to establish with a better precision, the position of the bedrock line. The method of drilling shall permit the continuous withdrawal of samples from alluvium, boulders, blocks and bedrock. The location of these drillholes shall be proposed by the Contractor and approved by the Engineer. The drillholes should penetrate the bedrock by about 10 to 15 m.

2) Drillings as approved or directed by the Engineer shall be paid accordingly as per actuals.

CONTINUITY

The method and procedure to be employed in the excavation must guarantee the continuity of the cut-off wall, i.e. produce a wall without open joints and without open areas in any plane, such that at each cross section of the wall, especially in the joints of alternating panels, the concrete has the specified contact. After excavation of each panel, the surfaces of the walls of the trench, and the alignment and depth of the trench section have to be checked. The Contractor has to re-excavate, at his expense, those sections which do not comply with the requirements of continuity between sections, and/or the minimum thickness of the wall. For re-excavation, it may be necessary to first fill the poorly excavated zones with plastic concrete.

VERTICALITY

During excavation and on completion of each panel, the Contractor shall verify its verticality in the presence of the Engineer. The Contractor shall employ methods and procedures which allow to maintain verticality with a deviation that assures the continuity of the wall at its joints. The maximum allowable deviation from vertical at any depth shall be less than 200mm in any direction.

CLEANILINESS OF EXCAVATION BOTTOM

Prior to placing reinforcement or concrete the Contractor shall clean the base of the excavation of as much loose, disturbed and remoulded material as practical and in accordance with the method of construction. Immediately before filling a section of the trench with plastic-concrete, a full check of the condition of the section shall be made in the presence of the Engineer.

8.1.9.3. STABILITY OF THE EXCAVATION

1) The Contractor is responsible for maintaining the stability of the trench walls permanently and shall select equipment, methods and procedures which are able to fully satisfy this objective.

2) The stability of the trenching shall be challenging in the permeable and semi permeable geological condition expected in the colluvium / Alluvium deposit. To ensure the stable trenching during execution, the pre-treatment of the colluvium/alluvium deposit may be considered by means of Tube-A-Manchette (TAM) grouting/ gravity grouting/ combination of both on either side of the proposed wall. The spacing shall be decided by the contractor.

3) The thickness of a panel shall be not less than the specified minimum cut off wall thickness. The length of any panel may be varied to suit an individual Contractor's equipment subject to any upper limits on length as specified. Within these constraints the Contractor shall be responsible for selecting panel dimensions which ensure stability.

4) The Contractor shall comply with the following requirements with respect to the slurry to be used for stabilizing the excavation:

- The bentonite powder shall be mixed thoroughly with water by a suitable high shearing action mixer until all lumps have been broken up and dispersed within the mix. The proportion of bentonite to be included shall take into account the rheological properties of the bentonite such that the slurry shall be sufficient to maintain the stability of the excavation in the ground conditions encountered.
- In order to minimize the risk of collapse of the trench faces, the level of the slurry in the excavation will be kept at least 1500 mm above the groundwater table of the adjacent terrain and not more than 0.5 m above the level of the working platform, except when, in the opinion of the Engineer, the losses of slurry would be excessive. In this case the Contractor, with the approval of the Engineer, could reduce the distance between slurry level and groundwater level. The Contractor shall make every effort to minimize the slurry losses but without compromising his responsibility to maintain the stability of the excavation.
- The slurry placed into the excavated trench must be circulated and agitated continuously employing adequate equipment. The slurry requirements must be maintained at all times including non-working periods and stoppages.
- The Contractor shall provide equipment of sufficient capacity to clean the slurry of unacceptable quantities of rock debris and sediments from the excavation. The Contractor shall check the slurry periodically to verify its capacity to retain the walls of the trench and if necessary shall remove excess solid particles from the suspension.
- The volume of slurry being used shall be measured and recorded so as to ensure that no excessive loss to surrounding strata will occur. Should such loss be detected and continue despite the addition of further slurry, or approved additives, and the stability of the trench be placed at risk, the Contractor shall immediately inform the Engineer and take remedial action as necessary to preserve the stability of the trench.
- After excavation and prior to concreting a panel, the entire volume of slurry in the excavated panel shall be circulated to remove all sand, gravel and other contaminants, and shall be replaced by circulated clean, fresh regenerated bentonite slurry containing not more than 3% of sand and gravel. In addition, this replacement slurry should have a unit weight of between 1.05 and 1.10 t/m3.

8.1.9.4. PLACING OF PLASTIC CONCRETE IN THE CUT-OFF TRENCH

1) Concrete placement cannot be started until each excavation step has been approved by the Engineer. Concrete shall be placed as soon as possible after excavation of a section or panel has been completed, the bottom of the trench has been cleaned, and the slurry circulated. If, after circulation and cleaning of

the slurry, more than two (2) hours elapse before the start of concrete pouring, the circulation and cleaning process has to be repeated.

2) Concrete placement has to be a continuous process without interruption until the level of the top of the wall as indicated on the Drawings is reached. The workability and method of placement of the concrete shall be such that a continuous monolithic concrete panel of the full cross-section is formed, and the placed concrete is dense and homogeneous. Before commencement of concreting of a panel, the Contractor shall satisfy the Engineer that adequate operational equipment, labour and materials are available to allow the placing in the specified time of the plastic concrete needed to construct the panel in a single continuous operation.

3) The concrete batches shall be placed without any interruptions of duration long enough to allow a previously placed batch to achieve stiffness which would prevent proper bonding with a subsequent batch. Should such an interruption occur, the Contractor has to remove and replace the concrete in question. No spoil, liquid or other foreign matter shall be allowed to contaminate the concrete.

4) The concrete shall be transported from the mixing plant to the position of the panel in such a manner that segregation of the mix does not occur.

5) Internal vibrators shall not be used to compact concrete placed in the panels or the cut-off wall.

6) Concrete shall be placed through tremie pipes in one continuous operation. Where one or more pipes are used in the same panel simultaneously, care shall be taken to ensure that the concrete level at each pipe position is kept about the same. The increase in the level of concrete in the trench has to be checked regularly. The Contractor shall perform this check at several points of a section being concreted. The maximum distance between tremie pipes shall not exceed 3 m.

7) All hoppers and tremie pipes shall be kept clean and watertight. The pipe shall extend to the base of the panel, and every time concreting is started a sliding plug or barrier shall be placed in the pipe to prevent direct contact between the first charge of concrete in the tremie and the slurry.

8) The tremie pipes shall be progressively withdrawn as the concreting proceeds, but the pipe shall at all times embedded in the fresh concrete to depth of at least 3 m until completion of concreting. The internal diameter of the tremie pipe shall be of sufficient size to ensure the easy flow of concrete. It shall be so designed that external projections are minimized, and the internal face of the tremie shall be free from projections.

9) The depth of the surface of the concrete shall be measured and the embedded length of the tremie pipe recorded at regular intervals for each charge of concrete truck load. The depths measured and the volumes placed shall be plotted immediately on a graph during the concreting process and compared with the theoretical relationship of depth against volume.

10) The Contractor shall be allowed to re-circulate and reuse the slurry, if he so chooses, but he shall always be responsible for the quality of the slurry. The slurry which is not reused shall be disposed of in an ecologically acceptable manner with the approval of the Engineer.

8.1.9.5. CONTROL MEASURES FOR THE CUT-OFF WALL

1) The Contractor shall demonstrate by sounding methods approved by the Engineer that the completed cut-off is continuous over its entire area. Contractor shall prove that the maximum allowable deviation from vertical at any depth shall be less than 200mm in any direction.

2) Table 2 lists control items and their frequency of application which the Contractor shall consider during excavation and concreting of the wall. The Contractor may propose control methods other than listed in Table 2; however, these shall be subject to approval by the Engineer.

Table 2: Control measures for cut-off wall

Control item	**Control method**	**Frequency of control test**
Stratigraphy (Soil/rock profile)	Excavation and geotechnical logging of trench	Continuously
Depth of panel	Plumbline with measuring scale	Once per panel
Bottom of wall on or inside bedrock	examination of excavated material	Once per panel
Verticality of wall	Ultrasonic measurement (e.g. Koden) or by proven and calibrated online verticality measurement devices	At required interval

8.2. MEASUREMENT AND PAYMENT

8.2.1. GENERAL

1) The Unit Prices provided in the Schedule shall include all costs necessary for the proper execution of the Works in accordance with this specification, taking into account the physical and climatic conditions at

the site. The following related activities will not be measured for payment and their cost has to be included in the Unit Prices:

- Removal and disposal of spoil from the cut-off trench.
- Disposal of bentonite slurry.
- Corrective measures arising from non-compliance with the specifications or with the directions given by the Engineer.
- Record keeping as per specification.
- All other incidental activities required for the construction of the cut-off wall.

2) All costs pertaining to the supply, transport, assembling, dismantling, and removal of the materials and equipment necessary to perform the Works shall be included in the Unit prices.

8.2.2. CONCRETE GUIDE WALL

The measurement of guide walls will be based on volume of concrete separately for each side of the trench. The unit price shall include the cost for all form work, installation of reinforcing bars, concrete placing and the removal of the guide walls after completion of the cut-off wall. Reference is made to section B.09 of these Technical Specifications

8.2.3. CUT-OFF WALL

1) Excavation of trench for the cut-off wall will be measured and paid according to square meters of wall separately for alluvium/colluvium/overburden and bedrock. The unit price shall include:
   - Setting out of the trench.
   - Trench excavation (including overcutting of joints for secondary panels)
   - Pretreatment
   - Bentonite slurry preparation, conveyance to trench, slurry circulation and cleaning, monitoring stability of trench and all quality control activities.
   - Checking the cleanliness of the trench bottom.
   - Measurement will be made from agreed elevation to the bottom of each panel of the wall.

2) Placement of plastic concrete will be measured and paid according to square meter of wall. The unit price shall include:
   - Supply and placement of plastic concrete (tremie concrete) including allowance for overconsumption due to soil condition (typically ~15%).
   - Joint construction.
   - All mix designs, testing and quality control activities according to technical specification
   - Measurement will be from agreed elevation to the bottom of each panel of the wall.

- Supply of material, aggregates, cement, bentonite, fly-ash etc., and water.
- Any deficient and wasted material (slurry, concrete, etc.) which has to be removed and replaced due to Contractor's non-compliance with the specifications or Engineer's directions, and all related cost shall be borne by the Contractor,
- Any material which the Contractor places or uses for his own convenience which shall be approved by the Employer,
- Developing alternative sources of material (e.g. aggregates) by the Contractor with the resulting additional material testing.

8.2.4. TESTS

1) All costs associated with the testing of construction materials and monitoring of the excavation as described in this Section shall be borne by the Contractor, who shall make allowance for such expenses in the Unit Prices for the cut-off wall.

2) These shall include but not be limited to the following:
   - The costs for all tests to be carried out prior to the start of the Works, i.e. testing on bentonite powder, water, bentonite slurry, cement aggregates, concrete mixes, etc.
   - Routine tests for quality control during execution of the cut-off wall carried out by the Contractor as specified herein and as directed.
   - Monitoring of the excavation for verticality and continuity before concrete placement by specialized equipment.
   - Other material tests required during execution of the Works to be carried out by one or more approved testing laboratories.
   - Preparation, storage, handling, curing and delivery of samples to a laboratory designated by the Engineer, if so required for additional independent testing

3) Should the Contractor fail to adhere to his testing and monitoring, all tests deemed necessary by the Engineer to check the manufacturing and placement of the slurry for stabilization, or the concrete for the cut-off wall will be performed by the Engineer or by a laboratory assigned by him, at the Contractor's expense.

END OF SECTION B.8

ANNEXURE-I
DEFINITIONS

1) A cut-off wall

A cut-off wall is a cast-in-place wall, excavated under a supporting slurry (bentonite slurry) and concreted, by tremie pipe, with normal or plastic concrete. It is usually carried out in a two-phase process with elements known as panels constructed in a "primary/secondary sequence" with joints made by stop-end tubes or overcut. Excavation is performed either by grabs or by reverse circulation cutters. The wall shall serve as hydraulic barrier to water seepage beneath the dam.

2) Tremie Pipe Method

The tremie pipe method is a procedure to place concrete under a supporting slurry (slurry). The concrete is introduced without contamination and under avoidance of dilution and/or segregation through a pipe whose lower end is submerged in the already placed concrete. The concrete column in the pipe must not be interrupted and the supporting slurry must not enter the pipe.

3) Guide Walls

Guide walls are used at the ground surface to ensure positional tolerance, to avoid surface erosion and to spread temporary loading. Guide walls are essential for maintaining the correct alignment of the wall and to provide a reservoir for the support slurry. The guide wall must be sufficiently robust to support any applied pressures from the ground and forces from the walling equipment. The guide walls should be founded in soils of sufficient strength and stability to minimize the possibility of undercutting beneath the guide wall.

4) Supporting Slurry

A supporting slurry, i.e. a suspension of fine-grained solid material (or slurry), preferably bentonite or other high-plastic clays, in water which prevents collapse of the trench during excavation and concrete placing.

5) Bentonite

"Bentonite" is an ultra-fine clay whose principal mineral constituent is sodium montmorillonite

6) Cement

Cements are hydraulic binders, the main constituents of which are anhydrous calcium silicates and aluminates; with water they give hydrated silicates and aluminates and free lime. Hydration is followed by a crystallization of these hydrates, which is the origin of the set and hardening of cement

7) Admixtures

Admixtures are to ensure a good workability of the concrete. They affect the set time and the placing characteristics of a concrete mix.

8) Mixing and homogenization

- Mixing refers to the preparation of a bentonite water suspension. The time taken for full hydration, at which bentonite attains the desired flow properties depends on the method of mixing. A well-mixed slurry must be fully hydrated.
- Homogenization refers to the agitating of the slurry in the trench with the purpose to reverse the process of segregation.

9) Joints

The interface between two adjacent wall panels is known as joint. Joints shall be watertight by taking special provisions during construction of the wall with sufficient overlapping where a panel is cast against a previously completed section.

ANNEXURE-II
TESTS FOR BENTONITE SUSPENSIONS

1. Marsh Funnel Viscosity Test

Apparatus and testing method shall be according to American Petroleum Institute Recommended Practice RP 13B-1 as follows:

1) Equipment:
   - Marsh Funnel

     A Marsh Funnel is calibrated to out-flow one quart (946 cm3) of fresh water at a temperature of 21±3°C in 26±0.5 seconds. A graduated cup is used as a receiver.

     Specification

     Funnel Cone
     - Length 305mm
     - Diameter 152mm
     - Capacity to bottom of screen 1500 cm3

     Orifice
     - Length 50.8mm
     - Inside diameter 4.7 mm

     Screen 12 mesh

     It has 1.6 mm openings and is fixed at a level 19.0 mm below top of funnel
   - Graduated cup: one-quart (946 cm3)
   - Stopwatch
   - Thermometer
2) Procedure:
   - Cover the funnel orifice with a finger and pour freshly sampled slurry through the screen into the clean, upright funnel. Fill until slurry reaches the bottom of the screen.
   - Remove finger and start stopwatch. Measure the time for mud to fill to one quart (946 cm^3) mark of the cup.
   - Measure temperature of slurry in degrees C.
   - Report the time to nearest second as Marsh Funnel viscosity. Report the temperature of slurry to nearest degree C.

2. Ball Harp test (Yield stress / Gel strength)

1) Principle
   - The Ball Harp consists of several glass and steel balls, each with different diameters. These balls are immersed in the supporting fluid at the same time. With a given density of the supporting fluid, each of

these balls is assigned a different yield point. Balls whose yield points are smaller than the yield point of the suspension float. Balls with a yield point greater than the supporting fluid are immersed in it. The balls of the Ball Harp are numbered 1 to 10 in the order of their increasing yield point. The yield point of the supporting fluid is thus between the yield point of the largest numbered ball that is still floating and the yield point of the smallest numbered ball that is immersed in the fluid.

2) Procedure

- Fill the cup (1-litre container) up to the mark with the suspension to be tested.
- Place the suspension filled cup onto the base place of the stand.
- Press the lever slowly downward until it reaches its limit, by this, it will lower the balls hanging on the ring into the suspension.
- Some balls will sink into the suspension, and some will remain floating on its surface.
- The lines on which the balls are hanging will be straight for the balls that sink into the test suspension.
- The lines of the balls that float on the surface will be loose and bent.
- The individual balls are numbered from 1 to 10 on the ring.
- Note the smallest designation number of the balls that have sunk into the test suspension (their supporting lines will be straight).
- The final yield stress result will be made from the designated chart after the interpolation of the ball no. and the respective density of the suspension.

3. Density test

1) Equipment

- A set of weight scales of sufficient accuracy to permit measurement of weight to within 0.1 g.
- A fixed volume container with a flat upper edge generally no smaller than 1.0- liter capacity with a closely fitting top plate.

2) Procedure

- The empty fixed volume container and the top plate is carefully weighed, and the weight is recorded.
- The fixed volume container is filled to the top with slurry to be tested. The top plate is carefully slid across the top of the container to rest on the top of the container. Any excess slurry is removed to avoid errors. The container, top plate and slurry are carefully weighed and the weight recorded.
- The density of the slurry is calculated by subtracting the weight in (a) from the weight in (b) above and finally dividing the result by the fixed known volume of the slurry.
- The accuracy of the weighing scales should be checked at least weekly by repeating the procedure above with the slurry being water and comparing the density calculated with that of water.

4. Filtration Measurement

The volume of water lost, and the thickness of the cake formed, when a given pressure is applied to a known volume for a known time are measured. The apparatus most often used is the Baroid filter-press.

The base cap is fitted to a cell with a Whatman no. 50 or equivalent filter paper covering the screen, and the unit is filled with a slurry sample to within 6 mm of the top.

Next the top cap is fitted, the entire unit is placed into a frame, and the T-bar screw is tightened. A pressure of 100 lb/in^2 (700 kN/m^2) is applied through the pressure inlet, and the volume of filtrate collected in 30 min is recorded. The filter cake thickness is measured after the excess slurry has been drained out and the cake is gently washed. The cake consistency is also described using such notations as hard, soft, tough, firm, etc.

A loss of 5 cm^3 in 30 min is interpreted to correspond to a permeability of 10-7 cm/s, but the test procedure hardly allows this correlation. For the usual situation the recommended allowable filtrate loss is from 15 to 25 cm^3 for a pressure of 700 kN/m^2.

5. Compliance values and testing frequency

Table II.1 indicates the suggested tests and compliance values for support slurry. Locations and frequency of bentonite suspension tests are given in Table II.2.

Table II.1: Test and compliance values for support slurry / Trench slurry

Property to be measured	**Test method and apparatus**	**Definition of measurement**	**Freshly mixed suspension**	**Sample from trench prior to concreting**
Density	Mud balance	Mass of given volume of slurry	1030-1150 kg/m3	1030-1100 kg/m3
Rheological properties a) Yield stress/Gel Strength	Ball Harp (DIN 4126/ DIN 4127)	Ball No.	≥ 3	≥ 3
b) Marsh cone viscosity	Marsh Cone	Time taken for 946ml slurry pass through the orifice	30 – 60 sec	30 – 90 sec
Sand content	Sand screen set	Percentage of sand greater than 200-mesh in suspension	< 4 %	< 4 %

Slurry loss- for appropriate range of temperatures, times and pressures	Slurry loss or filter press test	Volume of slurry lost in given time from fixed volume of slurry when filtered at given pressure through standard filter	< 30 cm^3	< 50 cm^3
Filter cake thickness	Slurry loss test	Thickness and strength of filter cake for standard or actual conditions	≤ 3 mm	≤ 6 mm
pH	Electrical pH meter BS 3445, range pH 7 to 14 pH paper strips usually not reliable	Logarithm of reciprocal of hydrogen-ion concentration	7-12	7-12

Table II.2: Location and frequency of bentonite suspension tests

Types of tests	**New/Fresh suspension**	**Reuse**	**Before concreting**
Density	Once per panel	Once per working shift per panel	Once per panel
Viscosity	-do-	-do-	-do-
Yield stress/Gel Strength	-do-	-do-	--
Slurry loss	-do-	-do-	--
Filter Cake	-do-	-do-	--
% of sand	--	--	-do-
pH	-do-	-do-	-do-
Temperature	-do-	-do-	--

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9 CONCRETE

9.1 SCOPE OF WORK

1) The work under this Section includes all labour, materials, equipment and services related to the concrete work to be carried out by the Contractor under this Contract.
2) The concrete work shall be performed to the dimensions as shown on the Drawings or as otherwise directed by the Engineer. Lift drawings shall be prepared by the Contractor and approved by the Engineer.
3) The Contractor shall cooperate with all other contractors and organizations related to the construction of Permanent Works where the material or equipment is to be fixed to or embedded in the concrete structures.
4) Formwork, reinforcement and shotcrete are covered separately in other Sections of these Specifications.
5) The approval given by the Engineer to the Contractor's plants and equipment or their operation or of any construction methods shall not relieve the Contractor of his full responsibility for the proper and safe execution of concrete work or any obligations under this Contract.

9.2 STANDARD

1) Unless otherwise specified, the standards and recommendations of Indian Standards Code of Practices along with Bhutan standards shall be followed in respect of all materials, equipment and performances.
2) The following Indian Standards are specifically mentioned:

   IS: 8112 - 43 Ordinary Portland cement

   IS: 12269- 53 Grade Ordinary Portland cement

   IS: 456 – Code of practice for Plain and Reinforced Concrete

   IS: 383 – Coarse and fine aggregates from natural sources for Concrete

   IS: 2386 (Part-IV) – Method of testing of aggregates for Concrete- Mechanical Property

   IS: 5878 (Part-V) Code of practice for Construction of tunnels conveying water

   Concrete Lining

   IS: 516 – Method of test for strength of Concrete

   IS: 1489 – Portland Pozzolana Cement Fly Ash based

   IS: 1199 – Method of sampling and analysis of Concrete

   IS: 457 – Code of practice for general construction of plain and reinforced concrete for dams and other massive structures

   IS:9103 - Concrete Admixtures : Specifications

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IS: 7861 (Part-I and Part-II) - Code of practice for Extreme weather concreting, Recommended Practice (Hot weather and Cold weather concreting)

IS: 2505 Concrete Vibrators – Immersion type general requirements IS: 4031- Method of Physical test of Hydraulic Cement (Part-1 to 15) IS: 4032- Method of Chemical Analysis of Hydraulic Cement

IS: 15388:2003- Silica Fume – Specifications

3) In absence of relevant Indian Standards and specifications the recommendations of "ACI Manual of Concrete Practice", U.S.B.R. Concrete Manual shall be followed.

9.3 SUBMITTALS

9.3.1 SUBMITTALS BEFORE CONSTRUCTION

1) Submittals listed herein are related to items which require the consent of the Engineer and are to be submitted by the Contractor before the appropriate work may proceed.
2) Within 28 days from the date of issue of Notice to Commence, but before procuring or mobilising to the Site the equipment, the Contractor shall submit to the Engineer updated and detailed plans and descriptions, consistent with those submitted with his Tender and any subsequent amendments and additions agreed to by the Engineer and the Contractor, of the following:
   a) Aggregates Processing Plant:
      Description, flow diagrams and drawings in sufficient details to indicate layout, type and capacity of crushing, screening, washing, conveying and other aggregate processing and handling equipment.
   b) Cement Transport and Storage system (from Owner's stockyard/store up to the batching plant).
   c) Batching and Mixing Plants:
      Description, flow diagrams, and drawings of the plants, and details of the equipment the Contractor intends to use to determine and control the amount of each separate concrete ingredient and mixing thereof into uniform mixture.
   d) Concrete Cooling Plant:
      Details of refrigeration and ice plants and methods which the Contractor proposes to use to comply with concrete temperature requirements.
   e) Transport and Placing of Concrete:
      Full details of the equipment and methods for transporting the concrete from the batching plant to the final point of placing, including numbers, type and capacity of transport vehicles, concrete pumps, vibrators, and details of standby plants to be installed.
   f) Mode and methodology of concrete compaction and concrete curing
   g) Sampling and Testing of Materials:
      List and details of equipment for sampling and testing, detailed program for quality control of concrete work, and qualification and experience of the proposed personnel.

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h) Foundation and surface preparation equipment.

3) At least 56 days in advance of any concrete work being carried out at site, the Contractor shall submit to the Engineer following notifications based on the results of the preliminary material testing:
   a) Notification of quantity requirement of cement;
   b) Notification of the mill or mills from which cement will be obtained and whether cement will be ordered in bulk or bags. If cement is to be obtained from several mills, the estimated amount of cement from each mill and the proposed schedule of shipment shall be stated;
   c) Notification of the quarry and/or borrow area from which concrete aggregates will be produced.
   d) Notification of any admixtures and pozzolans which the Contractor proposes to use, manufacturers thereof, and information about the chemical names of the principal ingredients and the effects of under or over dosage. Should the Contractor intend to use an accelerator in any concrete work for his own convenience, he shall give full details of the type, dosage, influence on construction, and the cost savings involved.
   e) Details of the materials for formwork and surface finishes, treatment of construction joints, and construction techniques which the Contractor proposes to use in order to achieve the required concrete surfaces and allowable tolerances
   f) Details of special additives like micro silica for production of high performance concrete.
4) At least 28 days prior to procuring or dispatch to the Site of the particular item of work to which the submittal relates, the Contractor shall submit to the Engineer the following:
   a) Details of curing compounds, if any,
   b) Details of epoxy mortar for concrete repair.
5) Drawings showing the location of construction joints proposed by the Contractor which differ from those shown on the Drawings, including formwork and reinforcement details, shall be submitted to the Engineer at least 28 days prior to commencement of work on that particular structure.

9.3.2 SUBMITTALS DURING CONSTRUCTION

1) Contractor shall provide the Engineer with a weekly placing schedule giving the detailed location of the pours, the approximate extent of pours, and the date on which the concrete will be placed. This weekly programme of concrete placement shall be submitted to the Engineer for his acceptance at least 2 days prior to the commencement of the week.
2) Before commencement of the concrete placement the Contractor shall prepare a checklist regarding all preparations for the specified work such as rock surfaces and foundations, cleaning, formwork, reinforcement, embedding, and submit this list to the Engineer, who after his satisfaction about the work preparations will permit the contractor in writing to commence concrete placement.
3) The Contractor shall keep and make available to the Engineer records of the date, amount, and storage location of each delivery of cement and of the part of the Works in which it was used and shall provide facilities for checking the stock of cement.

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4) During the performance of the concrete work, the Contractor shall keep a diary where he shall record the construction procedures related to concreting. This diary shall be made available to the Engineer upon request. The records shall contain at least the following:
   a) Commencement and termination of concreting of various parts of the structures.
   b) Quantities and quality of aggregates and cement provided, and the storage, from which they were drawn.
   c) Temperature of air, water, cement, aggregates, and concrete.
   d) Meteorological conditions and humidity of air.
   e) Sampling and testing performed and summary of results.
   f) Personnel employed during various stages of the concreting operation and name of the responsible inspector or foreman.
   g) Equipment used.
   h) Directives received from the Engineer.
   i) Any special material or procedures employed.
5) The Engineer reserves the right to require any additional information deemed necessary to be included in the submitted documents.
6) Contractor shall provide the monthly report prepared by the Laboratory inclusive of all tests executed during the progress of the works.

9.4 CONSTITUENTS OF CONCRETE

9.4.1 CEMENT

1) The Contractor shall supply Portland Pozzolana Cement (PPC) conforming to IS: 1489 Part-I. The Percentage of fly ash shall not be less than 30% in PPC. Average compressive strength of not less than three mortar cubes tested as per IS 4031 Part 6 at 672 + 4 hr. shall not be less than 43 MPa.
2) Cement shall be procured from the cement sources/plants approved by the Engineer. At least two sources/plants shall be selected out of those intimated by the Contractor so that one is a standby for any eventualities.
3) Each consignment of cement delivered to the Site shall be accompanied by a test certificate issued by the manufacturer in quadruplicate. The Engineer will have the right to attend the sampling and testing at the manufacturer's plant at any time. If delivery is not directly from the manufacturer, the intermediate storage and delivery arrangements shall be subject to the approval of the Engineer.
4) Cement which does not comply with relevant IS Code or is damaged in consignment; handling or storage shall be promptly removed from the Site.
5) All facilities for transport and storage of cement shall be subject to approval of the Engineer and shall be such that easy access for inspection is assured.
6) Bulk cement shall be transported from the port or mill to the Site in adequately designed weather-tight trucks, or other means where cement will be protected from exposure to moisture. Immediately upon

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receipt at the Site, cement shall be stored in a dry, weather-tight and properly ventilated structure with adequate provisions for the prevention of absorption of moisture, and constructed in such a way that there will be no dead storage. The vents of the bins and silos shall be equipped with dust collectors to reduce loss of cement during handling and inconvenience to the personnel.

7) Cement bags shall be stored in weatherproof buildings with a raised, well ventilated wooden floor, and placed so that each consignment can be segregated if required and used in order of its age. Bags shall not be stacked more than 1.5m high. Cement shall not be stored out of doors, except for immediate use, and in such event shall be protected during storage and handling by waterproof covers and a raised floor. Unused cement shall be placed back into the storage buildings. Bulk storage bins or silos shall be emptied completely and cleaned of all cement accumulations every 3 months.
8) Arrangements shall be made such that stocks of approved cement are adequate to meet the programme of work at all times. The programme shall allow time for testing and approval of each consignment before such cement is incorporated in the work.
9) Cement shall be preferably used in same order in which it has been received at the Site. Storage of cement shall be limited to 90 days in bags and 150 days in bulk. Cement that has been in storage for longer than these periods or which may have absorbed moisture shall not be used unless it has been re-tested by the Contractor and approved by the Engineer. Cement that has become lumpy shall not be used. The cements coming from different mills or of different makes shall be stored separately.
10) The temperature of cement upon arrival to the Site shall not exceed 70°C and when entering the mixers shall not exceed 50°C unless otherwise approved.
11) Fly ash (pozzolana) shall not be allowed to be mixed with cement for concrete mixes at place other than factory/manufacturing unit. Fly ash (pozzolana) mixed at factory shall conform to IS: 3812 and IS: 1344.
12) The Contractor is solely responsible for the timely supply of cement meeting the requirements of these Specifications and the Works. The delay due to the lack of suitable cement will not give the Contractor any right for the extension of time for the Completion of Works, or any claims resulting there from.

9.4.2 AGGREGATE

9.4.2.1 GENERAL

1) Unless otherwise specified, concrete aggregates shall conform to the requirements of IS: 456 and IS: 383. They shall be tested in accordance with the provisions of IS: 2386.
2) Sufficient storage and/or stockpiling shall be ensured at the storage facilities provided to meet the programme of work at all times.
3) Aggregates shall consist of clean, hard, dense, durable and uncoated materials, and shall have stable moisture content and grading when delivered to the batching plant. Aggregates shall not contain substances which may impair the quality of the concrete, attack reinforcing steel or reduce bond. The following substances are regarded as being harmful: loam, clay, pieces with large cavities, foam-like

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or vitreous pieces, and organic materials such as topsoil, roots, wood, coal, lignite, etc. In doubtful cases the effects of harmful substances shall be established by tests.

4) Use of aggregates containing minerals which can cause alkali reactivity shall not be permitted. Presence of such minerals in the stones to be used as aggregates shall be determined by testing.

5) The Flakiness and elongation indices of aggregate as determined in accordance with IS: 2386 shall not exceed 25% individually and the combined flakiness and elongation indices shall not exceed 30%. Rock which breaks down into such shape, regardless of the type of processing equipment used, will not be approved for use in the production of aggregates.

6) The Contractor shall make provisions for crushing and processing of material in accordance with recommendations contained in IS:383 to meet the gradation and other requirements of these Specifications, in order to obtain the total amount of aggregate required for concrete manufacture. Crushing, screening and washing operations, benefaction of aggregates, and blending of crushed and natural aggregates shall at all time be subject to the consent of the Engineer.

7) The Contractor's aggregate storage facility shall not allow contamination of the aggregates. In case, Engineer determines contamination of aggregate the contaminated portion shall be removed from the storage and disposed of at no cost to the Owner.

8) The optimum proportion of crushed to natural aggregate, and in particular the possibility to use crushed sand, shall be determined at trial mix stage.

9) Natural and crushed aggregates shall be stockpiled and batched separately.

10) The handling, transporting, and stockpiling of aggregates shall be such that there will be a minimum amount of fines resulting from breakage and abrasion of material resulting from free fall and improper handling. Excess in any of fine or coarse aggregate sizes shall be disposed of in approved manner.

11) The Contractor shall remove all rejected aggregate from the Site.

9.4.2.2 SOURCE

1) Coarse and fine aggregates shall be produced from suitable material obtained from required excavation for Permanent and Temporary Works and from the approved quarry and borrow areas shown on the Drawings and described in the Information to Tenderers, or from other sources as may be designated or approved in the course of the work by the Engineer.

2) The Contractor shall carefully clear the area from which aggregates are to be produced of unsuitable materials and other objectionable matter. The area shall be operated so as not to affect the usefulness of the area. All materials removed from the area and not used in the work shall be disposed of as directed.

3) Alternative sources developed by the Contractor shall be subjected to approval by the Engineer. The Contractor shall carry out tests to furnish satisfactory evidence that aggregates from such alternative sources comply with the requirements of this Section.

4) The aggregate source shall be subject to the approval of the Engineer of all materials to be taken from that source. However, such approval of source shall not be construed as acceptance of all

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materials to be taken from that source. The Engineer reserves the right to reject certain localised areas, strata, or channels within the approved areas and zones, when the material is unsatisfactory for use.

9.4.2.3 FINE AGGREGATES

1) The term "fine aggregate" is used to designate aggregate in which the maximum size of particles is 4.75 mm.
2) The gradation of fine aggregate shall be as given below:

Square Mesh Sieve Opening	Percentage passing (by weight)
4.750 mm	95-100
2.360 mm	80-100
1.180 mm	50-85
0.600 mm	25-60
0.300 mm	10-30
0.150 mm	2-10
0.075mm	0-3

3) The percentage of deleterious substance in the fine aggregate shall conform to IS: 383, except that the fine aggregate shall contain not more than 0.1% by weight of deleterious (reactive) ferrous sulphide. The total percentage of deleterious substance must not exceed 5% by weight.
4) Fine aggregate having specific gravity of less than 2.6 shall be rejected. Fine aggregates, when subjected to soundness test with a solution of sodium sulphate, after five cycles of tests, shall not suffer a loss of weight in excess of 10 per cent.
5) Fineness modulus of fine aggregate shall be 2.6 ± 0.4.
6) Fine aggregate, upon delivery to the batching plant, shall have uniform and stable moisture content. The amount of moisture shall be less than 6% by weight, and shall not vary by more than 0.5% per hour.
7) River sand shall not be used for concrete mix.

9.4.2.4 COARSE AGGREGATES

1) The term "coarse aggregate" is used to designate aggregate which is retained on sieve opening 4.75 mm. The coarse aggregate shall be well graded and its gradation will be decided based on the laboratory tests to obtain dense mass of concrete. The gradation will be approved by the Engineer before production of the concrete.
2) Coarse aggregates shall be stored separately in stockpiles or bins in such a manner to avoid intermixing of different size of aggregates. The storing shall be done in following sizes:

   4.75-10 mm

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10-20 mm

20-40 mm

40-80 mm

80-150 mm

3) The percentage of deleterious substance in the coarse aggregate shall conform to IS: 383, except that the coarse aggregate shall contain not more than 0.3% by weight of deleterious (reactive) ferrous sulphide.

4) When subjected to following tests as specified in IS: 2386 (Part IV), the coarse aggregate shall comply with following requirements:

	High Performance Concrete	All Other Concrete
(a) Aggregate Crushing Value	Less than 22%	Less than 45%
(b) Aggregate Impact Value	Less than 22%	Less than 45%
(c) Los Angles abrasion value	Less than 30%	Less than 50%

5) Coarse aggregate shall be hard, dense, durable, uncoated rock fragments. Rock having absorption greater than 3% or specific gravity less than 2.5 shall not be used.

6) Coarse aggregate, when subjected to soundness test with a solution of sodium sulphate, after five cycles of tests, shall not suffer a loss of weight in excess of 12 per cent.

7) Coarse aggregates, upon delivery to the batching plant, shall have uniform and stable moisture content.

8) The nominal maximum aggregate size in relation to the structure dimension shall not be larger than:
   a) 1/5 of the narrowest dimension between the side of forms
   b) 3/4 of the minimum clear spacing between the reinforcing bars
   c) 1/4 of the slab depth.

9.4.2.5 AGGREGATE STORAGE

1) Aggregates shall be stored in a manner so that each size of aggregate is stored separately in free-draining piles in a manner that reduces breakage, deterioration, contamination and segregation to a minimum. Storage arrangements shall be subject to acceptance by the Engineer.

2) The Contractor shall maintain sufficient aggregate storage at the Site at all times to permit continuous placement of concrete in accordance with the contractual time schedule.

3) The moisture content of aggregates shall be controlled and shall have uniform and stable moisture content, as far as practicable, by wetting the stockpiles and by adequate drainage. All aggregate shall remain in a free-draining stockpile for at least 12 hours prior to use. All aggregate shall remain in a free-draining stockpile for at least 12 hours prior to use.

4) The preparation of stockpile areas, the storage of processed aggregates and the disposal of any rejected material shall at all times be subject to the approval by the Engineer.

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5) Materials shall be removed from stockpiles by methods which minimise segregation and crushing. No fine aggregate from the bottom 500 mm of the stockpile shall be used for mixing concrete.

9.4.3 WATER

1) A reliable and adequate water supply shall be installed and maintained by the Contractor for washing of aggregates, for mixing and curing of concrete, mortar, plaster, and grout. Water shall be taken from a proper source and shall be clean, colourless, free from deleterious substances including salt, oil, acids, alkaline or organic matters, sugar compounds, etc. and shall not have brackish or saline taste and shall conform to IS:456. When shaken no permanent foam may be formed.
2) Water shall contain no more than 1,000 mg/l of sulphates (SO4), not more than 100 mg/l of chlorides (Cl) and shall have a turbidity limit of not more than 1,000 ppm.
3) Adequate water storage shall be provided at the batching plant to ensure smooth concrete production.
4) Contractor shall familiarise himself with source and quality of water available. Attention is drawn to the possible requirement of settling pond and other facilities that he may be required to provide.

9.4.4 ADMIXTURES

1) Admixtures shall be proposed by the Contractor and shall be used only upon written approval of the Engineer. Only alkali free admixtures that have been commercially used with satisfactory service in a similar type of concrete work shall be considered for approval. All admixtures shall be manufactured by a reputable company (ies), supported by a fully staffed technical service organisation and research group.
2) The Contractor may use the following admixtures when required with the approval of the Engineer:
   a) Super plasticizer meeting requirement of ASTM C-494, Type F.
   b) Air entraining agent, (complying to IS 9103: 1999)
   c) Accelerating agent (Alkali free) in the concrete, mortar or grout to increase the rate of hydration, shorten the setting time or increase the rate of hardening or strength development, (complying to IS 9103: 1999).
3) Admixtures shall be stored and handled so as to avoid contamination or damage to their properties by temperature or moisture changes or other influences according to manufacturer's instructions.
4) The quantity of admixture used and the method of mixing shall be strictly in accordance with the manufacturer's printed instructions, or as required to produce specified results and approved by the Engineer.
5) The Contractor shall be held liable for any damages and difficulties resulting from the selection and use of admixtures such as delay in concrete placing or damage to concrete during forms removal, and shall not be entitled to any time extension or claims resulting here from.

9.5 CONCRETE MIX DESIGN

9.5.1 GENERAL

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1) Concrete shall be composed of cement, water, fine and coarse aggregate and possible admixtures.
2) The design of concrete mixtures will be aimed to securing a plastic, workable mixture suitable for the specific conditions at placement and, when properly cured, a product having durability and strength in accordance with all the requirements of the structures covered by the Contract Documents. The water content of all concrete mixtures shall be the minimum necessary to produce a workable mixture. Admixtures shall only be used with the approval of the Engineer.
3) According to the use of the different structures of the Works and the stresses expected to be acting upon them, various concrete classes have been designated. Designation of concrete classes is based on characteristic compressive strength (in Newton per square mm) and maximum aggregate size.
4) The cube compressive strength is defined as the compressive strength of 150 mm cube as measured at 28 days. The strength shall comply with the requirements of IS: 456.
5) Concrete mixes with the indicated nominal compressive strengths and maximum aggregates sizes which will be required for the construction of the Permanent Works are indicated in the following Table. The class of concrete required to be used in any specific location shall be as shown on the Drawings or as directed by the Engineer :

Class of concrete	**Max. Size of aggreg.**	**Nominal cement content**	**Max. slump**	**28-day strength**	**Location/ Remarks**
	(mm)	**(kg/m^3)**	**(mm)**	**(N/mm^2)**	
HEADRACE TUNNEL, FEEDER TUNNELS, ADIT N. 1, CONNECTION TUNNEL from dam crest to Road Tunnel					
M40	20	400	120	40	Selected locations for Second Stage Concreting around Embedded Parts (Blockout concrete) and other selected locations.
M30	20	350	100	30	Self compacting concrete behind steel liner
M25	40	325	80/120	25	Concrete Lining of Tunnels invert, and Pavement concrete.
M25	20	350	120	25	Precast concrete Lagging, Concrete Lining of Tunnels overt.
M20	40	275	120	20	Various Unspecified Locations Included tunnel plug.
M20	20	300	120	20	Various Unspecified Locations
M15	40	225	120	15	Backfill concrete behind ribs in Tunnels.

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M15	40	200	50	15	Mass concrete, lean and plum concrete
M15	80	200	50	15	Backfill concrete in surface works
DAM COMPLEX (excluding RCC)					
HPC	40	475	120	60	1.0 m thick high performance concrete (abrasion resistant) on spillway crest, beyond steel liner
M35	40	375	80/120	35	Trunnion beams
M30	20	350	100	30	a. Concrete in overflow section lower part of the buttresses (from head of intake down), spillway slab b. Chute slab c. Protection Slab in Plunge-Pool
M25	40	325	80/120	25	a. Buttresses above head of intake b. Plastic diaphragm walls c. Pavement Concrete
M25	20	350	120	25	Precast concrete elements for dam drainage galleries ceiling.
M20	40	275	120	20	a. Fill the irregularities of foundation minimum 0.5 m to have uniform level b. 2.0 m thick in the U/S and D/S face of non-overflow blocks above el. 790 m asl
M10	40	180	20	10	No-fine concrete (Porous Concrete) to be placed along cold-joint below spillway crest for uplift dissipation
UPSTREAM COFFER DAM (excluding RCC)					
M25	20	350	120	25	Concrete curbs to be placed along upstream face of U/S Cofferdam for membrane placement

6) The consistency as measured by the slump test shall be determined according to its class and the structures to be cast, for which the range will be defined by laboratory tests. The slumps for the various classes of concrete, in principle, will be within the limits given in IS 456. Ranges of workability of concrete shall be measured in accordance with IS 1199

7) At least 4 months prior to commencement of any concreting of Permanent Works, the Contractor shall start the testing of materials, propose the composition of concrete mixes and prepare trial mix, of each of the proposed concrete class, The Contractor shall prepare the trial mixes using the cement, water, aggregates and admixtures intended for the work and, which conform to the requirements specified in this Section, IS standards and/or ACI Manual of Concrete Practice.

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8) This preliminary test program shall include the determination of following parameters:
   a) Cement properties,
   b) Characteristics of aggregates,
   c) Mix water properties,
   d) Admixture properties,
   e) Proportion of aggregate ranges in the mix,
   f) Proportion of uncrushed to crushed aggregates,
   g) Cement content,
   h) Water-cement ratio (W/C),
   i) Workability of concrete mixes,
   j) Compressive and tensile strength,
   k) Entrained air,
   l) Density,
   m) Water tightness.

9) The Contractor shall submit the test reports to the Engineer for approval.
10) These tests shall be carried out until the concrete mixes show appropriate strength, workability, density, and water tightness without the use of excessive cement and water. The actual cement content in the mix design shall be optimized and justified by using cement of various manufacturers during trial mix design.
11) To carry out these preconstruction tests, full scale machine-mixed test batches shall be made and test samples taken there from. Tests shall be carried out sufficiently in advance so that complete and acceptable results are available before placing the concreting at actual works.
12) Test samples shall be made in accordance with IS: 1199 and tested in accordance with IS: 516. The test results shall be analysed in accordance with IS: 456.
13) The mixes for different classes of concrete shall be approved by the Engineer.
14) During the progress of the work, the mixes may be changed whenever, in the opinion of the Engineer, such change is necessary or desirable to secure the required strength, workability, water tightness, density, economy, or to limit shrinkage. The Contractor shall not change the approved mix proportions without the written permission of the Engineer.
15) Water to be added to the mix shall be adjusted to compensate for any variation in the free moisture content of the aggregate as they enter the batch plant. Water beyond the specified water-cement ratio shall not be added without the written permission of the Engineer.

9.5.2 HIGH PERFORMANCE CONCRETE

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1) High performance concrete shall be obtained by adding micro silica or any other equivalent Supplementary Cementitious Material (SCM) such as ultrafine slag in the concrete and with the use of Superplasticizer.

   Following are the design requirements:

Characteristic 28 days compressive strength	60 MPa
Maximum aggregate size	40 mm
Design slump	120 mm
Maximum water/(cement +SCM) ratio	0.32

   To achieve the above requirement, tentative mix design may consist of the following:

Cement	475 kg
SCM	As required
Superplasticizer	As required

2) Actual mix proportion to be used will be determined by trial mix design.

3) Test samples shall be made in accordance with IS: 1199, tested as per IS: 516 and analysed as per IS: 456. Source of aggregate for high performance concrete shall meet the requirement of wearing surface and shall be as identified by Engineer.

4) SCM shall comply with the relevant ASTM/International Standards. However, Silica fume shall comply with ASTM C1240-03a and it shall meet the following requirements:

   Chemical Requirements

(a) SiO_2, min. %	85
(b) Moisture Content %	3
(c) Loss on ignition %	6

   Physical Requirements

   Oversize:

Percent retained on 45μm (no.325), %	10
Percent retained on 45μm (no.325), max. variation from average, percentage points	5
Accelerated pozzolanic strength activity index with portland cement at 7days	10
Min. percent of control	5
Specific Surface, min, m^2/g	15

5) The Contractor shall present the results of quality control tests carried on a representative sample by the supplier. Once approved, the silica fume shall only be supplied from the same production plant. Deliveries shall be accompanied by manufacturer's quality assurance certificates.

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9.6 QUALITY CONTROL

9.6.1 GENERAL

1) The Contractor shall be completely responsible for performing detailed quality control program during the execution of the work. This quality assurance program shall be subject to inspection and checking by the Engineer.
2) The Contractor shall keep records of test results which shall be presented to the Engineer upon request.
3) Should the Contractor wish to reduce his approved testing program he shall notify the Engineer, for approval, of these changes 2 weeks in advance.
4) Aside from Contractor's testing program the Engineer will make control test to the extent as he deems necessary. The Contractor shall give all required assistance in sampling and provide for the proper storage and transport of the specimens to be tested by the Engineer.
5) The Contractor shall make such arrangements or purchase a new equipment should the test results prove that changes in the aggregates or concrete plant are necessary to obtain required concrete quality.

9.6.2 SITE LABORATORY

1) The Contractor will be responsible of all tests for the Quality Control to be performed in connection with the concrete and other materials used for the construction of the Works.
2) The Contractor shall build, equip, and operate the site laboratory in which the tests included in the Quality Control Programme will be carried out. In some cases where special tests are required, they will be made in other specialised laboratories after approval by the Engineer.
3) The laboratory shall be run by Contractor's personnel experienced in sampling and testing of materials and quality control.
4) The laboratory shall be equipped with all the necessary equipment to carry out the tests indicated below.
   a) Tests on aggregates as per IS 2386 (Parts I, II, III, IV)
      - Sieve analysis
      - Compressive strength
      - Specific gravity
      - Water absorption
      - Flakiness
      - Sand equivalent
      - Soundness and organic matter
      - Los Angeles abrasion
      - Impact test
   b) Tests on cement

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- Equivalent alkaline content (IS 4032)
- Specific Blaine surface (IS 4031 (2))
- Standard Mortar Compressive Strength (IS 4031 (6))
- Shrinkage (IS 4031 (10))
- Heat of hydration (IS 4031 (9))
- Setting time IS 4031 (5)

c) Tests on fresh concrete
- Consistency through slump test (IS 1199)
- Workability
- Heat of hydration using thermometers, cells and recording instruments

d) Tests on hardened concrete
- Compressive strength on all classes of concrete (IS 516)
- Shrinkage IS 4031 (10))

5) The Contractor shall be responsible for the handling and transport of all materials that will be required by the Quality Assurance Laboratory.
6) The site laboratory shall be properly air-conditioned and equipped with temperature and relative humidity recording instruments.

9.6.3 CONCRETE SAMPLING AND TESTING

9.6.3.1 AGGREGATES

1) Aggregate samples shall be taken from silos at the batching plant or from the conveyor belt.
2) The sampling shall be done at the frequency of one every 1,000 m^3 of produced concrete (cumulative of all concrete classes) and once a week at minimum.
3) The following tests will be carried out:
   a) Sieve analysis
   b) Sand equivalent
   c) Cleanliness of gravel
   d) Flakiness of gravel
   e) Los Angeles abrasion
   f) Crushing Value
   g) Impact Value

9.6.3.2 CEMENT

1) Quality control of cement shall first take place at the cement factory. This will be exercised by the factory itself under the supervision and the follow up of the Contractor who shall submit the copies of test results of cement to the Engineer for final approval. The quality control program will be

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established jointly with the Contractor and shall be submitted for the approval of the Engineer. To ensure that this quality control program is properly conducted, the Contractor shall post at the factory one of his officials, when necessary.

2) The requirements on the Site laboratory are stipulated in the Section "Site Installations and Services".
3) Once a train has been loaded at the factory and is ready for departure, six samples will be taken in six different cars and mixed in order to prepare one unique sample which will be split into two parts:
   a) The first part will be analysed by the cement factory laboratory,
   b) The second part will be despatched to the Site laboratory.
4) The following tests will be carried out at both laboratories and compared:
   a) Setting time,
   b) Expansion
   c) Specific Blaine surface
   d) Equivalent alkali content
   e) Standard mortar compressive strength
   f) Heat of hydration
5) Furthermore, each week, a sample of cement shall be taken at the batching plant and the following tests shall be carried out:
   a) Setting time,
   b) Specific Blaine surface,
   c) Standard mortar compressive strength at 3, 7 and 28 days.

9.6.3.3 ADMIXTURES

1) All the admixtures to be used for concrete production shall be Alkali free and they shall meet the requirement specified in ASTM Specification C-494 or in EN 934-2.
2) Admixtures to be used for concrete production shall be tested for their suitability with the cement and other materials under actual working conditions. Each shipment of admixtures shall be tested for density and dry extract.
3) Admixtures older than 12 months, after their manufacture, shall be tested for deterioration.
4) Total lot of admixtures from which the tested sample failed the criteria shall be rejected.

9.6.3.4 WATER

1) The suitability of the water for concrete shall be with reference to the criteria given is IS 456. The permissible amount of solids shall not exceed the limit as specified in IS 456. A sample of water will be taken from the concrete batch plant every 3 months and submitted to chemical analysis.
2) Water which quality is questionable or suspected of having detrimental amounts of sulphates shall be chemically analysed in a specialized laboratory designated by the Engineer.
3) For the examination of mixing water the Contractor shall deliver to the laboratory at least one liter in a thoroughly cleaned and tightly sealed bottle.

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9.6.3.5 FRESH CONCRETE

1) The following tests shall be carried out by the Contractor on fresh concrete samples:
   a) Consistency (slump tests) on all concrete classes (sieved at 40 mm for 80 mm and above size of aggregate concrete),
   b) Air content,
   c) Temperature.

2) These tests shall be carried out at the beginning of production of the concrete for each work or part of the work and for large quantities once every 100 m^3.
3) All consistency tests shall be determined on that portion of the total sample which passes a 40 mm size.
4) Air content shall be determined in accordance with the established standard.
5) One air test (0.006 m^3 capacity bowl) is required at the beginning of each shift, whenever a grade change occurs, whenever air test results are deviating from specifications and at 500 m^3 intervals for each grade of concrete in production.
6) Routine air tests as noted above will be determined on that portion of the total sample which passes a 40 mm sieve size.

9.6.3.6 HARDENED CONCRETE

1) Set of six samples for compressive strength tests at 7 and 28 days will be taken and tested for each part of the work, being defined as the volume poured in one concreting operation.
2) For large concreting operations, this set of sample will be taken every 200 m^3.
3) Compressive strength specimens shall be prepared by the Contractor and shall be performed in accordance with Indian Standards and Code of Practice.
4) All coarse aggregate larger than one quarter the minimum dimension of the mould will be removed by wet screening. Portions of samples of concrete used for slump, air content, unit weight, etc. will not be used to mould specimens for compressive strength testing.

9.6.3.7 ANALYSIS OF RESULTS

1) The test results will include the different components analyses, the values obtained on fresh and hardened concrete and the characteristics of the corresponding batch given by the printer of the batching plant.
2) The Contractor shall present regularly to the Engineer a synthesis of all the results in the form of tables, charts, statistical analyses (weekly and monthly reports).

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9.6.3.8 CONCRETE PLANT

Monthly checks, or when requested by the Engineer, of the concrete plant's weight-batching accuracy, including the accuracy of any admixture dispenser, shall be made by the Contractor in the presence of the Engineer. When checked by standard weights and volumes its accuracy shall be within 0.5% or as specified by the manufacturer.

9.7 ACCEPTANCE CRITERIA

9.7.1 CONCRETE COMPONENT

1) The measured values shall be within the specified range of values indicated above.
2) Any unsuitable material should be eliminated and the concrete manufacturing be suspended until the Contractor justifies that the replacing component is acceptable.

9.7.2 FRESH CONCRETE

Any controlled batch which will not satisfy the specified conditions in terms of consistency, air content and temperature, will be eliminated and concreting suspended until it is shown that corrections brought to the following batches are satisfactory.

9.7.3 HARDENED CONCRETE

1) The acceptance criteria for hardened concrete shall be as per the IS: 456.
2) If analysis of test cube results indicates poorer concrete in the structure as per the acceptance criteria of of IS:456, the Engineer will order the Contractor to provide core tests. Location and number of cores will be decided by the Engineer. The Contractor shall take out the specified sizes of cores from the structure.
3) In case the concrete cores fail to meet the specifications and the Engineer is not satisfied with various tests results and quality, he will then instruct the Contractor for removal or subsequent suitable strengthening measures for such works.

9.8 BATCHING AND MIXING

9.8.1 GENERAL

1) The Contractor shall provide, operate, and maintain at the Site automatic batching equipment to determine and control the amount of each individual material entering the concrete. Batching equipment shall be designed for such capacities which will permit performance of the concrete work in accordance with Contractual Construction Program.
2) Water, bulk cement, admixtures, and fine aggregate and coarse aggregate shall be measured separately and not cumulatively.

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3) The accuracy of the measuring devices shall be maintained so that the indicated measure does not vary by more than 1 per cent from true measure throughout their range of use. The devices shall be capable of being operated to control the delivery of materials so that the combined inaccuracies in feeding and measuring do not exceed the following limits:

Material	Cement	Water and Ice (if any)	Admixtures	Aggregate
Error in percent	1%	1%	3%	1%
Measured by	Weight	Weight or volume	Weight	Weight

9.8.2 BATCHING EQUIPMENT

1) Bulk Portland cement silos shall be plainly marked as to their contents. Delivery slips shall be reviewed by the plant operator prior to unloading of each material, and extreme care shall be exercised to see that these are unloaded into their respective silos.
2) Aggregate batch bins shall be self-cleaning during draw-down. Finish-screening of coarse aggregate will not be required provided that the aggregate meets the grading requirements stipulated in this Section. Coarse aggregate not meeting the grading requirements, shall be finish-screened over vibration screen connected to the batching plant or on the ground adjacent to the batching plant. The finish screens, if installed on the batching plant, shall be so mounted that the vibrations of the screens will not affect the accuracy of the batching.
3) At the batching plant, standard certified test weights shall be provided and such other auxiliary equipment as may be necessary to check the operating performance of each scale or other measuring device. When required by the Engineer, operator shall make these tests in his presence. Unless otherwise required by the Engineer, check tests of equipment used for measuring water, cement aggregates and admixtures shall be made at least every week. Facilities for obtaining representative samples of concrete materials, between batch bins and the weighing hoppers or between the batch hopper and the mixer, shall be provided with the batching equipment. After completion of each check test, operator shall report the results to the Engineer and make such adjustment, repairs or replacement as the Engineer deems necessary to secure satisfactory performance before further use of the measuring devices. The Contractor shall make such adjustments, repairs, or replacements as may be necessary to meet the specified requirements for accuracy of measurement.
4) The batching equipment shall be capable of handling a minimum of three different sets of mix proportions concurrently, without having to reset scales manually, and recording the number of batches of each mix separately.
5) Each measuring unit shall include a visible springless dial (metric) which will register the scale load at any stage of the measuring operation or shall include an over-and-under indicator which will show the scale in balance at no load when loaded to the beam setting. The masses of the components of each batch shall be automatically recorded and the records submitted to the Engineer at daily intervals. For water measuring, two water meters shall be installed in parallel so that no delay due to faulty operation

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shall occur. No leakage shall occur when the valves are closed. Liquid admixtures dispenser shall be of the visual type and shall be interlocked with the batching plant to prevent overdosing.

6) The operating mechanism in the water measuring device shall be such that no leakage will occur when the valves are closed and the discharge valve cannot be opened until the filling valve is closed.

7) Each measuring indicator and volume measuring device shall be in full view of the operator, and the measuring equipment shall be arranged so that the operator may conveniently observe the operation of the bin gates, the materials discharging into the mixer and the concrete during mixing and discharging. The batch panel shall be equipped with chatter controls to control the dribble for each material batched and a volume selector capable of settings from 1 m^3 up to the mixer capacity in increments of 1 m^3.

8) The batching equipment shall be so constructed and arranged that the sequence and timing of the batcher discharge gates can be controlled to produce an intermixing of the aggregate, water and cementing materials, as the materials pass through the charging hopper into the mixer. The scales shall be interlocked so that a new batch cannot be started until the weighing hoppers have been completely emptied of the last batch and the scales are in balance. Provisions for easy removal of excess materials, adjustment for compensating the weight variations of aggregates due to moisture content, and changing the mix proportions shall be incorporated in the equipment. All weight indicators shall be visible to the operator.

9) The device for adding admixtures shall be interlocked with the batching and discharging operation of the water so that the batching and discharging of the admixtures will be automatic. The device shall be capable of permitting the quantity of admixture being batched to be adjusted should this prove necessary and shall be equipped with a suitable warning device to indicate when the level in the reservoir tank is low.

10) A calibrated container shall be incorporated in each admixture holding system such that normally the admixture will bypass the container during batching. However, at any time it will be possible to direct the batched material into the container to check the accuracy of measurement.

11) The batching equipment shall be computerized and shall include a printer listing weights of all materials, or an accurate recorder for making a continuous visible combined record on a single chart of the separate measurement of each concrete ingredient, including all mixing water and admixture. Summary of material batched at the end of each shift or a day shall also be provided. The recorder shall be located in an enclosed room adjacent to the batching and mixing plants where it can be viewed without interfering with batching operation and where it is isolated from vibration and dust.

12) The batching plant shall be equipped with an instrument to check the consistency of the batch in the mixer, and the equipment shall be capable of adjustment to compensate for the varying moisture content of the sand and coarse aggregates and to adjust the mix proportions as needed.

13) The measuring and recording equipment shall be supported on foundations independent of those for the mixing plant to prevent them from being affected by vibration.

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14) Effective communication system including telephone shall be provided between the concrete plant and the point of placement at all times, and such facilities shall also be available at either location for use by the Engineer as required.
15) In case of use of fully automated batching plant, all the recording and indicating system intentioned above shall be available and on-line control of all components of the batching plant shall be provided.
16) Conveying batched materials from weighing hoppers into the mixer shall be so constructed and operated that spillage of the batched materials and overlap of batches is prevented.
17) Construction and operation of the cement and pozzolan handling equipment shall be such that no noticeable dust will be raised during measuring and discharging of each batch of material.

9.8.3 MIXING

1) Concrete shall be mixed in power-driven stationary batch mixers of approved type and size. They shall be kept clean and in proper working order. The mixing blades in the drum shall be replaced when worn by 10% of their design dimensions.
2) Movable truck mixers shall not be permitted for mixing concrete mixes.
3) The batching plant shall be provided with a bypass such that the mix materials can be discharged directly into a transit mixer drum. This bypass is to be used only in emergency and with permission of the Engineer.
4) The mixing equipment shall be capable of combining the aggregate, cementing materials, water and other ingredients, within the time hereinafter specified, into a thoroughly mixed and uniform mass, and of discharging the mixture without segregation. In principle if more than one liquid admixture is used, these shall be added separately to the batch. The plant assembly shall be such as to facilitate the inspection of all operations at any time.
5) The mixers shall be so charged that some water will enter in advance of cement and aggregate and all materials shall continue to flow in as rapidly as possible. The construction of the mixers should prevent loss of materials during charging. Uniformity in concrete consistency from batch to batch is required.
6) The mixers shall not be charged beyond their rated capacities and the entire contents of the mixer shall be discharged before recharging.
7) Unless otherwise authorized by the Engineer for mixers of 1m³ capacity or less, the mixing of each batch shall continue for not less than +1.5 minutes as specified in IS:456 (but not more than 5 minutes when mixing air entrained concrete) after all materials, except the full amount of water, are in the mixer. For mixers of larger capacity, the minimum mixing time will be increased by 15 seconds for each additional 0.5 m³.
8) The mixing time shall be increased when, in the opinion of the Engineer, the charging and mixing operations fail to result in the required uniformity of composition and consistency within the batch and from batch to batch.
9) Mixers shall be rotated at the rate recommended by the manufacturer of the mixers.

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10) The arrangement for controlling, measuring and mixing operations shall be such that the operator may observe the concrete discharging from the mixer.
11) Each mixer shall be equipped with a mechanically or electrically operated timing and signaling device for indicating and assuring the completion of the required mixing period and for counting the batches.
12) Should a mixer at any time prove unsatisfactory, it shall be replaced or its use discontinued until it is made satisfactory.
13) Each mixer shall be cleaned after each period of continuous operation and shall be maintained in such a condition that the mixing action will not be impaired.
14) Where the distance between the batching plant and a concrete pour is such that it would in the opinion of the Engineer cause deterioration of mixed concrete in transit, dry batching may be permitted using transit mix trucks in accordance with IS:457. Water shall be added not later than 30 minutes after batching.
15) On no account shall any addition be made to any component of a concrete batched once that batch has been mixed and discharged from the mixer, whether for the purpose of retempering or for any other reason.
16) Batching and mixing of concrete shall not commence unless due notice, at least 24 hours in advance, has been given to the Engineer and written approval has been obtained for the placing arrangements, and for the preparation and accuracy of the part of the Works in which concrete is to be placed.
17) Mixing of concrete shall not commence without ensuring that the stocks of materials are adequate, with a reasonable safety margin, for the completion of the programmed pouring.
18) The mixing time of each batch shall be determined by the batching and mixing tests to be carried out at the Site laboratory.

9.8.4 TRIAL RUN AND PERFORMANCE CONTROL

1) Prior to start any Permanent Works concreting, the Contractor shall carry out a trial concrete production run.
2) All plants and materials used shall be those to be used for the actual production of concrete in the Permanent Works.
3) The Contractor shall make all adjustments necessary to produce concrete of the quality of the agreed trial mixes of each class.
4) The performance of mixers shall be controlled in accordance with the provisions of ASTM Specification C-94 and Designation 26 of USBR “Concrete Manual”.

9.8.5 COMMUNICATIONS

1) The Contractor shall furnish, install, maintain and operate a telephone or radio system, linking the points of placing concrete with the concrete batching and mixing plant.
2) When placing the concrete by pumping, direct communication shall be maintained between the concrete placing crew and the pump operators.

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9.9 HOT AND COLD WEATHER CONCRETING

9.9.1 TEMPERATURE OF CONCRETE

1) The maximum permitted temperature rise in concrete and temperature distribution after placement will be determined by the Engineer based on the laboratory test performed prior to the start of concrete work using the actual cement, concrete mix proportions, and diffusibility for the concrete under consideration, or by actual field monitoring.
2) As a general rule, the maximum temperature developed after placement should not be higher than 55-60°C, and the temperature difference within the pour or lining should not exceed 20°C. For linings of tunnels, these values shall be limited to 50°C for maximum heat of hydration, and 10°C maximum temperature gradient in any section of the lining.
3) The Contractor shall make the necessary provisions in the concrete materials storage, handling and batching facilities, as required to comply with the hot weather concreting requirements taking into account the heat of hydration of the cement used.
4) The temperature of concrete when being placed in hot weather shall be as follows, unless otherwise permitted by the Engineer:
   a) Mass concrete including 40 mm aggregate concrete plugs in tunnel not more than 12°C
   b) Structural concrete, not more than 20 °C
   c) All other concrete including reinforced concrete, not more than 30°C.

   Quality Assurance and Quality Control shall be pursued in order to guarantee the above requirements.
5) The Contractor shall supply and install thermocouples in the fresh concrete in the tunnel and perform temperature measurement.
6) The temperature of concrete when being placed in cold weather shall be as follows:
   a) Mass concrete, not less than 7°C,
   b) Structural concrete, not less than 10°C,
   c) Structures thinner than 300 mm, not less than 13°C.
7) Cold weather conditions will be considered to be in effect when the mean daily temperature drops below 5°C for more than 3 successive days.
8) When temperatures above 10°C occur during more than half of any 24-hour period, the concrete should no longer be regarded as "winter concrete", and normal concreting practice should apply.

9.9.2 HOT WEATHER PRECAUTIONS

1) The Contractor shall furnish, install, operate, and maintain equipment and make the necessary provisions in order to maintain the temperature of concrete, when being placed, below the maximum temperatures specified above.
2) To meet these requirements, the Contractor shall be prepared to undertake any, or all of the following measures:

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a) Pre-cooling of coarse aggregate by sprinkling, immersion in cold water or with cold air blast,
b) Refrigerating the mixing water or adding the chip or flake ice as a portion of the mixing water,
c) Insulating the water tanks and water supply lines, cement silos, mix drums, exposed pipelines for pumped concrete and sheltering the aggregates,
d) Prevent exposure of batching, mixing and conveying equipment to direct sunlight,
e) Mixing and placing the concrete at night.

3) Ice, when used for mixing water, shall be completely melted before mixing is completed.
4) The temperature of concrete at the mixing plant shall be 2°C lower than the placing temperature specified above.
5) The Contractor's concreting operations shall be in accordance with the recommendations contained in IS: 7861 (Part 1).
6) The use of liquid nitrogen in lieu of ice may be permitted by the Engineer after review of proposed details for its use submitted by the Contractor.

9.9.3 COLD WEATHER PRECAUTIONS

1) The Contractor shall furnish, install, operate, and maintain equipment and make the necessary provisions in order to maintain the temperature of concrete, when being placed, above the minimum temperatures specified.
2) Following means shall be employed to attain the specified concrete temperatures:
   a) Mixing water shall be heated under such a control and in sufficient quantity as to avoid appreciable fluctuation in temperature from batch to batch.
   b) Insulating the water tanks and water supply lines, cement silos, mix drums, exposed pipelines for pumped concrete and sheltering the aggregates.
   c) Mixing and placing the concrete at day.

3) The Contractor's concreting operations shall be in accordance with the recommendations contained in IS:7861 (Part II).

9.9.4 TEMPERATURE CONTROL FOR MASS CONCRETE IN DAM AND SPILLWAY

1) For mass concrete in spillway and dam, the maximum concrete hydration temperature shall not exceed 40°C within 3 m of foundation rock or on top of a previous concrete lift that is older than 28 days when covered. This is to conform to the "closure criterion" which limits the concrete hydration temperatures to no more than 25°C over the contraction joint grouting temperature. The contraction joint temperature will be taken as 15°C unless otherwise specified by the Engineer. This limitation shall be accomplished by restricting applicable lift thickness to 1.5 m.

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2) The temperature difference (i.e. the gradient) between the interior "core" and the coldest exterior concrete surface shall not exceed 22°C. Interior and exterior temperatures shall be monitored unless otherwise by the Engineer. The Contractor shall provide his proposed monitoring program for the Engineer's approval.
3) The Contractor shall supply and install thermocouples in the fresh concrete and perform temperature measurement.
4) If concrete placing at a given horizontal construction joint is held up for a period of more than 14 days during periods when the daily average ambient temperature is in the range of 20° to 40°C, Contractor shall place concrete in the lifts above that construction joint at reduced thickness as required by Engineer. When the daily average ambient temperature is less than 20°C this time period shall be reduced to 10 days.
5) Embedded pipe cooling method can be used to control the rise in concrete temperature in restrained zones near foundations when maximum temperatures cannot be limited by other, less expensive cooling measures. Aluminium or synthetic plastic pipe or tubing generally of 25 mm dia and 1.50 mm wall thickness placed in grid like coils over the top of each concrete lift. When the expected active cooling period exceeds 3 months, steel tubing should be used.
6) Contractor shall place concrete in a given block as rapidly as possible, consistent with temperature control requirements and rate of placing restrictions. If not instructed otherwise by Engineer, placing of concrete in any one block of the Dam shall be such that not more than one lift shall be placed in 72 hours.
7) The differential between adjacent blocks shall not exceed 9000 mm and the differential between any of the dam blocks at a given moment shall not exceed 16000 mm, unless directed otherwise by Engineer.

9.10 CONVEYING

1) The method and facilities for concrete transport shall be selected by the Contractor within the limitations of these Specifications, and he shall be responsible for adequacy and suitability of the transporting system. The time elapse between mixing and the initial set of the concrete shall be taken into consideration. All methods used shall be reviewed by the Engineer.
2) The concrete transporting methods and facilities shall be such that will prevent segregation of coarse aggregate, excessive loss of slump, and loss of ingredients. Equipment such as buckets, cars, conveyers and pumping equipment which may be used for conveying concrete, shall be of such size, design and condition as to ensure an even and adequate supply of concrete at the placement area. All equipment shall be kept clean and in good working condition.
3) The use of chutes to convey concrete will not be permitted, except that chutes less than 3m in total length may be used immediately adjacent to or in the forms with acceptance of the Engineer. Where

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chutes are used, they shall be so constructed and arranged as to permit continuous flow of the concrete without separation of the ingredients.

4) There shall be no vertical drop greater than 1.5m, except where equipment satisfactory to the Engineer is used to confine and control the falling concrete.
5) Concrete may be dropped through flexible elephant trunk chutes, provided methods are used at the lower end to retard the speed of the falling concrete and prevent it from segregating. Where it is necessary to drop concrete from more than 1.5m it shall fall into a hopper with a capacity of 1m³ more than the total capacity of the full trunk.
6) Buckets for transporting concrete shall be manufactured as low slump concrete buckets.
7) All conveying plant shall be supported independently of the forms, except as specifically permitted by the Engineer.
8) The conveying plant shall be kept free from hardened concrete and foreign materials and shall be cleaned at frequent intervals.

9.11 PLACING

9.11.1 GENERAL

1) Contractor shall place concrete in a given location only after the Engineer has agreed with the placement of such concrete. All concrete shall be placed in presence of the Engineer. Concrete placed without prior knowledge and approval of the Engineer may be required to be removed and replaced at Contractor's cost.
2) The Contractor shall furnish, install, maintain and operate a telephone system or radio, linking the points of placing concrete with the concrete batching and mixing plant. These facilities shall also be available to the Engineer at all times.
3) When placing the concrete by pumping, direct communication shall be maintained between the concrete placing crew and the pump operators.
4) In order to reduce bleeding, slump shall not be higher than necessary to achieve proper placement and consolidation. Concrete shall be placed before initial set has occurred, i.e. 60 to 90 minutes after adding water to the mix.
5) No concrete shall be placed when the atmospheric conditions are, as assessed by of the Engineer, such that proper placing and hardening of the concrete are not guarantied. Specifically, the Contractor shall have the responsibility for meeting the hot and cold weather concreting requirements and for postponing concreting whenever such requirements cannot be met or, based on weather forecast, probably cannot be met. Even if the above requirements are fulfilled, the Contractor has the responsibility of delivering concrete product that meets specified requirements.

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6) A typical pour card form will be provided to the Contractor by the Engineer. A form similar to this shall be designed and printed in sets of three by the contractor for use on all concrete placing operations. Each item of required work for a given concrete placing operation shall signed by contractor and countersigned by the representative of Engineer. The pour card form shall be prepared by the Contractor and it shall contain at least but not be limited to the following:
   a) Date and times of commencing and finish of placing
   b) Location
   c) Composition of concrete mix
   d) Volume placed
   e) Foreman in charge
   f) Equipment used
   g) Cleaning and preparation of foundation performed
   h) Reinforcement placed
   i) Formwork used
   j) Reference drawings

7) Notwithstanding the foregoing, contractor shall allow the Engineer or his representative sufficient time to check the preparation for each concrete placement.
8) The authorization in the form of signing the pour card shall be valid for 24 hours only after the authorization is issued. After 24 hours the Contractor must obtain another authorization which will only be given after a re-inspection of the proposed placing area by the Engineer.
9) Concrete, which placement does not comply with the requirements specified herein shall be removed from the Works and replaced by the Contractor.

9.11.2 PREPARATION FOR CONCRETE PLACING

1) Concrete shall not be placed until all formwork, installation of embedded parts, reinforcing steel, and surfaces against which concrete is to be cast have been inspected and accepted by the Engineer.
2) All surfaces of forms and embedded items that have become encrusted with dried material from concrete previously placed shall be cleaned of all such material before the surrounding or adjacent concrete is placed.
3) Concrete shall not be placed in any structure until all water entering the space to be filled with concrete has been properly cut off or diverted by pipes, or by other means, and carried out of the forms clear of the work. Water shall not be allowed to stand on any concrete surface until it has attained its final set. Water flow over the concrete, which may injure the surface finish, will not be allowed.
4) Pipes, conduits, dowels and other items to be embedded in concrete shall be so positioned and supported prior to placement of concrete to be stable and provide sufficient clearance (50 mm min.) between said items and steel reinforcement to allow proper concreting. Securing such items in position by wiring or welding to reinforcement will not be permitted.

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5) Where excavated surfaces which are to form the foundations for structural concrete, are absorptive or likely to become otherwise unsuitable, or where shown on the Drawings, the Contractor shall place a 'blinding course' consisting of a layer of Class M10 or M15 concrete 50 to 100 mm thick, as directed by the Engineer, uniformly over the foundation such that the upper surface is at grade elevation. Blinding concrete shall be placed before installing reinforcement and formwork.
6) Immediately before concreting, the forms and all other surfaces which will be in contact with the fresh concrete shall be cleaned of all loose material and debris including shavings, wood chips, sawdust, pieces of wire, nails, fragments of hardened concrete and mortar. Clean-out holes which may be needed for this purpose shall subsequently be securely closed in order to obtain the required surface finish.
7) The use of compressed air for cleaning will be allowed only if adequate precautions are taken to avoid the deposition of suspended oil on construction joint surfaces, reinforcement or other items which are to be bonded to concrete.
8) The Contractor shall provide such personnel and equipment so that the performance of the concrete work is in a satisfactory manner. The transporting and placing equipment shall be clean and in good condition, adequate, and properly arranged to proceed with the placing without undue delays. The number and condition of vibrators for use and standby shall be ample for the requirements during placement. The lighting system shall be sufficient to illuminate the inside of the forms when concrete is placed at night.
9) The Contractor shall have protective coverings available for fresh concrete surfaces if there is a possibility of rain, hail, sleet, or snow.
10) Rock surfaces against which concrete is to be placed shall be clean and free from oil, standing or running water, mud, loose rock, objectionable coating, debris, and loose or unsound fragment. Faults, fissures and seams shall be cleaned to sound rock, and if directed, backfilled with dental concrete, shotcrete or dry-pack as appropriate.
11) Immediately before concrete is placed, all surfaces shall be cleaned thoroughly by the use of high velocity air-water jets (at least 40.0 MPa), sweeping with brooms, wet sandblasting to avoid dust hazard, bush-hammering, or other satisfactory means including combinations of the above.
12) Where gravel drains are used to control seepage water, the drains shall be covered with low slump concrete which shall be allowed to reach its final set before placement begins. Alternatively, geotextile sheets may be used.
13) Rock surface against which concrete is to be placed shall be kept wet for at least 12 hours during the 24-hour period prior to placing concrete and shall be in a damp condition at the time of placing, with all pools of water removed.
14) All concrete placed on earth shall be placed over a clean, damp surface, free from standing or running water or, in alternative, a tremie placement method is adopted where the water cannot be drained.

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15) Rock surface against which concrete is to be placed shall be kept wet for at least 12 hours during the 24-hour period prior to placing concrete and shall be in a damp condition at the time of placing, with all pools of water removed.

16) Before placing the concrete for tunnel lining the following requirements should be met:

a) The excavated cross section profile shall be carefully checked to ensure the minimum lining thickness requirements and if necessary it should be corrected,

b) All loose rock which has been trapped by the wire mesh covering over the excavated surface shall be cleared and the mesh be repaired and if necessary replaced,

c) All timber supports, large wooden wedges used during the initial assembly and erection of steel supports shall be removed,

d) Inverts of tunnel and shafts shall be totally cleaned of debris leaving sound rock wherever required. The Contractor shall use mechanical tools to loosen and remove all loosened and blast damaged rock.

17) Before any concrete is cast against previously placed concrete, the surface of the old concrete shall be prepared as described in sub-section "Construction Joints".

9.11.3 CASTING SEQUENCES

1) The time between successive lifts and maximum permissible depth of concrete placed in one lift, unless otherwise directed or shown on the Drawings, shall be as follows:

Location	Maximum permissible depth of one lift	Minimum time between successive lifts
Mass concrete in massive structures	300 cm	48 hours
Walls and piers less than 5 m thick	500 cm	36 hours

2) The concrete shall be compacted and/or vibrated as the concrete is poured.

3) All concrete, with exception of concrete tunnel lining, shall be placed in continuous approximately horizontal layers. The thickness of the layers shall not exceed 500 mm. Each layer shall be soft when new layer is placed upon it so that no seams or planes of weakness within the section can form, and the two layers shall be made monolithic by the penetration of the vibrator.

4) The Engineer reserves the right to order a reduced thickness of layers where the layers as stated above cannot be placed in accordance with the requirements of these specifications.

5) Concrete for beams, slabs and similar members shall be poured to the full depth in a single lift.

6) Outdoor concreting shall not be started during rain. If concreting is already in progress during the rain, it shall be suspended if the rain adversely affects the quality of the placed concrete. Refer also to clause “General” of the present Section.

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7) Concrete that has been allowed to harden to the extent that additional concrete placed on it will not satisfactorily bond shall be treated as a construction joint. When stoppage of concreting operations occurs for any reason, construction joints shall be placed either horizontally or vertically as needed.

9.11.4 PLACING AND COMPACTION

1) Concrete shall be carefully placed in designated position. Where dense reinforcement or deep forms may cause segregation of concrete while placing, suitable methods shall be used to prevent segregation. The free fall of concrete shall not exceed 1.5 m. for all structures.
2) Concrete shall be placed directly in its permanent position and shall not be worked along the forms to that position. Vibrators shall not be used to move concrete laterally.
3) The addition of water into concrete after batching to compensate for stiffening of the concrete before placing shall not be permitted in any case.
4) All concrete, with exception of concrete tunnel lining, shall be placed in continuous approximately horizontal layers. The thickness of the layers shall not exceed 400 mm for mass concrete, and 500 mm for structural and all other concrete. Each layer shall be soft when a new layer is placed upon it so that no seams or planes of weakness within the section can form, and the two layers shall be made monolithic by penetration of vibrators.
5) The Engineer reserves the right to order a reduced thickness of layers where the layers as stated above cannot be placed in accordance with the requirements of these Specifications.
6) Time interval between successive lifts of mass concrete shall be determined by the Engineer. The minimum time suggested between successive lifts is indicated in the table of Section “Casting Sequences”.
7) No concrete shall be placed under water except if shown on the Drawings or specifically so required by the Engineer. No concrete shall be placed in running water. Water shall not be allowed to rise over freshly poured concrete until final set has been achieved.
8) Each layer of concrete shall be consolidated to the maximum practicable density, be free from pockets of coarse aggregate, completely fill all recesses in forms and around embedded parts, and be free of all voids. The concrete shall be compacted and worked into all corners and angles of the forms, around reinforcement and embedded items without permitting the component concrete materials to segregate.
9) No layer of concrete shall be placed until the previous layer in the same lift has been thoroughly consolidated. Each layer of concrete within a lift shall be covered with fresh concrete as soon as possible, strictly within the period when the lower layer is still capable of being re-vibrated so that successive layers can be thoroughly worked together.
10) The maximum permissible time between the placing successive layers in a pour shall not exceed initial setting time of cement or 45 minutes, whichever is less, and shall be reduced to suit the temperature,

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humidity and job conditions. Concrete shall not be piled up in the forms in a manner that causes movement of the unconsolidated concrete or permits mortar to segregate from the coarse aggregate.

11) On proposal of the Contractor and with the Engineer's approval, the concrete lining in tunnel may be placed in one continuous pour from invert to crown with construction joints normal to the axis of the tunnel over the full cross section, or continuous placing may be adopted with a sloping joint corresponding to natural angle of repose at end of each concreting cycle.
12) Concreting of lining shall be carried out by concrete pump using methods which do not cause segregation or requiring remixing of the concrete. The point of discharge when concreting the crown above the springing line shall be kept buried sufficiently to allow enough pressure to be built up to completely fill the crown including areas of rock over-break in the crown, if present.
13) Concrete shall be compacted with the aid of approved immersion type mechanical vibrators complying with IS: 2505 or electric or air driven vibrators operating at a speed of at least 7,000 cycles/minute when immersed in the concrete. The vibrating equipment shall at all times be adequate in number of units and power to penetrate concrete as it is being placed, to the satisfaction of the Engineer. Vibrators with flexible operating shafts shall be used for reinforced concrete and for concrete in restricted forms. At least one extra vibrator in working condition shall be constantly on hand at each point of placement for emergency use.
14) Vibrators shall be operated by experienced workers only. A spare vibrator of the appropriate type and capacity shall be available and shall be tested to ensure that it is working before concreting commences. At least one spare vibrator shall be available at each concrete pour, and a minimum of one spare for each 5 vibrators in service at each construction site.
15) Application of the vibrators shall be made systematically and at such intervals that the zones of influence overlap and the concrete is properly compacted.
16) Every vibrator shall be operated in a near vertical position and the vibrating head shall be allowed to penetrate under the action of its own weight. In consolidating each layer of concrete, the vibrating head shall be allowed to penetrate and revibrate the concrete in the upper portion of the underlying layers. Extreme care shall be taken to ensure that the vibrators do not touch or disturb the reinforcing, embedded steel or forms.
17) Extreme care shall be taken to ensure that the vibrators do not touch or disturb the reinforcing, embedded steel or forms. Over-vibration causing segregation, surface laitance, or leakage through formwork shall be avoided.
18) To ensure even and dense surfaces which are free from aggregate pockets, honeycombing or air holes, it may be necessary to supplement internal vibration with hand-spading along the boundaries of the concrete and around embedded parts while the concrete is plastic under the vibratory action, should slip forms be used, the equipment and methods shall be such that the finished concrete will be well consolidated and homogeneous.

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19) Contractor shall use any or all of the above methods of consolidation, if required, to produce the necessary finish. Form vibrators shall not be used unless the forms are designed for form vibration and unless specifically authorised by the Engineer.
20) Whenever Engineer orders for the extraction of cores to confirm that all the voids have been properly filled behind the concrete lining of tunnels, the contractor shall extract the cores and the cores shall be placed in wooden boxes marked with correct sequence and designated location of extraction.
21) Concrete for mass placements often contain cobbles and therefore placement should be in such a way that the segregation of coarser aggregates shall not take place. For concrete containing coarse aggregate 75 mm and larger, a bucket of size of 3 to 6m^3 should be used. Extra care must be taken to assure ample vibration deep in the centre of the piles of concrete after placement through bucket.
22) For mass concrete the stepped or benching method of concrete placement shall be used by Contractor. This stepped front progresses forward from one end of the block to the other until the form is filled and the lift placement is compacted.

    Mass Concrete – The proper procedure for placing mass concrete shall be as follows:

    a) Contractor shall prepare and submit to Engineer prior to placing of concrete – lift drawings, monthly and weekly concrete placing schedules and pour release.

    b) Lift drawings shall be submitted in triplicate a minimum of two weeks in advance.
23) Contractor shall be responsible for all aspects of the concrete placing system including the supply of all equipment, its operation and maintenance.
24) Contractor shall place concrete around embedded metalwork, anchors, piping, conduit, duct etc in such a manner as to prevent any displacement or damage to the embedded parts, ensuring at the same time adequate compaction without voids.

9.11.4.1 COMPACTION OF MASS CONCRETE BY HAND OPERATED VIBRATORS

Hand held vibrators shall be pneumatic and/ or electrical and shall meet the minimum requirements indicated below:

Mass low slump (0 to 50 mm) concrete, aggregate (75 – 150 mm) deposited in large open forms

Vibrator Diameter	140 - 170mm
Element length	200 - 460 mm
Frequency	5500 rpm
Amplitude Avg	1 - 2 mm
Radius of Action	400 - 610 mm
Rate of placement per vibrator	20 - 40 m^3/hr

As above deposited in relatively open forms, near formwork & embedded parts

Vibrator Diameter	80 - 120mm
Element length	300 - 460 mm

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Frequency	7000 rpm
Amplitude Avg	0.8 – 1.5 mm
Radius of Action	300 - 510 mm
Rate of placement per vibrator	10 - 30 m^3/hr

1) Vibration of concrete shall be carried out by means of immersion-type vibrators, supplemented, if necessary, by external vibrators of suitable design and capacity. Immersion vibrators, having head diameters equal to or less than 75 mm, shall have a minimum speed of 7,000 vibrations per minute when immersed in concrete. Those with head diameters more than 75 mm shall have a minimum speed of 6,000 vibrations per minute when immersed in concrete. Formwork vibrators shall operate at not less than 8,000 vibrations per minute when vibrating concrete.
2) Vibrators shall be inserted vertically, allowed to penetrate through the concrete by weight of the vibrator (no forcing), shall remain in place until the egress of air to the surface has stopped and the tone of the vibrator is constant, and shall be withdrawn at the same rate the vibrator penetrated the concrete. The normal period of vibration per penetration shall be 10 to 20 seconds.
3) The entire depth of a new layer of concrete shall be vibrated and the vibrator allowed to penetrate the underlying layer by 80 to 100 mm. The insertions of the vibrator shall be on a systematic basis and the spacing between the insertions shall be no greater than ½ the zone of influence (radius of action) of the vibrator.
4) When rock pockets occur (segregations), they shall be dug out and the rock spread over plastic concrete and vibrated into the mass.
5) After the concrete along formwork and around embedded parts has been poured and consolidated with the large 150 mm head diameter vibrators, these areas shall be re-vibrated using vibrators of 80 mm head diameters. The vibrators shall be inserted at locations approximately 250 mm from the form and embedded parts. The distance between insertions along the form shall be approximately 250 mm. Vibrators shall penetrate the full depth of the layer and 80 to 100 mm into the underlying area.
6) As the concrete for a given placing operation is brought to final grade, the exposed surface shall be levelled and made reasonably even by means of vibration. At the same time all loose large size aggregates shall be embedded in concrete and where any rock pockets occur, they shall be dug out and the surrounding area vibrated.
7) Plank walkways or other suitable means shall be employed to keep traffic off the completed surface until the concrete sets.

9.11.4.2 COMPACTION OF MASS CONCRETE BY GANG MOUNTED VIBRATORS

1) In general, concrete shall be consolidated using a combination of hand-held vibrators and gang vibrators. As such, all the requirements for vibration and re-vibration will apply equally well when gang vibrators are used.

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2) Gang vibrators are a series of three or four large diameter hydraulic vibrators mounted vertically on a horizontal bar which in turn is connected to a hydraulic lift mounted on a rubber tyre tractor. This group of vibrators shall be used as a gang for the consolidation of heavy mass concrete in large open forms. One specific area of use shall be the knitting together of the interface between the leading edge of an earlier placed lift and of freshly placed concrete, hence, ensuring the poorly compacted concrete back of the leading edge of the earlier placed concrete is thoroughly consolidated.

9.11.5 PUMPING CONCRETE

1) Positive displacement pumping or other approved methods by the Engineer may be used to place concrete where necessary. The type and arrangement of equipment shall be subject to approval, and the equipment shall be operated only by experienced persons. Pneumatic placing will not be allowed.
2) The equipment and its method of operation shall allow the concrete to enter the forms at a low velocity.
3) Concrete pumps and auxiliary equipment shall be in good condition and shall be maintained as such throughout the duration of the work. Thorough washing down of all parts that come in contact with concrete shall be performed after each concreting operation.
4) Pump lines shall consist of rigid steel pipe or flexible pipe made of rubber, spiral-wound flexible metal or plastic, or combination of both. Use of aluminium pipe for pump lines shall not be permitted. Couplings shall be leak proof and strong enough to withstand handling during erection and poor support along the lines. They shall provide a full internal cross section with no constrictions of the smooth flow of concrete.
5) Immediately prior to the start of all concrete pumping, the pump and pump lines shall be primed by pumping an approved grout mixture through the equipment.
6) Concrete pumping operations shall be planned in such a way that concrete does not set before the succeeding layer is placed thereon. An adequate supply of fresh concrete shall be provided at all times.
7) When placing the concrete by pumping in tunnel lining, the sides of the lining shall be brought up evenly through windows prepared in the formwork and care shall be taken that equal pressure is maintained on the formwork. The crown shall be filled through the slick line running along the top of the formwork. This line shall be deeply buried in the concrete at all times. Identifications marks to indicate the depth of burial shall be provided. The buried slick line shall be withdrawn from the form gradually as the placement is completed. Air boosters shall not be permitted until slick lines are buried at least 1.5 m into fresh concrete.

9.11.6 CONCRETE IN BLOCK OUTS AND 2nd STAGE IN RESTRICTED LOCATIONS

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1) All concrete required to be placed in block outs to permit the installation and adjustment of mechanical and other equipment, around formed holes and second stage concrete in other locations shall be included in respective concrete as described in these Specifications.
2) The concrete surfaces of blockouts and first stage concrete at other locations shall be chipped and roughened as described herein before second stage concrete is placed at such locations.
3) Exceptional care shall be taken to placing concrete in block outs in order to ensure satisfactory bond with concrete previously placed and to secure complete contact with all metal works in the blockouts.
4) The roughening of the first stage concrete surfaces shall be attained by chipping or sand blasting as approved by the Engineer and in such a manner as not to loosen, crack or shatter any part of concrete beyond the roughened surfaces.
5) After being roughened, the surfaces of concrete shall be cleaned thoroughly of loose fragments, dirt and the objectionable substances and shall be sound and hard to ensure good mechanical bond between the existing and new concrete.
6) Second stage concrete shall be placed in lifts of not more than 3.0 m and concrete placement rate shall not exceed 1.5 m per hour except as otherwise approved by the Engineer.

9.12 FINISHING OF CONCRETE

9.12.1 GENERAL

1) The quality of the surface finish shall be in accordance with the requirements for the particular class of finish specified hereunder. The finished surfaces of concrete shall be free from areas of honeycombs, segregation, loss of cement or fine material, from damage due to stripping of forms, from bolt holes, abrupt irregularities caused by movement of forms or components, loose knots and similar features, and bulges or depressions in the general plane of the surface.
2) Only one type of formwork shall be used for all parts of a concrete structure which is visible from any direction.
3) The classes of finish shall be as shown on the Drawings or as directed by the Engineer.

9.12.2 FORMED SURFACES

1) The classes of finish for formed surfaces are designated by the use of symbol F and the shape of the formwork panels required for concrete work shall be either plane (F1, F2, F3) or curved (F1C, F2C, F3C).
2) Surface finishes and other variations in finishing of concrete shall conform to the tolerances indicated below:

Type of finish	General areas of application and method of forming

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F1, F1C	Formed surfaces of construction joints and other surfaces which will not be permanently exposed, blockouts for equipment embedding or other parts which are to be built in. Small blemishes caused by entrapped air or water may be expected, but the surface shall be free from voids, honeycombs, or other large defects. The surface will require no treatment after formwork removal other than repair of defective concrete and specified curing, or treatment as specified for construction joints.
F2, F2C	All permanently exposed formed surfaces which are not in contact with flowing water. It may be achieved by the use of properly designed forms of closely-jointed wrought boards. Alternatively, steel or other suitable material may be used for the forms. Chamfer made of 25 x 25 mm timber strips shall be fixed to the tops of forms to ensure the formation of straight and even horizontal construction joints. Immediately after the removal of forms all unsightly ridges or fins shall be removed; all holes left by removal of ends of form rods shall be neatly filled with mortar and surfaces treated to meet the required tolerances by tooling and rubbing (as described in Section "Repair of Concrete"). When filling holes and repairing defective areas, every effort shall be made to match the color of the concrete. The use of release agents which may permanently stain or discolor the finished surface will not be permitted.
F3, F3C	Formed surfaces which will be exposed to flowing water. These surfaces shall be hard, smooth and dense, free from offsets, pits, voids, air holes and irregularities larger than 3 mm, and shall be chipped, ground and thoroughly cleaned as necessary to conform to the required tolerances. Variations in concrete color as a result of concrete repairs or staining due to release agents will be allowed. Chamfer is not required.
F4, F4C	Surfaces where plaster, stucco, or wainscoting is to be applied. Formwork shall consist of rough-faced form boards. Steel lining or steel sheathing shall not be permitted. No form oil may be used. Forms shall be removed as soon after pouring as conditions will permit. Surfaces shall be roughened with a heavy wire brush, cleaned of all materials that might prevent satisfactory bond and washed thoroughly. Immediately prior to plastering, concrete surfaces shall be re-cleaned and damped by means of a fog spray.

9.12.3 UNFORMED SURFACES

1) The classes of finish for unformed concrete surfaces are designated by the use of symbol U and shall be finished by screeding, floating and trowelling.
2) Surface finishes and other variations in finishing of concrete shall conform to the tolerances indicated below.

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Type of finish	General areas of application and method of forming
U1	Unformed, screeded surfaces which will be covered by fill materials. Finishing shall consist of sufficient levelling and screeding to produce an even, uniform surface meeting the required tolerance.
U2	Unformed surfaces not permanently concealed by fill material or concrete. Floating by means of hand or power-driven equipment shall be started as soon as the screeded surface has stiffened sufficiently and shall be the minimum necessary to produce a surface that is free from screed marks and that is uniform in texture. This finish is also the second stage of finish U3. If finish U3 is to be applied, floating shall be performed until a small amount of mortar without excess water is brought to the surface, so as to permit effective trowelling.
U3	Unformed, screeded surfaces which will be exposed to flowing water, as well as inside floors of buildings except where a bonded concrete finish or tile floor is foreseen. This finish shall be applied by steel troweling after the concrete has hardened enough to prevent excess of fine materials and water from being worked to the surface, free from blemishes, ripples and trowel marks. After the surface has nearly hardened, it shall be trowelled once more until the surface is hard and glossy in appearance.

3) Interior surfaces shall be sloped for drainage, where shown on the Drawings. Exterior surfaces, which will be exposed to the weather, shall be sloped for drainage even if there is no such indication on the Drawings. In such case the slope shall be at least 1% but not exceed 3%.

9.12.4 TOLERANCES FOR GENERAL CONCRETE STRUCTURES

1) Concrete surface irregularities caused by the roughness of the formwork facing or by inaccurately aligned joints between the formwork panels shall not exceed the following tolerances:

Specified Finishes	Permissible Irregularities	
	Abrupt	Gradual
F1, F1C, U1	15 mm	30 mm
F2, F2C, F4, U2	8 mm	15 mm
F3, F3C, U3		
i. Measured parallel to the flow direction	7 mm	10 mm
ii. Measured perpendicular to the flow direction	5 mm	8 mm

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2) Deviations of concrete structure outlines from the lines and grades shown on the Drawings shall not exceed the following values:

General Areas of Application		Tolerances in mm
Variations of the constructed line or outlines from established position in plan	In 6 meters In 12 meters In 24 meters or more	12 mm 20 mm 30 mm
Variations of dimensions to individual structural features from established position	In buried construction	Twice the above amount
Variations from the specified batter or from the curved surface of all structures, including the lines and the surfaces, walls and vertical joints	In 3 meters In 12 meters or more In buried construction	12 mm 30 mm Twice the above amount
Variations from the level or from the grades indicated on the drawing	In 3 meters In 12 meters or more In buried construction	6 mm 12 mm Twice the above amount
Variation in cross sectional dimensions of columns, beams, buttresses, piers and similar members and variation in the thickness of slabs, walls and similar members.		-6 mm +12 mm
Variation from plumb and level for sills and side walls for gates and similar watertight joints	Not greater than:	3 mm/3 m

3) The Contractor shall repair hardened concrete which is not within specified tolerances as stipulated in Subsection 9.18 “Repair of Defective Concrete”.

9.12.5 BUSH HAMMER FINISH

1) Bush hammer finish shall be applied on the surfaces when required by the Engineer. Bush hammering shall not commence until at least one month after placement of concrete. The tool used for bush hammering shall be electrically driven and have a head 3 cm² with 16 pyramid shaped teeth. The surfaces shall be finished at a rate of 250 to 400 cm²/min. indenting the concrete surface approximately 2 mm.

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9.13 CONSTRUCTION JOINTS IN CONCRETE STRUCTURES

1) Construction joints are defined as concrete surfaces on or against which concrete is to be placed and to which new concrete is to adhere and which have become so rigid that the new concrete cannot be incorporated integrally with that previously placed.
2) Construction joints shall be located in the positions shown on the Construction Drawings or as required by the Engineer and the Contractor shall not be permitted to form any additional joints or deviate from the joints indicated on the Drawings, without the written authorization of the Engineer. Necessary rearrangement of steel reinforcement arising from such modifications shall be to the Contractor's debit.
3) Horizontal construction joints shall be arranged, wherever possible, to coincide with joints in the formwork.
4) Joints at exposed surfaces of concrete shall be straight and continuous. Feather- edged construction joints will not be permitted.
5) The faces of vertical joints shall be shuttered with expanded metal or other approved rough material. The expanded metal shall be removed as far as possible, before the adjacent lift is poured. If required, the surface shall be cleaned by wet sandblasting and roughened by light bush hammering.
6) The surface of construction joints upon or against which new concrete is to be placed and to which new concrete is to adhere shall be clean, rough, and free of water when covered with fresh concrete. The laitance, loose or defective concrete and foreign material shall be removed from the surface of existing concrete. The previous concrete lift shall be saturated by water but surface dry when the successive lift is placed.
7) The surface of the hardened concrete shall be cleaned and roughened by wet sandblasting and washing thoroughly with air-water jet. Care shall be taken to prevent undercutting of aggregate in the concrete during sandblasting.
8) Wet-sandblasting equipment shall be operated at an air pressure of approximately 7 bars. Sand to be used for blasting shall be dense, hard, not easily broken and sufficiently dry.
9) In lieu of wet-sandblasting the Contractor may propose high-pressure water blasting utilising pressures not less than 400 bars, provided that such high- pressure water blasting produce equivalent results to those obtainable by wet- sandblasting.
10) The horizontal surfaces of construction joints may be treated by cutting with an air-water jets ("green-cutting"). This shall be performed after the initial set has taken place but before the concrete has become too hard for effective cutting. The fresh concrete surface shall be cut with air-water jets to remove all laitance and to expose clean, sound aggregate. After cutting, the surface shall be washed with clean water. Care shall be taken that the treated surface does not become contaminated before new concrete is placed upon it. Should the surface become contaminated that a satisfactory joint with new concrete is not ensured the Contractor shall clean it by means of wet sandblasting.
11) Water used in cutting, washing and rinsing of concrete surfaces shall be disposed of in such a way that it does not stain, discolour or affect exposed surfaces of the structures.

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12) When necessary, as determined by the Engineer, structural concrete placement in forms shall be started with an oversanded mix with 20 mm maximum size aggregate, an extra 50 kg of cement per cubic meter and a 100 mm slump. This mix will be referred to as a starter mix and shall be placed approximately 50 mm deep.
13) Disturbance of the surface at a joint during the early stages of hardening shall be avoided, and traffic on the concrete will not be permitted until the concrete has hardened sufficiently to withstand such treatment without injury.
14) All construction joints shall be kept continuously moist until they are covered with concrete, provided that, if it becomes necessary to delay the placement of new concrete on or against a construction joint for an extended period, moist curing of the surface of the joint may be discontinued at the expiration of the regular prescribed curing period. If the moist curing is so discontinued, it shall be resumed not later than 24 hours prior to the placement of new concrete against the joints.
15) The High ribbed permanent formwork (expandable sheet type material) shall be used to form the construction joints in concrete structure wherever required to produce monolithic construction. The material for permanent high ribbed shall conform to BS EN 10142.
16) Where indicated on the Drawings, flexible PVC waterstops (or equivalent) shall be placed in construction joint.

9.13.1 COLD JOINTS

1) Cold joint is an unplanned joint which is the result of hardening of the concrete surface before the next batch is placed against it. Cold joints are undesirable and should be avoided. However, in the event of equipment breakdown, prolonged heavy rainfall, or other unforeseen prolonged interruption the continuous placing may not be reasonable. When such event becomes apparent, and the unconsolidated concrete may harden to the extent that later vibration would not fully consolidate it, the Contractor shall immediately consolidate such concrete to a stable and uniform slope.
2) If delay in placement is short and it is still feasible to penetrate the underlying concrete, placement shall resume with care to thoroughly penetrate and re-vibrate the concrete surface placed before the delay.
3) If the concrete cannot be penetrated with the vibrator, the cold joint shall be treated as a construction joint, if the design requirements tolerate such joint. If such joint would impair the structural integrity of the structure, the concrete, or a part of it, shall be repaired or removed.

9.13.2 CONSTRUCTION JOINTS FOR STAGE CONCRETING

1) Constructions joints for stage concreting are joints, or joint systems where in-fill concrete or bays shall not be placed before one or two months after placing of the first stage concrete.

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2) Where indicated in the Drawings, waterstops shall be provided in construction joints for stage concreting. Waterstops shall be joined and fixed in place strictly in accordance with manufacturer's recommendations and Section B12“Waterstops and Joints” of the Technical Specifications.
3) Notwithstanding the design provisions, if the construction requires the implementation of joints not foreseen in the drawings or waterstops not indicated in the drawings, the Contractor shall provide them in order to ensure the construction site design variations to be fit for the purpose.

9.14 CURING AND PROTECTION OF CONCRETE

1) Plant for curing and protection of concrete shall be available at the location of each concrete placement before concrete placement is started. The water used for curing shall meet the requirements for water used for mixing concrete. The curing water temperature shall not exceed 25C. degrees
2) Exposed surface of concrete which has been finished as specified shall be protected from the direct rays of the sun for at least 2 days after placing. Freshly placed concrete shall be protected from damage by rainfall
3) Exposed surfaces shall be kept moist or the moisture in the concrete shall be prevented from evaporating for at least 14 days after placing by means of continuous sprinkling or spraying with water or by other methods approved by the Engineer.
4) Care shall be taken not to disturb the steel reinforcement projecting from any placement for at least 24 hours after the completion of such placement.
5) The Contractor shall not move any load on concrete surfaces, which in the opinion of the Engineer have not attained sufficient strength. In case loads are required to be moved, the Engineer may permit Contractor to do so on condition that Contractor provides the means for protecting the concrete surface subject to approval of the Engineer.
6) The Engineer may permit the use of curing by means of membrane forming compounds. Sealing compounds proposed by the Contractor will be subject to sampling and testing and will have to be approved by the Engineer.
7) Curing compounds shall be applied according to the manufacturer's recommendations to provide a continuous uniform membrane over all area. Curing compounds shall be applied only after moist curing has been carried out for at least 24 hours. Curing membranes shall be protected from damage at all times.
8) Curing compound shall not be used on any unformed surface where, in the opinion of the Engineer, the irregularities in that surface would prevent the membrane forming an effective seal, on any surface which has a temperature lower than manufacturer's recommended application temperature, on any surface where a bond is required for additional concrete, or where a bonded surface coating is to be applied. Where a curing compound is placed on a surface where a bond is required, it shall be removed by sand blasting or by other means satisfactory to the Engineer.

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9) Concrete poured in tunnels to form tunnel linings shall be cured by membrane curing, as described above. Curing compounds used in tunnels shall not contain solvents, which may create hazardous conditions.

10) Curing compounds used for surfaces exposed to view shall degrade completely when exposed to air for more than 3 months. They are to remain at least 80% impermeable for 1 month after application.

9.15 REPAIR OF CONCRETE

9.15.1 GENERAL

1) Repair of damaged or defective concrete shall be performed by skilled workmen only, and in the presence of the Engineer. No repair work shall be carried out until the Engineer has inspected the location of the proposed repair and accepted the method of repair proposed by the Contractor.

2) Contractor shall correct all imperfections on the concrete surface as necessary to produce surface that conforms to the requirements specified

3) Where concrete is exposed to flowing water or to weather (concrete requiring F2, F2C, U2, F3, U3 or U3C) contains surface depressions which exceed the allowable tolerances specified, or where it is porous and fractured to which additions are required to bring it to prescribed lines shall be treated as follows:

- Minor areas: the Contractor shall drill a hole of such diameter in the defective area into sound concrete, that the defective concrete is completely removed. The minimum diameter of such hole shall be 50 mm, the minimum depth shall be equal to the diameter of the hole drilled and the maximum depth shall be 70 mm. The hole shall then be reamed out such that the diameter at the bottom of the hole is at least 20 mm larger than the hole at the surface. Finally, the hole shall be cleaned and washed out, the surplus water removed, and then filled with concrete incorporating a non-shrink agent.
- Large areas: defective concrete should be removed by chipping openings into the concrete a minimum of 75 mm below the reinforcing or to the depth required by the Engineer-in-Charge if sound concrete is not encountered at 75mm. Repair areas shall be formed and area filled with fresh concrete. If the concrete section to be repaired contains no reinforcement, concrete shall be chipped to a minimum depth of 100mm.

4) The chipped openings shall be sharp edged and keyed and shall be filled to the required lines with fresh concrete or patching mortar, as approved by the Engineer. Where concrete is used for filling, the chipped openings shall not be less than 75 mm in depth and the fresh concrete shall be reinforced and doweled to the surface of the openings, as directed by the Engineer.

5) Dry pack mortar for patching shall consist of 1 part cementing material, 2 parts by volume of regular sand, and just enough water so that after thorough mixing of the ingredients the mortar will barely held together when compacted by squeezing with the hand. The mortar shall be fresh when placed, and any mortar that is not used within 1 hour after preparation shall be wasted. Just prior to mortar

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application, the surface to which the mortar is to bond shall be kept wet for at least 2 hours, then scrubbed with a small quantity of cement grout using a wire brush.

6) When repairs are more than 25 mm deep, the mortar shall be applied in layers not more than 20 mm thick to avoid sagging. After each layer, except the last is placed, it shall be thoroughly roughened by scratching with a trowel to provide an effective bond with the succeeding layers. The last or finishing layer shall be smoothened with a trowel to form a continuous surface with the surrounding concrete. All patches on exposed surface shall be neat and smooth and as nearly as possible of the same colour as the adjoining concrete. All patches shall be thoroughly bonded to the surfaces of the chipped openings, shall be cured to the satisfaction of the Engineer and shall be sound and free from shrinkage cracks and drummy areas.

7) For concrete surfaces where high velocity flows may occur, and as required by the Engineer, repairs to surfaces having F3 and U3 finishes shall be bonded with an epoxy adhesive approved by the Engineer and used in accordance with the manufacturer's instructions.

8) All repairs to the surface of concrete required for flowing water shall be ground smooth to meet the tolerances specified for that surface.

9) Minor cracks, from 0 to 3 mm (such as shrinkage cracks) shall be treated as per the following table. Major cracks (>3mm) shall be treated case by case according to the structure and the relevant method statement approved by the Engineer.

Type of cracks	**Width in mm**	**Treatment**
Hair cracks	From 0 to 0.2	No treatment required
Small cracks in massive structure	From 0.3 to 1.5	Monitoring of the width during the time. No treatment required
Small cracks in concrete sensitive structure	From 0.3 to 1.5	Shall be repaired by the use of an appropriate methodology using a low viscosity injection resin approved by the Engineer
Medium cracks	From 1.5 to 3.0	Shall be repaired by the use of an appropriate methodology using a low viscosity injection resin approved by the Engineer

9.15.2 STRUCTURAL REPAIR WORKS / CLOSURE OF GROUT HOLES WITH CEMENTITIOUS MORTAR

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9.15.2.1 CEMENTITIOUS MORTAR

The material shall be cementitious mortar conforming to EN 1504-3 (R4). The properties/ performance characteristics of the cementitious mortar are as follows:

SL NO.	PERFORMANCE CHARACTERISTIC	TEST METHOD	REQUIREMENT BASED ON EN:1504-3(R4)
1.	Compressive strength	EN:12190	≥ 45 MPa
2.	Chloride ion content	EN:1015-17	≤ 0.05%
3.	Adhesive bond	EN:1542	≥ 2.0 MPa
4.	Carbonation resistance	EN:13295	d_k ≤ control concrete [MC(0,45)]
5	Elastic modulus	EN:13412	≥ 20.0 GPa

9.15.2.2 STRUCTURAL REPAIR WORKS

9.15.2.2.1 SURFACE PREPARATION

1) Remove loose, delaminated or unsound concrete to obtain a keyed surface by non-impact/ vibrating cleaning methods like compressed air/ high pressure water blast/ sand blast, chipping, wire brush or other means as per site requirement. Remove dust, micro fractured particles and foreign material from the repair area by pressure washing or other suitable means necessary to clean surface to obtain desired bond. If reinforcing steel is visible, the same shall be cleaned all around. The surface shall be prepared as per manufacturer's recommendation.

9.15.2.2.2 EXECUTION

1) Manufacturer's guidelines shall be followed for application procedure. The structural repair work of concrete (10mm - 50mm) on surface of concrete structures shall be performed with Cementitious Repair Mortar conforming to EN: 1504-3 (R4). The material shall also be suitable for application on vertical surface.
2) The mix shall conform to manufacturer's specifications. The quantity of water shall conform to the recommended mix design of manufacturer. The water shall be measured with calibrated container. The ready to use mix shall not contain any lump of unwanted filler and shall be uniform in colour. Best results are achieved using a mechanical mortar mixer with low speed continuous blending. For small quantities of material a paddle mixer can be substituted.
3) Saturate the area to be repaired with clean water. The surface must be mat-damp, but without standing water. Apply slurry coat/ scrape coat of repair mortar or primer onto the prepared wet surface as required. Thereafter apply full coat of repair mortar up to the desired thickness, line and level while

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previous coat is still wet within the specified time. The top surface should be smoothed with a trowel or finishing by float or sponge as soon as the mortar has begun to stiffen. However, the application of material shall conform to manufacturer's specifications.

4) Curing for 3-7 days is essential to obtain optimum quality and durability of the repair mortar. For moist curing, apply continuous source of moisture by spraying or wet burlap and or other suitable means.

9.15.2.2.3 CLOSURE OF GROUT HOLES IN TUNNEL

1) Upon completion of grouting work each hole shall be filled with thick grout and connections not embedded in the concrete shall be removed. The drilled holes in the concrete lining shall be reamed or re-drilled to a 200mm depth and cleaned with water, and the wet hole shall be filled with Cementitious Mortar conforming to EN 1504-3 (R4).

9.15.3 EPOXY MORTAR FOR REPAIR OF CONCRETE (BASED ON ASTM C881 TYPE-IV CLASS C)

9.15.3.1 MATERIAL

The epoxy mortar shall comprise of epoxy binder and aggregate/filler.

1) EPOXY BINDER FOR EPOXY MORTAR: Epoxy binder shall be 2-components epoxy resin bonding system (Resin & Hardener) conforming to ASTM C881 TYPE-IV CLASS C. The mechanical properties of Epoxy binder (Neat Resin System) shall be as below:

Sl No.	Performance Characteristics	Test Method	Requirement
1.	Compressive strength after 7 days	ASTM D-695	≥ 70 MPa
2.	Tensile strength after 7 days	ASTM D-638	≥ 50 MPa
3.	Bond Strength after 14 days	ASTM C-882	≥ 10 MPa

The epoxy-resin bonding systems for application to Portland cement concrete shall be applicable under humid conditions and bond to damp surfaces. The system shall be suitable for use during placement at temperature 15°C and above (Class C) as per manufacturer's recommendation.

2) AGGREGATE/ FILLER FOR EPOXY MORTAR: Quartz sand/ filler material for use in preparation of mortar shall be dry, clean and well graded as per manufacturer's specification.

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9.15.3.2 SURFACE PREPARATION

1) Remove loose, delaminated or unsound concrete to obtain a keyed surface by non-impact/ vibrating cleaning methods like compressed air/ high pressure water blast, chipping, wire brush or other means as per site requirement. Remove dust, micro fractured particles and foreign materials from the repair area by pressure washing or other suitable means necessary to clean surface to obtain desired bond. If reinforcing steel is visible, the same shall be cleaned all around.

9.15.3.3 EXECUTION

1) The mix proportioning/ ratio of the components shall conform to manufacturer's specifications. These ratios shall be expressed by weight. Primer/ coating and mortar shall be prepared separately.
2) Primer/ coating application: The respective material components i.e. resin and hardener shall be mixed by weight. Mixing shall be done for at least 3 minutes with a mechanical mixer to obtain a homogeneous mix and uniform colour. Aeration while mixing shall be avoided. The whole mix shall be poured into a container and stirred for a minute to expel out the entrapped air. The primer shall be prepared upto that quantity which can be used within its pot life.
3) Mortar application: First of all, the resin and hardener shall be mixed and then filler/ sand shall be added slowly until it achieves uniform consistency. Quantity of sand shall be 5-6 times the weight of epoxy binder (resin + hardener) or as per direction of Engineer.
4) The material as per specification is suitable for application at temperature of 15°C and above. If the temperature of the substrate concrete is lower than 15°C, it should be heated to achieve the desired temperature by electric heater or any other suitable means. The prepared surface shall be primed with neat epoxy binder. For proper coverage, priming shall be kept as specified by the manufacturer. Primer coat shall be applied on the cleaned surface with brush or other suitable means. The coverage of primer coats shall be as specified by the manufacturer. Prepared epoxy mortar (with graded quartz sand) shall be placed before primer becomes tack-free. Epoxy mortar shall be placed using trowels in minimum thickness layer of 6mm or as specified by the manufacturer. The mortar shall be compacted and leveled with trowels.
5) Subsequent layer of epoxy mortar shall be applied as per advice of Engineer and authorized applicator.
6) Seal coat shall be applied by neat epoxy binder as per ratio/ coverage given by manufacturer, if required.

9.15.4 CRYSTALLINE MATERIAL AS WATER PROOFING TREATMENT WORKS

1) Crystalline material comprising of proprietary active hydrophilic chemical is a permeability reducing admixture. The active ingredients of this material react with cement and water particles present in concrete to form calcium silicate hydrate (CSH) and pore blocking precipitates in the existing micro cracks and capillaries. The resulting crystalline deposits develop throughout the depth of concrete and

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become integral part with hydrated cement paste. The resulting concrete gets significantly increased resistance to water penetration under pressure. The hairline cracks if again develop, crystalline admixtures continue to activate in the presence of moisture and seal the additional gaps. It has been reported that once fully cured crystalline systems can withstand hydrostatic pressure of about 122m of head. This admixture is best suited under moist/ underwater conditions.

2) The crystalline slurry are used for waterproofing treatment by applying to concrete structures like retaining walls, water tank, tunnels, surge shaft, etc. by mixing in ratio of 5:2 (5 parts integral crystalline slurry: 2 parts water) for vertical surfaces and 3:1 (3 parts integral crystalline slurry : 1 part water) for horizontal surfaces and applying the same from internal\external side with the help of synthetic fiber brush. The material shall meet the requirements as specified in ACI-212-3R-2010 i.e. by reducing permeability of concrete by more than 90% compared with control concrete as per DIN 1048 and resistant to 16 bar hydrostatic pressure on negative side. The crystalline slurry shall be capable of self-healing of cracks up to a width of 0.50mm. The work shall be carried out all complete as per specification and the direction of the Engineer. The details of this product are available in the Delhi Schedule of Rates (Code no. 22.23).

3) Crystalline mortar are used by mixing in the ratio of 4.5 : 1 (4.5 parts crystalline mortar : 1 part water) for the treatment of construction joints, cracks, tie rod holes and spalled & honeycombed surface of PCC/ RCC surface and underground structures like Barrage, Head Regulator, Desilting Basin, Intake structure, tunnels, basement, water tanks etc. to ensure water tightness. The crystalline mortar shall conform to the EN 1504-3 having compressive strength Class R4 > 45 MPa and adhesive bond strength Class R3 > 1.5 MPa. The work shall be carried out all complete as per specification and the direction of the Engineer. The details of this product are available in the Delhi Schedule of Rates (Code no. 22.25).

4) Crystalline mortar used for sealing cracks and faulty construction joints, by preparing the surface, making U-shape groove size of 25x25mm and then priming the surface with integral crystalline slurry @0.05kg per running meter and while the surface is tacky then filling the groove upto top edge with crystalline mortar @1.50kg per running meter. Once crystalline mortar is touch dry then finally applying two coats of integral crystalline slurry @0.05kg per running meter per coat on treated surface.

5) Crystalline mortar used for patching of tie rod holes, preparing tie rod hole surface and then priming the area with integral crystalline slurry @0.070kg per sqm and while the surface is tacky, repairing and then filling the tie rod holes with crystalline mortar @0.040kg per hole. The crystalline mortar shall be tightly rodded into tie rod holes or packed tightly (For 25x25x25 mm tie rod hole, use 0.040 kg to fill the hole).

9.15.5 EPOXY RESIN

1) For concrete surfaces where high velocity flows may occur, and as required by the Engineer, repairs to surfaces having F3 and U3 finishes shall be bonded with an epoxy adhesive approved by the Engineer and used in accordance with the manufacturer's instructions. All repairs to the surface of

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concrete required for flowing water shall be ground smooth to meet the tolerances specified for that surface.

2) In areas exposed to public view, the concrete surfaces repaired with epoxy-resin bonded system shall be lightly ground to eliminate gloss of the finished epoxy mortar surface and to produce a surface color and texture that closely matches the surrounding concrete surface.

9.15.6 CONCRETE FILLING

1) Concrete filling shall be used for holes extending entirely through concrete sections, for holes in which no reinforcement is encountered and which are greater in area than 0.1 m2 and deeper than 100 mm and for holes in reinforced concrete which are greater in area than 0.05 m2. Holes in reinforced concrete which extend beyond the reinforcement shall be enlarged as necessary to permit satisfactory filling of the hole with concrete.
2) Concrete filling shall be tightly packed and completely bonded to the surfaces of the holes. The mix proportions of the filling materials shall be such as to provide a strong, dense repair.
3) On surfaces permanently exposed to view the Contractor shall supply white cement in sufficient amount, as determined by trial, which when blended with normal cement, will produce a finish of similar appearance to the adjacent concrete. Non-shrink agent shall be used where a watertight joint is required. The surface of patches shall be smooth and flush with the surrounding concrete.

9.15.7 SEALING WORK IN CONCRETE LINING OF UNDERGROUND STRUCTURES

1) The Contractor shall carry out sealing work to reduce water inflow and water losses through, and to guarantee the normal water-tightness of the concrete lining of underground structures according to criteria stated hereafter and as requested by the Engineer.
2) The work shall consist of sealing the cold joints or construction joints, wherever specified, shrinkage cracks both vertical and horizontal,
    a. Water inflow equals or exceed 1 litre/min measured at each single inflow source,
    b. Any water inflow from grout holes and through honeycombs is unacceptable,
    c. Cracks or joints, regardless whether they are dry or wet, of width greater than:
        i. 0.2 mm in tunnels containing reinforcing steel
        ii. 0.5 mm in unreinforced stretches of tunnels
    d. Areas of porous concrete (e.g. due to poor vibration) where depth of porosity is obviously deeper than superficial.
3) The sealing work shall be executed as follows:
    a. Crack or joint 0.2-0.6 mm wide shall be repaired as stipulated in the Section "Drilling and Grouting".

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b. Crack or joint wider than 0.6 mm shall be repaired as under (1) above, followed by cutting a groove 25x25 mm along the joint or crack and subsequent filling with an epoxy mortar.
c. Wet joint may also be sealed by applying the "Oberhasli Method", which consists of cutting a groove as for the dry joint and by collecting the seepage water into one or several flexible plastic pipes. As soon as the groove is without running water is shall be filled with a quick-setting mortar and, after its hardening, followed by pumping the cement- bentonite-water slurry through the plastic pipes.
d. Areas of porous concrete shall be grouted under high pressure (30 bar) with cement grout mix W/C=0.7, by weight, containing suitable water- reducing air-entraining admixture. Grout holes shall be drilled at 500 mm spacing until the rock. After grouting, the area shall be repaired with epoxy mortar.
e. Grout holes filled only with water/cement mix shall be redrilled up to 2/3 of the theoretical lining thickness and filled with dry-pack mortar.

9.15.8 FIXING OF STEEL ANCHORS IN THE EXISTING CONCRETE

9.15.8.1 SURFACE PREPARATION

1) All type of dust/clay lying on the surface will be removed with the help of compressed air or high pressure water blast. After chipping/chiseling of concrete up to desired size and depth the concrete surface shall be got inspected by the representative of the Engineer. The contractor shall remove all the chipped materials to the suitable disposal site and shall keep the area clean.

9.15.8.2 ANCHORING

1) Anchorage shall generally comprise of 25mm diameter Fe500 deformed steel bars conforming to Section B.11 Reinforcing Steel, embedded in 32mm diameter holes in the substrata or as shown in the drawings and shall be fixed in place with epoxy grout conforming to ASTM C881 Type IV, Class C. Spacing of anchorage shall be 1m c/c staggered or as per drawing and as per the directions of the Engineer. Diameter of anchorage, length and spacing may vary to suit site conditions. Other anchorage types may be used when indicated in the Drawings.
2) The surface of the anchor bars shall be clean of rust, scale, dirt or other foreign matter.
3) Holes drilled for anchor bars shall be kept plugged until just prior to commencement of grouting operations. Before grouting, each hole shall be thoroughly flushed with water and cleaned with compressed air.
4) Water shall be removed from the hole before grouting. If the hole cannot be kept dry during grouting, the grout shall be introduced into the end of the hole through a pipe, which shall be gradually withdrawn as the hole is filled.

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5) The depth of anchor into old concrete shall be a minimum of 500mm, except when specifically indicated on the Drawings. The anchor at the top shall be bent at 90 degree and shall be placed towards d/s direction along the flow.
6) Grouting material for anchor shall be two parts solvent free moisture insensitive epoxy resin which can be easily placed in the full depth of drilled hole. Bond strength (moist cure) of the bonding material shall be 10 MPa and shall be tested in accordance to ASTM C882. Certified quality test reports from the manufacturer in this regard shall be submitted by the contractor.
7) Drilling in old concrete will be carried out by the contractor with the help of pneumatic jackhammers /equivalent means to the desired depth. The drilling of holes shall be done in such a way that the hole is exactly normal to the finished surface of concrete.
8) The hole shall be filled up to 350mm depth with grouting material and thereafter the anchor shall be inserted into the hole before the initial set of the grout. This will ensure that some of the grout comes out of hole, when the anchor is inserted. The bar shall be vibrated or tapped in order to ensure good contact between the steel surface and the grout.
9) The scaffoldings and safety measurements required for doing drilling shall be arranged by the Contractor with no additional cost.
10) Anchors bars shall be protected after installations in such a manner as to prevent any movement until the grout has hardened. The Contractor shall replace any bars found to be loose after the grout has set.

9.16 PARTICULAR REQUIREMENTS FOR INDIVIDUAL CONCRETE STRUCTURES

9.16.1 CONCRETE IN SPILLWAY

1) Concrete grade used for construction of the spillway and the Spillway chute (or glacis) shall be as per table given under clause 9.5.1 and as shown on the Drawings.
2) Contractor shall be required to place multiple grades of concrete within the confines of one lift of mass concrete as shown on the Drawings and as required by Engineer.
3) Where the overbreak in excavation below the theoretical lines and grades exceeds acceptable limits, as determined by the Engineer, the Contractor shall place blinding unreinforced concrete (commonly indicated as “rock reconstruction”) as indicated in table given under clause 9.5.1 over the rock foundation in such thickness that the upper surface is at the theoretical grade elevation. Surface shall be roughened before placing the structural spillway concrete.
4) No construction joints shall be allowed in the chute, unless otherwise approved or directed by the Engineer. In case such joint is permitted, additional steel reinforcement shall be placed across the joint and the joint surface shall be shuttered with expanded metal. In such a case, all the necessary provisions shall be undertaken to avoid also hydraulic malfunctioning, cavitation and chute structure undermining.

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5) Contraction joints shall be executed in the chute walls at the distances as shown in the Drawings. Steel dowels shall be placed through these joints and the surface shall be painted with bituminous coat or other approved bond breaker.
6) All movement joints exposed to flowing water shall be chamfered 1:1 on upstream side and 1:8 on downstream side.
7) The top layer of the spillway chute and other wearing surface, concrete shall be terminated approximately 500-1000 mm below the final surface to provide room for placing the high-performance concrete to increase the abrasion resistance of the structure. Similarly, in the walls which will come into contact with rapidly flowing water, recesses will be blocked out to a depth of 300-500 mm and height as shown in the Drawings.
8) The concrete surface finishes in the gate structure and chute shall be F3, F3C, U3, and U3C. For surfaces in contact with high velocity water flow the permissible surface irregularities shall not exceed the values indicated in the section “Tolerances for General Concrete Structures”.

9.16.2 CONCRETE FOR TRUNNION BEAM AND BREAST WALL

1) Concreting of trunnion beam and the breast walls is to be monolithically cast with the piers of the spillway. No cold joint will be allowed between piers and trunnion beam.
2) The contractor has to evolve his construction program including the staging requirement for the trunnion beam, keeping in view the requirement stated above.
3) The contractor shall cooperate with HM contractor (Hydromechanical supplier) during the fixing of the embedment for gates & other parts including provision of bracing and ties necessary to maintain all equipment in their correct position during placement of the surrounding concrete.

9.16.3 BRIDGE OVER THE SPILLWAY

1) The bridge over spillway shall be constructed as simply supported structure comprising pre-cast/cast in-situ concrete girders and cast-in-situ deck slab.
2) Precast concrete beams shall be placed on Elastomeric bearings pads in position and arrangement as shown on the Drawings.
3) Elastomeric bearings shall be laid on cement mortar pads having minimum 28-days compressive strength of 40 N/mm² placed with a finished surface within 3 mm of the elevation shown on the Drawings (precision) or as directed by the Engineer. The deviation from a straight edge laid across the bearing pad shall not exceed 2 mm.
4) The Contractor shall furnish and install drain pits for drainage of the surface water from the bridge as shown on the Drawings or as directed by the Engineer. The drain pits shall be made of galvanized steel plate with steel grating or precast concrete with removable lid. PVC pipe with a minimum diameter of 100mm shall be attached to each pit to eject and drain the water.

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9.16.4 ELASTOMERIC BEARING PADS IN SPILLWAY BRIDGE

1) The bridge over the spillway shall be constructed, as simply supported structure comprising precast concrete girders and cast-in-situ deck slab.
2) Concrete girders may be placed on Elastomeric bearings pads in position and arrangement.
3) Elastomeric bearings shall be laid on cement mortar pads having a minimum 28-days compressive strength of 40 N/mm^2 placed with a finished surface within 3 mm of the elevation shown on the Drawings or as directed by the Engineer. The deviation from a straight edge laid across the bearing pad shall not exceed 2 mm.
4) The Contractor shall furnish and install drain boxes for drainage of the surface water from the bridge as directed by the Engineer. The drain boxes shall be made of galvanized steel plate with steel grating. PVC pipe 100 mm dia. shall be attached to each drain box.

9.16.5 CONCRETE GRAVITY STRUCTURES

1) Concrete used for the construction of mass concrete gravity structures shall be as specified in construction drawing or as directed by the Engineer. However, surface exposed to weathering and standing or flowing water shall be constructed of higher class concrete as indicated on the Construction Drawings. Where higher strength concrete is used, part of each lift will therefore normally be composed of two classes of concrete. Water-cement ratio shall not exceed 0.45.
2) Reinforcement shall be provided at the surfaces in contact with standing or flowing water and at all openings in mass concrete.
3) Mass concrete of retaining wall shall be water cured for at least 10 days unless otherwise directed by the Engineer. When curing compound is used as a bond breaking membrane at contraction joints, it shall also be considered acceptable in meeting the curing requirements.
4) Where the over break in excavation below the theoretical lines and grades exceeds acceptable limits, as determined by the Engineer, the Contractor shall place blinding unreinforced concrete class M15/A40 over the rock foundation in such thickness that the upper surface is at the theoretical grade elevation. Surface shall be roughened before placing the structural concrete.

9.16.6 CONCRETE LININGS OF TUNNELS

1) Concrete used for the construction of the linings of tunnels shall be as specified on the Drawings or as directed by the Engineer.
2) The Contractor's proposed method of concrete placement is subject to the approval of the Engineer.

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3) The vault and invert of the tunnel lining shall be cast in separate operations. The Contractor shall propose the sequence of the casting operations. The proposed method of concrete placement is subject to the approval of the Engineer.
4) The tunnel lining shall either be poured in sections or by "continuous pouring". If the Contractor wishes to use the latter method, then it should be demonstrated to the Engineer that the concrete production, transport and placing equipment to be used has sufficient capacity to produce and handle the amount of concrete necessary for continuous pouring of the lining sections. In addition, the Contractor shall provide details of the steps to be taken in the event of an interruption in the concrete supply.
5) The number of vertical construction joints shall be reduced to minimum. Inclined construction joints will have the naturally running slope of placed concrete. In addition to the treatments specified in the section "Joints in Concrete Structures", in case of inclined construction joints, the concrete in the crown and the invert shall be removed before placing the next stage to avoid an acute angled construction joints relative to the inside surface of the tunnel lining concrete.
6) Prior to concreting, the rock surface shall be cleaned and shall be free from oil, mud, loose rock, objectionable coating, debris and loose or unsound fragments. All surfaces shall be cleaned with air-water jets or by other satisfactory means. Particular attention shall be given to the drainage of flowing and the removal of standing water where concrete will be placed.
7) The extent of the steel reinforcement required in the concrete lining is subjected to approval by The Engineer who shall assess it, based on the results of the rock mechanics test (if any) performed in the excavated tunnel or according to the Drawings. The maximum spacing of the steel rebars will be 200 mm.
8) At any point where an inspection (e.g. by coring or sounding) indicates that a cavity exists between concrete lining and the surrounding rock, as determined by the Engineer, the Contractor shall backfill the voids with grout at no additional payment. The grout mix and grouting pressures shall be as directed by the Engineer. After grouting, all grout holes shall be sealed. Alternatively, contact grouting operation will be systematically carried out by the contractor, where specified on the Drawings.

9.16.7 CONCRETE BEHIND STEEL LINERS IN SPILLWAY GLACIS

1) No windows for introduction of vibrators will be provided in the permanent steel liners. Special care shall be taken to ensure compaction of concrete and complete filling of the space beneath the steel lining, and the filling of the crown according to the procedure specified in aforesaid "Pumping Concrete".
2) Prior to concreting, the rock surface shall be cleaned and shall be free from oil, standing or running water, sand, loose rock, objectionable coating, debris and loose or unsound fragments. All surfaces shall be cleaned with air-water jets or by other satisfactory means. Particular attention shall be given to the drainage of flowing and the removal of standing water where concrete will be placed.

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3) The Contractor shall co-operate closely with the HM contractor/supplier of all the steel-linings during their erection prior to backfilling.
4) Embedding concrete around steel liners in tunnels shall be placed at a maximum rate of rise of 150 mm per hour unless reliable bracing has been installed to prevent uplifting of the pipes. In no case shall the differential level of concrete on either side of the liner exceed 150 mm at any time of placing.
5) Installation of subsequent steel liner units shall not proceed until 24 hours have elapsed since placing of the backfill concrete, or the concrete has been shown to have obtained 20% of its required 28-days cylinder compressive strength.

9.16.8 BACKFILL CONCRETE

1) Backfill concrete in surface and underground works shall be placed for providing immediate support to the rock during excavation.
2) In the lined tunnels, where the extents of over breaks are not significant, the Engineer may direct the contractor to fill the gaps concurrently with the tunnel lining.
3) In order to confirm that the gaps have been completely filled or the desired thickness has been achieved as the case may be, the contractor shall take out the cores from the locations as directed by the Engineer.
4) From the coring, if it is established that the voids have not been completely filled, the Engineer shall direct the Contractor to fill the remaining voids with grouting at his own cost.

9.16.9 CONCRETE IN BLOCKOUTS FOR EQUIPMENT EMBEDDING

1) The Contractor shall form blockouts, place reinforcement and concrete as shown on the Drawings under the supervision of the Engineer, and in such manner as to ensure good bond with the existing concrete, to secure complete contact with the metalwork to be embedded in the blockout concrete and to avoid displacement of the metalwork.
2) Blockout concrete shall include concrete around second stage gate parts, as well as anchor bolts and anchor plates.
3) The concrete in blockouts shall be M40/A20 and self-compacting, unless otherwise indicated in the Drawings or directed by the Engineer. On the instruction of Engineer or as indicated in the Drawings, the second stage blockouts may be filled with pourable non-shrink epoxy mortar. The non-shrink cement Grout shall fulfil the criteria as specified in clause “Non-shrink cement based grout”.
4) Except as otherwise specified the hydro-mechanical, mechanical, and electrical equipment will be provided and installed by the suppliers in co-operation with the Contractor.
5) Before placing concrete, all parts to be embedded shall be checked to ensure that they are firmly fixed in their required position. The surfaces of blockouts or holes shall be thoroughly cleaned and wetted.

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Oil or grease shall be removed by brushing and chipping of affected surfaces to a sufficient depth, or by application of approved chemicals and flushed with clear water.

6) The parts to be embedded shall be cleaned of rust, mill scale, paint, oil or grease before they are set into place. Where bond between metal parts and concrete or grout is not desired, approved material such as flake graphite or paraffin shall be applied to the metal parts. The metal surfaces shall be wetted before placing the concrete or grout.

7) Only self-compacting Concrete containing approved admixtures shall be used for the concrete in second stage in block outs for equipment embedding as shown on the Drawings or required by the Engineer.

9.16.10 CONCRETE PLUG IN DIVERSION TUNNEL & ADIT 1

1) When no longer required for river diversion purposes, the Contractor shall plug the diversion tunnel as shown on the Drawings.

2) The concrete shall be placed in sections with drainage pipes to allow the removal of ground and service water. No independent cooling system for limiting the temperature rise is foreseen if sufficient time is available for elapsing between placing of the individual concrete lifts.

3) Before commencing the construction of the plug, the surface of the existing tunnel shall be cleaned and roughened in those stretches where the plug will be constructed. Damaged existing shotcrete shall be removed as necessary without recourse to blasting.

4) Air vents, grout stops, and grouting system shall be provided for assuring good bond with the plug concrete.

5) The Contractor shall supply and install thermocouples and their junctions and extension wires in the fresh concrete, and perform temperature measurement to monitor temperatures within the concrete mass. Based on these measurements the time for next concrete lift shall be determined by the Contractor and approved by the Engineer.

6) Once cooling of the concrete is substantially progressed, contact grouting between plug and the surrounding concrete, grouting of construction joints, and grouting up of the air vents and drainage pipes installed shall be carried out in accordance with the requirements of the Section "Drilling, Grouting and Pressure Relief Holes". Grout shall be forced through previously installed longitudinal feeder pipes along the channel axis, with radial riser pipes extended into the surrounding concrete, and to grout outlets placed in construction joints between the plug sections.

7) Not less than 15 days after completion of contact grouting of the plug, the Contractor shall carry out consolidation grouting of the surrounding rock, in accordance with the requirements of the Section "Drilling, Grouting and Pressure Relief Holes" and installation of the rock anchor in accordance with the requirements of the Section Rock Supports.

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9.16.11 OTHER PARTS EMBEDDED IN CONCRETE

1) Anchors, anchor bolts, structural shapes, plates shapes, plates for gates, hoists, valves, machinery etc. and other miscellaneous parts shall be installed in the concrete by the Contractor, as shown on the Construction Drawings or as required by the Engineer. Wherever practicable, anchors shall be installed before the concrete is placed. Except as otherwise specified, drilling and installation of anchors in the concrete after concrete is placed, will not be permitted. Before being placed in position, all anchors and embedded parts shall be thoroughly cleaned of rust, grease, paint, splashed concrete, or other coatings that will reduce bond. Where the installation of the anchors is not practicable before the concrete is placed, formed openings shall be provided, and the anchors grouted into the openings at a later time in a manner acceptable to the Engineer.
2) Embedded anchors shall be supported during embedding and embedded so that the tolerances specified will not be exceeded. Care shall be taken not to disturb or displace embedded items during concrete placement.
3) Concrete may be placed to embed items erected by other agencies in the locations and to the dimensions shown on the Construction Drawings or as required by the Engineer. The methods of placement and rates of placing concrete shall be subject to the approval of the Engineer. Care shall be exercised that such parts shall not be damaged or disturbed by placing operations.

9.16.12 GROUTING OF THE EQUIPMENT BEARING PLATES AND ANCHORS

1) Limited spaces and small blockouts where equipment bearing plates, anchors, rails, etc., are placed shall be grouted under pressure.
2) The grouting shall be performed using non-shrink cement-based grout or non-shrink epoxy grout as proposed by the Contractor and approved. All mixing and grouting shall be performed in accordance with the manufacturer's recommendations and shall be tested prior to grouting. Technical service by manufacturer shall be organised by the Contractor upon request by the Engineer.
3) Before placing grout, the surfaces of the base concrete to which the grout will be bonded shall be roughened and cleaned of all laitance, loose or defective concrete, any coatings or other foreign material, followed by thorough washing with water.
4) Forms for grouting shall be installed where necessary and care shall be taken that the grout fills all spaces under the plates leaving no voids. The exposed surfaces of the grout shall be cured as recommended by the manufacturer and no loads shall be applied until the grout has reached the design strength.

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9.16.12.1 NON-SHRINK CEMENT BASED GROUT

1) Non-shrink cement based grout shall be essentially of Portland cement mixed with anti-shrinkage compounds. Grout shall be prepared by adding water as per the instruction of manufacturer and as approved by the Engineer to achieve desired flowability.
2) Non-shrink cement based grout shall conform to the following requirements:
   a) For the dimensional stability, the grout shall meet the requirement of ASTM C1107 Grade C, when prepared according to manufacturer's instruction and tested at 4ºC and 32ºC.
   b) Grout shall be capable of being pumped flowable without segregation. Vibration allowed only when expressly stated by the manufacturer.
   c) Non-shrink cement-based grout shall have minimum compressive strength of 50 N/mm^2 at 7 days, as determined by test on 50 mm cubes as per ASTM C109.

9.16.12.2 NON-SHRINK EPOXY GROUT

1) The non-shrink epoxy grout shall be a mixture of epoxy resin, curing agent as per the instruction of manufacturer. Accelerator for faster curing can be added. Non-shrink epoxy grout shall conform to the following requirements:
   a) For the dimensional stability, the length change after hardening shall be negligible when tested according to ASTM C531.
   b) The grout shall be capable of maintaining at least a flowable consistency for a minimum of 30 minutes at 21ºC.
   c) Non-shrink epoxy grout shall have minimum compressive strength of 68 MPa at 7 days, when tested according to ASTM C579.

9.16.13 PRECAST CONCRETE

1) Precast concrete shall be produced in an enclosed area separate from other construction works.
2) Precast units shall generally conform to the other parts of the same technical specifications where applicable and as required by the Engineer.
3) Precast units shall be protected at all times from damage at the place of fabrication and during handling, storage and erection.
4) Precast concrete units shall be placed in their correct relative location and temporarily braced and secured to prevent collapse or distortion of the structure until completion of the work to the satisfaction of the Engineer.
5) Following removal of formwork, any hole, voids or other blemishes in the surfaces of precast concrete units which are to be exposed shall be patched and a smooth rubbed finish provided. Rubbing shall be done with a carborundum stone and water.
6) Pre-cast concrete lagging in tunnels shall be dealt separately under section "Rock Supports".

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9.16.14 PAVEMENT CONCRETE

1) Concrete used for the pavement of roads shall be of M25/A40 grade or as directed by the Engineer.
2) The concrete placement shall be as per the item B.21 “Roadworks” of Technical Specifications. However the contractor may modify the same, if required with the approval of Engineer.

9.16.15 POROUS CONCRETE

1) Porous concrete shall be placed where free drainage is required and shall be produced by gap grading or single size aggregate grading.
2) Porous concrete porosity shall be such that water will pass through a slab 30 mm thick at a minimum rate of 500 l/min/m² with a constant depth of water on the slab of 100 mm.
3) Porous concrete shall not be vibrated but only placed and lightly rammed. Formed surfaces shall be Class F1 finish. Exposed surfaces of the porous concrete shall be sealed in an approved manner, such as the use of polyethylene or rendering with sand and cement, before structural concrete is placed against it.

9.16.16 SLUSH GROUT

1) The slush grout shall be composed of cement, sand, and water in the proportion of one part cement, two parts sand by weight, with sufficient water to produce a workable mixture, e.g. with water/cement ratio, by weight, ranging between 0.45 and 0.5. All materials shall conform to the specifications of this Section. The slush grout shall be mixed in a concrete mixer.
2) Foundation surfaces shall be moist at the time of slush grouting. The grout shall be swept with brooms into foundation surfaces in such a manner as to fill thoroughly all cracks, crevices, and minor imperfections in the rock. The slush grout shall be cured after it has attained its initial set as specified in the section “Protection and curing of concrete”.

9.16.17 PAVEMENT CONCRETE

1) Concrete used for the pavement of roads shall be of M25/A40 grade or as directed by the Engineer.
2) The concrete placement shall be as per the item B.23 “Roadworks” of Technical Specifications. However the contractor may modify the same, if required with the approval of Engineer.

9.16.18 CONCRETE FILL IN EXPLORATORY DRIFT

1) The exploratory drift shall be filled with the concrete, as stated on the Drawings or instructed by the Engineer. The placement of concrete shall be as per clause 9.11 of Technical Specifications.

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9.17 MEASUREMENT AND PAYMENT

9.17.1 GENERAL

1) Measurement for payment for each class of concrete, unless specified otherwise hereafter, will be of the volume placed within the lines, grades, and pay-limits shown on the Drawings or as established at the Site by the Engineer.
2) Unless otherwise stated, no payment will be made for concrete placed outside these limits, other than in additional excavation directed by the Engineer. The measurement shall not include any filling of overbreak unless recognised as due to geological conditions conforming to the limits defined in other Sections of these Specifications.

3) Payment will be made at the Unit Prices for different classes and types of concrete entered in the Bill of Quantities, which shall include, but not be limited to, the following:
   a) Excavation, loading, transportation, crushing, screening, washing, blending, and storage of aggregates,
   b) Batching, supply of mixing water, mixing, transportation, placing, and compacting the concrete,
   c) Provision, delivery, transportation, storage and mixing of cement at the nominal content per different classes of concrete indicated in Sub-Section "Concrete Mix Design" and complying with all requirements specified,
   d) Labour, tools and equipment for cleaning, and preparing surfaces prior to concreting,
   e) Forming and treatment of construction joints including furnishing and spreading of mortar layers, or starter mixes before concrete placing,
   f) Surface finishing including bush-hammering,
   g) Attaining the concrete temperature as specified, and hot and/or cold weather precautions,
   h) Protection and curing of concrete,
   i) Repair of defective concrete and removal of rejected concrete,
   j) Communication system connecting the points of placing concrete with the relevant mixing plant or delivery equipment,
   k) Furnishing the trial bays and panels, provision of material samples and all activities required in connection with the performance of the tests including their transportation to the testing laboratory.
   l) Any kind of formwork required
4) All associated concrete work, such as removal of forms and repairs and finishing of concrete shall be completed as soon as practicable after concrete is placed. Concrete will not be considered for payment until all associated works have been completed. The assessment of correct completion of the concrete works will be carried out by the Engineer.

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5) Measurement for payment and payment for steel reinforcement are stipulated in other Sections of these Specifications.

9.17.2 HIGH PERFORMANCE CONCRETE

1) Measurement for payment of high performance concrete will be of the volume placed. Payment will be made at the Unit Price per cubic meter entered in the Schedule, which shall include the entire cost of preparation of contact surfaces with parent concrete, furnishing, mixing and casting of such concrete and any other related work.
2) Measurement for payment of micro silica/SCM (Supplementary Cementitious Material) and Superplasticizer mixed into the concrete will be of the weight based on the dosages agreed and approved by the Engineer. Payment will be made at the Unit Price per kg entered in the Schedule, which shall include the entire cost of supply, handling, mixing of the micro silica/SCM and Superplasticizer and provision, operation and maintenance of equipment for mixing these into the concrete.

9.17.3 STRUCTURAL REPAIR WORKS / CLOSURE OF GROUT HOLES WITH CEMENTITIOUS MORTAR

1) The actual consumption of cementitious mortar actually used for closure of grout holes shall be measured in kg (dry weight) and payment shall be made at Unit Price per kg of mortar as entered in the Bill of Quantities.
2) No measurement and payment shall be made for the cementitious mortar used for repair and rehabilitation of concrete in permanent works arising from the contractor's negligence or poor working practices. However, the cementitious mortar used for modification of concrete structures ordered by Engineer shall be measured and payment shall be made at appropriate unit price entered in the Bill of Quantities.
3) Technical service rendered by the manufacturer as needed, will not be separately reimbursed but will deem to be included in the Unit Prices. Further, the cost of mixing, placing and compaction etc. required for complete work in a workman like manner is deemed to be included in the unit cost of constituents of Epoxy mortar and no separate measurement and payment for the same shall be made.

9.17.4 CRYSTALLINE MATERIAL AS WATER PROOFING TREATMENT WORKS

1) Measurement for payment for application of integral crystalline slurry for waterproofing treatment shall be made for the actual surface areas.
2) Measurement for payment for application of integral crystalline mortar for waterproofing treatment shall be made for the linear metre entered in Bill of Quantity.

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3) Payment shall be made at the rates quoted by the contractor for a particular item contained in the Bill of quantities.
4) The rates of the items in bill of quantities shall be inclusive of cost of labour, surface preparation, carriage, staging, scaffolding, and application including making U-shape groove size as mentioned in clause 9.15.4 cost of providing safety measures etc including diversion of seepage water by means of soil filled gunny bags or by any method suggested by the Engineer and nothing extra shall be paid on this account.

9.17.5 CONCRETE LINING OF TUNNELS

1) Measurement for payment for concrete placed in the tunnels lining will be of the volume of concrete placed within the "B-line" (B-line is defined in the section “Underground Excavation”). Deductions from this volume will be made for the in-situ concrete or shotcrete placed earlier, which will be paid separately.
2) Measurement for payment and payment will be made separately for the concrete placed in the invert and for concrete placed in the vault of the tunnels.
3) The Unit Prices shall include, in addition to works described under "General", the entire cost of the following:
    a) Design, furnishing, maintenance, erection, and removal of and all other type of formwork, including formwork for transitions and formwork as bulkhead for concreting in approved over break areas, formwork,
    b) Pumping of the concrete,
    c) Grouting materials and placing grout for contact grouting carried out in the tunnel,
    d) Sealing of cracks, cold joints etc., where directed by the Engineer,
    e) Provision and installation of thermocouples for temperature measuring,
    f) Concrete in unapproved overbreaks in tunnel vault,
    g) Concrete beyond “B-Line” in the invert of tunnel (Overbreak in the invert is not recognised.)

4) Concrete placed beyond “B-Line” in the geologically accepted overbreaks in the vault of the tunnel will be paid at 75% of the Unit Prices quoted for concrete lining in the overt, when the concreting is done simultaneously and is of the same grade as of structural concrete lining.
5) When backfill concrete (M15/A40) is placed behind steel ribs in geologically approved overbreaks, the same shall be paid at the appropriate Unit Prices per cubic meter entered in the Bill of Quantities.
6) Concrete for filling the overbreak not accepted by the Engineer as being due to geological reasons will not be paid for.

9.17.6 BACKFILL CONCRETE IN SURFACE EXCAVATION

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1) Where backfilling with concrete is directed by the Engineer, payment will be made for concrete placed as backfill in geologically accepted overbreak, dental excavation and in additional excavation directed by the Engineer.
2) Payment will be made at the Unit Price entered in the Bill of Quantities for the concrete classes used, as appropriate.

9.17.7 BACKFILL CONCRETE BEHIND STEEL LINERS

1) Measurement for payment and payment will be made separately for concrete placed behind steel-linings.
2) Measurement for payment will be of the volume of concrete placed within the "B"-line shown on the Construction Drawings. Deduction from this volume will be made for the in-situ concrete or shotcrete placed which will be paid for separately.
3) Concrete placed beyond “B-Line” in the geologically accepted overbreaks will be paid at 75% of the Unit Prices quoted for Backfill concrete behind steel liners, when the concreting is done simultaneously and is of the same grade.

9.17.8 CONCRETE BEHIND STEEL LINERS IN SPILLWAY GLACIS (CHUTE)

1) Measurement for payment and payment will be made separately for concrete placed behind steel-linings.
2) Measurement for payment will be of the volume of concrete placed within the "B"-line shown on the Drawings. Deduction from this volume will be made for the in-situ concrete or shotcrete placed which will be paid separately.
3) Concrete placed beyond “B-Line” in the geologically accepted overbreaks will be paid at 75% of the Unit Prices quoted for concrete behind steel liners in Spillway Chute, when the concreting is done simultaneously and is of the same grade.

9.17.9 CONCRETE PLUGS IN DIVERSION TUNNEL & ADITS 1

1) In addition to works described under "General", the entire cost of labour and material related to concreting in stages, cooling of concrete, and contact grouting shall also be included in the Unit Prices entered in the Bill of Quantities for concrete plugs in Diversion Tunnels and adits 1 to HRT.

9.17.10 SECOND STAGE CONCRETE AND CONCRETE IN BLOCKOUTS FOR EQUIPMENT EMBEDDING

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1) Measurement for payment of second stage concrete and concrete in blockouts (including Self-Compacting Concrete) will be of the volume of placed concrete. Only second stage concrete placed in spaces exceeding 0.10 m^3 in volume or 0.05 m^2 in cross section will be considered for payment. Concrete placed in blockouts or spaces less then stated above shall be deemed to be included in the Unit Price for concrete in the structure with which it is associated.
2) Payment will be made at the Unit Price per cubic meter entered in the Bill of Quantities, which shall include, in addition to works included under "General", the entire cost of preparation of contact surfaces with parent concrete, furnishing of non-shrink agent, where directed, and any other related work.
3) Separate payment will be made for the superplasticizer used in preparing self-compacting concrete. The payment will be made at the appropriate Unit Price per litre (or kilogram) entered in the Bill of Quantities.

9.17.11 NON-SHRINK EPOXY MORTAR IN BLOCKOUTS/REPAIR/REHABILITATION AND MODIFICATION OF CONCRETE

1) Measurement for payment for the non-shrink epoxy mortar will be of the actual total weight of constituents i.e. epoxy binder (resin & hardner) and filler material (well graded quartz sand) placed in the blockouts.
2) No measurement and payment shall be made for the non-shrink epoxy mortar used for repair and rehabilitation of concrete in permanent works arising from the contractor's negligence or poor working practices. However, the non-shrink epoxy mortar used for modification of concrete structures ordered by Engineer shall be measured and payment shall be made at appropriate unit prices entered in the Bill of Quantities.
3) The two-component epoxy binder (resin & hardner) used in the mortar actually placed in blockouts shall be measured in kg. The payment shall be made at appropriate unit price per kg entered in Bill of Quantities.
4) The well graded quartz sand/filler actually used in mortar placed in the blockouts shall be measured in kg. The payment shall be made at appropriate unit price per kg entered in the Bill of Quantities.
5) Technical service rendered by the manufacturer as needed, will not be separately reimbursed but will deem to be included in the Unit Prices. Further, the cost of mixing, placing and compaction etc. required for complete work in a workman like manner is deemed to be included in the unit cost of constituents of Epoxy mortar and no separate measurement and payment for the same shall be made.

9.17.12 GROUTING OF EQUIPMENT BEARING PLATES AND ANCHORS

1) Measurement for payment for the non-shrink cement-based grout or non-shrink epoxy grout will be of the actual volume placed in the blockouts and under bearing plates.

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2) Payment will be made at the appropriate Unit Price per kilogram entered in the Bill of Quantities. Technical service rendered by the manufacturer as needed, will not be separately reimbursed but will deem to be included in the Unit Prices.

9.17.13 PRECAST CONCRETE

1) Measurement for payment for precast concrete units will be of the volume of concrete used in the various types of precast concrete units, supplied and installed in the Permanent Works.
2) Payment will be made at the appropriate Unit Price per cubic meter entered in the Bill of Quantities, which shall include, in addition to works described under "General", the entire cost of formwork, cement, admixtures, storage, transportation, and erection. Reinforcing steel is to be paid separately.

9.17.14 POROUS CONCRETE

1) Measurement for payment for porous concrete will be of the volume of concrete placed, and payment will be made at the Unit Price per cubic meter entered in the Bill of Quantities.
2) No variation in cement content is payable for porous concrete.

9.17.15 CONCRETE CURBS (UPSTREAM COFFERDAM)

1) Measurement for payment for concrete curbs will be of the volume of concrete, constructed in place and completed in the Permanent Works.

2) Payment will be made at the appropriate Unit Price per cubic meter entered in the Bill of Quantities, which shall include, in addition to works described under "General", the entire cost of subgrade preparation, formwork, concrete materials (including cement and admixtures), production, placement, finishing, curing, and all labor and equipment necessary to complete the works as specified.

9.17.16 SLUSH GROUT

1) Measurement for payment for slush grout will be based on the weight of material placed, and payment will be made at the Unit Price per kilogram entered in the Bill of Quantities.
2) No variation in cement content is payable for slush grout.

9.17.17 CONCRETE FILL IN EXPLORATORY DRIFT

1) Measurement for payment for concrete in exploratory drift will be of the volume of concrete placed.
2) Payment will be made at the unit price per cubic meter entered in the Bill of quantities.

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9.17.18 CONCRETE IN BRIDGE DECK SLAB AND ABUTMENTS, PIERS, WING WALLS

1) Measurement for payment for concrete in bridge deck slab, abutments, piers, wing walls will be of the volume of concrete placed.
2) Payment will be made at the unit price per cubic meter entered in the Bill of Quantities.

9.17.19 ELASTOMERIC BEARING PADS IN SPILLWAY BRIDGE

1) Measurement for payment for the supply and installation of Elastomeric bearings pads will be of the number actually installed
2) Payment will be made at the Unit Price per nos. entered in the Bill of Quantities.

9.17.20 FIXING OF STEEL ANCHORS IN THE EXISTING CONCRETE

1) The measurement and payment for drilling for anchors shall be made in running meters as specified in Section-B.7 of technical specification for the actual depth drilled into the old concrete and shall include surface preparation, washing and cleaning of the holes.
2) The measurement for epoxy resin of approved make for grouting of anchor bars shall be made in Kg actually used for filling of the hole as per specification.
3) The measurement and payment of reinforcing steel and anchors including cost of supply, cutting, fixing, binding, welding and holding etc shall be made in weight in Kg for the actual length placed as specified in Section B.11.

9.17.21 PAVEMENT CONCRETE

1) Measurement for Payment for Cement Concrete pavement shall be in cubic meters and shall be paid per cubic meter of concrete at the rate as entered in the Bill of Quantities.
2) The unit cost shall include all provisions of this specification and placing, compacting, finishing, curing together with all formwork, polythene film, all contraction, expansion, construction, and longitudinal joints. It shall also include joint filler, keys, caulking rod, debonding strip, sealant primer & joint sealant etc

9.17.22 EXCLUSIONS - CONCRETE

3) (1) No separate measurement for payment or payment will be made for the following:
   a. Any rounded or bevelled edges, fillets, scoring, chamfers, or any deduction made for voids or embedded items which are either less than 0.10m^3 in volume or 0.05 m2 in cross section. No allowance will be made for approved temporary openings, drains, embedded pipes, or recesses created by the Contractor for his own convenience during construction provided they are filled as directed,

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b. Any collecting of seepage water or water inflow from rock surfaces and diverting it into the drainage systems as specified in the Section "Dewatering during Construction",
c. Any defective and wasted concrete; concrete which has to be removed and replaced due to Contractor's non-compliance with the Specifications or Engineer's directions, and all related cost shall be at the Contractor's expense,
d. Any concrete which the Contractor places or uses for his own installations or for his own convenience,
e. Developing alternative sources of aggregates by the Contractor and the resulting additional material testing,
f. Pumping of the concrete and plasticiser,
g. Any precast and precast-prestressed concrete units damaged by improper storing, handling or transportation,
h. Any pipe work or material incorporated into the work to aid in placement of concrete.
i. All types of formwork including steel formwork for concrete lining of the tunnels.
j. Backfill concrete in over break in surface and underground excavation except geologically approved over break.
k. Backfill concrete as ordered by the Engineer in extra excavations in underground works created for the contractor's own convenience.
l. Coring required for establishing the efficacy of void filling as ordered by the Engineer.
m. For meeting the handing over requirements as contained here in for HM works.

9.17.23 CEMENT VARIATION

1) No separate payment will be made for the nominal cement content indicated in Sub-Section "Concrete Mix Design" for the respective class of concrete.
2) In case the required minimum specified compressive strength of a particular concrete class cannot be reached, or is in excess of, with the cement content indicated therein, variation of cement content (increase or decrease) will be assessed separately and paid to or recovered from the Contractor as the case may be.
3) Measurement for payment for variations of cement content used for concrete will be of the quantities, by weight in kg, of cement approved for the different classes of concrete specified, and computed on the basis of the number of cubic meters of concrete measured and approved for payment. The amount of cement required per cubic meter of concrete of each class will be as established at trial mix stage or the approved modifications thereof as established by the Engineer in the course of concrete work.
4) The aforesaid variation in cement shall be paid to or recovered from the contractor as the case may be at the rates stipulated in Bill of Quantities.
5) No measurement for payment or payment will be made for cement used for:
   a) Contractor's own convenience,

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b) Used for defective and wasted concrete,

c) Concrete placed outside of the concrete paylines (e.g. for filling the overbreak other than approved overbreak due to geological conditions) or required as a result of careless excavation,

d) Concrete produced with overuse of admixture.

6) No extra measurement for payment or payment will be made for cement used in precast concrete units and the cost thereof shall be included in the appropriate Unit Prices for such concrete elements.

9.17.24 ADMIXTURES

1) Measurement for payment of Superplasticizers and air entraining agents will be of the weight of the agreed dosages established at trial mix stages or the approved modifications thereof, for different classes of concrete, and computed on the basis of the number of cubic meters of concrete measured and approved for payment.
2) Payment will be made at the applicable Unit Price in kg, entered in the Bill of Quantities, which shall include the entire cost of supply, handling, storage, and dispersing.
3) No extra payment will be made for other kinds of admixtures for concrete such as accelerators and non-shrink agents.
4) No payment will be made for admixtures used for Contractor's convenience only, without the approval of the Engineer.

9.17.25 TESTS

1) All cost associated with testing as described in this Section shall be borne by the Contractor, who shall make allowance for such expense in the Unit Prices for the concrete work. These shall include, but not be limited to, the following:
   a) The costs for all tests to be carried out prior to the start of concrete work, whether carried out at Site or elsewhere
   b) Routine tests for quality control during the execution of the concrete work carried out by the Contractor as specified herein and as directed,
   c) Other tests required during execution of the work to be carried out by an approved test laboratory,
   d) Preparation, storage, handling, curing and delivery of samples to a laboratory designated by the Engineer, if so required for additional independent testing.
2) Should the Contractor fail to adhere to his testing program, all test deemed necessary by the Engineer to check concrete work will be performed by the Engineer or a laboratory assigned by him, at Contractor's expense.

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END OF SECTION B.9

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10. FORMWORK

10.1. SCOPE OF WORK

The work under this Section shall comprise supply of all labour, plant and material and the performance of all work necessary for the design, fabrication, supply, erection, maintenance and removal of formwork and false work to form concrete structures as shown on the Construction Drawings or as otherwise directed by the Engineer.

10.2. DEFINITIONS

For the sake of clarity, the terms used in this Section are defined as follows:

1) "Forms" or "Formwork" shall mean the moulds into which concrete is placed,
2) "Falsework" or "Shoring" shall mean the structural supports and bracings for forms used in any part of the Works,
3) "Curved forms" shall mean any form not composed of plain surface and limits of curved forms shall not extend beyond the lines of tangency or intersections with flat surfaces.

10.3. SUBMITTALS

1) At least 42 days in advance of any concrete work being carried out at the Site, the Contractor shall submit to the Engineer details of the materials for formwork and surface finishes, and construction techniques which the Contractor proposes to use in order to achieve the required concrete surfaces and allowable tolerances.
2) At least 42 days prior to the construction of the steel formwork for the tunnel lining, the Contractor shall submit to the Engineer the Drawings, details, and structural computations of the formwork construction.
3) At least 28 days prior to commencement of work on each particular structure the Contractor shall submit to the Engineer 4 copies of the detail Drawings with all formwork details and 2 copies of the structural computations of the formwork construction.
4) Review by the Engineer of Drawings and calculations shall not relieve Contractor of its responsibility for the adequacy of form and falsework, or for the safety of persons or property, for the successful completion of the work.

10.4. MATERIALS

1) Materials used for form sheathing and lining shall be of wood, steel, plywood, or fibreglass. All materials used in formwork construction shall be of adequate strength and quality for their intended purpose and shall be satisfactory to the Engineer.
2) Timber shall be sound, straight, free from warp, decay and loose knots and shall be dressed smooth. Except as expressly approved by the Engineer, all timber brought to the Site for use as forms, shoring or bracing shall be new material.

3) Plywood for use as form shall be mill-oiled and edge-sealed. Plywood shall be non-warping, non-wrinkling and manufactured with special water proof glues. Plywood sheets shall be of uniform width and length.
4) The surface of steel of steel lined forms shall be smooth. Forms with dents, buckled areas or other surface irregularities shall not be used.
5) Forms for concrete surfaces exposed to flowing water (other than tunnel lining) shall be lined with sanded, uncoated, plywood veneer. Steel or impermeable plastic liners will not be permitted.
6) Rough sawn boards may be used only for the lowest grade of surface finish (F1).
7) Reuse of forms will be allowed only if they are thoroughly cleaned and repaired and capable of producing the finish required for the concrete. Timber or plywood forms repaired with metal patches shall not be used.
8) Damaged forms which have deteriorated through use shall not be used again.
9) Where required, expanded metal fixed to the formwork shall be used in vertical construction joints.

10.5. FORM TIES

1) The type, number and positions of internal formwork supports and ties shall be selected by the Contractor and subjected to the approval of the Engineer. Form inserts or other similar permanently embedded items shall be accurately located and securely fastened in place. The number and location of form ties and bolts shall be such as to ensure that forms fit tightly against the concrete previously placed and remain in tight contact during operations.
2) The whole or part of such formwork supports and ties shall be removed without damage to the concrete so as to leave no part embedded nearer the surface of the concrete than the designed cover of the reinforcement or 50 mm in the case of unreinforced concrete. Only metal portions of formwork supports and ties shall be allowed to remain in place.
3) Through-bolts will not be permitted in water retaining walls.
4) Holes left after the removal of supports and ties shall be filled as described in Section "Concrete" and shall be finished off neatly to the standard of the concrete surface. Such filling shall be adequately cured.

10.6. DESIGN

1) Contractor shall be solely responsible for the adequate design, construction and maintenance of any and all formwork and falsework required in the Works. Forms shall be designed to permit the concrete to be deposited as nearly as is practicable directly in its final position, and to allow inspection, checking the clean-up of the formwork and reinforcement to be completed without delay.
2) Formwork and falsework shall be designed, fabricated, erected and removed in accordance with the applicable provisions of the recommended practice for concrete form of IS:456.
3) All falseworks shall be designed to withstand safely all live and dead loads which might be applied to the falsework during all stages of construction, service and removal. All formworks shall be designed to withstand the full hydrostatic head of concrete.

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4) For the purpose of formwork and falsework design, the Contractor shall assume a value of 2.5 t/m³ for the density of concrete.
5) Detailed drawings of shoring and formwork shall be prepared by Contractor. The calculations and drawings shall show the size and specification of the formwork, including the type and grade of all materials used in the construction, design loads on the formwork supports, horizontal forces imposed on the false work and used for design purpose, and details of splices and connections, including nailspikes and other fasteners. If mechanical equipment such as concrete buggies, screeding machines, etc. are to be used, this information shall be shown on these drawings.

10.7. ERECTION OF FORMWORK

1) Formwork and falsework shall be constructed only after the formwork drawings have been accepted by the Engineer.
2) The Contractor shall construct the falsework in strict accordance with the approved formwork drawings, one set of which shall be kept at the Site at all times. No change will be allowed without prior written acceptance of such change by the Engineer.
3) All timber forms shall be given a preliminary oil treatment by the manufacturer or shall be oiled by the Contractor at least 2 weeks in advance of their use.
4) Suitable and effective means shall be provided on all forms for holding adjacent edges and ends of panels and sections tightly together and in accurate alignment so as to prevent the formation of ridges, fins, offsets, or similar surface defects in the finished concrete.
5) The surface of the forms shall be free from encrustation of mortar, grout, or other foreign matter at the time of concrete placement.
6) Formwork shall be erected and maintained such as to confine the concrete without loss of mortar and produce required finished surfaces. Forms shall be set and maintained within the specified tolerance limit such that the complete concrete surfaces are within these limits.
7) Forms for concrete against which backfill is to be placed or which will not be exposed to view may be constructed of smooth tight boards not less than 25 mm nominal thickness.
8) Forms for concrete exposed to view shall be constructed of steel or plywood which is smooth and free from defects with matched and sanded joints to give a symmetrical pattern over the entire area. Chamfer strips, 35 mm by 35 mm shall be used on all exposed corners, unless otherwise directed by the Engineer.
9) Any forms which in the opinion of the Engineer are unsafe or inadequate in any respect may, at any time, be rejected and the Contractor shall promptly remove the rejected forms from the Works and replace them.
10) An adequate number of temporary clean-out holes or short pipes shall be provided in the forms to secure the draining of rainwater.
11) When a second lift is placed on hardened concrete, the number, location and tightening of ties at the top of the old lift and bottom of the new shall be such as to prevent any damage to concrete. The form of a new lift shall overlap the hardened concrete by 100 mm, to prevent abrupt irregularities.

12) Forms for sloping concrete surfaces shall permit their placing board-by-board or panel-by-panel immediately ahead of concrete placement so as to enable access for placement, vibration, and inspection of the concrete.
13) All form surfaces shall be thoroughly cleaned before erection and shall be lubricated with a non-staining mineral oil. All excess oil shall be wiped off the forms prior to placement of concrete. Oil shall not be allowed to come into contact with reinforcement steel or other embedded items.
14) Immediately before concrete is placed, all forms shall be inspected to ensure that they are properly placed, sufficiently rigid, clean, tight, properly surface treated and free from excess of oil or other foreign materials. No concrete shall be placed until formwork has been inspected and accepted by the Engineer.
15) The formwork for the gate groove areas shall be accurately drilled to be held with first stage anchor couplings/plates to be embedded in primary concrete. Both shall be fixed through formwork into the first stage anchors couplings/plates to ensure that the couplings/plates remain flush with primary concrete face and the couplings do not get plugged.

10.8. TUNNEL (GALLERY EXTENSIONS & DRIFTS) FORMWORK

1) Steel faced forms shall be used to achieve the F3C finish required on the hydraulic tunnels lining surface. The forms shall be fitted with ample windows at appropriate spacing and locations to allow the introduction of vibrators and to carry out inspections and any other work needed behind the form.
2) The formwork shall allow for continuous concrete pouring of the whole face. It shall be of rigid construction, non-deformable due to working loads imposed upon it. Once installed in the position the form shall maintain it without displacement during concrete placement.
3) The formwork shall be constructed in such a way that no abrupt irregularities arise at vertical construction joint. The joint in formwork shall overlap the vertical construction joint at least 500 mm and one formwork element remains in contact with placed concrete while others are being stripped down and installed for following concreting stages.
4) The windows shall be provided in each side about the mid height at the tunnel and the crown on alternate sides of the centreline. The windows shall be at least 600 mm in the least dimension and shall be spaced at a distance not exceeding 2.5 m.

10.9. FINISHED TOLERANCES

Forms shall be so constructed that the finished concrete surfaces shall be of uniform texture in accordance with the types of finish specified in Section "Concrete".

10.10. REMOVAL OF FORMWORK

1) Removal of forms shall be performed with care so as to avoid injury to the concrete and as soon as permissible in order to avoid delay in curing and repair of surface imperfections. Forms shall not be removed without the approval of the Engineer.

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2) Forms shall not be removed until the concrete has attained sufficient strength to prevent damage to concrete. Damaged concrete shall be repaired or treated by the Contractor as soon as possible, after the Engineer has inspected such damage and accepted the remedial works.

3) The elapsed time between the completion of concrete placing and the removal of forms shall generally be in accordance with IS:456, but not less than the following:

Type of Formwork	Day(s)	% of 28-day compressive strength
Vertical formwork of columns, walls and large beams	1	30%
Ceiling formwork to slab	7	70%
Ceiling formwork to beams	10	80%
Tunnel lining	2	-
Mass Concrete	2 (*)	-

(*) or otherwise specified by temperature control analysis

Removing time for propping under beams, slabs etc., will be taken as per IS: 456

4) The minimum periods indicated above are only indicative. The governing rule to be observed in the 28-day compressive strength, which shall be determined by the cube test in addition to those required by the provisions as described in Section "Concrete – Quality Control" and "Concrete – Acceptance Criteria". When fixing the minimum period for formwork removal, the shrinkage and creep of the concrete shall be taken into consideration.

5) Considering the weather conditions and type of pour, the Engineer may modify the minimum elapsed time required before formwork can be removed from individual pours, and in case of formwork for beams and deck slabs it shall remain in place until concrete has developed the specified design strength.

6) Notwithstanding the above or any approval given by the Engineer, Contractor shall be fully responsible for ensuring that sufficient time has elapsed for the concrete to attain adequate strength before removal of formwork.

7) Forms shall be removed so as to avoid cracking, spalling, peeling, breaking of edges or surfaces, or other damage to concrete. If it is necessary to use wedges, only wooden wedges shall be used against the concrete. Damaged concrete shall be repaired or treated by the Contractor as soon as possible, but not before the Engineer has inspected such damage and agreed to the remedial works.

10.11. MEASUREMENT AND PAYMENT

1) No measurement for payment or payment will be made for any kind of formwork, the cost thereof shall be included in the applicable Unit Price for concrete in the structure with which it is associated.

END OF SECTION B.10

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11. REINFORCING STEEL

11.1. SCOPE OF WORK

1) The Contractor shall furnish, fabricate and install all reinforcement steel as shown on the approved detailed reinforcement drawings and bar lists prepared on the basis of Engineer's Construction Drawings. The work shall further include the furnishing, fabrication and installation of all tie wires, clips, supports, chairs, spacers, couplers and other appurtenances necessary to produce finished concrete structures.

11.2. STANDARDS

1) Unless otherwise specified, the standards and recommendations of Indian Standards Code of Practices shall be followed in respect of all materials, equipment and performances.
2) Cutting, bending, cleaning, placing and fastening in position shall conform to the requirements of the following Indian Standards (latest edition):
   - IS: 432 (Part 1) – Specifications for mild steel and medium tensile steel bars and hard drawn steel bars for concrete reinforcement.
   - IS: 456 – Code of practice for plain and reinforced concrete.
   - IS: 1786 – Specifications for high strength deformed steel bars and wires for concrete reinforcement.
   - IS: 2502 – Code of practice for bending and fixing of bars.
   - IS: 2751 – Code of practice for welding of mild steel bars.
   - IS: 13920 – Code of practice for Ductile detailing of reinforced concrete structures subjected to seismic forces.
   - IS: 2090 – Specification for high tensile steel bars used in pre-stressed concrete.
3) Tolerances for reinforcement placing and fastening in position shall be in accordance with IS: 456.
4) In case of a conflict between the above Standards and the Specifications given herein, these Specifications shall take precedence.

11.3. MATERIALS

1) All deformed reinforcing bars shall be high yield strength, deformed steel bars conforming to IS:1786 Grade Fe 500.
2) All plain reinforcing bars shall be mild steel and medium tensile strength steel bars conforming to IS:432 (Part I).
3) Wire for tying reinforcing steel shall be black annealed iron wire, or acceptable equivalent, with a diameter not less than 1.6 mm.

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11.4. SUBMITTALS

1) Within 28 days from the date of issue of Notice to Commence, but before procuring or mobilizing to the Site the equipment, the Contractor shall submit to the Engineer updated and detailed plans and descriptions, consistent with those submitted with his Tender and any subsequent amendments and additions agreed to by the Engineer and the Contractor, of the equipment proposed for the fabrication of reinforcing steel.
2) During the progress of the work, Engineer will prepare reinforcement drawings which will indicate the main structural reinforcement required in the particular structure. The Contractor shall notify in writing to Engineer at least 10 weeks before such drawings are required for each section of work. On the basis of these drawings the Contractor shall prepare the detail bar bending schedules. All bars shown on the detail reinforcement drawings shall be identified on the bar lists and all bars shall be defined and dimensioned in clear and unambiguous way and be referenced to the relevant reinforcement drawings. The Contractor shall be responsible for the correctness of the reinforcement drawings and bar lists. The Contractor shall submit to the Engineer blue prints and transparencies of the reinforcement drawings and bar lists as stipulated in the Conditions of Contract.

11.5. TESTING

1) Reinforcing steel shall be accompanied by a mill certificate and, when directed by the Engineer, tested in a recognized laboratory to demonstrate compliance with IS: 1786.
2) In the course of concrete works the Contractor shall conduct the following tests on the high yield strength deformed steel bars and plain mild steel bars:
    a) One tensile strength for every 1,000 tons or as per standards; acceptance shall be as per IS: 1608 and IS: 2062.
    b) Welded joints or mechanical connections wherever used shall be tested to prove that the joints are of full strength of bars connected.

11.6. STORAGE

1) Reinforcing steel shall be stored above the ground in separate groups according to size and length in such a manner that it is not contaminated with deleterious matter. Reinforcing steel which has been cut and bent according to the schedules approved by the Engineer shall be marked with a bar number shown on the schedule, by using weatherproof tag or by placing in marked bins and shall be stored in such a manner as to be readily accessible when required and to facilitate inspection.
2) Reinforcement coming from different manufacturers shall be stored separately.
3) Reinforcement fabric supplied in rolls shall be straightened into flat sheets before being placed.

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11.7. FABRICATION

1) Contractor shall cut and bend all reinforcing steel in accordance with bar schedules supplied by himself and duly approved by the Engineer..
2) Reinforcing steel bars shall be cut and bent at the site of the works or at a fabricator's plant in an acceptable workmanlike manner in accordance with Indian Standards. Notwithstanding the above, a bar-bending machine and a representative stock of reinforcing steel shall be maintained at the Site, sufficient to allow minor revisions and additions to be carried out as required by the Engineer.
3) The bars shall be bent cold at temperature greater than 5°C. Bending below that temperature or warm bending will only be permitted when adequate precautions are taken to comply with the corresponding direction issued by the steel manufacturer for such bending.
4) Reinforcing steel shall not be straightened or rebent in a manner that will damage the materials. Temporary bending and subsequent straightening of bars partially embedded in concrete shall not be permitted, except when shown on the Drawings or with the written approval of the Engineer. Bars with kinks or bends other than those indicated on the Drawings and schedules shall not be used.
5) Reinforcement bars, other than tie bars, shall not be spliced at points other than those shown on the Construction Drawings without the consent of the Engineer. On occasions when it becomes necessary to alter the position of such splices, the new position and the type of splice shall be subject to the written approval of the Engineer.
6) Should the necessity of welding of reinforcement arise, the provisions of the IS 2751 and Indian Standard's recommendations for welding cold worked steel bars for reinforced concrete shall be followed.
7) Mechanical couplers conforming to Indian/International Standards shall be used for splicing the reinforcing bars 32 mm dia. or more as indicated in the Construction Drawings or as directed by the Engineer.
8) Patent reinforcement splicing methods shall only be used with approval of Engineer.
9) The Contractor shall not weld any item to reinforcing steel except as approved by the Engineer and in conformance with accepted procedures.
10) Reinforcing bars available from the rejected concrete structures shall not be used without prior approval by the Engineer.
11) Reinforcement bars, other than tie bars, shall not be spliced at points other than those shown on the Drawings.

11.8. PLACING

1) Before being placed in position, the reinforcing steel shall be thoroughly cleaned of loose mill scale and rust, grease, paint, or other coatings that would reduce bond. All splashed concrete that has dried on reinforcing steel shall be removed.

2) Reinforcing steel to be incorporated in the works shall be placed accurately in the positions shown on the Drawings and shall be held firmly in place during the placing and setting of the concrete.
3) Reinforcing steel shall be so placed that there will be a clear distance of at least 50 mm between the reinforcing steel and anchor bolts or embedded metal work, if not shown otherwise on the Drawings or required otherwise by the Engineer.
4) Reinforcing steel shall be maintained in position by the use of small concrete blocks, steel chairs, steel spacers, steel hangers and other steel supports and ties, acceptable to the Engineer. Wood supports or spreaders shall not be used. All intersections shall be securely tied except those where the bar spacing is less than 300 mm in each direction, where only alternate intersections need be tied.
5) The steel chairs, steel spacer and similar reinforcement support devices that touch the forms shall be galvanized or shall have plastic tips at the point where the support device touches the forms.
6) The bottom layer of reinforcing steel in slabs on the ground shall be supported by means of pre-cast concrete blocks (dobies). The concrete blocks shall have a horizontal surface approximately 7 x 10 cm and be of concrete quality at least equivalent to that which is to be placed. The upper layer of reinforcement in slabs on ground and all other slabs and in beams shall be supported by means of metal chairs. In all cases, sufficient supports for horizontal reinforcement shall be used so that there will be no sagging of the bars.
7) Binding wire, and steel supports shall not be carried to permanently exposed surfaces and shall be subject to the same requirements with regard to concrete cover as for the reinforcing steel.
8) The cover of the reinforcement shall be as shown on the Construction Drawings.
9) All reinforcement shall be inspected in place and approved by the Engineer before placing the concrete. Concrete placed in violation of this provision may be rejected and removal required.

11.9. TOLERANCE ON PLACING OF REINFORCEMENT

Unless otherwise specified by the Engineer, reinforcement shall be placed within the following tolerances:

Protective cover:	For cover up to 50 mm	± 6 mm
	For cover 75 mm and more	± 12 mm
Spacing:	For effective depth 200 mm or less	± 10 mm
	For effective depth between 200 and 2000 mm	± 15 mm
	For effective depth more than 2000 mm	± 25 mm

11.10. MEASUREMENT AND PAYMENT

1) Measurement for payment for reinforcing bars will be of the weight of reinforcing steel, including splices (if any), as stated in the bar lists furnished by the Contractor in the course of the work. The weight

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entered in the bar lists will be computed using the nominal weight per linear meter of different bar diameters based on the specific weight of 7850 kg/m^3.

2) Payment will be made at the Unit Price per metric ton entered in the Bill of Quantities, which shall include the entire cost of storage (if necessary), cutting, bending, placing as well as the fabrication and installation of wire clips, ties, separators, chairs, spacer bars, and any other fastening devices.
3) Measurement for payment for couplers will be the number of pieces placed. Payment will be made at the Unit price according to Coupler diameter per piece as entered in the Bill of Quantities.
4) No extra measurement for payment or payment will be made for the following:
    a) Wire for tying reinforcement.
    b) Any additional reinforcement or splices required when Contractor's casting sequences differ from construction joints shown on the Construction Drawings.
    c) Any reinforcing steel placed by the Contractor for his own convenience in addition to those shown on the Construction Drawings and entered in the bar lists.
    d) Any welding of reinforcement.
    e) Any testing of welded joints or mechanical connections
    f) Any reinforcing steel delivered for and testing of the steel.
    g) Installing the couplers including threading of reinforcing bars.

END OF SECTION B.11

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12. WATERSTOPS AND JOINTS

12.1. SCOPE OF WORK

1) The works under this Section include all labour, materials and equipment required for the supply, fabrication (if any), storage, handling, placing and splicing of waterstops and other components to be incorporated in the movement joints in concrete structures as shown on the Construction Drawings, or as required by the Engineer.
2) The extent, type and dimensions of the joints and relative waterstops shall be indicated on the Construction Drawings.
3) The works shall include all the necessary supports and ties required for placing waterstops and other materials.

12.2. STANDARDS

1) Material, testing, placing and sealing of joints shall conform to the requirements of the following Indian Standards (latest edition):
   - IS: 290 - Specifications for coal tar Black Paint
   - IS: 456 – Code of practice for plain and reinforced concrete
   - IS: 11433 – Specifications for one part gun grade polysulphide-based joint sealants
   - IS: 12118 – Two-part polysulphide-based sealants
   - IS: 1834 – Specifications for Hot applied sealing compounds for joints in concrete
   - IS: 1838 – Specifications for Preformed fillers for Expansion joints in concrete pavement structures
   - IS: 3400 – Methods of tests for Vulcanised Rubbers
   - IS: 14811 – Rolled Copper Plate, Sheet, Strip and Foils for General Engineering Purposes- Specification
   - IS: 3873 – Laying Cement Concrete / stone slab lining on canals
   - IS: 4461 – Code of practice for joints in surface hydroelectric power station
   - IS: 3384 – Specification for bitumen primer for use in waterproofing and damp proofing
   - IS: 2508 – Low Density polyethylene film
   - IS:12200 – Provision of waterstops at transverse contraction joints in masonry and concrete dams - Code of Practice.
   - IS:15058 – PVC waterstops at transverse contraction joints for use in masonry and concrete dams- Specifications.
   - IS: 13360 - Plastics - Methods of Testing

Other standards may be used for non-PVC waterstops such as the following:

- EN ISO 527-2 – Plastics — Determination of tensile properties
- DIN 53505 – Testing of rubber, elastomers and plastics; Shore hardness testing A and D
- DIN 53504 – Testing of rubber - Determination of tensile strength at break, tensile stress at yield, elongation at break and stress values in a tensile test

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- ASTM D-412 – Tension Testing Rubber & Elastomers
- ISO 815 – Rubber, vulcanized or thermoplastic

2) In case of conflict between the above Standards and the Specifications given herein, these Specification shall take precedence.

12.3. SUBMITTALS

At least 56 days prior to procuring or dispatch to the Site of the particular item of work to which the submittal relates, the Contractor shall submit to the Engineer the details covering the properties and performance, including the certified copies of reports of all tests made by the manufacturers, along with material samples of the products, of:

a) PVC Waterstops
b) Copper Waterstops
c) Joint fillers
d) Joint sealing compounds
e) Hyplon Band
f) Joint sealant.

12.4. MOVEMENT JOINTS IN GENERAL CONCRETE STRUCTURES

1) The term movement joint comprises both the expansion and the contraction joints in concrete structures. Movement joints shall be constructed at such locations and to such dimensions as shown on the Drawings or as directed by the Engineer. The Contractor shall supply and install the various joint components as specified herein, as shown on the Drawings and in accordance with the manufacturer's recommendations.
2) No fixed metal embedded in concrete shall be continuous through a movement joint except where expressly shown on the Drawing.
3) Expansion joints may be comprised of, but not limited to, the following elements:
   a) PVC waterstop
   b) Copper waterstops
   c) Joint filler
   d) Joint sealing compound
   e) Bituminous coating
4) Contraction joints may be comprised of, but not limited to, the following elements:
   a) PVC waterstop
   b) Copper Waterstops
   c) Bituminous coating or other approved bond breaker.

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12.5. MATERIALS

12.5.1. PVC WATERSTOPS

1) Waterstops shall be made of extruded polyvinyl chloride (PVC), or thermoplastic and/or elastomeric rubber Material for waterstops shall be clean, homogeneous and free from porosity and other imperfections.
2) The PVC waterstops shall be conforming to IS: 15058.
   The thermoplastic waterstops shall meet the following properties:

Shore hardness A (DIN 53505 or IS 13360)	75±5
Tensile strength (EN ISO 527-2 or IS 8543)	Not less than 13.8 N/mm^2
Ultimate elongation (ASTM D-412 or IS 8543)	Not less than 285%

The elastomeric waterstops shall meet the following properties:

Shore hardness A (DIN 53505)	62±5
Tensile strength (DIN 53504)	Not less than 10 N/mm^2
Ultimate elongation (ASTM D-412)	Not less than 380%
Compression set (ISO 815)	< 20%

3) The waterstops in the concrete structures shall be constructed at such locations and to such dimensions as shown on the Drawings. Waterstops will have minimum width of 250 mm for joints. Minimum wall thickness shall be 10 mm. Waterstop width of 500 mm shall be used in the Dam and Spillway joints. Waterstops up to 250 mm of width (min.) may be used at other locations except when explicitly specified on the Drawings.
4) The wings of the PVC waterstop shall be provided with corrugations or bulbs to achieve good bond. PVC waterstops in expansion joints shall be provided with hollow centre bulb.
5) Storage of material prior to placement shall be made in such a way as not to alter the properties of the material during storage. Water stops shall be stored so as to permit free circulation of air around them. All materials shall be protected from contact with oil and grease. Waterstops shall be stored in a place protected from the direct sunlight or to any other heat source.
6) Waterstops shall be joined and fixed in place in accordance with manufacturer's recommendations to form a continuous watertight barrier. All cross-pieces, T- pieces and corner-pieces shall be factory produced. All joints shall be welded with approved, thermostatically controlled electric heat equipment. The temperature at which the splices are made shall be sufficient to melt but not char the plastic material. All splices shall be neat with the ends of the joined waterstops in true alignment. A mitre-box guide and portable knife shall be provided for cutting the ends to be joined to ensure good contact between joined surfaces.

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12.5.2. JOINT FILLER

1) Bituminous fibre sheets shall be 12 mm thick and shall conform to IS 1838 (Part 1) for preformed expansion joint fillers for concrete paving and structural construction (non-extruding and resilient bituminous types) as shown on the Drawings. Depending upon the structural requirements the thickness of expansion joints may be 24mm (or more) as shown in the Drawings. In such cases, two or more sheets of 12mm thickness shall be placed for forming the joint and shall be paid separately.
2) Expanded polystyrene joint filler shall consist of panels from 10 to 20 mm thick having a specific weight approximately 20 kg/m^3.

12.5.3. JOINT SEALING COMPOUNDS

1) Hot-applied sealing compounds for joints in concrete shall be as per specification IS: 1834.
2) Where limited movement and mild conditions are anticipated, the sealing compounds shall be oleo-resinous or acrylic latex base compounds.
3) Sealants for external use or internal conditions where cyclic movement exposure to weather or above normal levels of moisture are anticipated, shall be elastomeric compounds, silicone, polysulphide polymer or butyl rubber based.
4) For sealing joints adjacent to or above membrane surfaces of conventional asphaltic or bituminous materials, a sealant based on materials similar to those in the membrane will be used.

12.5.4. BITUMINOUS COATING

Bituminous coating shall consist of two (2) layers of coating as per IS: 290.

12.5.5. GUN GRADE JOINT SEALANT

Gun grade joint sealants shall be as per IS: 11433 and IS: 12118.

12.6. EXECUTION OF MOVEMENT JOINTS

1) Where grouting is not required, the movement joints shall be formed with F1 finish. If grouting is required, joints shall be formed with F2 finish as specified in section "Concrete".
2) The Contractor shall supply all necessary supports and ties required for placing the sealing strips and/or waterstop and shall position it so that its central axis coincides with the joint center. Care shall be taken that sealing strip and waterstop do not bend or deflect during concreting. Concrete adjacent to the sealing strip and waterstop shall be thoroughly worked to ensure full contact with the sealing strip and waterstop but without damaging it. PVC materials shall be protected from sunlight until installation is completed.
3) Waterstops shall be joined and fixed in place in accordance with manufacturer's recommendations to form a continuous watertight barrier along the joint. All cross-pieces, T-pieces and corner-pieces shall be

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factory produced. All joints shall be welded with approved, thermostatically controlled electric heat equipment. The temperature at which the splices are made shall be sufficient to melt but not char the plastic material. All splices shall be neat with the ends of the joined waterstops in true alignment. A mitre-box guide and portable knife shall be provided for cutting the ends to be joined to ensure good contact between joined surfaces.

4) The work shall include all the necessary supports and ties required for placing waterstops and other materials.

5) In the structures founded on the rock, the sealing strip and waterstops shall be sealed 500 mm minimum in the drilled or excavated slot below the effective foundation surface, and the space around the sealing strip and waterstop in the slot shall be filled with non-shrink grout. Prior to commencement of concrete placing, the sealing strip and waterstops placed shall be inspected by the Engineer.

6) Before casting the second part of a movement joint, the whole surface shall be covered with bituminous coating, bituminous fibre sheet joint filler, or other approved bond breaker as shown on the Construction Drawings.

7) Before applying the joint sealant, the joint shall be raked out to a depth as specified. All laitance, dirt, oil and foreign matter shall be removed from the joint by sandblasting, compressed air, grinding discs, or other effective means, and the concrete surfaces coated with an approved suitable primer. Joint sealant shall be placed after the concrete curing period in accordance with manufacturer's instructions. The concrete surface temperature shall not be higher than 30°C at the time of placing, and the concrete shall be surface dry. After placing, the sealant shall be protected from the effects of water for a period of 10 hours.

8) Sealants that become unbonded from the concrete, or cracks, or shows any other defects before final acceptance of the work, shall be replaced by the Contractor.

12.7. MEASUREMENT AND PAYMENT

1) Measurement for payment will be made for the following items in the units stated:

PVC water stop	Per linear meter placed
i) Joint filler 12mm thick	Per square meter
ii) Joint filler 24mm thick	Per square meter
iii) Joint filler 10mm thick (expanded polystyrene)	Per square meter
Joint sealant	Per linear meter
Bituminous coating	Per square meter

2) Payment will be made at the appropriate Unit Price entered in the Bill of Quantities, which shall include the entire cost of all materials, plant and labour for furnishing and construction movement joints as specified, all temporary protection of the joints from damage.

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3) Payment will only be made for the movement joints shown on the Drawings or directed by the Engineer. Additional joints for Contractor's convenience may be approved by the Engineer, but no payment will be made for materials used in such joints.

END OF SECTION B.12

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13. METAL WORKS

13.1. SCOPE OF WORK

1) The work under this Section includes all labour, materials and equipment required for the supply, fabrication, and installation of various metal works as shown on the Drawings. The specifications contained in this Section are applicable for all metal works to be carried out by the Contractor under this Contract. Furthermore, the Contractor shall install metal works supplied by others.

2) This section mainly covers the following items:

   a) Lattice steel girders for composite beams
   b) Gratings
   c) Beams for gratings
   d) Steel covers for hatches and cable channels
   e) Handrails
   f) Fixed and removable railings
   g) Ladders, handles, and climbing irons
   h) Stairs and landings
   i) Steel anchoring
   j) Kick plates
   k) Woven wire mesh
   l) Erection hooks
   m) Steel pipes
   n) Embedded elements
   o) Guardrails
   p) Metal works supplied by others
   q) Miscellaneous steel sections

3) Unless otherwise stated or shown, all miscellaneous metalwork shall be fabricated from carbon steel sections, plates and bars complying with the requirements of IS: 2062.
4) Unless otherwise stated or shown, all miscellaneous metalwork shall be painted as specified hereinafter where specifically so stated, steelwork shall be hot-dip galvanised.
5) The Contractor shall be responsible for material quality control and shall ensure compliance of the metal works to the pertinent standards and these Specifications.

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13.2. STANDARDS

1) Unless otherwise specified, the standards and recommendations of Indian Standards Code of practices shall be followed in respect of all materials, equipment and performances.
2) The metal works shall conform to the requirements of the following Indian Standards (latest edition), codes of practices and rules:
   - IS: 432 – Specification for Mild Steel and Medium Tensile Steel Bars and Hard-Drawn Steel Wire for Concrete Reinforcement
   - IS: 800 – General Construction in Steel (Code of Practice)
   - IS: 801 – Code of Practice for Use of Cold Formed Light Gauge Steel Structural Members in General Building Construction
   - IS: 806 – Code of Practice for Use of Steel Tubes in General Building Construction
   - IS: 808 – Hot Rolled Steel beam, column, Channel and Angle Sections – Dimension and properties
   - IS: 811 – Specification for Cold Formed Light Gauge Structural Steel Sections
   - IS: 814 – Covered Electrodes for Manual Metal Arc Welding of Carbon and Carbon Manganese Steel Specification
   - IS: 816 – Code of Practice for Use of Metal Arc Welding for General Construction in Mild Steel
   - IS: 819 – Code of Practice for Resistance Spot Welding for Light Assemblies in Mild Steel
   - IS: 1136 – Preferred Sizes for Wrought Metal Products
   - IS: 1161 – Steel Tube for Structural Purposes (Specifications)
   - IS: 1173 – Specification for Hot Rolled and Slit Steel Tee Bars
   - IS: 1182 – Recommended Practice for Radiographic Examination of Fusion Welded Butt Joints in Steel Plates
   - IS: 1239 – Steel Tubes, Tubulars and Other Wrought Steel Fitting, part 1 of 2 (Specification)
   - IS: 1252 – Hot Rolled Steel Bulb Angles (Dimensions)
   - IS: 1323 – Code of Practice for Oxy-acetylene Welding for Structural Work in Mild Steel
   - IS: 1730 – Steel Plates, Sheets, Strips and Flats for Structural and General Engineering Purpose (Dimensions)
   - IS: 1732 – Steel Bars, Round and Square for Structural and General Engineering Purposes (Dimensions)
   - IS: 1863 – Specifications for Rolled Steel Bulb Flats
   - IS: 1865 – Iron Casting with Spheroidal or Nodular Graphite (Specification)
   - IS: 1929 – Specification for Hot Forged Steel Rivets for Hot Closing
   - IS: 2062 – Hot Rolled Medium and High Tensile Structural Steel (Specifications)
   - IS: 2074 – Ready Mixed Paint, Air Drying, Red Oxide Zinc Chrome, Priming (Specifications)
   - IS: 2932 – Enamel, Synthetic, Exterior: (a) Undercoating (b) Finishing (Specifications)
   - IS: 3502 – Steel Chequered Plates
   - IS: 3589 – Steel Pipes for Water and Sewage (168.3 to 2540 mm Outside Diameter) (Specification)

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- IS: 3601 - Steel Tubes for Mechanical and General Engineering Purpose (Specifications)
- IS: 3757 – Specification for High Strength Structural Bolts
- IS: 4000 – High Strength Bolts in Steel Structures (Code of Practice)
- IS: 4736 – Specification for Hot-Dip Zinc Coatings on Mild Steel Tubes
- IS: 4759 – Hot dip zinc coating on structural steel and other allied products (Specifications).
- IS: 7205 – Safety Code for Erection of Structural Steelwork
- IS: 7215 – Tolerances for Fabrication of Steel Structures
- IS: 7226 – Specification for Cold-rolled Medium, High Carbon and Low Alloy Steel Strip for General Engineering Purposes
- IS: 12843 – Tolerances for Erection of Steel Structures
- SP 6 (Part 4) – Handbook for Structural Engineer (Use of High Strength Friction Grip Bolts)
- SP 6 (Part 5) – Handbook for Structural Engineer (Cold-Formed, Light-Gauge Steel Structures)

3) In case of a conflict between the above Standards and the Specifications given herein, these Specifications shall take precedence.

13.3. SUBMITTALS

1) The Contractor shall supply certificates of compliance with specified Indian Standards or other relevant standards for all materials, supplied by him. Manufacturers catalogues and samples of materials proposed for incorporation in the Works shall be submitted for approval, if requested by the Engineer.
2) From the information given in the Drawings, the Contractor shall prepare, prior to the manufacture, his own shop drawings showing sections and plans of all parts, assemblies, connections and supports for all metalworks shown on the Drawings. Two copies of each drawing, calculation sheet and schedule of materials shall be submitted to the Engineer for comments and approval. Within 14 days from the submission, the Engineer will return such drawings either as approved or with requests for modifications. Within 7 days the Contractor shall revise the drawings, calculations and schedules accordingly and resubmit a new set (in two copies) of these for the final approval.
3) After the final approval, the Contractor shall deliver one transparency and two copies of the documents to the Engineer for his files.
4) The approval of shop drawings and calculations shall not in any way relieve the Contractor of his responsibility and obligations under this Contract, particularly those relating to the adequacy and accuracy of the final product. Any materials ordered, or fabrication work performed, before the Contractor's drawings are approved will be at his own risk.
5) The Contractor shall not be entitled to any time extension based upon the rejection of his drawings if these fail to conform to sound engineering practises or to the stipulations contained in these Specifications.

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13.4. FABRICATION

1) The work shall be shop fitted and shop assembled where possible, and shall conform to the details on approved Contractor's shop drawings.
2) Workmanship shall conform to the best modern shop and field practice. All joints and intersecting members shall be accurately fitted and all work shall be fabricated in true planes (to tolerances as provided on shop drawings) with adequate fastenings.
3) Plates and steel sections shall be perfectly straight with smooth surfaces. Edges shall be sharp, clean and without burrs after the cutting. Thick plates may be flame cut, provided that the material is not damaged and that the edges of the cut are ground clean or machined. Plates shall be cold-rolled. Correction of bent members by heavy blows shall be avoided. Special care shall be taken when hot-rolling becomes necessary.
4) All members shall be carefully and accurately assembled by welding, screws, bolts, or rivets as approved. The joints shall be filled, milled, or machined as necessary to provide closed and perfect connections. All frames shall be provided with suitable bracing to maintain alignment during transport. Units shall not be subject to overstressing during transport and erection. Hammering which would injure or distort the members will not be tolerated.
5) All fastenings, anchors and accessories required for fabrication and erection of the work shall be provided. Exposed fastenings shall be kept to an absolute minimum evenly spaced and neatly set out. Wood plugs shall not be permitted.
6) The Contractor shall check the actual dimensions and shapes of existing concrete openings before fabricating steel frames and metal supporting parts of steel covers and gratings.

13.5. WELDING

1) All welding shall be carried out by experienced welders using the shielded-arc method as described in the SP12 BIS Handbook for Gas Welders and BIS Handbook of Manual Metal Arc Welding for Welders and complying with the requirements of IS: 814, IS: 816, IS: 819 and IS: 1182.
2) Welding rods shall be of the heavily coated type designed for all position welding, and the appropriate size, type and manufacture of the rods shall require the consent of the Engineer.
3) All welding shall be continuous along the entire line of contact, except where tack welding is permitted. Bevelling of the materials shall be done as shown on the approved shop drawings and shall be finished to a smooth and true finish with an automatic gas cutter or grinder. The use of manual gas cutters shall require the consent of the Engineer.
4) The surface of the working materials shall be free from slag, moisture, rust, oil, paint or other impurities. Mill scale which cannot be removed with a stiff wire brush will be allowed to remain.

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5) The face of welds shall be smooth and form a uniform bead. The size and thickness of weld neither shall nor be less than specified, nor there be an excessive build-up or marked irregularities in the surface appearance.
6) Blow holes, slag, overlap, undercut and unsatisfactory melting of welded joints shall be removed with grinders or by other means and then rewelded. Due care shall be taken to protect the surrounding part from any injury or damage. Deformation of members resulting from welding shall be repaired by an approved mechanical method. The heating temperature for correcting deformations shall not exceed 650 °C.
7) Steel which has been previously galvanised shall not be welded.
8) Welding of aluminium shall be done employing a "parent metal" or other approved filler rods. Surfaces which have been previously treated such as anodising shall not be welded.
9) The Contractor shall propose the type and carry out the non-destructive testing of the welds as approved. All joints which are to be watertight shall be tested by dye penetrate.

13.6. SURFACE FINISH AND CORROSION PROTECTION

13.6.1. PAINTING

1) All metal components other than stainless steel, aluminium, embedded parts and those that are required to be galvanised, shall be prepared, primed and painted in the shop prior to erection.
2) Paints used for both prime and finish coats shall be two component epoxy based, shall be obtained from the same manufacturer and shall be the best quality of their kind. They shall be suitable for application in environments where the relative humidity may exceed 90%. The Contractor shall submit samples of all paints he proposes to use to the Engineer for approval, who will select the colour of the finish coats.
3) Prior to painting, steel surfaces shall be sandblasted down to rust degree SA 2-1/2 according to SIS Standard 055900, to remove all mill scale, weld splatter, rust and any other deleterious material. Oil and grease shall be removed by an approved solvent. The surface shall be wiped clean of any dust prior to priming.
4) Immediately after cleaning, steelwork shall receive two coats of two component zinc epoxy primer, each of dry film thickness 0.05 mm. Any primer applied surface that shows signs of rusting, flaking, powdering or peeling of the prime coat, or any finish coat, shall be sandblasted to remove the paint bare to the metal as described above and repainted.
5) After priming, steelwork shall receive a further two coats of two component epoxy based paint, each of dry film thickness 0.08 mm. The total theoretical thickness of paint applied, including prime coats, shall be 0.26 mm, but in no case less than 0.22 mm.
6) All painting work shall be carried out in accordance with the manufacturers recommendations in a clean dust-free environment with temperature and humidity controlled to comply with these specifications and the recommendations of the paint manufacturer. All the surrounding works shall be protected in a suitable manner from paint drops and overspray. All smeared and damaged surfaces shall be cleaned or repaired.

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7) After erection of painted miscellaneous metalwork, the Contractor shall make good any damage to the paint coating in accordance with the manufacturer's recommendations. The Engineer may require items which are badly damaged to be removed, returned to the shop and repainted.

13.6.2. GALVANISED STEELWORK

1) All steel assemblies required to be galvanized shall, after the steel has been thoroughly cleaned of rust and scale, be galvanized in accordance with IS:4759 (Hot dip zinc coating on structural steel and other allied products). The zinc coating shall be 350 g/m^2 minimum. Any galvanized part that becomes warped during the galvanizing operation shall be straightened.
2) Bolts, nuts and similar threaded fasteners, after being properly cleaned, shall be galvanized in accordance with ASTM Specification A 153 "Spec, for Zinc Coating (Hot-Dip) on Iron and Steel Hardware". Threads on galvanized bolts and nuts shall be formed with suitable taps and dies such that they retain their normal clearance after hot-dip galvanizing.
3) After installation on the final place all areas of damage to the galvanized coating shall be sandblasted and prepared and given 2 coats of approved zinc rich paint. The preparation of the steelwork surface and application of the paint shall be in accordance with the paint manufacturer's instructions.
4) The Contractor shall supply certificates of compliance with the above standards for all galvanized material delivered to the Site.

13.6.3. FASTENERS

1) Fasteners for miscellaneous metalwork including bolts, anchor bolts, cap screws and nuts shall be of steel unless otherwise stated or shown. Nuts and bolts heads shall be hexagonal in shape and truly faced. Nuts, bolts and screws which might become loose during operation shall be locked in fastened position by means approve by the Engineer.
2) Studs and anchors for fixing metalwork to concrete shall be of steel and shall be of the expanding anchor type (e.g. Nelson or Hilti). Grouted or resin types shall require the consent of the Engineer.

13.6.4. ANODISING

1) All aluminum parts exposed to view shall have an anodizing finish of uniform appearance and shall be free from marks and blemishes.
2) Sulfuric acid shall be employed as electrolyte for anodizing unless otherwise directed. The coating thickness shall be 0.02 mm.

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13.7. INSTALLATION

1) All items of the miscellaneous metalwork shall be installed in correct position and alignment. Damaged or defective materials shall not be installed. Damaged or defective areas of paint or galvanizing shall be cleaned and repaired as directed by the Engineer.
2) Metalwork to be embedded in concrete shall be located accurately and shall be held in correct position and alignment during concrete placing and setting of the concrete.
3) Unless otherwise provided, the anchor bolts shall be set and held in position before concrete is placed. Where it is impractical to embed anchor bolts or anchors for the comparatively light metalwork before the concrete is placed, and where it is necessary to anchor parts but inserts or anchor bolts have not been provided, holes shall be drilled in the concrete and approved expansion anchors shall be installed. All holes for the anchors shall be straight and true to the diameter recommended by the manufacturer of the expansion anchors. If necessary, the Contractor shall use diamond bits to achieve true, fitting holes. When drilling water is used, surfaces of concrete permanently exposed shall be cleaned immediately to prevent discoloration by the drilling water and cuttings.
4) Supports and base plates shall be levelled or aligned accurately and rigidly secured in place. Adjustment with steel shims shall be done as necessary. All spaces under the supports or base plates shall be filled with concrete or shall be grouted as specified in the Section "Concrete".
5) Each complete unit shall be serviced and tested after installation. The servicing shall include lubricating, adjusting, cleaning all parts, and all other work and material required for operation. After each unit has been serviced, it shall be given an operation test, and adjustments shall be made until the operation of the unit is approved by the Engineer.

13.8. METAL WORKS SUPPLIED AND INSTALLED BY THE CONTRACTOR

13.8.1. STEEL PIPES

1) The Contractor shall supply and install steel pipes of various diameters and fittings in the positions shown on the Drawings or as directed by the Engineer.
2) Steel Pipes used shall be ERW (Electric Resistance Welded) of Steel grade Fe 410 as specified in IS 3589. The pipes of various diameters and thicknesses shall also be required.
3) Weight of the pipe shall be calculated as per Table 5 of IS 3589.
4) Pipes shall be carefully fastened and supported within the shuttering, in order to avoid any movement when pouring concrete.
5) Pipes, where not cast into concrete shall be adequately supported by galvanized mild steel holderbats or other approved means. The distance between pipe supports shall not exceed 2.0 meters.

13.8.2. MISCELLANEOUS STEEL SECTIONS

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1) The Contractor shall supply and install all small galvanized steel sections such as edge protection, angles, frames, bearing plates, brackets, beads at plastered corners, etc., of various dimensions. Bolts, screws, anchors and other accessories for interior or exterior purposes shall be included.

13.8.3. STEEL COVERS, FRAMES AND GRATINGS

1) The Contractor shall supply and install all steel hatch covers, cable channel covers, frames, gratings for channels, drains etc., as required by the Engineer or as shown on the Drawings and specified herein. All items shall be fabricated according to shop drawings prepared by the Contractor in the course of Works.
2) Covers shall be manufactured from 6 mm steel checker plate with reinforcing steel sections where required, steel flats and lifting handles. Supporting frames shall consist of steel angles and welded steel flats provided with continuous watertight rubber seal. Frames shall be adjusted during installation to ensure a good fit and water tightness of the cover. The covers shall be placed flush with finished floors.
3) Steel gratings shall consist of welded steel flats. Mesh size shall be 30x30 mm. Frames and steel sections as supports for gratings shall consist of steel angle or channel sections fixed in the concrete. Frames shall be adjusted during installation to ensure a good fit and even bearing for the grating. Gratings shall be placed flush with finished floors.
4) Steel covers, frames and reinforcing members for supporting gratings shall be painted or galvanized as specified above in this Section. Gratings shall be hot-dip galvanized and shall be fixed to support platforms using stainless steel screws and fittings.

13.8.4. HANDRAILS

1) The Contractor shall supply and install in the buildings handrails fabricated from galvanized steel pipes supported on welded steel flats and steel plates as shown on the Drawings and as specified herein. Material for steel pipes shall be of standard weight. The coating shall conform to IS:4736. All items shall be fabricated according to shop drawings prepared by the Contractor in the course of Works.
2) Handrails shall be installed following the slopes and in the positions shown on the Drawings and shall be supported to avoid movement when placing concrete in the blockouts. Handrails shall be painted or galvanized as specified above in this Section.

13.8.5. RAILINGS

1) The Contractor shall supply and install steel pipe railings (stainless steel/GI) as shown on the Drawings. The coating on the steel pipes shall conform to IS: 4736. All items shall be fabricated according to shop drawings prepared by the Contractor in the course of Works.
2) Railings shall be installed indoor and outdoor, horizontal or inclined in the positions shown on the Drawings and shall be supported to avoid movement when placing concrete in the blockouts. Steel pipe railings shall be painted as specified above in this Section.
3) The Contractor shall submit the shop drawings for the stainless-steel railings to the Engineer for approval in the course of works.

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13.8.6. GUARDRAILS

1) The Contractor shall supply and install guardrails where indicated on the Drawings as protection along the permanent roads, parking places and retaining walls. The guard rails shall be Beam crash barrier type conforming to IRC: 119. All items shall be fabricated according to the shop drawings prepared by the Contractor during the work progress. All guardrails shall be galvanized conforming to IS: 4736.
2) Guardrails shall be installed in the locations shown on the Drawings. The whole assembly shall be galvanized as specified above. Guardrail shall resist vehicle impact loads, according to specific standards.

13.8.7. LADDERS AND CLIMBING IRONS

1) The Contractor shall supply and install ladders, and climbing irons fabricated out of steel flats and plain round bars as shown on the Drawings. Ladders may have protection cages whenever required for safety of personnel. Bolts, nuts and washers of fixings and fittings in aggressive environment shall be of stainless steel, otherwise they shall be of galvanized steel. All items shall be fabricated according to the shop drawings prepared by the Contractor in the course of Works.
2) Ladders, climbing irons and protection cages shall be painted as specified above in this Section if installed indoor or galvanized as specified in IS: 4736 if installed outdoor.
3) Ladders permanently in water shall be provided in galvanized steel.

13.8.8. ERECTION HOOKS

1) The Contractor shall supply and install steel erection hooks as required by the Engineer. Erection hooks shall be formed out of structural steel conforming to IS: 2062. Erection hooks shall be hot bent and shall be firmly held during placing of concrete.
2) Erection hooks shall be galvanized as specified above in this Section.

13.8.9. STEEL ANCHORAGES

1) The Contractor shall supply and cast into concrete steel anchoring as required by the Engineer or when shown on the Drawings. Anchorages shall consist of 150 mm long, 16 mm diameter anchors made of mild steel conforming to IS: 432 (Part I).
2) Steel Anchoring shall require no surface treatment.
3) Where anchoring is to be done after concreting either for convenience or per specification or Drawings, approved expansion anchors shall be used or same shall be grouted by cement or resin grout as directed by the Engineer.

13.8.10. STAIRS

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1) The Contractor shall supply and install all steel stairs and the relevant landings. All items shall be fabricated according to the shop drawings prepared by the Contractor during the progress of works. Stairs shall resist the live load defined by the Designer according to applicable codes.
2) Steel stairs shall comprise the steel profiles sections, checkered steel plates 6 mm thick and steel pipe railing.
3) Frames and steel sections as supports for steel stairs shall consist of steel angle or channel sections fixed to the concrete according to the shop drawings. Frames and platforms shall be adjusted during installation to ensure a good fit and even bearing.
4) Steel stairs, landings and supporting members shall be galvanized conforming to IS: 4736.

13.8.11. OTHER STEEL SECTIONS

1) The Contractor shall supply and install all small black and galvanized steel sections such as edge protection, angles, frames, bearing plates, brackets, beads at plastered comers etc., of various dimensions.
2) Bolts, screws, anchors and other accessories for installation purposes of these elements shall be included in the supply and installation.

13.9. METAL WORKS SUPPLIED BY OTHERS

1) Anchoring and conduits furnished by suppliers of hydro and electro-mechanical equipment shall be installed by the Contractor at the locations shown on the Drawings or on the installation drawings prepared by others and approved by the Engineer.
2) The pieces to be incorporated in the concrete shall be furnished and stored in the warehouse of the Contractor at the Site. Every piece handed over to the Contractor shall have a handover card on which the following is stated:
    a) Installation site,
    b) Number of pieces,
    c) Number of reference drawings,
    d) Weight of the pieces, without packing,
    e) Special connections for fixing if necessary.
3) The Contractor shall transport the pieces from the warehouse to the installation site and fix it stiffly and with due precision behind the formwork before concreting. It is the responsibility of the supplier to check the correct fixing of these pieces behind the formwork before concreting takes place.
4) The Contractor shall provide unless otherwise specified any foundations, wall and roof openings and coverings, concrete floor filling, sleeves in foundations etc. for metal works supplied by others.

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5) All adjustments to foundation levels, embedding, bedding and grouting works on foundations and cementing into walls and floors will be done by the civil contractor but all levelling and adjustment of works by the foundations will be done by the HM contractor.
6) Grouting, when required, will be done by the Contractor under the supervision of the HM contractor who will also approve the mix and the grouting pressures.

13.10. MEASUREMENT AND PAYMENT

13.10.1. GENERAL

1) Supply and installation by the Contractor when used in this Section shall be deemed to include the provision of all labour, plant and materials necessary for:
    a) Preparation and submittal of the shop drawings, calculation sheets, schedule of materials, and providing catalogues about, and samples of the materials.
    b) Purchasing or manufacturing, including surface and corrosion protection.
    c) Transporting to Site, including loading and unloading.
    d) The provision of certificates of compliance with required standards, as specified.
    e) Storing and protecting.
    f) Transporting to point of incorporation into the Works.
    g) Incorporating into the Works, including all necessary fasteners, fittings and accessories, formation of concrete blockouts, and casting into concrete or grouting.
    h) Servicing and testing of completed units.
2) For installation by the Contractor of items of miscellaneous metalwork supplied by others, only e) through g) shall apply.

13.10.2. STEEL PIPES

1) Measurement for payment for the supply and installation of steel pipes will be of the weight of pipe work installed.
2) Payment will be made at the appropriate Unit Price per kg entered in the Bill of Quantities.

13.10.3. MISCELLANEOUS STEEL SECTIONS

Measurement for payment for the supply and installation of steel sections of various dimensions will be of the weight installed. Payment will be made at the Unit Price per kilogram entered in the Bill of Quantities.

13.10.4. STEEL COVERS, FRAMES AND GRATINGS

1) Measurement for payment for the supply and installation of steel covers will be of the weight of steel cover, including frames, installed as shown on the Drawings. Payment will be made at the Unit Price per

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kilogram entered in the Bill of Quantities, which shall include the supply and installation of suitable steel frames.

2) Measurement for payment for the supply and installation of steel gratings will be of the weight of gratings, including frames, installed. Payment will be made at the Unit Price per kilogram entered in the Bill of Quantities.

13.10.5. HANDRAILS AND RAILINGS

1) Measurement for payment for supply and installation of handrails, railings (GI pipe or Stainless steel) will be of the weight installed.
2) Payment will be made at the appropriate Unit Price per kg entered in the Bill of Quantities.

13.10.6. GUARDRAILS

1) Measurement for payment for supply and installation of guardrail will be of the length installed.
2) Payment will be made at the appropriate Unit Price per kg entered in the Bill of Quantities.

13.10.7. LADDERS AND CLIMBING IRONS

1) Measurement for payment for supply and installation of ladders, handles and climbing irons, as shown on the Drawings will be of:
    a) The weight for ladder composition with protection cage installed, measured vertically from the top to the base of ladder,
2) Payment will be made at the appropriate Unit Price per kg entered in the Bill of Quantities.

13.10.8. ERECTION HOOKS

1) Measurement for payment for the supply and installation of erection hooks will be of the weight of erection hooks installed as shown on the Drawings.
2) Payment will be made at the Unit Price per kilogram entered in the Bill of Quantities.

13.10.9. STEEL ANCHORING

1) Measurement for payment for the supply and installation of steel anchoring will be of the total weight of anchoring in kilograms installed as shown on the Drawings or as required by the Engineer.
2) Payment will be made at the Unit Price per kilogram entered in the Bill of Quantities.

13.10.10. METAL WORKS SUPPLIED BY OTHERS

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1) Measurement for payment for the installation will be of the weight as indicated by the supplier or in absence of such the metal works will be weighted directly on the Site.
2) Payment will be made at the Unit Price per kilogram entered in the Bill of Quantities.

END OF SECTION B.13

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14. STRUCTURAL STEELWORK

14.1. SCOPE OF WORK

(1) The work under this Section includes all labour, materials and equipment required for the design, supply, fabrication, and installation of structural steelworks shown in the drawings or as directed by the Engineer.

(2) Rock anchors/bolts, steel ribs and miscellaneous steel required for the works shall be dealt with as per relevant sections of specifications.

14.2. SUBMITTALS

(1) The material shall be purchased by the contractor from the sources approved by the Engineer. The Contractor shall supply certificates of compliance with specified Indian Standards or other standards for all materials supplied to the Works. Manufacturers' catalogues and samples of materials proposed for incorporation in the Works shall be submitted for approval, if requested by the Engineer.

(2) Not less than 28 days before starting erection, the Contractor shall submit for approval drawings showing the method and sequences of erection proposed including temporary guys and bracing during erection and the amount and type of equipment to be used. Works shall not be commenced until such approval has been obtained.

(3) The approval of shop drawings, calculations and erection methods shall not in any way relieve the Contractor of his responsibility and obligations under this Contract, particularly those relating to the adequacy and accuracy of the final product. Any materials ordered, or fabrication work performed, before the Contractor's drawings are approved will be at his own risk.

(4) The Contractor shall not be entitled to any time extension based upon the rejection of his detail drawings if these fail to conform to sound engineering practices or to the stipulations contained in these Specifications.

14.3. STANDARDS FOR FABRICATION

1) The fabrication, welding, and erection of structural steel shall be carried out in accordance with relevant Indian Standards. This operation shall be performed by approved experienced specialised personnel or approved firms.

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14.4. MATERIALS

(1) All steel rolled sections and steel plates shall comply with the requirements of IS:2062. Steel for general structural purpose.

(2) All black bolts shall comply with IS:1367 Technical supply conditions for threaded steel fasteners.

(3) All high tensile steel bolts shall comply with IS 3757.Specifications for high strength structural bolts. High tensile bolts, nuts and washers for use in galvanised structural steelwork shall be galvanised or cadmium plated.

(4) All threaded fasteners shall comply with ISO metric standards, normal series, coarse pitch.

(5) All types of steel material for Rocker bearing for roof truss.

14.5. TOLERANCES

1) All structural members shall satisfy the tolerances as follows:
   (a) Straightness of struts, columns, beams, chord members and latticed girders: length of member x 0.001
   (b) Camber: length of span x 0.001
   (c) Length: + 0 mm / -3 mm
   (d) End of beams, out of squareness: depth x 0.025

2) The Contractor shall be responsible for completing the work within the tolerances specified. Steelwork which exceeds the specified tolerances shall be remedied or removed and replaced by, and at the expense, of the Contractor.

14.6. FABRICATION

1) Materials shall not be transported to the Site until all tests, analyses and final inspections have been made or certified copies of reports of tests and analyses or manufacturer's warranties have been approved. The tests specified in the standard specifications shall be carried out by the manufacturers of the materials or by an approved testing laboratory and certified copies of test reports shall be supplied to the Engineer. Materials for which test reports or certificates have not been approved shall not be used in the Works.

2) When doubts exist as to the soundness of any part, such part shall be subjected to a non-destructive testing, if requested by the Engineer, which may include X-rays or gamma rays.

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3) All materials stored at the fabricating plant before fabrication and all fabricated materials shall be supported above the ground so as not to cause over-stressing, shall be protected properly from rust, and shall be kept free from water, dirt, grease, oil and other foreign matter.

4) Before being laid out or worked on in any way, rolled material shall be straightened and shall be cleaned of all loose rust and dirt. Material which shows signs of pitting caused by rust may be rejected.

5) Sharp kinks or bends will be cause for rejection of the material. If straightening is necessary, it shall be done by methods not likely to produce fracture or other injury. The metal shall not be heated without prior approval, but if approved, heating shall not be to a higher temperature than 650°C. After heating, the metal shall be cooled slowly.

6) All cut edges shall be finished neatly. Corners shall be square and true unless otherwise shown on the Construction Drawings.

7) Welded splices that develop the full strength of the material being joined may be made at approved locations, but shall be kept to a minimum.

8) Unless otherwise approved or directed by the Engineer, no changes shall be made in any of the Contractor's drawings after they have been approved, nor any substitutions of sections having dimensions different from those shown on such drawings shall be made.

9) Before shipment, each member shall be marked with erection marks for identification and ease of erection and the Contractor shall furnish to the Engineer one transparency of an erection diagram showing the erection marks. Bolts, nuts and washers shall be suitably bagged and tagged to ensure their use in the correct place. Splice plates, cleats and other small pieces required for making field connections shall be temporality shop bolted to their members for delivery.

14.7. BOLTED CONNECTIONS

1) Bolted connections shall be made using black bolts and/or high strength friction grip bolts. Black bolts shall be either cold forged or hot forged swaged head bolts.

2) All holes for bolts, unless otherwise specified, shall be not more than 1.5 mm larger than the nominal diameter of bolts and drilled full size or, where permitted, punched 0.8 mm undersize and reamed to full size. Burnt holes punched full size will not be permitted under any circumstances. After assembly of the parts to be jointed, all holes shall be true throughout, perpendicular to the face of the member and aligned so as to permit

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the bolts to be positioned without damage to the threaded portion. Contacting surfaces of parts being jointed shall be free from distortion and all burns or ridges shall be removed.

3) The length of each bolt shall be such that the threaded portion will project through the nut for at least one complete thread. The shanks of bolts used in bearing shall be of sufficient length to prevent a smooth bearing surfaces for the full thickness of parts being joined and no portion of the thread shall be within the thickness of the parts being joined.

4) At least one washer shall be placed under the nut.

5) Bolts in tension, and with their axis at an angle to horizontal, and bolts subject to severe vibration, and all bolts carrying hoist loads, shall be locked in position in a manner approved by the Engineer.

6) Black bolts shall be tightened so that the jointed parts shall be firmly drawn together using a standard ring spanner or a calibrated torque or pneumatic impact wrench. While black bolts shall be tightened as firmly as practicable by those means, care shall be taken not to overstress the bolts and the applied torque shall not exceed that recommended by the bolt manufacturer. In no case shall the bolt tension exceed 65% of the guarantied yield load of the bolt.

14.8. WELDING

1) All welding shall conform to requirements stipulated in the Section "Metalworks".

2) Shop welds shall be used wherever possible and the use of field welds shall be kept to a minimum. Unless otherwise approved field welds shall not be used where shop welds are shown on the drawings.

3) The Contractor shall be responsible for the control of distortion and the limiting of shrinkage stresses.

4) Steelwork which has been galvanised shall not be welded unless the galvanising is removed carefully by grinding before welding. When the galvanising has been removed for welding or damaged, the area affected shall be cleaned and coated with approved zinc rich paint or zinc metalizing.

14.9. ERECTION

1) The Contractor shall furnish all necessary equipment and shall erect the structural steel in accordance with these Specifications and approved shop drawings.

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2) Structural steel members to be stored shall be placed on blocks so that no part of the members will touch the ground or be over-stressed and shall be kept clean and properly drained.

3) Proper allowance shall be made to compensate for shrinkage of field welds so that the structure will not be unduly stressed or correct alignment affected.

4) The Contractor shall set out lines and levels, and fix and maintain works for the erection and checking of positions of steel work. Arrangements shall be such that no allowable stresses shall be exceeded doing erections.

5) All temporary flooring, planking and scaffolding necessary for the erection work or the support of erection machinery shall be provided conforming to the applicable safety regulations.

6) The framing shall be carried out true and plumb, and temporary bracing shall be provided wherever necessary to take care of all excessive loads. Such bracing shall be left in place as long as required for safety. The steelwork shall be progressively inter-connected to take all dead, wind, and erection caused stresses in a secure manner.

7) Anchor bolts shall be positioned with a template before the concrete is placed to ensure that the anchor bolts are maintained in the correct position during the placing of concrete.

8) Hammering that will injure or distort the members will not be approved. The members shall not be over-stressed during the process of erection. Any error in the work which prevents proper assembling and fitting of parts shall be reported immediately to the Engineer, and his approval of the proposed method of correction obtained.

9) Erection in the field will be by bolting, high-strength friction grip bolting, arc welding or a combination of these methods, as shown on the Construction Drawings or directed. In bolted connections where black bolts are used, the bolts shall be drawn tight and, where directed, the threads shall be burred or spot welded so that the nuts cannot be loosened. Where high tensile bolts are required, the method of fabrication and assembly of the connections shall comply with the provisions of the Indian standards for friction type joints.

10) After erection, all temporary bracing and its connections shall be removed, holes plugged and the steelwork, including the protective coating specified, made good. All field bolting and welding shall be subject to inspection and any faulty work shall be removed and replaced by the Contractor upon requested by the Engineer.

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14.10. PROTECTIVE COATING

1) All structural steelwork members shall be sandblasted down to grade Sa 2 - 1/2 according to SIS Standard 055 900.

2) The corrosion protection of structural steel members shall be as follows :

- 2 shop coats of 2-component zinc-rich primer, dry film thickness min. 0.04 mm, max. 0.06 mm per coat; total dry film thickness min. 0.80 mm, max 120 mm,
- 1 intermediate coat of 2-component epoxy micaceous iron oxide paint, dry film thickness min.0.06 mm,
- 1 finish coat of 2-component epoxy paint or 2-component polyurethane paint, dry film thickness min. 0.06 mm.

3) The finish coat shall be applied after the erection of the steel structure at its final location. The intermediate shop coat shall be cleaned and lightly roughened before application of the finish coat.

14.11. ROCKER BEARING FOR TRUSS

In the Rocker type of bearing the main girder is connected to a top saddle. This rests on a round cylindrical rocker pin resting on the bottom saddle. The bottom saddle shall rest on the steel plate over the concrete to provide more height and consequent rigidity. Since the top saddle is rigid to the girder, it rotates over the pin when the girder deflects. The bottom saddle is not affected by this movement and thus angular movement of the girder is permitted. This permits free deflection of the girder along the length. The dimension of saddle, rocker pin, bearing plates, anchor bolts, shear key plates shall be finalized to effectively transfer the load from truss to the column.

The Rocker bearing shall consist of the following parts:

	ITEM	MATERIAL
1.	Bearing Plate	Mild Steel
2.	Top Bearing Saddle	Cast Steel
3.	Bottom Bearing Saddle	Cast Steel
4.	Rocker Bearing Pin	Hot Rolled Steel
5.	Anchor Bolts	Bolt Steel
6.	Nuts for Rocker Bearing Pin	Bolt Steel
7.	Cotton Pin	Brass
8.	Shear Key Plate	Mild Steel

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For each Truss two Rocker bearings of equal size are to be used. Bolts shall be of tested quality confirming to IS: 1367 & IS: 5624.

14.12. MEASUREMENT AND PAYMENT

1) No measurement for payment or payment will be made for structural steelworks defined in this section, the cost thereof shall be included in the applicable Unit Price of the work with which it is associated.

END OF SECTION B.14

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15 BUILDING AND ARCHITECTURAL WORKS

15.1. SCOPE OF WORK

1) The work under this Section includes design, all labour, materials and equipment, and performance of all operations required for the execution of the finishing and architectural works inside or outside of buildings, rooms or chambers to be constructed under this Contract.

2) This Section covers the following items:

a) Masonry walls
b) Wall, floor and roof finishes
c) Tile works
d) Suspended ceiling
e) Wall panelling
f) Bituminous waterproofing membranes
g) Doors and louvers
h) Windows and Sun blinds
i) Glass and glazing
j) Painting works
k) Carpentry and joinery
l) Caulking and damp-proofing
m) Perforations and cuts in the finished concrete and masonry
n) Temporary closures and protection
o) False Ceiling
p) Sanitary fittings

3) The building and architectural works not specified herein shall be defined by the Contractor during the course of the Work.

4) All materials and equipment which will become a part of the Permanent Works shall be new and of good quality.

5) If the Specification and Annex. do not contain particulars of materials and works which are obviously necessary for the proper completion of the work and the intention to include such is nevertheless to be inferred, all such materials and works shall be supplied and executed by the Contractor and shall be reimbursable.

6) Similarly, the Contractor shall supply, place and attach to the structure all timber, metal or other accessories necessary for the proper completion of the work.

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7) The Contractor shall provide and fix all incidental flashings, damp proofing, weather seals or other approved materials necessary to render the buildings completely watertight and weatherproof.

8) The Contractor shall furnish, erect and maintain during the work as required all scaffolding, walkways and other temporary structures required for the execution of the works.

9) The Contractor shall collect and dispose of all material, debris and rubbish as it accumulates from time to time as the work proceeds. On completion of this work, the Contractor shall thoroughly clean interior and exterior of the buildings and the other works.

10) No architectural works shall be taken up unless the architectural drawings for the same as given here in under have been approved by Engineer.

15.2. SUBMITTALS

1) The contractor shall propose an experienced architect (preferably experienced in architectural services related to hydroelectric projects) to the Engineer for approval at least 180 days prior to start of work, who shall be responsible for the following:

a) Planning and detailing of architectural works of Dam Complex based upon the general layouts given by the owner and the technical specifications.

b) Preparing shop and detailed drawings and measuring schedules for the building and submit to Engineer for approval.

c) Providing expert advice to the owner on patented products like wall finishes, doors and windows and other related material.

d) Work as a coordinator between contractor and the owner in respect of architectural works.

e) Coordinate with water supply consultant for design/layout of sanitary items, water supply and sewerage system.

f) Assist the owner in the supervision of architectural work being executed by the contractor and suggest changes as required.

2) The Contractor shall prepare and submit for approval at least 28 days prior to the date he wishes to place or confirm purchase order:

a) Lists and schedules of materials to be purchased,

b) Manufacturers' catalogues for the various items specified in this Section,

c) Samples of materials and hardware with specimens of workmanship,

d) Colour and finish for the various items specified in this Section.

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15.3. NOMINAL SIZES

The Contractor shall allow for variations between nominal sizes and actual sizes where such variation is within the required tolerances or is normal trade practice.

15.4. FINISHING WORKS

Finishing work shall not commence until each or all of the following conditions have been met to the satisfaction of the Engineer:

a) The area concerned and such adjacent areas, which may affect the finishing work, have been weatherproofed,

b) All construction including installation of permanent plant, fittings and equipment has been completed,

c) The concrete or other materials have dried out sufficiently. The Engineer may request a test for dryness to be performed by the Contractor.

15.5. MASONRY WALLS

15.5.1. GENERAL

1) The Contractor shall construct masonry walls where shown on the "Drawing(s)" or as directed by the Engineer. All masonry walls shall be constructed after the structural concrete work has been completed.

2) The work shall include, but not limited to, the brickwork.

15.5.2. MATERIALS

1) Masonry units shall be bricks units. The Contractor shall submit samples of bricks to the Engineer for approval.

2) Cement, sand and water shall be as specified in the relevant section of "Concrete".

3) Masonry units shall have a moisture content (expressed as a percentage of total absorption) of not more than 30% at time of delivery. Units made from cinder aggregate shall not be used.

4) All bricks shall be adapted to the wall thickness and approved by the Engineer.

5) All bricks shall be uniform in size and shape, deep red in colour and sufficiently well burnt. They shall be clean and free from flaws, cracks and under burnt lumps or defects of any kind. The bricks may be local

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product available in the vicinity of the Site, but the quality shall conform to a standard acceptable to the Engineer.

6) The mortar shall be thoroughly mixed until uniform in colour and shall be used before it has taken initial set. Mortar, which has partially set, shall not be used, nor shall more water be added to it.The Proportion of cement /sand for mortar shall be in ratio of 1:3 (Cement 1: Sand 3).

15.5.3. EXECUTION

1) The masonry units shall be laid on horizontal courses, true to line and plumb, and vertical joints shall be staggered with respect to those in the courses next above and below. No broken bricks and blocks, except as are required as closures for the proper sizing of courses, cracked or misshapen bricks will be used in the works. Corners, and at edges of framed openings, bricks shall have finished return ends. All exposed bricks, which are to be cut, shall be cut with a carborundum wheel.

2) All units shall be laid with full buttered ends and side joints, and shall be shoved to bear on a full bed of mortar. All joints shall be 10 mm and cut flush, except that joints in areas to be plastered shall be raked 7 mm to provide a mechanical joint for the scratch coat. After initial set exposed joints shall be burlap rubbed.

3) The bricks shall be dampened before scratch or setting bed is placed. The thickness of mortar setting bed shall not exceed 20 mm.

4) The masonry units shall be stored on platforms to prevent contact with soil and water and shall be covered with non staining tarpaulins for protection against the elements.

15.6. WALL, FLOOR AND ROOF FINISHES

15.6.1. GENERAL

1) The Contractor shall install finishes on walls, floors and roofs according to his shop drawings as approved by the Engineer.

2) The work shall include, but not limited to, the following:

a) Plastering
b) Floor finish
c) Roof finish (cement mortar)
d) Special floor finish

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15.6.2. MATERIALS

1) Cement, sand and water shall be as specified in the relevant section of "Concrete".

2) Waterproofing and epoxy resin shall be approved by the Engineer and shall be used in perfect accordance with the manufacturer's instructions.

3) The mortar shall be thoroughly mixed until uniform in colour and shall be used before it has taken initial set. Mortar, which has partially set, shall not be used, nor shall more water be added.

4) The cement mortars shall be composed as follows:

a) For wall plastering: 350 kg cement per 1 m^3 of sand and water,

b) For flooring finish: 500 kg cement per 1 m^3 of sand and water,

c) For waterproofing of floor & walls: 600 Kg cement 1 m^3 sand and Water and waterproofing agent in accordance with the Manufacturer's instructions,

d) For roof finish: 450kg cement per 1 m^3 sand and water

5) Wall putty shall be applied where required to achieve smooth finish and shall be deemed included in the lump sum rate.

15.6.3. EXECUTION

1) Concrete surfaces, which are to receive a rendering coat, shall be roughened, scratched and free from all laitance, scum. Loose carbonate scale, loose aggregate, dirt and other foreign matter and shall be kept thoroughly wet for 24 hours prior to the application of mortar.

2) All masonry and concrete surfaces to which cement mortar is to be applied without furring shall receive one coat of an epoxy resin type bonding agent or other agent approved by the Engineer.

3) The various finishes shall be executed as follows:

a) Exterior wall plastering

On exterior wall plaster shall be applied, by hand or mechanically, to a total thickness of 15/25 mm.

b) Interior wall plastering

On interior walls plaster shall be applied by hand or mechanically, to a total thickness of 12/15 mm.

c) Roof finish cement plaster shall be minimum 6mm.

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15.7. TILE WORKS – FLOORS AND WALLS

15.7.1. GENERAL

1) The Contractor shall install tiles on walls and floors as given in Annexure-I (Room schedule) and according to his shop drawings as approved by the Engineer.

2) The work shall include, but not limited to, the following:

a) Ceramic tiles
b) Vitrified glazed ceramic tiles
c) Vitrified ceramic tiles
d) Kota stone
e) Pre-polished granite tiles
g) Acid-proof tiles
h) Granolithic/Ironite flooring with or without inmate
i) Epoxy flooring
j) Terrazzo Tile work
k) Ironite flooring

3) The Contractor shall submit samples of tiles for approval by the Engineer with respect to quality and colour. Tile samples shall include the manufacturer's full colour and texture range of the series specified by the Engineer. The detailed execution procedure has been highlighted in Annexure-II

15.8. FALSE CEILING

The contractor shall provide the false ceiling as stipulated in the room schedule at Annexure-I.

15.8.1. GENERAL

1) Designer false ceiling shall be provided, made from combination of formed FRP panel, mineral fibre ceiling & curved perforated steel. The exact type/design of false ceiling shall be finalized during detailed engineering for which the contractor shall submit 3D views of different options for the proposed ceiling before final approval.

2) The Modular Acoustic Mineral Fibre Ceiling shall consist of hot dipped galvanized steel sections and Pre-finished coated mineral fibre board ceiling tiles 20mm thick of size 600mm x 600mm or 600 x 1200 with durable edging. Tiles shall be free from warpage, splits and other defects and all edges bevelled square. Slip-on moulding shall be semi-rigid white cover moulding sized to fit the tile.

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3) The moulded anodized Aluminium ceiling shall comprise of moulded aluminium panels including accessories shall be of standard quality and make.

4) The mineral board tiles of the suspended ceiling shall be laid on continuous main beams and intersecting cross tees that are joined together to form the required grid system and patterns.

5) Exposed grid system shall comprise the following:
Main beams shall not be less than 38mm high by 25mm wide and 0.5mm thick, cold rolled electro-galvanized steel with white backed enamel finish.
Cross tees shall be cold rolled galvanized steel with white baked enamel finish,
Wall moulding shall be 25 x 20mm minimum, matching the tee in material and finish; wall mouldings with reveal shall be provided where required,
Hanger wires shall be not less than 2.10mm pre-straightened galvanized annealed steel wire,
Spacers shall be tempered spring steel and shall be fitted into wall moulding to provide tension on the ceiling system

6) Toughened Glass used for decoration purpose shall not be less than 12 mm thick.

7) Acrylic solid surface sheets should be at least 12 mm thick and of reputed make for decoration purpose. Additional thermal insulation boards or mats of minimum 6cm thickness shall cover the suspended ceiling at passing partition walls, projecting into each room minimum 1.5m for achieving sound absorption and preventing sound transfer to adjacent rooms through open spaces above the false ceiling.

8) Fire-proof partition walls shall be continued above the false ceilings to the solid structural slab. Ceiling materials shall be able to withstand fire for 30 minutes (fire class T30).

9) The contractor of false ceiling shall coordinate with vendor of illumination system, air-conditioning system and fire fighting system for cutout and fixing of lighting fixture and outlets for the air-conditioning system and fire sensor and nozzle shall be integrated into the suspended ceiling by means of special carriers and shaped metal frames matching the selected type of openings and meeting the additional load.

10) Supply and installation of materials and installation of suspension system components, hangers and fastening devices, ceiling tiles, panels, sound absorbent materials, and all the materials mentioned here above in 1) to 10) and any other material required for the completeness of the false ceiling work described in this section.

11) The architectural design in control rooms and conference room, false ceiling, wall and column panelling, window toughened glass panels and door etc. shall be compatible to design of equipment /furniture.

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The detailed execution of false ceiling is enclosed in Annexure-III.

15.9. BITUMINOUS WATERPROOFING MEMBRANES

15.9.1. GENERAL

1) The Contractor shall supply and install bituminous waterproof membranes on roofs and floors with or without thermal insulation as directed by the Engineer.

2) Membranes on roofs shall include protective mortar, roof drain and downspouts.

15.9.2. MATERIALS

1) Bituminous waterproof roofing shall consist of 3-ply built-up roofing layers applied as follows:

3-ply built-up roofing	
Asphalt primer	0.4 l/m^2
Asphalt compound	1.5 kg/m^2
1st layer felt	39 kg / 42 m^2 roll
Asphalt compound	1.5 kg/m^2
2nd layer felt square meshed	35 kg / 21 m^2
Or perforated fibre glass felt	28 kg / 10 m^2 roll
Asphalt compound	2.0 kg/m^2
3rd layer felt	35 kg / 21 m^2 roll
Asphalt compound	2.1 kg/ m^2
Plastic sheet protection	One layer

15.9.3. THERMAL INSULATION

1) Thermal insulation shall be provided in the form of thermal insulation panels laid directly on the bituminous roofing felt covering the cement mortar screed. The thermal insulation material shall in turn be covered with a second layer of bituminous roofing felt.

2) Panels for thermal insulation shall be of synthetic insulating material having a density of approximately 30 kilograms per cubic meter. The panels shall have a thickness of 30 mm. organic material like cork shall not be permitted. Consideration shall be given to the chemical composition of panels, with regard to any possible chemical reaction with bitumen.

3) Insulating panels shall be laid with staggered joints and with their joints coated with bituminous paint. They shall then be covered by a layer of bituminous roofing felt. Joints in bituminous roofing felt shall consist

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of a minimum overlap of 100 mm sealed with a layer of hot bituminous paste. Roofing felt shall be laid such that it overlaps the insulation layer and joins with the roofing felt beneath the insulation layer. The 2 layers of felt shall be joined together to completely surround and seal the insulation layer on all sides and edges.

15.9.4. EXECUTION

1) Concrete roof slabs shall be prepared to receive bituminous 3-ply built up roofing by first laying a 1:3 cement mortar to form the slopes. The thickness of the screed shall vary between 20 mm (minimum) and 120 mm (maximum) thickness. The surface of the concrete slab prior to the laying of the screed shall be prepared in accordance with the requirements for concrete construction joints as specified in Section "Concrete". After lying, the surface of the cement mortar screed shall be compacted with a screed board prior to receiving a wood float finish. External and internal angles shall be finished with a rounded surface of minimum radius of 50 mm. The cement mortar screed shall be allowed to cure for a minimum period of 3 weeks before covering with the specified insulation and waterproofing layers.

2) A layer of bituminous roofing felt, thermal insulation panels and a second layer of bituminous roofing felt shall be placed over the cement mortar screed as specified above.

3) 3-ply built-up roofing shall then be applied follows:

a) Asphalt primer shall be evenly applied in accordance whit the manufactures recommendations over the surface of the bituminous roofing felt covering the thermal insulation panels. Asphalt compound shall then be evenly poured and sprayed over the asphalt primer. Compound heated to a temperature exceeding 140 degree C above the melting point shall not be used.

b) Asphalt felt, roofing and special roofing shall be laid over each respective asphalt compound with care to avoid bulges. The sides and ends of these sheets shall be provided with an overlap of at least 90 mm. The joints shall be completely watertight.

c) The whole surface shall be covered by plastic sheet protection in order to allow the movement of the top protective mortar screed without damaging the 3-ply built-up roofing. Care shall be exercised when carrying out roofing work surrounding anchor bolts, parapets and roof drains to prevent leakage.

4) The top protective screed shall be placed in two 25 mm thick layers with wire mesh laid in between. Wire mesh shall consist of 0.9 mm diameter galvanized steel wire with a mesh size of 25 mm or similar approved.

15.9.5. ROOF DRAIN

1) The roof drain shall be made of cast iron, heat coated with asphalt. Care shall be exercised in fitting the surrounding waterproofing works to the drains for preventing any damage to the waterproofing membrane. Caulking shall be applied as required.

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2) Roof drain grates shall be convex in profile at least as high as the pipe diameter and the total area of the openings of the gratings shall be 1.5 times the cross sectional area of the drain pipe. Grates shall be fixed with non-corrosive screws.

3) Roof drain shall have two flanges. The bottom flange shall be integral with the drain body and shall be set to the top surface of the surrounding concrete. The top flange shall be adjustable to permit this flange to be set to the finished roof elevation. The two flanges shall be provided to allow seepage to drain from beneath the top flange.

15.9.6. DOWNSPOUT

1) Downspouts shall be provided as shown on the "Drawing(s)" or as directed by Engineer. Downspouts shall be 100 mm in diameter polyvinyl chloride pipes provided with adaptable fittings. The downspouts shall be securely fixed to the walls with steel ring suspenders at adequate intervals.

2) Flexible joints shall be synthetic rubber, 4-ply approximately 80 cm in length and shall be provided at expansion joint of each downspout. The flexible joints shall be tightly connected to both ends of the downspouts with adequate metal bands.

15.10. uPVC DOORS, WINDOWS AND ROLLING SHUTTERS

15.10.1. uPVC DOORS

15.10.1.1. GENERAL

1) The Contractor shall supply and install uPVC doors and windows doors as approved by the Engineer. They shall be installed in accordance with approved Contractor's shop drawings.

2) All uPVC doors, frames and hardware shall be to the approval of the Engineer.

15.10.1.2. FABRICATION

1) Prior to fabricating or ordering the uPVC doors, the Contractor shall check the actual dimensions and shape of existing concrete openings.

2) The detailed execution of uPVC doors and windows is enclosed in Annexure-IV.

15.10.2. ROLLING SHUTTERS, MOTORIZED AUTOMATIC INDUSTRIAL OVERHEAD DOOR

15.10.2.1. FABRICATION

1) The contractor shall supply and install steel rolling shutters as required. These shall be installed in accordance with contractor's approved shop drawings.

2) Prior to fabrication or order of the rolling shutters the contractor shall check the actual dimensions of existing openings.

3) The rolling shutter shall be of approved make, made of required size of m.s. laths interlocked together through their entire length and jointed together at the end by end locks mounted on specifically designed pipe shaft with brackets, side guides and arrangement for inside and outside locking with push and pull operation complete including wire springs and m.s. top cover of required thickness.

4) The rolling shutter may also required to be fitted with motorised arrangement and related works.

5) Rolling shutters for DG room, diesel tank room and similar service areas shall be included in the lump sum price and no separate payment shall be made.

15.11. GLASS AND GLAZING

15.11.1. GENERAL

1) Glass Door

Special Frameless fittings for Doors will be with door spring and locking arrangements and both way SS handle (12mm thickness). The size of the door shall be finalized during detailed engineering as per layout requirements with the approval of Engineer.

2) Glass Partitions

Full glass wall partitions of 12mm toughened glass with frameless at the bottom shall be used. It may have suitable decorative 3M film on the glass. All partitions and doors shall be erected using frameless joineries.

3) Glass Partition wall

Full glass wall partitions of minimum 12mm laminated glass with structural support frame shall be provided in the control room towards machine hall & passage or as decided during detailed layout engineering with the approval of Engineer. It may have suitable decorative itching on the glass.

15.11.2. MATERIALS

1) Each glass sheet shall bear the manufacturer's label showing its grade, thickness and type. Labels shall remain until the glass has been set and inspected.

2) When glass is not cut to size by the manufacturer, the contractor shall furnish an affidavit certifying the grade, thickness, type and manufacturer of the glass supplied.

3) Glazing Glass shall be heat-tempered, safety glass 16 kg/m^2 and of 6 mm thickness, free from any distortion or imperfection. Toughened and laminated safety glass shall have minimum 30 kg/m^2 weight and 12 mm thickness, free from any distortion or imperfection.

4) Sealant and glazing compound shall be compatible with the frame as recommended by the manufacturer.

5) Glazing beads and seals shall be black neoprene or vinyl chloride.

6) All glasses to be used shall conform to relevant Standards.

15.11.3. INSTALLATION

1) All single glass panels shall be accurately shop-cut to size of opening with allowances for maximum grip on all edges. Concealed edges of glass shall be clean, straight cut and free from chips and fissures. Glass shall be set with equal bearing on entire width of pane and shall not move nor rattle.

2) Glass and glazing system shall be installed complete with all stops, blocks, channels, beads, sealants and glass to form a watertight installation in accordance with the manufacturer's recommendation.

3) After installation, all exterior glazing shall be given a leak test by flooding the glazing from bottom to top using 20 mm hose with nozzle. Any defective work shall be repaired or replaced by the Contractor to the satisfaction of the Engineer.

4) All glass shall be cleaned at the completion of the work. Any defective, cracked or scratched glass shall be replaced.

5) Detailed execution of glass & glazing system shall be as per Annexure-IV.

15.12. PAINTING WORKS

15.12.1. GENERAL

1) The work includes preparing and painting various surfaces as directed by the Engineer, including protection and finish painting of metal surfaces, except those metal surfaces specified under the Technical Specifications for equipment supplied by others.

2) Architectural finishes, including Bhutanese architectural elements and painting schemes, shall be included in the lump sum and developed in coordination with the approved Architect.

2) The Contractor shall provide all labour, materials, supplies, equipment and scaffolding to perform all operations necessary to complete the work.

15.12.2. MATERIALS

1) Colour of paints shall be in accordance with the colour schemes selected by the Engineer. Exact tones of the colour selected shall be in accordance with the samples supplied and applied on test areas in the Works approved by the Engineer.

2) All paint materials shall be delivered to the Site in their original containers, with labels intact and seals unbroken. All paints shall be of well known registered brands.

3) All tinting colours and thinning materials shall be of the same brand as the oil paint specified for the particular area. Tinting colours for oil paint shall be colours-in-oil, ground in pure linseed oil of the best grade.

4) With the exception of ready mixed materials in original containers, all mixing shall be done at the Site.

5) The Contractor is responsible to ensure that the storage and handling of paint material complies with the requirements of pertinent codes and fire regulations. Proper containers placed outside of the building shall be provided and used for painting wastes, which shall be properly disposed of or removed from the premises at the close of each day's work. No plumbing fixture shall be used for this purpose.

6) The Contractor shall provide for the purpose of maintenance one unopened 4-liter can of each type and each colour of paint used, on completion of the work.

15.12.3. PREPARATION OF SURFACES

1) Concrete and masonry work shall be left for one month and any surface defects repaired before painting.

2) Cracks, holes and other defects in plaster shall be filled or patched with an approved filling compound. The filling shall finish flush with and in the same plane as the adjoining surface. Where patches in cement plaster are required, the surfaces shall be coated with an approved bonding agent, the defects filled with an approved mortar mix for patching, and the patched areas finished to match the texture of the cement plaster. Plaster surfaces that will be painted for the first time shall be uniformly coated with a solution composed of 1 kg of zinc sulphate to 4 litres of water, to which shall be added 28 g of dry sienna to each 4 litres of zinc sulphate

solution. 24 hours after application of the zinc sulphate solution, the surfaces shall be thoroughly washed with clear water and allowed to dry thoroughly.

3) Metal surfaces to be painted shall be clean and thoroughly dry before painting. Rust, loose scale, oil, grease and dirt shall be removed with approved solvents, wire brushing or sanding. Metal welds and blisters shall be ground and sanded smooth, pits and dents filled and imperfections corrected so as to leave a smooth surface.

4) Wood surfaces to receive paint shall be cleaned of all dirt, grease, dust or any other deleterious matter. All surfaces shall be thoroughly sanded and all nail holes, cracks and any other defects shall be coloured to match the colour of the finish paint. The finish surfaces shall be smooth, level and uniform, free from any stains and shall be uniform in colour and shade.

5) The Contractor shall be responsible for and shall rectify any surface finish which in the opinion of the Engineer is unsatisfactory to receive paint.

15.12.4. WORKMANSHIP

1) All paint shall be applied by brush unless spray painting or other method is specifically approved by the Engineer. Spray painting equipment shall be adequate for the work to be performed and shall have suitable air pressure and paint flow controls.

2) Material shall be applied in accordance with the manufacturer's printed directions. Any thinning that may be required shall be added only with the approval of the Engineer and then with an approved type of thinner and in the amount recommended by the paint manufacturer.

3) One litre of paint as originally supplied by the manufacturer shall not cover a greater area when applied by spray gun than when applied unthinned by brush. Deficiencies in film thickness shall be corrected by the application of additional coat(s). Application on masonry surfaces may vary according to surface texture but in no case shall the manufacturer's coverage rate be exceeded. On porous surfaces, it shall be the Contractor's responsibility to achieve a finish comparable to the manufacturer's coverage rate by decreasing the coverage or applying additional coats of paint.

4) Painting shall be equal in quality to the samples as submitted to and approved by the Engineer.

5) The Contractor shall remove all lighting fixture, including canopies, surface hardware and similar items before painting; safely store them and replace them when painting is complete. Dripped, spilled or splattered paint shall be cleaned up promptly. Drop cloths shall be laid to completely cover flooring and all other work items during painting, and shall remain in position until the paint work is dry, finished and inspected.

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6) The premises shall at all times be kept free from an accumulation of waste material and rubbish. On completion of the painting, all tools, scaffolding and surplus materials shall be removed from and about the building, ready for inspection by the Engineer.

7) Painting shall not be done in the rain, fog or mist, or at any other time considered unsuitable by the Engineer.

8) All the surrounding works shall be protected in a suitable manner from paint drops and overspray. All smeared and damaged surfaces shall be cleaned or repaired to the satisfaction of the Engineer.

15.13. CARPENTRY AND JOINERY

15.13.1. GENERAL

1) The work to be done under this Section includes the furnishing of all labour, materials, equipment, tools and other incidentals for all carpentry and joinery works, complete as directed by the Engineer. Shop drawings showing all essential dimensions and details of construction for millwork shall be submitted to the Engineer for approval before actual construction.

2) All carpentry and joinery works shall be performed and completed in a workmanlike manner in accordance with generally accepted modern practice in carpentry, notwithstanding any omission from these Specifications.

3) Lumber and woodwork shall be covered and protected from the elements until used. Buildings shall be thoroughly dry before the finish is placed on them. As far as practicable, nailing shall be done in concealed places, and all nails in exposed woodwork shall be set.

4) All lumber shall be surfaced on four sides. Exterior and interior shall be dressed and smooth. Finishing woodwork shall be hand-smoothed and sanded at the site as necessary to produce the proper finish. All dents on surfaces and counter sunk nails or screws shall be filled with acceptable wood filler before sanding of surfaces.

5) When practicable, millwork shall be fabricated in the shop, doweled, mortised and sanded to a smooth surface, and delivered to the site ready to be secured in place.

6) All cuttings, framings and fittings necessary for the accommodation of other works shall be provided.
7) Detailed execution shall be as per Annexure-V.

15.13.2. MATERIALS

1) All lumber to be incorporated into the Works shall be sound stock delivered dry and fully protected at all times from injury and dampness. Kinked, split, knotted, broken, insect bored, or otherwise damaged pieces will not be allowed.

2) Gradation shall be select, defined as selected lumber, generally clear, high quality, of good appearance, and suitable for use without waste and for natural finish.

3) Cabinets, closets and other wood furniture shall be constructed as shown on the shop drawings. Toilet partitions and doors shall be pre-fabricated units. The Contractor shall prepare shop drawings and submit them for approval.

4) Nails shall be smooth shank, zinc-coated steel wire nails.

5) Putty for woodwork shall be of the color to match wood finish where exposed, and shall be subject to the approval of the Engineer.

6) Glue shall be approved phenol-resorcinol base glue.

15.13.3. SEATS, SLATS, CABINETS, TOILET PARTITIONS

Doors, slats, cabinets, shall be installed as shown on the approved shop drawings complete with all necessary hardware. All fastenings shall be concealed where practicable. Counters and cabinets shall be fitted neatly with a high degree of craftsmanship, installed in a rigid and substantial manner and scribed to joining surfaces. Prefabricated toilet partitions and doors shall be provided with a 300 mm floor clearance.

15.13.4. MISCELLANEOUS WOOD FORMWORK

1) Miscellaneous wood formwork as may be required for the completion of the work shall be provided by the Contractor.

2) Exterior and interior staging shall be erected by the Contractor, and maintained in safe condition.

3) Edges of sills, projected masonry courses, concrete steps, and masonry liable to be damaged during construction shall be protected with temporary wooden covers.

15.13.5. DIMENSIONS

The sizes shown for wood on the drawings are the nominal sizes. All dressed lumber after planning shall not vary from the indicated dimensions by more than ±10%. Thickness and width of lumber shall be uniform throughout its length. Lumber shall not be delivered to the Site in lengths shorter than 2.5 m.

15.14. CAULKING AND DAMP PROOFING

15.14.1. GENERAL

The Contractor shall supply all labour, materials and equipment necessary to complete the caulking and damp proofing of the buildings. The work shall consist of, but not be limited to the following:

a) Masonry control and expansion joints,
b) Caulking for roof penetrations and masonry wall openings such as for windows and doors,
c) Damp proofing the outside surfaces of all exterior concrete hollow block Q

15.14.2. MATERIALS

1) Joint backing shall be polyethylene foam, neoprene or butyl rope. Oakum, bituminous or impregnated metals will not be permitted.

2) Caulking material shall be elastic, non-corrosive and water resistant polysulphide liquid polymer which when set shall be firm but not brittle. It shall be delivered in original sealed containers and applied in accordance with the manufacturer's directions. The colour shall be grey and the material characteristics shall permit concave tooling when in place.

3) Damp-proofing shall be of a clear silicon formulation for application to exterior masonry surfaces.

15.14.3. CAULKING AND JOINTING

1) Application of caulking material shall be done in accordance with the manufacturer's directions, and only by tradesmen fully experienced in this type of work.

2) Joints, reglets and openings to be caulked shall be clean, dry and free of dust and foreign matter, and a joint cleaner shall be used where necessary. Deep joints shall be packed tightly with joint backing to not less than 10 mm from the surface. Joint backing shall be provided by the caulking material supplier, and joint primer applied as required by the manufacturer's instructions.

3) Excess caulking material shall be cleaned from all surfaces adjacent to and in proximity of the work area, and the joint left smooth and clean.

15.14.4. DAMP PROOFING

1) Surface shall be cleaned of oil, dirt and foreign matter, and prepared in accordance with the manufacturer's instructions before application of the damp proofing material. The concrete shall have been completely cured and the surface kept dry at the time of application.

2) Surfaces shall receive two heavy coats of damp proofing. The first coat shall be carefully applied so that untreated air-bubble depressions in the surface shall be completely filled and the second coat shall ensure a 100% coating of the surface. Particular care shall be taken to apply the damp proofing at all construction and other joints.

15.15. SANITARY FITTINGS

The contractor shall deliver & install toilet & bath accessories. Contractor shall provide one sample complete with fixing device of each accessory. Accessories shall be delivered in manufacturer's original packing & due care shall be taken to avoid damage. Delivery, installation/execution shall be as per Annexure-VI.
Internal plumbing pipes shall be uPVC or CPVC. GI pipes shall not be used unless otherwise approved by the Engineer.

15.16. MEASUREMENT AND PAYMENT

1) Payment for building and architectural works will be made as lump sums entered in Bill of Quantities the schedule, provided for the following structures:

a) Dam Complex and control building

b) Dam Area

- HPU Room
- Lift Control Room
- Power Pack Rooms (n. 3)
- E-flow Valve House Room

The lump sum quoted shall include the entire cost of rendering Architectural design and supervision services, labour, furnishing of materials and installation for various architectural items described in these technical specifications including formworks, brick masonry, cement plasters, flooring, railings, doors, windows and all necessary sanitary items.
All architectural finishes, flooring types, doors, windows, rolling shutters, painting, wall putty, plumbing materials and architectural detailing shall be deemed included in the lump sum price unless explicitly stated otherwise.

2) The individual lump sum shall cover the entire cost of the design, labour, equipment and furnishing of materials and their installation in the Permanent Works except the concrete structure, which shall be dealt with as per the relevant section of the specifications.

3) Payment for the Lump sum will be made proportionally according to the progress of the work as estimated by the Engineer.

4) Architectural finishes, including Bhutanese architectural elements and painting schemes, shall be included in the lump sum.

15.17. EXCLUSIONS

1) Concrete and reinforcement for the construction of buildings shall be paid separately and not included in the Lump Sum for Building and Architectural works.

2) The stainless steel railings envisaged in Dam control building shall be paid for under Section B.13 "Metal Works" and not included in the Lump Sum for Building and Architectural works.

3) All the required Architectural works/finishes need to be completed prior to handing over the site to HM contractor. No Architectural works/finishes etc. shall be permitted in the vicinity of already installed HM equipment/panel etc. in the area without express written instructions from Engineer.

4) All lighting and illumination works not included in the Lump Sum for building and architectural works.

END OF SECTION B.15

ANNEXURE-I

ROOM SCHEDULE

DAM AREA- CONTROL BUILDING

Stair case

Item	Description	Detail reference Drawing / Specification	Painting	Colour
Flooring	Kota Stone	Annex-II		Natural
Skirting	Kota Stone	Annex-II		Natural
Dado (up to 900 mm)	Granite tiles	Annex-II		Natural As approved
Walls	Cement plaster, 12 mm / 15 mm	Tech. Spec. Section-15.6	Textured Acrylic emulsion	As approved
Ceiling	6 mm Cement plaster	Tech. Spec. Section-15.6	Acrylic emulsion	White
Door	uPVC	Annex-IV	-	Brown
Railing	Stainless steel	B.13		Natural steel

DAM AREA- CONTROL BUILDING

Toilet / WC

Item	Description	Detail reference Drawing / Specification	Painting	Colour
Flooring	Epoxy flooring	Annex-II		As approved
Dado up to 2100 mm	Ceramic wall tiles with decorative ceramic highlighter tile band	Annex-II		As approved
Walls	Cement plaster 12 mm / 15 mm	Tech. Spec. Section-15.6	Acrylic emulsion	As approved
Ceiling	Cement plaster 6 mm	Annex-III	Acrylic emulsion	White
Door	uPVC	Annex-IV	-	Brown
Window	uPVC	Annexure-IV	-	Brown

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Fitting	Wash basin with chrome fittings, Water closet with water jet, Toilet paper holder, Mixer for bath shower, mixer spout, Coat hooks, Mirror, Soap dispenser, Urinals, Towel rail, Electric hand drier	Annex-VI		
Accessories	Electric geysers.	Branded		As approved

DAM AREA – CONTROL BUILDING

Entrance Area

Item	Description	Detail reference Drawing / Specification	Painting	Colour
Flooring	Epoxy flooring	Annex-II		As approved
Skirting	Ceramic vitrified tiles	Annex-II		As approved
Walls	Granite tiles	Annex-II		Natural As approved
Ceiling	Cement plaster 6 mm	Annex-III	Acrylic emulsion	White
Door	uPVC	Annex-IV	-	Brown
Door opening	Opening trim in granite slab			Natural Black

DAM AREA – CONTROL BUILDING

Diesel Tank Room and Diesel Generator Room

Item	Description	Detail reference Drawing / Specification	Painting	Colour
Flooring	Ironite flooring	Annexure-II		Natural Concrete
Dado 2100	Granolithic flooring	Annexure-II		As approved
Walls	Cement Plastered 12 mm / 15 mm	Annexure-II	Acrylic emulsion	As approved
Ceiling	6 mm Cement plaster	Tech. Spec. Section-15.6	Acrylic emulsion	White

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Door	uPVC	Annexure-IV	-	Brown
Window	uPVC	Annexure-IV	-	Brown
Columns	Terrazzo tiles with aluminium angle protection for edges up to 3000 mt.			
Furniture	Over head cabinet	Annexure-V		Approved Laminate
Drain	1. Ceramic tiles 2. Drain cover; 150 wide(clear) 3. Drainage Catchment Area			White Natural steel

DAM AREA – CONTROL BUILDING

Control Panels Room

Item	Description	Detail reference Drawing / Specification	Painting	Colour
Flooring	Epoxy flooring	Annexure-II		As approved
Skirting	Ceramic tile vitrified	Annexure-II		As approved
Walls	Granite tiles	Annexure-II		Natural As
Ceiling	False ceiling with Aluminium tile 600 x 600, perforated.	Annexure-III	Pre-paint	Ivory
Door	uPVC	Annexure- IV	-	Brown
Window	uPVC	Annexure- IV	-	Brown
Columns	Ceramic vitrified tiles with aluminium angle protection for edges			

DAM AREA – CONTROL BUILDING

Office Room / Conference Room

Item	Description	Detail reference Drawing / Specification	Painting	Colour
Flooring	Epoxy flooring	Annexure-II		As approved
Skirting	Ceramic vitrified tiles	Annexure-II		As approved
Walls	Cement plaster, 12 mm / 15 mm	Annexure-II	Acrylic emulsion	As approved

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Ceiling	False ceiling with Aluminium tile 600 x 600, perforated	Annexure-III	Pre-painted	Ivory
Door	uPVC	Annexure-IV	-	Brown
Window	uPVC	Annexure-IV	-	Brown
Furniture	Laminated board, cabinets, Over-head lockers	Annexure-V		As approved Laminate

DAM AREA – CONTROL BUILDING

Modular Kitchen

Item	Description	Detail reference Drawing / Specification	Painting	Colour
Flooring	Epoxy flooring	Annexure-II		As approved
Dado up to 2100mm	Ceramic wall tiles	Annexure-II		As approved
Walls	Cement plaster, 12 mm / 15 mm	Annexure-II	Acrylic emulsion	As approved
Ceiling	Cement plaster 6 mm	Annexure-II	Acrylic emulsion	As approved
Door	uPVC	Annexure-IV	-	Brown
Window	uPVC	Annexure-IV	-	Brown
Counter	Modular kitchen system including base units, wall cabinets, countertop with sink, plumbing connections and accessories, complete as approved by the Engineer.			Natural black
Furniture		Annexure-V		Approved Laminate
Accessories	Water Purifier	Branded		As approved

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DAM AREA – CONTROL BUILDING

Terrace

Item	Description	Detail reference Drawing / Specification	Painting	Colour
Flooring	Kota stone	Annexure-II		Natural
Skirting	Kota stone	Annexure-II		Natural
Walls	Cement plaster	Annexure-II	Acrylic emulsion	As approved
Door	uPVC	Annexure-IV	-	Brown
Railing	Stainless steel			Natural

DAM AREA – CONTROL BUILDING

Store / Service Room

Item	Description	Detail reference Drawing /	Painting	Colour
Flooring	Ironite flooring	Annexure-II		Natural Concrete
Walls	Cement Plastered 12 mm / 15 mm	Annexure-II	Acrylic emulsion	As approved
Ceiling	6 mm Cement plaster	Tech. Spec. Section-15.6	Acrylic emulsion	White
Door	uPVC	Annexure-IV	-	Brown
Window	uPVC	Annexure-IV	-	Brown
Drain	1. Ceramic tiles 2. Drain cover; 150 wide(clear) 3. Drainage Catchment Area			White Natural steel

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DAM AREA

HPU Room

Item	Description	Detail reference Drawing / Specification	Painting	Colour
Flooring	Ironite flooring	Annexure-II		Natural Concrete
Walls	Cement Plastered 12 mm / 15 mm	Annexure-II	Acrylic emulsion	As approved
Ceiling	6 mm Cement plaster	Tech. Spec. Section-15.6	Acrylic emulsion	White
Door	uPVC	Annexure-IV	-	Brown
Window	uPVC	Annexure-IV	-	Brown
Drain	4. Ceramic tiles 5. Drain cover; 150 wide(clear) 6. Drainage Catchment Area			White Natural steel

DAM AREA

Lift Control Room

Item	Description	Detail reference Drawing / Specification	Painting	Colour
Flooring	Epoxy flooring	Annexure-II		Natural Concrete
Walls	Cement Plastered 12 mm / 15 mm	Annexure-II	Acrylic emulsion	As approved
Ceiling	6 mm Cement plaster	Tech. Spec. Section-15.6	Acrylic emulsion	White
Door	uPVC	Annexure-IV	-	Brown
Window	uPVC	Annexure-IV	-	Brown

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DAM AREA

Power Pack Rooms (n. 3)

Item	Description	Detail reference Drawing / Specification	Painting	Colour
Flooring	Epoxy flooring	Annexure-II		Natural Concrete
Walls	Cement Plastered 12 mm / 15 mm	Annexure-II	Acrylic emulsion	As approved
Ceiling	6 mm Cement plaster	Tech. Spec. Section-15.6	Acrylic emulsion	White
Door	uPVC	Annexure-IV	-	Brown
Window	uPVC	Annexure-IV	-	Brown

DAM AREA

E-Flow Valve House Room

Item	Description	Detail reference Drawing / Specification	Painting	Colour
Flooring	Epoxy flooring	Annexure-II		Natural Concrete
Walls	Cement Plastered 12 mm / 15 mm	Annexure-II	Acrylic emulsion	As approved
Ceiling	6 mm Cement plaster	Tech. Spec. Section-15.6	Acrylic emulsion	White
Door	uPVC	Annexure-IV	-	Brown
Window	uPVC	Annexure-IV	-	Brown

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ANNEXURE-II

EXECUTION PROCEDURE OF TILES

TERRAZO TILE FLOORING

1.1 WORK INCLUDED

A. Terrazzo tiles in Flooring as specified on drawings and in Room Schedules.

1.2 ALLOWABLE TOLERANCES

A. Tiles: As per relevant standards.
B. Execution: As described in the following sections

1.3 REFERENCE STANDARDS

IS: 1237 – 1980

1.4 SAMPLES

A. Submit four samples of each type and colour of Terrazzo floor tiles.
B. Submit one sample length 150 mm., of each colour of proprietary coloured grout for joints.

1.5 SHOP DRAWINGS

A. Layout shall be as per approved shop drawing showing true locations of items of works of other trades and also joints.

PART 2 – MATERIALS

2.1 MATERIAL

A. The Terrazzo tiles shall be of approved make and shall generally conform to IS: 1237 – 1980. Unless otherwise specified, the tiles shall be supplied with initial grinding and grouting of wearing layer.

2.2 DIMENSIONAL AND TOLERANCES

A. **Dimensions**:
The size of tiles shall be 300 mm x 300 mm x 20 mm thick. Half tiles for use with the full tiles shall be such as to make two half tiles when joined together, match with the dimensions of one full tile.

B. **Tolerances**:
Tolerances on length and breadth shall be plus or minus one millimetre, and tolerance on thickness shall be plus 5 mm. The range of dimensions in any one delivery of tiles shall not exceed 1 mm on length and breadth and 3 mm on thickness.

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The tiles shall be manufactured in a factory under pressure process subjected to hydraulic pressure of not less than 140 kg per square centimetre and shall be given the initial grinding with machine and grouting of the wearing layer before delivery to site. The wearing layer shall be free from projections, depressions, cracks, holes, cavities and other blemishes. The edges of wearing layer may be rounded.

2.3 PRODUCTION OF TILES:

The proportion of cement to aggregate in the backing of tiles shall be not leaner than 1:3 by weight. Where colouring material is used in the wearing layer, it shall not exceed 10 percent by weight of cement used in the mix.

The finished thickness of the upper layer shall not be less than 5 mm for size of marble chips from the smallest upto 6 mm and also, not less than 5 mm for size of marble chips ranging from the smallest upto 12 mm, and not less than 6 mm for size of marble chips varying from the smallest upto 20 mm.

PART 3 – WORKMANSHIP

3.1 PREPARATION OF SURFACE

A. **Mortar**:
This shall consist of uniform and smooth layer of plaster of 20 mm thickness and of mix 1:5 (1 cement: 5 coarse sand) unless otherwise specified, finished with a floating coat of neat cement. In both plaster and floating coat the ratio specified in the description of item shall be adopted. The full quantity of dry mortar required of a room shall be prepared in one lot in order to ensure uniform colour. Wet mortar shall be prepared in the usual manner as and when required.

3.2 LAYING

A. Base concrete or RCC slab on which the tiles are to be laid shall be cleaned, wetted and mopped. The bedding for the tiles shall be with cement mortar of 1:4 (1 cement 4 coarse sand).

B. The average thickness of the bedding mortar shall be 30 mm and the thickness at any place shall not be less than 10 mm.

C. Cement mortar is laid in bedding the terrazzo tiles, these shall be set immediately after laying the mortar. Over this bedding neat grey cement slurry of honey like consistency shall be spread at the rate of 4.4 kg of cement per square metre over such an area as would accommodate about twenty tiles. The tiles shall be soaked in water, washed clean and a coat of cement slurry applied liberally at the back of tiles. Tile shall then be fixed in the grout on bedding mortar one after another, each tile being gently

tapped with a wooden mallet till it is properly bedded, and in level with the adjoining tiles. The joints shall be kept as thin as possible not exceeding 1.5 mm and in straight lines or to suit the required pattern.

D. The surface of the flooring during laying shall be frequently checked with a straight edge at least 2 metre long, so as to obtain a true surface with the required slope.

E. Full tiles or half tiles can not be fixed, tiles shall be cut (sawn) from full tiles to the required size and their edges rubbed smooth to ensure a straight and true joint.

F. Tiles which arc fixed in the floor adjoining the wall shall enter not less than 12 mm under the plaster, skirting or dado. The junction between wall plaster and tile work shall be finished neatly and without waviness.

G. After the tiles have been laid, surplus cement grout that may have come out of the joints shall be cleared off.

3.3 CURING POLISHING AND FINISHING

A. The day after the tiles are laid all joints shall be cleaned of the grey cement grout with a wire brush or trowel to a depth of 5 mm and all dust and loose mortar removed and cleaned. Joints shall than be grouted with grey or white cement mixed with or without pigment to match the shape of the topping of the wearing layer of the tiles. The same cement slurry shall be applied to the entire surface of the tiles in a thin coat with a view to protect the surface from abrasive damage and fill the pin holes that may exist on the surface.

B. The floor shall then be kept wet for a minimum period of 7 days. The surface shall thereafter be grounded evenly with machine fitted with coarse grade grit block (No. 60). Water shall be used profusely during grinding. After grinding the surface shall be thoroughly washed to remove all grinding mud, cleaned and mopped. It shall then be covered with a thin coat of grey or white cement, mixed with or without pigment to match the colour oi the topping of the wearing surface in order to fill any pin hole that appear. The surface shall be again cured. The second grinding shall then be carried out with machine fitted with fine grade grit bloc (No 120).

C. The final grinding with machine fitted with the finest grade grit blocks (No.320) shall be carried out the day after the second grinding described in the preceding para or before handing over the floor, ordered by the Engineer.

D. For small areas or where circumstances so require, hand polishing may be permitted in lieu of machine polishing after laying. For hand polishing the following carborundum stones, shall be used:
1st grinding - coarse grade stone (No. 60)
Second grinding - medium grade (No 80)
Final grinding - fine grade (No 120)

In all other respects, the process shall be similar as for machine polishing.

E. After the final polish, oxalic acid shall be dusted over the surface at the rate of 33 gm per square metre sprinkled with water and rubbed hard with a namdah' block (pad of woollen rags).. The following day the floor shall be wiped with a moist rag and dried with a soft cloth and finished clean.

F. If any tile is disturbed or dam aged. it shall be refitted or replaced, properly jointed and polished. After curing, the surface shall be washed and finished clean. The finished work shall not sound hollow when tapped with a wooden mallet.

3.4 INSPECTION

A. Verify that surfaces to receive DADO tiling, are free of dust, loose particles, oil and other foreign matter which would adversely affect bonds of mortar layer.

B. Examine construction, grounds, and accessories to ensure that finished tiled surfaces will be true to line and required pattern.

C. Verify that concrete surfaces are prepared in a manner to provide bond for mortar layer.

D. Ensure that all works by other trades, affecting wall tiling are correct located, sized and completed.

3.5 EXECUTION – GENERAL PRECAUTIONS

A. Cut and fit tiles accurately around equipment, electrical outlets, pipes etc., and overlap all cuts with plates or collers.

B. Execute joints straight, true and even.

C. Align joints in floor and wall, when tiles are of equal size.

D. Execute 5mm. wide expansion joints at frames in openings at fixed equipment and internal angles between walls, ceiling and floor.

E. Do not grout until 24 hours after tiling.

F. Adhesive mortar may be used, subject to approval.

3.6 CLEANING

A. Clean surfaces from grout wash.

B. Rinse tile work thoroughly with clean water after using chemical cleaning agents

TERRAZO TILES IN SKIRTING AND DADO

PART 1 – GENERAL

1.1 WORK INCLUDED

A. Terrazzo tiles in Dado as specified on drawings and in Room Schedules.

1.2 ALLOWABLE TOLERANCES

A. Tiles: As per relevant standards.
B. Execution: As described in the following sections

1.3 REFERENCE STANDARDS

Standards

IS: 1237

1.4 SAMPLES

A. Submit four samples of each type and colour of Terrazzo tiles in DADO.

B. Submit one sample length 150 mm., of each colour of proprietary coloured grout for joints.

1.5 MANUFACTURER LITERATURE

A. Submit manufacturer material specifications and colour schedules.

B. Submit manufacturer's instructions for storage of material.

1.6 SHOP DRAWINGS

A. Layout shall be as per approved shop drawing showing true locations of items of works of other trades and joints.

PART 2 – MATERIALS

2.1 MATERIAL

A. The Terrazzo tiles shall be of approved make and shall generally conform to IS: 1237. Unless otherwise specified, the tiles shall be supplied with initial grinding and grouting of wearing layer.

2.2 DIMENSIONS AND TOLERANCES

A. The size of tiles shall be 300 mm x 300 mm. Half tiles for use with the full tiles shall be such as to make two half tiles when joined together, match with the dimensions of one full tile.

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B. Tolerances on length and breadth shall be plus or minus one millimetre, and tolerance on thickness shall be plus 5 mm. The range of dimensions in any one delivery of tiles shall not exceed 1 mm on length and breadth and 3 mm on thickness.

The tiles shall be manufactured in a factory under pressure process subjected to hydraulic pressure of not less than 140 kg per square centimetre and shall be given the initial grinding with machine and grouting of the wearing layer before delivery to site. The wearing layer shall be free from projections, depressions, cracks, holes, cavities and other blemishes. The edges of wearing layer may be rounded.

2.3 2.03 PRODUCTION OF TILES

The proportion of cement to aggregate in the backing of tiles shall be not leaner than 1:3 by weight. Where colouring material is used in the wearing layer, it shall not exceed 10 percent by weight of cement used in the mix.

The finished thickness of the upper layer shall not be less than 5 mm for size of marble chips from the smallest upto 6 mm and also, not less than 5 mm for size of marble chips ranging from the smallest upto 12 mm, and not less than 6 mm for size of marble chips varying from the smallest upto 20 mm.

PART 3 – WORKMANSHIP

3.1 PREPARATION OF SURFACE

A. Mortar:

This shall consist of uniform and smooth layer of plaster of 12 mm thickness and of mix 1:3 (1 cement: 3 coarse sand) unless otherwise specified, finished with a floating coat of neat cement. In both plaster and floating coat the ratio specified in the description of item shall be adopted. The full quantity of dry mortar required of a room shall be prepared in one lot in order to ensure uniform colour. Wet mortar shall be prepared in the usual manner as and when required.

3.2 LAYING

A. 12mm. thick plaster of cement mortar 1:3 (1 cement and 3 coarse sand) mix or as specified shall be applied and allowed to harden. The plaster shall be roughened with the wire brushes or by scratching diagonal at closed intervals.

The tiles shall be soaked in water, washed clean, and a coat of cement slurry applied liberally at the back of tiles and set in bedding mortar. The tiles shall be tamped and corrected to proper plane and lines. The tiles shall be set in the required pattern and jointed. The joints shall be as fine as possible. Tiles on the walls shall rest on the top of flooring. Where full size tile can not be fixed, these shall be cut (sawn) to the required size and their edges rubbed smooth.

3.3 CURING POLISHING AND FINISHING

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A. The day after the tiles are laid all joints shall be cleaned of the grey cement grout with a wire brush or trowel to a depth of 5 mm and all dust and loose mortar removed and cleaned. Joints shall than be grouted with grey or white cement mixed with or without pigment to match the shape of the topping of the wearing layer of the tiles. The same cement slurry shall be applied to the entire surface of the tiles in a thin coat with a view to protect the surface from abrasive damage and fill the pin holes that may exist on the surface.

B. Tiles shall then be kept wet for a minimum period of 7 days. The surface shall thereafter be grounded evenly with hand with coarse grade grit carborandum stone block (No. 60). Water shall be used profusely during grinding. After grinding the surface shall be thoroughly washed to remove all grinding mud, cleaned and mopped. It shall then be covered with a thin coat of grey or white cement, mixed with or without pigment to match the colour of the topping of the wearing surface in order to fill any pin hole that appear. The surface shall be again cured. The second grinding shall then be carried out with machine fitted with fine grade grit bloc (No 80).

C. The final grinding with the finest grade grit blocks (No.120) shall be carried out the day after the second grinding described in the preceding para or before handing over the floor, ordered by the Engineer.

D. After the final polish, oxalic acid shall be dusted over the surface at the rate of 33 gm per square metre sprinkled with water and rubbed hard with a namdah' block (pad of woollen rags).. The following day the floor shall be wiped with a moist rag and dried with a soft cloth and finished clean.

E. If any tile is disturbed or damaged it shall be refitted or replaced, properly jointed and polished. After curing, the surface shall be washed and finished clean. The finished work shall not sound hollow when tapped with a wooden mallet.

3.4 INSPECTION

A. Verify that surfaces to receive tiling is free of dust, loose particles, oil and other foreign matter which would adversely affect bonds of mortar layer.

B. Examine construction, grounds, and accessories to ensure that finished tiled surfaces will be true to line and required pattern.

C. Verify that concrete surfaces are prepared in a manner to provide bond for mortar layer.

D. Ensure that all works by other trades, affecting wall tiling are correct located, sized and completed.

3.5 EXECUTION – GENERAL PRECAUTIONS

A. Cut and fit tiles accurately around equipment, electrical outlets, pipes etc., and overlap all cuts with plates or collers.

B. Execute joints straight, true and even.

C. Align joints in floor and wall, when tiles are of equal size.

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D. Execute 5mm. wide expansion joints at frames in openings at fixed equipment and internal angles between walls, ceiling and floor.

E. Do not grout until 24 hours after tiling.

F. Adhesive mortar may be used, subject to approval.

3.6 CLEANING

A. Clean surfaces from grout wash.

B. Rinse tile work thoroughly with clean water after using chemical cleaning agents.

CERAMIC WALL TILES

PART 1 – GENERAL

1.1 WORK INCLUDED

A. Ceramic wall tiling as specified on drawings and in Room Schedules.

1.2 ALLOWABLE TOLERANCES

A. Titles: As per relevant standards
B. Execution: As described in the following sections

1.3 REFERENCE STANDARDS

Standards	Name of Standard
IS: 15622	Pressed Ceramic Tiles-Specification

1.4 SAMPLES

A. Submit four samples of each type and colour of Terrazzo tiles in DADO.

B. Submit one sample length 150 mm., of each colour of proprietary coloured grout for joints.

1.5 MANUFACTURER LITERATURE

A. Submit manufacturer material specifications and colour schedules.

B. Submit manufacturer's instructions for storage of material.

1.6 SHOP DRAWINGS

A. Layout shall be as per approved shop drawing showing true locations of items of works of other trades and joints.

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PART 2 – MATERIALS

2.1 MATERIAL

A. The tiles shall be of approved make and shall generally conform to IS standards. The tiles shall be of earthenware covered by a glaze thoroughly matured and fitted to the body. The tiles shall be sound, true to shape, flat and free from flaws and other manufacturing defects affecting their utility.

The top surface of the tiles shall be glazed. The underside of the tiles shall not have glaze on more than 5% of the area in order that the tile may adhere properly to the base. The edges of the tiles shall be free from glaze, if unavoidable shall be permissible on only upto 50% of the surface area of edges.

The glaze shall be free from welts, chips, craze, specks, crawling or other imperfections detracting from the appearance when viewed from a distance of 1 meter. The glaze shall either be glossy or matt as approved. The glaze shall be white in colour except in the case of coloured tiles when colours shall be as approved. There may be more than one colour on a tile.

2.2 DIMENSIONS AND TOLERANCES

A. Ceramic wall tiles shall be made square or rectangular in sizes as specified and shall be straight or cushion edge type. Half tiles for use as full tiles shall have dimensions which shall be such as to make the half tiles when jointed together with 1mm. joint) match with dimensions of full tiles. Tiles may be manufactured in sizes in other than those specified above. Thickness of tiles shall be 5mm. or 6mm. as per approved.

B. Tolerances:

Facial Dimensions: The length of all the four sides of the tile shall be measured to the nearest 0.1mm. The average value of length/breadth shall not vary more than + or - 0.8mm. from the above specified dimension.

The variation of the individual dimensions from average value of length/breadth shall not exceed + or - 0.5mm. Tolerances on thickness shall be + or - 0.4mm.

Check for Squareness: Any variation from a right angle in the angle contained by any two adjoining sides shall be limited so that if a builder's steel square is placed against the angle, the distance between the inner edge of the square and the adjacent side of the tile or fitting shall not be more than 0.5mm. per 100mm. run.

Warpage: The tiles when tested for warpage on the edges and on the diagonal as per IS:777- 1988.

Water Absorption: The average water absorption of the tiles when tested and evaluated in accordance with IS standards and shall not exceed 20%.

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Crazing: Tiles subjected to two cycles of crazing test as per IS standards and shall not show any sign of crazing.

Impact Resistance: Tiles when tested as per IS standards shall remain intact, apart from surface marking.

Chemical Resistance: When tested as per IS standards, the glazed surface of tiles and/or the fittings having a white or cream coloured glossy glaze shall show no modifications.

PART 3 – WORKMANSHIP

3.1 PREPARATION OF SURFACE

A. The joints shall be raked out to a depth of at least 15mm. in masonry walls. In concrete walls, the surface shall be hacked and roughened with wire brushes. The surface shall be cleaned thoroughly, washed with water and kept wet before skirting is commenced.

3.2 LAYING

A. 12mm. thick plaster of cement mortar 1:3 (1 cement and 3 coarse sand) mix or as specified shall be applied and allowed to harden. The plaster shall be roughened with the wire brushes or by scratching diagonal at closed intervals.

The tiles should be soaked in water, washed clean, and a coat of cement slurry applied liberally at the back of tiles and set in bedding mortar. The tiles shall be tamped and corrected to proper plane and lines. The tiles shall be set in the required pattern and jointed. The joints shall be as fine as possible. Tiles on the walls shall rest on the top of flooring. Where full size tile can not be fixed, these shall be cut (sawn) to the required size and their edges rubbed smooth.

3.3 CURING AND FINISHING

A. The joints shall be cleaned off the grey cement grout with wire/coir brush or trowel to a depth of 2mm. to 3mm. and all dust and loose mortar removed. Joints shall then be flush pointed with white cement added with pigments if required to match the colour of tiles. The work shall then be kept wet for 7 days after which, the surface shall be washed and finished clean. The finished work shall not sound hollow when tapped with a wooden mallet.

3.4 MEASUREMENT

A. Length and height shall be measured correct to a cm. The area shall be calculated in square meter, correct to two places of decimal. Length and height shall be measured along the finished face of the wall including curves where specials such as coves, internal and external angles and beads are used. Nothing extra shall be paid for cutting (sawing).

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Areas where coloured tiles or different types of decorative tiles are used the same shall be included in the main wall tiles and no extra shall be paid.

3.5 INSPECTION

A. Verify that surfaces to receive wall tiling, are free of dust, loose particles, oil and other foreign matter which would adversely affect bonds of mortar layer.

B. Examine construction, grounds, and accessories to ensure that finished tiled surfaces will be true to line and required pattern.

C. Verify that concrete surfaces are prepared in a manner to provide bond for mortar layer.

D. Ensure that all works by other trades, affecting wall tiling are correct located, sized and completed.

3.6 EXECUTION – GENERAL PRECAUTIONS

A. Cut and fit tiles accurately around equipment, electrical outlets, pipes etc., and overlap all cuts with plates or collers.

B. Execute joints straight, true and even.

C. Align joints in floor and wall, when tiles are of equal size.

D. Execute 5mm. wide expansion joints at frames in openings at fixed equipment and internal angles between walls, ceiling and floor.

E. Do not grout until 24 hours after tiling.

F. Adhesive mortar may be used, subject to approval.

3.7 CLEANING

A. Clean surfaces from grout wash.

B. Rinse tile work thoroughly with clean water after using chemical cleaning agents

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GRANOLITHIC or IRONITE FLOORING

PART 1 – GENERAL

1.1 WORK INCLUDED

A. Granolithic or Ironite Flooring as specified on drawings and Room Schedules.

1.2 ALLOWABLE TOLERANCES

A. Planer tolerance of surface: 2 mm tolerance in a distance of 2 m.

1.3 SAMPLES

Prepare samples of 1 sqm of granolithic/ironite flooring for each type of pigment and texture for approval and reference.

1.4 MANUFACTURER LITERATURE

A. Submit manufacturer material literature, specifications and storage recommendations for various materials including hardeners, if required, and colour pigment.

B. Submit details of miscellaneous items used such as galvanized strips for embedding in the flooring thickness for expansion joints.

1.5 SHOP DRAWINGS

A. Layout shall be as per approved drawing showing true locations of expansion joints, formation of panels and deciding method for executing the flooring, other construction details such as drains and slopes for the items of work.

1.6 MATERIALS

A. Before executing the work, all materials shall be checked for their suitability and fitness for use by the executing agency and a record for such assessment shall be maintained for the reference of Engineer. It shall be ensured that the excess materials shall not be taken out of proper storage space which might have to be returned in case the entire lot is not utilised, especially the ones which can get damaged in short exposures.

B. Material for preparation of appropriate mix shall be dumped in a suitable place to ensure avoidance of mixing of undesirable elements / materials.

PART 2 – WORKMANSHIP

2.1 MATERIAL MIXING

A. The granolithic/ironite flooring shall consist of 1 : 1: 2 cement : coarse : fine aggregate mix. The cement shall be mixed with 13 kg of ironite with 50 kg of cement in dry state before it is mixed with the aggregates in the dry state. All constituents to granolithic/ironite flooring shall be mixed in the dry state before water is added to it. The aggregates shall be of approved type of granite, basalt or quartzite.

B. A suitable hardener or the colour pigment may have to be added to the flooring concrete mix as desired by the Engineer.

2.2 BASE CONCRETE

A. Flooring shall be laid on base concrete. The base concrete shall be normally provided with the slopes required for the flooring. However, if the same is not provided in specific cases, then the same shall be adjusted in the granolithic/ironite flooring. Base concrete should be set properly and not loose and cured with sufficient water.

B. If the cement concrete flooring is to be laid directly on the RCC slab, the top surface of RCC slab shall be cleaned and the laitance shall be removed and a coat of cement slurry at 2 kg of cement spread over an area of one sqm so as to get a good bond between the base and concrete floor.

2.3 THICKNESS

The average thickness of floor shall be 35 mm and at no place it shall be less than 15 mm while adjusting the slopes of the flooring finish.

2.4 LAYING

A. Panels

Flooring of the specified thickness shall be laid in the pattern including the border / or as given in the drawings or as directed by the Engineer. The panels shall generally be of uniform size and no dimension of a panel shall exceed 2 m and the area of a panel shall not be more than 2 sqm.

B. Laying of flooring with strips

Normally granolithic/ironite flooring shall be laid in one operation using glass/plain asbestos/aluminium/PVC/brass strips or any other strips as required as per drawing or instructions of the Engineer, at the junction of two panels. This method ensures uniformity in colour of all the panels and straightness at the junction of the panels. 4 mm thick glass strips or 5 mm thick plain

asbestos sheet, 2mm PVC strips or 2 mm aluminium or brass strips shall be fixed with their tops at proper level, giving required slopes.

C. Concreting for granolithic/ironite flooring

Cement concrete shall be placed in the panels and levelled with the help of straight edge and trowel. The blows shall be fairly heavy in the beginning but as consolidation takes place, light rapid strokes shall be given. Beating shall cease as soon as the surface is found covered with a thin layer of cream of mortar. The evenness of the surface shall be tested with straight edge and made true to required slopes. While laying concrete, care shall he taken to see that the panel strips are not damaged/disturbed by the labourers. The tops of strips shall be visible clearly after finishing with cement slurry.

2.5 LAYING OF FLOORING WITH OUT STRIPS

Laying of cement concrete flooring in alternate panels may be allowed by the Engineer in case strips are not to be provided using alternative method of shuttering.

A. Shuttering

The panels shall be bounded by angle iron or flats. The angle iron/flat shall have the same depth as the concrete flooring. These shall be fixed in position, with their top at proper level giving required slopes. The surface of the angle iron or flats, to come in contact with concrete shall be smeared with soap solution or non sticking oil (Form oil or raw linseed oil) before concreting. The flooring shall butt against the un-plastered masonry wall.

B. Concreting

The concreting of granolithic/ironite flooring shall be done in the manner described in the previous section above. The angle iron/flats used for shuttering, shall be removed on the next day of the laying of cement concrete. The ends thus exposed shall be repaired, if damaged with cement mortar 1:2 (1 cement: 2 coarse sand) and allowed to set for minimum period of 24 hours. The alternate panels shall then be cleaned of dust, mortar, droppings etc. and concrete laid. While laying concrete, care shall be taken to see that the edges of the previously laid panels arc not damaged and fresh mortar is not splashed over them. The joints between the panels should come out as fine straight lines.

2.6 FINISHING POLISHING AND CURING

Finishing

A. The finishing of the surface shall follow immediately after the cessation of beating. The surface shall be left for some time; till moisture disappears from it or surplus water can be mopped up.

Use of dry cement or cement and sand mixture sprinkled on the surface to stiffen the concrete or absorb excessive moisture shall not be permitted. Excessive trowelling shall be avoided.

B. Fresh cement shall be mixed with water to form thick slurry and spread at the rate of 2 kg of cement over an area of one square meter of flooring while the flooring concrete is still green. The cement slurry shall then be properly processed and finished smooth.

C. The junctions of floor with wall plaster, dado or skirting shall be rounded off.

D. The men engaged on finishing operations shall be provided with raised wooden platform to sit on so as to prevent damage to new work.

2.7 CURING

The curing shall be done for a minimum period of ten days. Curing shall not be commenced until the top layer has hardened. Covering with empty gunnies shall be avoided as the colour of the flooring is likely to be bleached due to the remnants of cement dust from the bags. The quality of water shall be ensured to be free for minerals and solids which can damage the natural finishing surface.

3.1 PRECAUTIONS

A. Flooring in shall be laid only after fixing of other items such as drain cover frames and railing supports.

B. During cold weather, flooring shall not he done when the temperature falls below 4°C. The flooring concrete placed shall be protected against frost by suitable covering. Concrete damaged by frost shall be removed and work redone. During hot weather, precautions shall be taken to see that the temperature of wet concrete does not exceed 38°C. No flooring concrete shall be laid within half an hour of the closing time of the day, unless permitted by the Engineer. To facilitate rounding of junction of skirting, dado and floor, the skirting/dado shall be laid along with the border or adjacent panels of floor.

IRONITE FLOORING

PART 1 – GENERAL

To withstand heavy wear and tear, concrete flooring with metallic concrete hardening compound such as Ironite /hardonate shall be laid as wearing layer.

1.1 WORK INCLUDED

A. Ironite flooring as specified on drawings and Room Schedules.

1.2 ALLOWABLE TOLERANCES

A. Planer tolerance of surface:2 mm tolerance in a distance of 2m.

1.3 SAMPLES

A. Prepare samples of 1Sq. M. of granolithic/ironite flooring for each the type pigment and texture for approval and reference.

1.4 MANUFACTURER LITERATURE

A. Submit manufacturer material literature, specifications and storage recommendations for various materials including hardeners, if required, and colour pigment.

B. Submit details of miscellaneous items used such as galvanized strips for embedding in the flooring thickness for expansion joints

1.5 SHOP DRAWINGS

A. Layout shall be as per approved drawing showing true locations of expansion joints, formation of panels and deciding method for executing the flooring, other construction details such as drains and slopes for the items of work.

1.6 MATERIALS

A. Before executing the work, all materials shall be checked for their suitability and fitness for use by the executing agency and a record for such assessment shall be maintained for the reference of Engineer. It shall be ensured that the excess materials shall not be taken out of proper storage space which might have to be returned in case the entire lot is not utilised, especially the ones which can get damaged in short exposures.

B. Material for preparation of appropriate mix shall be dumped in a suitable place to ensure avoidance of mixing of undesirable elements / materials.

PART 2 – WORKMANSHIP

2.1 MATERIAL MIXING

A. Cement concrete flooring of specified thickness and mix shall be laid as specified and generally conforming to specifications laid down for cement concrete flooring. The top surface shall be roughened with brushes while the concrete is still green and the form shall be kept projection up 12mm over the concrte surfaces, to receive the metallic hardening compound topping.

B. The Ironiteflooring shall consist of 52mm thick layer of mix 1:2 (1part of cement mixed with hardener: 2 parts of stone aggregate of 6 mm nominal size by volume). The metallic concrete hardener compound being mixed with cement in the ratio of 1:4 (1metallic concrete hardener: 4 cement used by weight) or as specified by the manufacture. Concrete hardener shall be dry mixed thoroughly with cement on a clean dry pucca platform. This dry mixture shall then mixed with stone aggregate 6mm nominal size or as otherwise specified in the ratio of 1:2 (1 cemennt mixed with hardener : 2 stone aggregate) by volume, and well turned over. Just enough water shall then be added to this dry mix as required for floor concrete, water cement ratio and exceeding 0.4.

C. A suitable hardener or the colour pigment may have to be added to the flooring concrete mix as desired by the Engineer.

2.2 BASE CONCRETE

A. Flooring shall be laid on base concrete. The base concrete shall be normally provided with the slopes required for the flooring. However, if the same is not provided in specific cases, then the same shall be adjusted in the granolithic/ironite flooring. Base concrete should be set properly and not loose and cured with sufficient water.

B. If the cement concrete flooring is to be laid directly on the RCC slab, the top surface of RCC slab shall be cleaned and the laitance shall be removed and a coat of cement slurry at 2 kg of cement spread over an area of one sqm so as to get a good bond between the base and concrete floor.

2.3 THICKNESS

The average thickness of floor shall be 35 mm and at no place it shall be less than 15 mm while adjusting the slopes of the flooring finish.

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2.4 LAYING

A. Panels:

Flooring of the specified thickness shall be laid in the pattern including the border / or as given in the drawings or as directed by the Engineer. The panels shall generally be of uniform size and no dimension of a panel shall exceed 2 M and the area of a panel shall not be more than 2 Sq. m.

B. Laying of flooring with strips:

Normally Ironite flooring shall be laid in one operation using glass/plain asbestos/aluminium/PVC/brass strips or any other strips as required as per drawing or instructions of the Engineer, at the junction of two panels. This method ensures uniformity in colour of all the panels and straightness at the junction of the panels. 4 mm thick glass strips or 5 mm thick plain asbestos sheet, 2mm PVC strips or 2 mm aluminium or brass strips shall be fixed with their tops at proper level, giving required slopes.

C. Concreting for Ironite flooring:

The mixture so obtained shall be laid in 52mm thickness on cement concrete floor within 1 to 4 hours of its laying.

D. Cement concrete shall be placed in the panels and levelled with the help of straight edge and trowel. The blows shall be fairly heavy in the beginning but as consolidation takes place, light rapid strokes shall be given. Beating shall cease as soon as the surface is found covered with a thin layer of cream of mortar. The evenness of the surface shall be tested with straight edge and made true to required slopes. While laying concrete, care shall he taken to see that the panel strips are not damaged/disturbed by the labourers. The tops of strips shall be visible clearly after finishing with cement slurry.

2.5 LAYING OF FLOORING WITH OUT STRIPS:

Laying of cement concrete flooring in alternate panels may be allowed by the Engineer in case strips are not to be provided using alternative method of shuttering.

A. Shuttering:

The panels shall be bounded by angle iron or flats. The angle iron/flat shall have the same depth as the concrete flooring. These shall be fixed in position, with their top at proper level giving required slopes. The surface of the angle iron or flats, to come in contact with concrete shall be smeared with soap solution or non sticking oil (Form oil or raw linseed oil) before concreting. The flooring shall butt against the un- plastered masonry wall.

B. Concreting:

The concreting of Ironite flooring shall be done in the manner described in the previous section above. The angle iron/flats used for shuttering, shall be removed on the next day of the laying of cement concrete. The ends thus exposed shall be repaired, if damaged with cement mortar 1:2 (1

cement: 2 coarse sand) and allowed to set for minimum period of 24 hours. The alternate panels shall then be cleaned of dust, mortar, droppings etc. and concrete laid. While lying concrete, care shall be taken to see that the edges of the previously laid panel's arc not damaged and fresh mortar is not splashed over them. The joints between the panels should come out as fine straight lines.

2.6 FINISHING AND POLISHING

Finishing:

A. The finishing of the surface shall follow immediately after the cessation of beating. The surface shall be left for some time; till moisture disappears from it or surplus water can be mopped up. Use of dry cement or cement and sand mixture sprinkled on the surface to stiffen the concrete or absorb excessive moisture shall not be permitted. Excessive trowelling shall be avoided.

B. Fresh cement shall be mixed with water to form thick slurry and spread at the rate of 2 kg of cement over an area of one square meter of flooring while the flooring concrete is still green. The cement slurry shall then be properly processed and finished smooth.

C. The junctions of floor with wall plaster dado or skirting shall be rounded off.

D. The men engaged on finishing operations shall be provided with raised wooden platform to sit on so as to prevent damage to new work.

2.7 2.07 CURING

The curing shall be done for a minimum period of ten days. Curing shall not be commenced until the top layer has hardened. Covering with empty gunnies shall be avoided as the colour of the flooring is likely to be bleached due to the remnants of cement dust from the bags. The quality of water shall be ensured to be free for minerals and solids which can damage the natural finishing surface.

3.2 PRECAUTIONS

A. Flooring in shall be laid only after fixing of other items such as drain cover frames and railing supports.

B. During cold weather, flooring shall not he done when the temperature falls below 4°C. The flooring concrete placed shall be protected against frost by suitable covering. Concrete damaged by frost shall be removed and work redone. During hot weather, precautions shall be taken to see that the temperature of wet concrete does not exceed 38°C. No flooring concrete shall be laid within half an hour of the closing time of the day, unless permitted by the Engineer. To facilitate rounding of junction of skirting, dado and floor, the skirting/dado shall be laid along with the border or adjacent panels of floor.

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KOTA STONE FLOORING

PART 1 – GENERAL

1.1 WORK INCLUDED

A. Delivery of Kota Stone slabs of approved size and quality, and complete installation of interior flooring as shown in drawings and in Room Schedules.

1.2 ALLOWABLE TOLERANCES

A. Slabs: As per relevant standards.

B. Execution: As described in the following sections.

1.3 SAMPLES

A. Submit four samples of each type and colour of Kota stone slab.

B. Submit one sample length 150 mm of each colour of proprietary coloured grout for joints.

1.4 MANUFACTURER / PRODUCTION DATA

A. Submit all relevant data concerning manufacturer / production, location of query, type of stone, available finishes, colour, sizes etc.

1.5 SHOP DRAWINGS

A. Layout shall be as per approved shop drawing showing patterns, joints, skirting, and sizes.

1.6 CERTIFICATES

A. Submit manufacturer's / suppliers certificates / record for quality of actual quality of stone. Supplier shall furnish proof that all tiles conform to same quality from the same quarry and from the same block.

1.7 DELIVERY, HANDLING AND STORAGE OF MATERIALS

A. Deliver materials in manufacturer's protective packaging. Material shall be inspected by the supplier before delivery to site as described later. Inspection report should accompany the delivery lot.

B. Handle and store as to avoid damages. Damaged materials shall be sorted out immediately be removed from site.

C. Store materials off the ground and under cover.

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PART 2 – MATERIALS

2.1 MATERIAL

A. Kota Stone Slabs

The slabs shall be of selected quality, hard, sound, dense and homogeneous in texture free from cracks, decay, weathering and flaws. They shall be hand or machine cut to the requisite thickness. They shall be of the colour indicated in the drawings or as instructed by the Engineer.

The slabs shall have the top (exposed) face polished before being brought to site, unless otherwise specified. The slabs shall conform to the size required. Before starting the work the contractor shall get the samples of slabs approved by the Engineer.

2.2 DRESSING

A. Every slab shall be cut to the required size and shape and fine chisel dressed on the sides to the full depth so that a straight edge laid along the side of the stone shall be in full contact with it. The sides (edges) shall be table rubbed with coarse sand or machine rubbed before paving. All angles and edges of the slabs shall be true, square and free from chippings and the surface shall be true and plane.

B. The thickness of the slab after it is dressed shall be 20 mm as specified in the description of the item. Tolerance of ± 2 mm shall be allowed for the thickness, In respect of length and breadth of slabs Tolerance of ± 5 mm for hand cut slabs and ± 2 mm for machine cut slabs shall be allowed

PART 3 – WORKMANSHIP

3.1 PREPARATION OF SURFACE

A. Mortar

This shall consist of uniform and smooth layer of plaster of 30 mm thickness and of mix 1:5 (1 cement: 5 coarse sand), finished with a floating coat of neat cement. In both plaster and floating coat the ratio specified in the description of item shall be adopted. The full quantity of dry mortar required of a room shall be prepared in one lot in order to ensure uniform colour, Wet mortar shall be prepared in the usual manner as and when required.

3.2 LAYING

A. Base concrete or the RCC slab on which the slabs are to be laid shall be cleaned, wetted and mopped. The bedding for the slabs shall be with cement mortar 1:5 (1 cement 5 coarse sand).

B. The average thickness of the bedding mortar under the slab shall be 30 mm and the thickness at any place under the slab shall be not less than 12 mm.

C. The slabs shall be laid in the following manner:

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Mortar of the specified mix shall be spread under the area of each slab, roughly to the average thickness specified in the item. The slab shall be washed clean be fore laying. It shall be laid on top, pressed, tapped with wooden mallet arid brought to level with the adjoining slabs. It shall be lifted and laid aside. The top surface of the mortar shall then be corrected by adding fresh mortar at hollows. The mortar is allowed to harden a bit and cement slurry of honey like consistency shall be spread over the same at the rate of 4.4 kg of cement per sqm. The edges of the slab already laid shall be buttered with cement with or without admixture of pigment to match the shade of the stone slabs.

The slab to be paved shall then be lowered gently back in position and tapped with wooden mallet till it is properly bedded in level with and close to the adjoining slabs with as fine a joint as possible. Sub sequent slabs shall be laid in the same manner. After each slab has been laid, surplus cement on the surface of the slabs shall be cleaned off. The flooring shall be cured for a minimum period of seven days. The surface of the flooring as laid shall be true to levels, and, slopes as instructed by the Engineer.

Due care shall be taken to match the grains of slabs which shall be selected judiciously having uniform pattern of Veins / streaks or as directed by the Engineer.

3.3 POLISHING AND FINISHING

A. The day after the Kota stone tiles are laid all joints shall be cleaned of the grey cement grout with a wire brush or trowel to a depth of 5 mm and all dust and loose mortar removed and cleaned. Joints shall than be grouted with cement mixed with matching pigment.

B. The floor shall then be kept wet for a minimum period of 7 days. The surface shall thereafter be grounded evenly with machine fitted with coarse grade grit block (No. 60). Water shall be used profusely during grinding. After grinding the surface shall be thoroughly washed to remove all grinding mud, cleaned and mopped. The surface shall be covered with cement slurry to fill in grout in joints that might have fallen off again cured. The second grinding shall then be carried out with machine fitted with fine grade grit block (No 120).

C. The final grinding with machine fitted with the finest grade grit blocks (No.320) shall be carried out the day after the second grinding described in the preceding para or before handing over the floor, ordered by the Engineer.

D. For small areas or where circumstances so require, hand grinding may be permitted. For hand grinding the following carborundum stones, shall be used:

1st grinding - coarse grade stone (No. 60)

Second grinding - medium grade (No 80)

Final grinding - fine grade (No 120)

In all other respects, the process shall be similar as for machine polishing.

E. After the final polish, oxalic acid shall be dusted over the surface at the rate of 33 gm per square meter sprinkled with water and rubbed hard with a namdah' block (pad of woollen rags).. The following day the floor shall be wiped with a moist rag and dried with a soft cloth and finished clean.

F. If any stone slab is disturbed or damaged it shall be refitted or replaced, properly jointed and polished.

After curing, the surface shall be washed and finished clean. The finished work shall not sound hollow when tapped with a wooden mallet.

3.4 INSPECTION

A. Verify that the works of the preceding trades are completed and that surfaces to receive tiles are in satisfactory condition.

3.5 EXECUTION – GENERAL PRECAUTIONS

A. Cut and fit Stone slabs accurately.
B. Execute joints straight, true and even.
C. Align joints in floor and wall, when slabs are of equal size.
D. Execute 5mm. wide expansion joints at frames in openings at fixed equipment and internal angles between walls, ceiling and floor.
E. Do not grout until 24 hours after tiling.
F. Adhesive mortar may be used, subject to approval

3.6 CLEANING

A. Thoroughly clean with water to remove face dirt.

B. To remove adherent face dirt, thoroughly clean with neutral sulphate-free detergent and then thoroughly rinse off with clean water. Soda, soda-ash, alkaline or sulphate containing agents or scouring powder shall be used.

PRE-POLISHED GRANITE TILES FOR WALLS AND DADO

PART 1 – GENERAL

1.1 WORK INCLUDED

A. Granite tiles (pre-polished) as specified on drawings and in Room Schedules

1.2 ALLOWABLE TOLERANCES

A. Tiles: As per relevant standards.
B. Execution: As described in the following sections

1.3 SAMPLES

A. Submit four samples of each type and colour of Granite tiles (pre-polished).
B. Submit one sample length 150 mm., of each colour of proprietary coloured grout for joints.

1.4 MANUFACTURER LITERATURE

A. Submit manufacturer/supplier's material specifications, colour schedules and packing type

1.5 SHOP DRAWINGS

A. Layout shall be as per approved drawings showing true locations of items of works of other trades and also expansion joints

PART 2 – MATERIALS

2.1 MATERIAL

A. The granite (pre-polished) tiles shall be of approved shade and type from one stone block to ensure basic color and grain characteristic consistency. The tiles shall be sound, true to shape, flat and generally free from quarrying flaws and other processing and transportation defects affecting their utility.

The top surface of the tiles shall be polished. The underside of the tiles shall not have polish. The tiles shall be diamond cut, true in size on all four sides.

2.2 DIMENSIONS AND TOLERANCES

A. Granite tiles (pre-polished) shall be made in sizes of 600 mm x 300 mm x 10 mm and shall be straight edge, diamond cut. The sizes of tiles shall be consistent in dimension on all four edges.

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B. Tolerances

Facial Dimensions: The length of all the four sides of the tile shall be measured to the nearest 0.1mm. The average value of length/breadth shall not vary more than + or - 0.8mm. from the above specified dimension. The variation of the individual dimensions from average value of length/breadth shall not exceed + or - 0.5mm. Tolerances on thickness shall be + or - 0.4mm.

Check for Sqaureness: Any variation from a right angle in the angle contained by any two adjoining sides shall be limited so that if a builder's steel square is placed against the angle, the distance between the inner edge of the square and the adjacent side of the tile or fitting shall not be more than 0.5mm. per 100mm. run.

PART 3 – WORKMANSHIP

3.1 PREPARATION OF SURFACE

A. The joints shall be raked out to a depth of at least 15mm. in masonry walls. In concrete walls, the surface shall be hacked and roughened with wire brushes. The surface shall be cleaned thoroughly, washed with water and kept wet before the tile work is commenced.

3.2 LAYING

A. 12mm. thick plaster of cement mortar 1:3 (1 cement and 3 coarse sand) mix or as specified shall be applied and allowed to harden. The plaster shall be roughened with the wire brushes or by scratching diagonal at closed intervals. The tiles shall be applied a cement slurry liberally at the back and set in backing mortar. The tiles shall be tamped and corrected to proper plane and lines. The tiles shall be set in the required pattern and jointed. The joints shall be as fine as possible. Tiles on the walls shall rest on the top of flooring. Where full size tile can not be fixed, these shall be cut to the required size and their edges rubbed smooth.

3.3 CURING AND FINISHING

A. The joints shall be cleaned off the grey cement grout with wire/coir brush or trowel to a depth of 2mm. to 3mm. and all dust and loose mortar removed. Joints shall then be flush pointed with white cement added with pigments if required to match the colour of tiles. The surface shall be washed and finished clean. The finished work shall not sound hollow when tapped with a wooden mallet.

3.4 INSPECTION

A. Verify that surfaces to receive wall tiling, are free of dust, loose particles, oil and other foreign

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matter which would adversely affect bonds of mortar layer.

B. Examine construction, grounds, and accessories to ensure that finished tiled surfaces will be true to line and required pattern.

C. Verify that concrete surfaces are prepared in a manner to provide bond for mortar layer.

D. Ensure that all works by other trades, affecting wall tiling are correct located, sized and completed.

3.5 EXECUTION – GENERAL PRECAUTIONS

A. Cut and fit tiles accurately around equipment, electrical outlets, pipes etc., and overlap all cuts with plates or collers.

B. Execute joints straight, true and even.

C. Align joints in floor and wall, when tiles are of equal size.

D. Execute 5mm. wide expansion joints at frames in openings at fixed equipment and internal angles between walls, ceiling and floor.

E. Do not grout until 24 hours after tiling.

F. Adhesive mortar may be used, subject to approval.

3.6 CLEANING

A. Clean surfaces from grout wash and rinse tile work thoroughly with clean water after using chemical cleaning agents.

ACID-PROOF TILES

1) The acid-proof tiling shall be placed in the battery rooms

2) The execution of acid-proof tiling shall consist of a chemical-resistant and liquid-tight base insulation, the material depending on the kind of chemical aggressiveness, i.e. either ceramic tile in case of acid or carbon tiles in case of alkalis. The same applies to the mortar materials.

3) The required chemical resistance and liquid-proof insulation shall be achieved by acid-proof ceramic tiles of 20 mm thickness - split tile grade I unglazed grey- white - embedded and jointed with synthetic resin cement, based on unsaturated polyester, resistant to the specified media.

EPOXY FLOORING

PART 1 – GENERAL

1.1 SCOPE OF WORK

A. The scope of work shall include providing and laying 4mm thick high density epoxy based heavy duty industrial screen flooring and topped with 1mm thick of self levelling compound to achieve total thickness of +5mm. This system will make a smooth surface and will be used to take load movements. The floor should also offer resistance to absorb water, oil, and industrial chemicals etc and should be very easy to clean the surface.

Epoxy Flooring shall be provided as specified on drawings and Room Schedules.

1.2 ALLOWABLE TOLERANCES

A. Planer tolerance of surface: 2 mm tolerance in a distance of 2m.

1.3 SAMPLES

A. The contractor shall prepare samples of 1Sqm. of Epoxy flooring for approval and reference at a location approve by Engineer.

1.4 MANUFACTURER LITERATURE

A. Within 21 days of completion of the floor concreting the contractor shall submit manufacturer material literature, specifications and storage recommendations for various materials including colour pigment if required.

B. Submit details of miscellaneous items used such as galvanized strips for embedding in the flooring thickness for expansion joints.

1.5 SHOP DRAWINGS

A. Layout shall be as per approved drawing showing true locations of expansion joints, formation of panels and deciding method for executing the flooring, other construction details such as drains and slopes for the items of work.

PART 2 - MATERIALS

A. Before executing the work, all materials shall be checked for their suitability and fitness for use by the executing agency and a record for such assessment shall be maintained for the reference of Engineer. It shall be ensured that the excess materials shall not be taken out of proper storage space which might have to be returned in case the entire lot is not utilised, especially the ones which can get damaged in

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short exposures.

B. Material for preparation of appropriate mix shall be dumped in a suitable place to ensure avoidance of mixing of undesirable elements / materials.

PART 3 – WORKMANSHIP

3.1

A. Epoxy flooring shall consists of prime coat, screed coat and topping coat.

Primary coating: The primary coat is a two component full solids coating with excellent bonding on to concrete surface. The application is by lambskin short pile roller / screeder at a spreading rate of 0.25 to 0.75 kgs per square meter. Total built-up thickness should be 200 micron. Primary coat is allowed to get track free before application of heavy duty industrial screed.

Screed coating: Base lining is done with a three component solvent free epoxy urethane urea screed to fill the post holes /dents on the base floor and level the undulation / pot holes of the base floor. The spreading rate for this is to be determined by the extent of levelling required for the base floor and thickness that is proposed to build up. The built up thickness of this screed floor shall be around 3000microns. The screed is kept for curing upto 4 to5 hours to get workable strength for next procedure. An intermediate coat (Base coat) is to be applied to avoid any pinholes, waviness etc.

Top finish coat: Two component epoxy urethane urea coating which is applied by lambs wool roller / roller notched trowel. Total built up thickness shall be around 2000microns. Dust & dirt has to be removed from the surface before starting the top coat.

B. A suitable colour pigment may have to be added to the flooring mix as desired by the Engineer.

3.2 BASE CONCRETE

A. Flooring shall be laid on base concrete. The base concrete shall be normally provided with the slopes required for the flooring. Base concrete should be allowed to set properly and cured with sufficient water.

The floor shall be laid on bone dry surface for which suitable heaters/burners shall be necessarily required.

B. If the cement concrete flooring is to be laid directly on the RCC slab, the top surface of RCC slab shall be cleaned properly as described here below.

3.3 THICKNESS

The minimum thickness of floor shall be 5 mm.

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3.4 LAYING

Acidic water is to be used to clean the floor. By means of scrubber (machine or manual) and washing with sufficient water, all oil, grease & foreign particles are to be cleaned properly from the surface.

Cleaning of the soaked oil : to get good bonding of the epoxy floor & durability it is essential to check the presence of oil (if any) inside the floor. Burning procedure may also be carried out(if required)to remove the oil till the floor become bright white.

Filling of the pot holes / cracks: The pot holes and expansion joints (if any) are to be filled with the suitable material. The pot holes are to be filled & levelled with pot filling compound. Similarly, the cracks & expansion joints have to be filled with crack seal compound which is having the expansion & compression properties as per the surrounding temperature. The areas around openings shall be so worked that neither protrusions nor gaps remain visible.

Self levelling compound: After final coating, it should be kept for 24 hours for functional cure. Self-levelling compound can be applied if required. to make the surface smooth and level.

3.5 PRECAUTIONS

A. Flooring shall be laid only after fixing of other items such as drain cover frames and railing supports.

B. During cold weather, flooring shall not he done when the temperature falls below 4°C. The flooring concrete placed shall be protected against frost by suitable covering. Concrete damaged by frost shall be removed and work redone. During hot weather, precautions shall be taken to see that the temperature of wet concrete does not exceed 38°C. No flooring concrete shall be laid within half an hour of the closing time of the day, unless permitted by the Engineer. To facilitate rounding of junction of skirting, dado and floor, the skirting/dado shall be laid along with the border or adjacent panels of floor.

ANNEXURE-III

EXECUTION PROCESS OF FALSE CEILING

FALSE CEILING (DEMOUNTABLE)

PART 1 – GENERAL

1.1 WORK INCLUDED

A. Delivery of materials and installation of suspension system components, hangers and fastening devices.

B. Delivery of materials and installation of ceiling tiles and panels.

C. Delivery and installation of sound absorbent materials.

1.2 SAMPLES

A. Submit one sample of each type of finish and colour of ceiling tiles and panels, suspension system components and insulation pads for reference.

1.3 MANUFACTURER LITERATURE

A. Submit manufacturer's certificates and material specifications as well as written instructions for storage and installation.

1.4 SHOP DRAWINGS

A. Submit shop drawings showing details and reflected ceiling plans of suspension and wall support systems. Show location of ceiling units and items of other trades, that are to be coordinated with the finished ceiling and show framing and support details integrating for such items.

1.5 STORAGE OF MATERIALS

A. Store materials indoor in original protective packaging with manufacturer's labels and tags intact.

1.6 ENVIRONMENTAL REQUIREMENTS

A. Do not install suspended ceilings until building is enclosed, dust generating activities are terminated and overhead mechanical / electrical works are completed, tested and approved.

PART 2 – GENERAL

2.1 MATERIALS

A. All proprietary materials for a particular system shall be supplied by the same manufacturer.

B. Delivery of materials and installation of ceiling tiles and panels.

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C. Tiles and panels shall be de-mountable without requiring use of tools

D. Design suspension and support system to carry the loads of the complete suspended false ceiling. The suspension system shall be independently supported as far as possible and supports from other plenum works shall be avoided. However, it shall be ensured that the suspension system for the false ceiling shall not support any other work.

E. Design suspension hangers to allow adjustment of span up to 100 mm.

F. Ceiling types shall be as approved and mentioned in the room schedules.

PART 3 – WORKMANSHIP

3.1 INSPECTION

A. Verify that all works of preceding trades, such as electrical, civil and fire fighting systems, affecting work under this section, are finalized.

3.2 EXECUTION

A. Install proprietary ceiling system in accordance with manufacturer's recommendations to produce finished ceiling true to lines and levels and free from warped, soiled or damaged grid or lay in panels / tiles.

B. Install ceiling system in a manner capable of supporting all superimposed loads, with maximum permissible deflection of 1 in 500 of span and maximum surface deviation of 1 in 1000.

C. Install after major above-ceiling works are completed.

D. Co-ordinate the location of hangers with other works and ensures that hangers and carrying channels are located to accommodate fittings and units of equipment which are to be placed after the installation of ceiling grid systems.

E. Where ducts or other equipment prevent the regular spacing of hangers, reinforce the nearest adjacent hangers and related carry ing channels as required to span the actual distance.

F. Centre ceiling system on room axis leaving equal border pieces.

G. Do not support fixtures from or on main runners or cross runners if weight of the fixture causes the total dead load to exceed the deflection capability. In such cases, support fixture by supplementary hangers located within each corner, or supports the fixtures independently.

H. Do not install fixtures so that main runners and cross runners will be eccentrically loaded.

I. Where fixture installation would produce rotation of runners, provide stabilizer bars.

J. Install edge moulding at intersections of ceiling and vertical surface using maximum lengths, true to line and level and mitre corners. Similarly install edge moulding at junctions with other ceiling finishes. Where bull nose concrete block corners occur, provide preformed closers to match edge moulding.

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K. Install panels in position to ensure that they fit in the right place easily and are not unduly loose.

3.3 FINAL CLEANING

A. Final cleaning shall be carried out using cleaner of type specified by ceiling manufacturer.

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ANNEXURE-IV

EXECUTION PROCESS OF uPVC DOORS AND WINDOWS

uPVC DOORS AND WINDOWS

PART 1 – GENERAL

1.1 WORK INCLUDED

A. Delivery and installation of doors and windows complete with glass, hardware and fittings, according to drawings and room schedules.

1.02 INSTALLER'S QUALIFICATIONS

A. The entire uPVC doors and windows shall be furnished and installed with complete responsibility as stated in this section.

B. Installer shall have the requisite expertise and resources to carry out work to the satisfaction of the Engineer.

C. Installer shall be responsible to ensure compatibility of various sections and other materials used in the product.

D. Installer shall coordinate with other agencies to ensure that the floor and wall finishing is carried out in proper sequence. Reworking on the wall and floor finishing shall not be permitted.

E. Installer shall familiarise himself / herself with the type of floor and wall finishing used and then according proceed with the work to ensure that the final product is in proper level and position in the opening. In case any door and wall trims used in the openings, the fixing method shall be suitably adjusted.

1.03 REFERENCE STANDARDS

Standards	Name of Standard
IS: 6057	Hard anodic coatings on aluminium and aluminium alloys
IS: 1868	Anodic coatings on aluminium and alloys
IS: 7088	Recommended practice for anodizing of aluminium alloys

All other relevant IS standards for uPVC

1.04 ALLOWABLE TOLERANCES

A. Flatness tolerance

Measuring at points between the face of the door / window unit and a straightedge laid diagonally from corner to corner, the frame surface shall not vary more than + or - 1.5 mm. Both diagonals shall be checked on both sides.

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1.5 SUBMITTALS

A. Submit manufacturer's descriptive literature, installation, handling, storage of raw material as well as finished product and maintenance instructions for each type of door and window.

1.6 SHOP DRAWINGS

A. Submit drawings as required, showing illustrations and schedule of door, windows and accessories and preparation for installing hardware.

B. Submit details of the fabrication, use of angles etc for internal support, extruded section details, the information about the weather stripping as to be used, glass type, laminate particle board (as approved) in the final product.

1.7 SAMPLES

A. Submit one sample door and windows set for approval complete with all the hardware and panel material (glass and laminated particle board) for reference.

B. Approved samples shall remain as part of the work.

C. Submit manufacturer's literature for hardware, door springs and other items used as accessories for future reference.

1.8 CERTIFICATES

A. Submit manufacturer's test certificates in doors and windows for material quality, anodizing and hardware, including catalogues.

1.9 MATERIALS HANDLING

A. Deliver, store and handle uPVC framing items in manner to prevent any damage and deterioration.

B. Provide packaging such as cardboard containers, separators, banding and wrappings to protect finish of uPVC items.

C. Follow the storage and handling requirements of assembled units manufacturer for site handling with the following instructions not limiting those of the manufacturer:

1. Store materials in a protected dry interior area, at least 25 mm. off the floor and with a minimum distance of 10 mm. between individual units.
2. Store open-able units upright, i.e. with threshold or bottom member downwards.
3. Mark all uPVC units with chalk or similar removable material using same reference number as in supply documents.

1.10 DISSIMILAR MATERIALS

A. Where uPVC abuts into adjacent dissimilar materials, the juncture shall be executed in a manner that will prevent electrolysis between the two materials as recommended by the manufacturer.

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PART 2 – PRODUCTS

2.1 GENERAL

A. Tools for maintenance

1. Supply a complete set of tools required for adjustment and maintenance.

2.2 uPVC DOORS AND WINDOWS

A. Built up of manufacturer standard profiles, material thickness minimum 2 mm.

B. Anodization layer shall be 20 microns.

C. Profiles shall be suitably connected by means of heavy angle or in standard detail of manufacturer.

D. Vertical and horizontal members shall be positively fastened to form hairline joints with surfaces flush at intersections.

E. Glazing profiles shall be removable.

F. Bottom profiles for uPVC doors, windows and partitions shall be furnished with weep holes.

G. Screws and bolts shall be stainless steel.

H. Install reinforcement for door closers where ever required.

I. Install weather seal which is permanently elastic, non–shrinking and weatherproof.

J. Install hardware indicated as per approved sample. Locks shall facilitate master- key arrangement as specified separately.

K. Install glass type according to the drawings.

2.3 QUALITY

A. Resistance to air infiltration shall be in accordance with ASTM E282.

B. Resistance to water infiltration shall be in accordance with ASTM 5331.

C. Maximum deflection of any member under uniform loading shall not exceed 1/175 of its span and when the load is removed there shall be no evidence of any permanent deformation or damage to any member under a load of 10 0kg/sq
.m.

D. External units shall be dimensioned to take a wind load of 100 kg/sq.m.

PART 3 – EXECUTION

3.1 INSTALLATION

A. Door and window units shall be installed in the respective locations as shown in the drawings

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and room schedules.

B. Door and window units shall be fixed in plumb against walls with the suitable number of fasteners to ensure adequate rigidity.

C. Door springs in the flooring shall be embedded to ensure that the top cover plate matches with the floor finish after completion of the job.

D. Before fabricating the final product, the installer shall verify the opening sizes and accordingly proceed.

E. Fabrication of allied works, such as glass cutting and cutting of laminated boards in the required sizes, shall be carried out as per standard instructions of the material manufacturer. Proper tools and the expertise shall be available with the agency and the Engineer shall be satisfied in this respect.

3.2 CLEANING

A. Remove protective materials and clean with plain water or water with soap or household type detergent.

3.3 ADJUSTMENTS

A. Adjust and lubricate movable parts.

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ANNEXURE-V

EXECUTION DETAIL OF CARPENTRY AND JOINERY

CABINET WORK

PART 1 – GENERAL

1.1 WORK INCLUDED

A. Fabrication, delivery and installation of cabinets for pantry, workshops and offices according to room schedules and drawings.

B. The work shall include supply of raw material, complete fabrication of individual units and installation in the right locations as shown in the drawings.

1.2 ALLOWABLE TOLERANCES

A. Length, height and width dimensions: +0, -3 mm.

1.3 DRAWINGS

A. Work shall be carried out according to approved drawings, showing arrangement of cabinets, construction details, sizes of units, sections, thicknesses of materials, and method of structure support.

1.4 SAMPLES

A. Submit one complete floor and overhead wall unit complete with installation instructions for approval with sample of finishing quality.

PART 2 – MATERIALS

2.1 MATERIALS

A. As specified in the shop drawings.

B. Floor and wall units:

1. Facing and backing of high pressure laminate boards with hardboard edge upping in colour as specified.
2. Frameworks of wood sections and/or block board as shown in drawing.
3. All units with back panels of hardboard, painted white.

C. Infill panels of the same materials and finishes as specified for units.

PART 3 – WORKMANSHIP

3.1 WOOD FITMENTS AND METAL HARDWARE

A. As per approved samples

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3.2 ERECTION

A. Verify measurements on site prior to shop manufacturing, especially hot and cold water supply water points, location of waste pipe, wall tile & cabinet heights and other necessary works

B. Erect all items square, level, plumb and free from distortion or defects detrimental to appearance and performance.

C. Provide all necessary fixings to connect items to structure.

D. Ensure alignment with adjacent construction and co ordinate with related work to ensure that no interruption occurs to installation.

E. Use concealed bolts and screws whenever possible.

F. After erection, touch—up damages to painted surfaces both on structure and items.

G. Joints of cabinet top, wall tile cabinet and sink shall be filled with sealant.

H. The work shall be coordinated with the other agencies such as installation of plumbing pipes and fixtures, fixing of granite on the work tops etc.

3.3 SCHEDULE OF CABINET UNITS

The detailed schedule of cabinets shall be provided separately showing the location and the broad dimensions

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ANNEXURE –VI

SANITARY FITTINGS

TOILET AND BATH ACCESSORIES

PART 1 – GENERAL

1.1 WORK INCLUDED

A. Deliver and install toilet and bath accessories as herein and as shown in the Room Schedules and on the drawings.

1.2 QUALITY ASSURANCE

A. Propose manufacturers with purpose that accessories shall be products of the same manufacturer for each type of accessory unit.

1.3 SAMPLES

A. Provide one sample complete with fixing device, of each accessory specified in the following sections.

1.4 MATERIALS DATA

A. Submit manufacturer's relevant data in original printing including warrantees and technical data.

1.5 MATERIALS DATA

A. Submit manufacturer's certificate for specified quality.

B. Submit manufacturer's test report / certificate for specified finish layers.

1.6 DELIVERY - STORAGE AND HANDLING OF MATERIALS

A. Deliver accessories in manufacturer original packing.

Accessories shall be packed in a Manner to protect each individual item and its finish.

B. Store materials indoor.

C. Handle materials as to avoid damage.

PART 2 – MATERIALS

2.1 BRASS ITEMS

A. Manufacturer's standard materials to be checked.

B. Accessories: Fasteners, screws and bolts of brass finished to match the fitting. Expansion shields, fibre, lead or rubber as recommended by accessory manufacture for component and substrate.

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C. Finish: Chrome plated satin finish or other as per approved sample.

2.2 SCHEDULE OF ACCESSORIES

1. Toilet roll holder, C.P. (chromium plated) brass or vitreous china as per colour scheme.
2. Holder for spare rolls, C.P. brass or vitreous china as per colour scheme.
3. Soap dispenser, volume minimum 0.5 litres, concealed fixing, C.P. brass or decorative plastic as per colour scheme.
4. Soap dish with drainage, C.P. brass or vitreous china as per colour scheme.
5. Toilet brush, handle and wall mounted support, stainless steel, mild steel with plastic coating of approved design.
6. Paper towel dispenser for lose towels, carbon steel, baked enamel finish, concealed fixing, made-to-order or Manufacturer's standard.
7. Waste basket, wall model, 450*400*300 mm., plastic coated steel mesh.
8. Dispenser for plastic cups, made-to-order or Manufacture's standard.
9. Bevelled edge mirror of approved quality complete with 6 mm. thick asbestos cement sheet ground fixed to wooden cleats with C.P. brass screws and washers:
   i) Size 600*450 mm. with g shelf with edges rounded off supported on uPVC/anodised aluminium angle frame with C.P. brass brackets and guard rail complete fixed to wooden cleats with C.P. brass screws and washers in toilets and ditto without shelf, in ante-room to showers;
   ii) Size 1200*450 mm. n dressing room.
10. Shower rail, C.P. brass tubing, complete with reinforced PVC curtain and curtain fixings as per approved design.
11. Coat hooks, chromium plated brass as per design requirements.
12. C.P. brass towel rail, complete with two C.P brass brackets fixed to wooden cleats with C.P. brass screws size 600*20 mm. or Manufacturer's standard.

PART 3 – WORKMANSHIP

3.1 INSPECTION

A. Verify that works of preceding trades affecting installation are completed.

B. Before commence of work notify the client in writing of any conflicts detrimental to installation or operation of units.

C. Verify with the client, exact location of accessories.

3.2 PREPARATION

Deliver inserts and rough—in frames to the site at appropriate time for building - i and provide templates and rough-in measurements as required.

3.3 EXECUTION

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A. Install fixtures, accessories and items in accordance with the manufacturer' printed instructions

B. Install true, plumb and level, securely and rigidly anchored to substrate

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16. MISCELLANEOUS AND ANCILLARY WORKS

16.1. SCOPE OF WORK

1) The work under this section includes all labour, materials and equipment, and performing all operations required for the execution of miscellaneous or complementary works described herein.

2) This section covers the following items:

a) Fencing and gates,
b) Concrete pipes,
c) PVC pipes
d) Geotextile

3) The extent, type and dimensions of the miscellaneous and ancillary works are shown on the Drawings or shall be as required by the Engineer.

16.2. FENCING AND GATES

1) The Contractor shall supply and install chain link fences and gates at the locations and to the dimensions as shown on the Construction Drawings or as directed by the Engineer. They shall be constructed according to approved Contractor's shop drawings showing details of all fencing components, fittings, materials, accessories and construction.

2) Fencing shall be manufactured by a reputable company regularly engaged in the manufacture of chain link fencing, to be approved by the Engineer.

3) Zinc coated steel wire fence material shall meet the requirements of IS:2721. Chain link fabric shall be 4 mm steel wire woven in a 50 mm mesh and hot-dip galvanised after weaving.

4) Posts, top and brace elements, and gate frames shall be of hot-dip galvanised standard weight seamless steel pipes conforming to IS: 4736 and shall have following minimum outside diameters:

a) Intermediate posts: 50 mm
b) Top and brace: 40 mm
c) Corner and pull posts: 75 mm
d) Gate posts: 100 mm
e) Gate frames/brace: 60/32 mm

5) Intermediate posts shall be placed every 2.5 to 3 m. Pull posts shall be executed every 15 m. Every post shall be equipped with pipe head covering and fastenings for wire tensioning. Posts shall be set plumb and in alignment.

6) Chain link fabric for gates shall be as specified for fences. Each gate leaf shall be equipped with one pair of heavy hinges that will allow a full gate opening between gate posts. The hinges shall be designed to not twist or turn under gate action and shall allow the gate to swing a full 180 degrees. Hinges shall be of hot-dip galvanised ductile iron or malleable iron.

7) Gates shall be equipped with a heavy latching device and cylinder door lock. Locking bars to secure gates in open and closed position shall be provided. Double wing gates shall be provided with one safety stop fixing the wing in its closed position by means of a vertical shaft. The locks and other rotating materials shall be brass or bronze.

8) Barbed wire on the top of the fence shall be 3-strand 4-point wire, tack-welded to extension arms at the top of each post.

9) Posts shall be set concrete M15/40 compacted so that no movement will occur after installation of the fence. Posts shall be set in blockouts and grouted. The blockouts shall be protected from standing water and freezing.

10) Curb stone laid in concrete M15/40 shall be provided along the whole length of the fencing.

16.3. CONCRETE PIPES

1) The Contractor shall supply and install prefabricated concrete pipes, either full section or perforated, at the locations and of diameters as shown on the Construction Drawings or as directed by the Engineer.

2) The following types of concrete pipes are envisaged to be installed in the Works:

a) Type 1: Concrete pipe fully embedded in concrete
b) Type 2: Drain pipe on concrete / sand base

3) The Contractor shall furnish concrete pipes of the best possible quality to be found on the local market and shall be PN-3 Reinforced concrete (medium duty) conforming to IS 4589. The sand bedding shall comply with the requirements for fine aggregates stipulated in the Section "Concrete". The drainage layer shall consist of crushed rock or gravel of minimum diameter 35 mm. The concrete for the base or embedding shall be M15/40 or M20/40.

4) The pipeline shall be aligned to the slope and direction shown on the Construction Drawings or as directed by the Engineer. The joints between pipes shall be sealed with cement mortar and cleaned immediately after matching of the pipes.

5) After installation of the perforated drain pipes, filter and drainage layers shall be placed and tamped around the pipe with all care as not to displace them, especially in the case of sand bedding.

6) All laid pipe systems shall be tested after the trenches have been backfilled by pulling or flushing a ball 2 cm smaller than the pipe diameter through each segment of the system.

16.4. PVC PIPES

1) PVC Pipes of various sizes may be required for various application.

2) PVC Pipes used shall conform to IS: 4985 (Unplasticised PVC pipes for potable water supplies). PVC Pipes used shall be Class 4 i.e. working pressure 8 kg/cm^2 as per Table 5 of IS 4985

3) The pipes may be required to be embedded in Concrete, embankment or any other material.

4) Half round PVC pipes shall be required for draining the rock contact in the walls or foundation as shown on the Construction Drawings or as directed by the Engineer. The pipes may be required to be filled with graded filter. The joints of the pipes shall be effectively sealed with 1:3 cement sand mortar to prevent any slurry from entering in these pipes shall be connected to a main header for guiding the seepage water to sumps.

16.5. CONCRETE CABLE CHANNELS

(1) The Contractor shall supply and install the concrete cable channels (cable ducts) where shown on the “Drawing(s)” or where directed by the Engineer. They will principally be used for electrical inter-connections between various locations, but may be used for other purposes as well.

(2) The channels shall be composed of precast or cast in-situ concrete elements manufactured either at Site or by an established manufacturer of similar items. They shall include all necessary special parts such as covers, lifting hooks (precast), angles, bends, and blockouts for the passage of the cables.

(3) Channels shall be manufactured of a concrete class M25/20 and shall be sufficiently reinforced to prevent shrinkage cracks, transport caused stresses, and traffic loads where relevant. The elements shall be provided with groove and tongue for fitting and connecting.

(4) Channels shall be laid and adjusted on a layer of fine sand with an average thickness of 60 mm.

16.6. STONE WARE GLAZED PIPES (SWG)

(1) The Contractor shall supply and install SWG pipes at the locations and of diameters as shown on the Construction Drawings or as directed by the Engineer.

(2) The following types of burnt clay pipes are envisaged to be installed in the Works:

(a) Type A: SWG pipe on sand base

(b) Type B: SWG pipe fully embedded in concrete

(3) The Contractor shall furnish clay pipes of the best possible quality to be found on the local market. The pipe joints shall be bell fitting. The inner and outer surfaces shall be glazed (vitrified). All branch pieces, elbows, bends, and reduction pieces shall be factory made of the same quality as the straight pipes. No cutting of the branch pieces on the site will be permitted.

(4) The sand bedding shall comply with the requirements for fine aggregates stipulated in the Section "Concrete". The concrete for the base or embedding shall be M15/A40 or M20/A40.

(5) The pipeline shall be aligned to the slope and direction shown on the Construction Drawings or as directed by the Engineer. The joints between pipes shall be sealed with bituminous hemp rope strongly rammed into the joint and covered with cement mortar.

(6) After installation of the SWG pipes, backfill layers shall be placed and tamped around the pipe with all care as not to displace them, especially in the case of sand bedding.

(7) Half round stone ware pipes shall be required for draining the rock contact in the walls or foundation as shown on the construction drawings or as directed by Engineer. The pipes may be required to be filled with graded filter. The joints of the pipes shall be effectively sealed with 1:3 cement sand mortar to prevent any slurry from entering in these pipes shall be connected to a main header for guiding the seepage water to sumps.

16.7. WEEP HOLES

(1) The Contractor shall install weep holes at the locations as shown on the Construction Drawings or as directed by the Engineer.

(2) The pipes for the weep holes shall be of PVC and not less than 50 mm inside diameter conforming to IS: 12231 (UPVC pipes for use in suction and delivery lines of agricultural pumps). They shall be perforated at one end and capped or plugged.

(3) The perforated end shall be surrounded by layer of coarse aggregates of minimum diameter 12 mm, which in turn shall be surrounded by layer of sand to form a filter surrounds. The gradation of the sand and gravel shall be as follows:

Square mesh sieve opening in (mm)	Percentage of sand passing by weight	Percentage of gravel passing by weight
38	-	100
19	-	65-80
9.5	-	40-60
4.75	95-100	20-40
2.36	75-95	10-25
1.18	55-85	0-5
0.60	30-60	-
0.30	15-25	-
0.10	3-7	-
0.075	0-3	-

(4) The pipes shall be secured in position so that they will not be displaced during placement of concrete in the walls. The filter and drainage surrounds shall be constructed on compacted backfill and then the backfill material shall be placed over the filter with care as not to disturb the filter.

16.8. GEOTEXTILE

1) The Geotextile shall be woven conforming to the requirements of Type 1, Specifications for Road and Bridge Works, Ministry of Road Transport & Highways, Govt. of India/AASHTO M288 Class 1.

2) The Geotextile shall be free of defects and any chemical treatment or coating that significantly reduces its porosity. The fibres shall contain stabilizers and/or inhibitors to enhance resistance to ultraviolet light.

3) Before use, the geotextile shall be stored in a clean, dry location out of direct sunlight, not subject to extremes of either hot or cold temperatures, and with the manufacturer's protective cover undisturbed. Receiving, storage, and handling at the job site shall be in accordance with the requirements listed in ASTM D 4873.

4) The surface on which the geotextile is to be placed shall be graded to the neat lines and grades as shown on the drawings. It shall be reasonably smooth and free of loose rock and clods, holes, depressions, projections, muddy conditions, and standing or flowing water (unless otherwise specified in drawings).

5) The geotextile shall be placed on the approved prepared surface at the locations and in accordance with the details shown on the drawings. It shall be unrolled along the placement area and loosely laid, without stretching, in such a manner that it conforms to the surface irregularities when material or gabions are placed

on or against it. The geotextile may be folded and overlapped to permit proper placement in designated area(s).

6) The geotextile shall be joined by overlapping a minimum of 18 inches (unless otherwise specified) and secured against the underlying foundation material. Securing pins, approved and provided by the geotextile manufacturer, shall be placed along the edge of the panel or roll material to adequately hold it in place during installation. Pins shall be steel or fiberglass formed as a U, L, or T shape or contain “ears” to prevent total penetration through the geotextile. Steel washers shall be provided on all but the U-shaped pins. The upstream or upslope geotextile shall overlap the abutting downslope geotextile. At vertical laps, securing pins shall be inserted through the bottom layers along a line through approximately the midpoint of the overlap. At horizontal laps and across slope labs, securing shall be inserted through the bottom layer only. Securing pins shall be placed along a line about 2 inches in from the edge of the placed geotextile at intervals not to exceed 12 feet unless otherwise specified. Additional pins shall be installed as necessary and where appropriate to prevent any undue slippage or movement of the geotextile. The use of securing pins will be held to the minimum necessary. Pins are to remain in place unless otherwise specified.

16.9. WATERWAY BARRIERS (BOOMS)

1) The Contractor shall supply, install and commission floating waterway barriers (booms) for debris interception and safety exclusion at the locations shown on the Drawings or as directed by the Engineer.

2) Waterway barriers shall be of modular floating type, equivalent to the TUFFBOOM A70/TUFF-16 system or approved equal, specifically designed for long-term outdoor exposure and hydraulic service conditions.

3) Boom floats shall be manufactured from UV-stabilized polyethylene with a minimum density of 0.935 g/cm³ and a nominal wall thickness not less than 4 mm. Floats shall be foam-filled to maintain buoyancy even in the event of puncture.

4) Each boom unit shall be cylindrical, incorporate longitudinal reinforcing ribs, and provide a minimum freeboard of 300 mm under still-water conditions. The nominal float diameter shall be approximately 400 mm and the nominal module length approximately 3.0 m.

5) Internal structural members and connection hardware shall be galvanized steel. Inter-boom connections shall be designed to allow articulation in all directions while maintaining structural continuity of the boom line.

6) The complete boom assembly, including floats, connectors, shackles, chains, anchor attachments and accessories, shall have a minimum tensile resistance of 240 kN (54,000 lbs). The Contractor shall submit manufacturer's certificates and technical data demonstrating compliance.

7) All steel components exposed to the atmosphere or water shall be hot-dip galvanized in accordance with ASTM A123/A123M and ASTM A153/A153M or equivalent approved standards.

8) Debris screens shall be installed beneath the floating booms. Screens shall be galvanized steel mesh panels of dimensions and opening sizes as indicated on the Drawings or directed by the Engineer.

9) The Contractor shall submit detailed shop drawings, design calculations, buoyancy calculations, anchoring arrangements, manufacturer's data sheets and installation procedures for approval prior to procurement and installation.

10) Installation shall include all anchors, mooring lines, chains, connectors, floats, debris screens, warning markings and accessories required to provide a complete and operational system.

16.10. MEASUREMENT AND PAYMENT

16.10.1. GENERAL

Supply and installation, when used in this Section shall be deemed to include the purchasing or manufacturing, provision of all labour, plant, materials, and performing all operations required for the execution of the work specified in this Section.

16.10.2. FENCING AND GATES

1) Measurement for payment for the supply and installation of fencing will be of the length of fencing installed. Payment will be made at the Unit Price per linear meter entered in the Bill of Quantities, which shall also include bracing, tensioning, welding, and curb stone set in concrete.

2) Measurement for payment for the supply and installation of gates will be in weight of gates installed including all accessories. Payment will be made at the unit Price per metric tonne entered in the Bill of Quantities.

3) The excavation and concrete for the foundations will be paid separately at the Unit Prices applicable for such work.

16.10.3. CONCRETE PIPES

1) Measurement for payment for the supply and installation will be of the length of pipelines of various diameters and types of installation, actually installed.

2) Payment will be made at the appropriate Unit Price per linear meter entered in the Bill of Quantities, which shall also include in each particular case, the concrete or sand bedding, embedding in concrete or drainage layer, and any special pieces such as bends, branches, elbows or reductions.

3) The excavation and backfill of the trenches will be paid separately at the Unit Prices applicable for such work.

16.10.4. PVC PIPES

1) Measurement for payment for the supply and installation of PVC pipes of various diameters will be of the length of pipe work installed.

2) Payment will be made at the appropriate Unit Price per linear meter entered in the Bill of Quantities, which shall include cost of pipes, fittings, joining and installation.

3) Measurement for payment for the supply and installation of half PVC pipes of various diameters will be of the length of pipe work installed.

4) Payment will be made at the appropriate Unit Price per linear meter entered in the Bill of Quantities, which shall include cost of pipes, fittings, joining and installation.

16.10.5. CONCRETE CABLE CHANNELS

(1) Measurement for payment for the supply and installation of concrete channels will be of the volume of concrete for channels and covers actually installed. The grade of concrete shall be as specified in Section B.9 of Technical specification.

(2) Payment will be made at the Unit Price per cubic meter entered in the Schedule, which shall include all cost for manufacturing, transport and placing, cement, formwork, and sand layer.

(3) Payment for the excavation, backfilling, and reinforcing steel will be made separately at the appropriate Unit Prices entered in the Schedule applicable for such work.

16.10.6. SWG PIPES

(1) Measurement for payment for the supply and installation will be of the length of pipelines of various diameters and types of installation, actually installed.

(2) Payment will be made at the appropriate Unit Price per linear meter entered in the Bill of Quantities, which shall also include in each particular case, the concrete or sand bedding, embedding in concrete or drainage layer, and any special pieces such as bends, branches, elbows or reductions.

(3) The excavation and backfill of the trenches will be paid separately at the Unit Prices applicable for such work

16.10.7. WEEP HOLES

(1) Measurement for payment for the supply and installation of weep holes will be in running meters.

(2) Payment will be made at the Unit Price per meter length entered in the Bill of Quantities, which shall include all cost for the supply and installation of perforated PVC pipes, caps, filter and drainage surrounds, and performing all construction including the re-excavation of backfill outside of the structure for placing the filter and drainage surrounds.

16.10.8. GEOTEXTILE

1) Measurement for payment for the supply & installation of the geotextile will be the surface area on which the geotextile is installed.

2) Payment will be made at the appropriate Unit Price of geotextile per square meter entered in the Bill of Quantities, which shall include all the cost of supply of geotextile, surface preparation and installation including the securing pins etc. as required for its installation.

16.10.9. WATERWAY BARRIERS (BOOMS)

1) Measurement for payment for the supply, installation, testing and commissioning of the complete waterway barrier system will be made at the Lump Sum Price entered in the Bill of Quantities, which shall constitute full compensation for the complete design (where required), supply, transport, installation, anchoring system, debris screens, accessories, testing, commissioning, maintenance during construction and all incidental works necessary for a fully operational waterway barrier system.

END OF SECTION B.16

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17. SLOPE PROTECTION

17.1. SCOPE OF WORK

1) Work under this Section includes all labour, materials, equipment and services required to protect the slopes either excavated or those of embankments and backfills and nallah training works and at the areas as directed by the Engineer.

2) This Section covers the following Engineering and Bio-engineering measures:

a) Engineering measures
i) Rock paving
ii) Stone Pitching
iii) Gabions
iv) Random Rubble Masonry walls
v) Concrete blocks

b) Bio-Engineering measures
i) Wattling Trenches
ii) Mulching/ Plantation of grass / shrubs
iii) Jute- Geo textile
iv) Balley Benching
v) Bamboo Piling

3) The Contractor shall place the various items specified herein as protection to slopes or lining to ditches to the lines and thicknesses and in the locations shown on the Construction Drawings, or as directed by the Engineer.

4) Excavation, Concrete, Sprayed concrete, rock anchors, wire mesh, and drainage work, which may also be required for the slope protection, are specified in other Sections of these Specifications.

17.2. ENGINEERING MEASURES

17.2.1. ROCK PAVING

17.2.1.1. MATERIALS

1) Fragments of rock for paving shall be selected from required excavation or quarries. They shall be chosen such that they have a reasonably flat upper surface when laid. Stones for dry rock paving shall not have a round or spherical form and shall be of regular shape. Stones for rock paving in mortar shall be not less than 150 mm thick and not less than 3,0000 mm^2 in area.

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2) Bedding material for dry rock paving shall consist of a mixture of sand and gravel reasonably well graded between 0.5 and 25 mm.

3) Mortar for rock paving in mortar shall comprise 3 parts of clean fine aggregate to one part of cement by volume. Fine aggregate and cement shall comply with the requirements specified in the Section "Concrete".

17.2.1.2. EXECUTION

1) The Contractor shall place selected pieces of rock on a mortar bed and fill the joints with mortar. Experienced masons, duly qualified in their trade shall perform the work.

2) Prior to placing, the rock shall be cleaned of all adherent soil, dust and earthy or organic impurities, and wetted sufficiently to saturate it, but leaving the surface in a damp condition.

3) Rocks shall be placed on a mortar bed of minimum thickness of 50 mm and carefully arranged in such a way that the minimum of voids remains between rocks, no continuous horizontal or vertical joints exist, and the largest rocks are evenly distributed.

4) After rock placing, the joints shall be completely filled with mortar. Splashing of exposed rock surfaces with mortar shall be avoided, and where splashing does occur, the surface of the rock shall immediately be cleaned down with a sponge and clean water.

5) Finished surfaces shall be adequately protected against rainfall until the mortar has set. After setting, mortar shall be raked out to a depth of approximately 15 mm from the face of the rock, and the rocks sponged off along their edges.

6) Joints and weep holes shall be provided in the locations and in accordance with the details shown on the Construction Drawings, or as directed by the Engineer.

17.2.2. STONE PITCHING

17.2.2.1. GENERAL

1) Stone pitching without cement mortar shall be used along with concrete grid beam as shown in drawings or as directed by Engineer.

17.2.2.2. MATERIAL

1) Stones used for stone pitching shall be rounded or sub angular cobbles selected from river or from required excavation or quarries with sufficient base area to be stable. The specific gravity of stones shall not be less than 2.5.

2) Cobbles and rocks shall be free of cracks, seams and other defects that would increase their susceptibility to destruction by erosive action. Individual cobbles or rock fragments shall be rounded and well graded in size between 120 and 300 mm. Flat rock fragments shall not be used.

3)All the stones should have a reasonable uniform size and shall be not less than 300 mm along the length and thickness not less than 150 mm.

17.2.2.3. EXECUTION

1) The stone pitching shall be laid over graded filter within the area bounded by concrete grid beam as shown in the drawings or as directed by the Engineer.

2) The stone pitching shall be laid as per IS: 4515 (Code of practice on Stone pitched lining for canals)

17.2.3. GABIONS (WIRE CRATES)

17.2.3.1. MATERIALS

1) Gabions (or wire crates) shall have a volume varying between 1 and 4 m^3, depending on the local requirement. They shall be rectangular in shape and constructed of double twisted galvanized mild steel wire formed into a hexagonal shaped mesh, of area between 5,000 and 8,000 mm^2. Corners shall be reinforced with larger diameter galvanized wire.

2) Gabions shall be either prefabricated or assembled at the required place of installation, and then filled with cobbles or rock fragments.

3) The iron wire for gabion construction shall be hard drawn conforming to IS 16014:2012. The galvanized coating on wire shall conform to IS 4826. The wires shall have the following minimum diameters:

Net and tension rods	3 mm
Wires for corner reinforcement	5 mm
Seam wires	2 mm

4) Fill material shall comprise cobbles or rock fragments that are dense, sound and resistant to abrasion. Cobbles and rocks shall be free of cracks, seams and other defects that would increase their susceptibility to

destruction by erosive action. Individual cobbles or rock fragments shall be rounded and well graded in size between 120 and 200 mm. Flat rock fragments shall not be used.

17.2.3.2. EXECUTION

1) Gabions shall be assembled, connected together and filled as shown on the Drawings and described herein.

2) Foundation surfaces upon which gabions are to be placed shall be reasonably smooth and even, with excessive high spots removed and voids filled with small rock fragments. Gabions to be placed at the toe of slopes shall be laid in a trench at least 250 mm deep.

3) Gabions shall be secured in position by tying to adjacent gabions, and where laid on slopes, shall be fixed to the slope surface by 2 m long hardwood stakes driven through the gabions into the ground at 2 m interval. Internal galvanized wire tension rods shall be provided to reduce distortion of the cages.

4) After several gabions have been placed in position adjacent to one another they shall be securely tied together continuously at their corners over their full height, and filled by hand with cobbles and rock fragments as specified. Once full, the cage lid shall be placed in position and securely tied around its whole perimeter.

5) Further gabions to be added, either above or adjacent to those already placed, shall be securely and continuously tied to existing gabions along all edges of contact before filling.

17.2.4. POLYMER ROPE GABIONS

1) Polymer rope gabions are envisaged in location shown in the construction drawings or as directed by the Engineer.

2) The polymer rope gabions to be provided under the scope of this contract shall be of two type i) in-situ assembling and boulder filling of the polymer rope gabions at the specified location, ii) assembling and pre-filling with boulders and subsequently lifted and placed by the crane at desired location.

3) Polymer rope Gabions are prefabricated collapsible cuboids in which ropes are woven in continuous net. Material of rope shall be of polypropylene with adequate UV stabilizer. The material properties such as liner weight, breaking load, punching shear strength etc. shall conform to IS:5175 and IS:7071.

4) Gabion will be of sizes of two sizes:

i) 1 m x 1 m x 1 m with mesh size of 100mm x 100mm with provision of lid and sling of 3 m length. The polymer rope shall be of 10 mm having 3 strand structures. These shall be in-situ assembled and filled with boulders at specified location.

ii) 2 m x 2 m x 1.5 m with mesh of 100 mm x 100 mm with provision of lid and sling of 3 m length. It should comprise of 24 mm body and 32 mm border rope, with 3 strand woven joint hawser laid. These

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can be in-situ assembled and filled with boulders and/or assembled at any other location and pre-filled with boulders subsequently lifted with carne and placed at desired location as directed by Engineer.

5) Fill material shall comprises of cobbles, rock fragments as envisaged in Gabions (Wire crates).

17.2.5. RANDOM RUBBLE MASONRY

17.2.5.1. WET MASONRY WALL

1) The Contractor shall construct wet masonry walls (or random rubble masonry) for slope protection to the lines and in locations shown on the Construction Drawings or as directed by the Engineer.

2) The stone for masonry walls shall be natural or crushed stone having sufficient strength and durability required for its use, not less than 150 mm thick. The rock shall be of suitable colour and appearance as determined by the Engineer. The rocks in the exposed face shall be approximately flat.

3) Mortar for masonry walls shall comprise 3 parts of clean fine aggregate to one part of cement by volume. Fine aggregate and cement shall comply with the requirements specified in the Section "Concrete".

4) Stones shall be moistened and hand-placed with un-coursed close joints onto a bedding of 200 mm thick drainage and 150 mm thick filter layers. Spaces between stones shall be filled with mortar. Surface joints shall be finished struck.

5) Weep holes of 50 mm dia. PVC pipe shall be installed through the wall to the pattern shown on the Construction Drawings or as directed by the Engineer. The upper surface of the walls shall be finished smooth with troweled layer of 10 cm capping concrete.

6) After completion of a section of masonry walls, it shall be cured with water for a minimum of 72 hours.

17.2.5.2. DRY MASONRY WALL

1) For certain sections of wall, only dry masonry may be required, in such case, stones shall not be filled with mortar.

17.2.6. PRECAST CONCRETE BLOCKS

1) Concrete blocks shall have a volume varying between 1 m^3 and 2.5 m^3 depending on the local requirement.

2) They shall generally be of cubical shape and constructed in accordance with the specification of the section "Concrete".

3) The Grade of Concrete shall be M25/A20.

4) A central hook shall be provided to facilitate lifting and placement. Care shall be taken to avoid the breakage of edges during lifting, transportation and placement.

5) The concrete blocks may need to be reinforced in some cases, in which case they shall be reinforced as directed by the Engineer.

6) The concrete blocks may be required to be tied together, with in-situ welded anchors.

17.2.7. ROCK FALL PROTECTION BARRIER

1) The rockfall protection barriers consist of steel posts supporting a steel netting duly anchored by means of opportune devices consisting of anchorage bars, cables of strength adequate for the specific case and energy dissipating devices installed on the bracing cable or on the perimeter of the interception structure. The connection of the cables by means of ferrules (pressed in the workshop) or U-bolt wire rope.

2) The characteristics of the barrier components including steel netting, posts, anchorage devices, foundation plates etc., shall be in accordance with details shown on the Construction Drawings, or as directed by the Engineer.

3) The Contractor shall provide the certificate of the crushing tests on a full scale prototype executed by an internationally recognized body and the homologation certificates for the supplied materials for approval by the Engineer.

4) The crushing tests will consist of both the Maximum Energy Level test and the Service Energy Level test, with the service energy level being equal to 1/3 of the maximum energy level.

5) The Maximum Energy Level will not be in any case lower than 1000 kJ.

6) The posts shall be hot dip galvanized having a tubular or a beam (HEA, HEB, IPE etc.) profile, arranged at a distance between 5 and 10 m, connected by hinge to the steel base plates;

7) The interception structure is formed by a steel cable net, shaped into ring panels with at least 6 connecting points, having a diameter not exceeding φ= 350 mm. The weight of the net should not be less than 6.0 daN/sqm, and consisting of a continuous wire with a diameter not less than φ= 11 mm.

8) The connecting structure consists of two longitudinal braces (in the plane of the barrier), one upper and one lower, upslope bracing cables, lateral bracing cables and downslope bracing cables (if required) with

a tensile strength not lower than 1770 N/mm^2 and diameter depending on the selected Impact Energy Level.

9) All the metallic components shall be protected against corrosion with zinc galvanization in accordance of Subsection 13.7.2, including:
   - Steel wire ropes
   - Supporting structure (steel posts and base plates)
   - Wire of the main net
   - Electroplated coatings for minor components

10) The foundation structure involves mountain and lateral anchorage connected by steel cables with a minimum diameter of 16 mm, or an equivalent structure capable of supporting the design load.
The foundation structure must meet the forces expected during impact and have dimensions suitable for the geological and geotechnical characteristics of the site.

11) The placement plan of the strut base shall be made of reinforced concrete M25 with plan dimensions of 0.5x0.5 m and a minimum height of 20 cm, sufficient to position the base at the necessary level for barrier installation.

17.2.8. SLOPE PROTECTION NETTING

1) The slope protection netting consists of steel wire mesh or cable nets that are anchored to the slope or cliff face to prevent falling rocks from reaching the ground below. The netting is designed to control rockfall movement and prevent them from causing damage or injury to people and infrastructure.

2) The characteristics of the protection net components including, anchorage devices, ropes, nets., shall be in accordance with details shown on the Construction Drawings, or as directed by the Engineer.

3) The protection is formed by:
   - Primary Steel Rope Mesh 3.0x3.0m, equipped with top and bottom steel anchoring ropes, fixing clamps and 3m long cemented anchorages.
   - Secondary Steel Rope Mesh @1.5x1.5m, by Ø10mm, anchored with 1.5x1.5m mesh of 2m long anchors
   - double torsion hexagonal wire mesh 8x10x3 mm fastened to steel cables of primary and secondary mesh;

- where necessary for the local protection of single wedge, an additional steel cable net, shaped into ring panels having a diameter not of φ= 250 mm, shall also applied as shown on the Construction Drawings, or as directed by the Engineer Ø18mm steel rope

4) All the metallic components shall be protected against corrosion with zinc galvanization in accordance of Subsection 13.7.2, including:
   - Steel wire ropes
   - Wires of double torsion hexagonal mesh
   - Electroplated coatings for minor components

17.3. BIO-ENGINEERING MEASURES

17.3.1. WATTLING TRENCHES

1) Trenches of size about 0.4 m wide and 1 m deep shall be dug up on the contours at spacing of 3 to 5 m and filled with brush wood bundles (5 to 6 cm in diameter) placed horizontally. These will act as permeable barriers entrapping the erodible soil.

2) The wooden post 8 to 10 cm diameter shall be erected about 50 cm above and 75 cm below the ground and 1 to 1.25 m apart. These posts shall be tied with 20 mm diameter Jute rope.

3) The trenches shall be backfilled with available earth etc.

17.3.2. MULCHING/ PLANTATION OF GRASS/SHRUBS

1) Seeds of plants/ mulching which can grow on the existing slopes shall be mixed with fertile soil and fertilizer and spread on the slopes stabilized by wattling trenches, Jute Geo-textiles, bailey benching or bamboo piling.

2) The type, method and timing of mulching and planting of grass shall be decided in consultation with the agronomist of the area as approved by the Engineer.

3) The plants/shrubs shall be fast growing and deep rooted.

17.3.3. JUTE GEO-TEXTILE

1) Open weave Jute geo-textile (730 gsm) shall be used for slope stabilization to reduce the velocity of surface run-off and to prevent the erosion of topsoil of the slope. Jute being agro-mulching and having high moisture absorption capacity will ensure fast growth of vegetation.

17.3.4. BALLEY BENCHING

1) The wooden posts of about 10 to 12 cm diameter shall be driven into the slope about 1 m into the ground and 10 to 15 cm left out above ground.

2) The spacing of the driven wooden posts shall be about 1 to 2 m as decided by the Engineer.

3) This measure alone or together with slope surface protection measures shall be used to increase the sliding resistance of the slopes.

17.3.5. BAMBOO PILING

1) A group of 5 to 7 bamboos each of approx. 4 to 6 cm diameter shall be driven into the ground very close to each other and tied together with half bamboo and jute tie ropes. They shall be around 1 m inside the ground and 1 m above the ground.

17.4. MEASUREMENT AND PAYMENT

17.4.1. ROCK PAVING

1) Measurement for payment will be of the volume of rock paving, placed to the lines and thicknesses shown on the Construction Drawings or those determined by the Engineer. The actual surface area will be determined by survey.

2) Payment will be made at the appropriate Unit Price per cubic meter entered in the Bill of Quantities, which shall include for the cost of furnishing, handling, transportation, and placing of paving materials including sand and gravel or mortar bedding.

17.4.2. STONE PITCHING

1) Measurement for payment will be of the volume of stone pitching, placed to the lines and thickness shown on the Construction Drawings or those determined by the Engineer. The actual surface area will be determined by survey.

2) Payment will be made at the appropriate Unit Price per cubic meter entered in the Bill of Quantities, which shall include for the cost of furnishing, handling, transportation, and placing of pitching materials.

17.4.3. GABIONS

1) Measurement for payment and payment will be made separately for gabions (or wire crates) and for filling with boulders.

2) Measurement for payment for the Gabions/ or wire crates will be of the area of the gabions / crates placed in situ. Payment will be made at the Unit Price per square meter entered in the Bill of Quantities which shall

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include all labour, equipment, and materials required for manufacturing, handling, transportation, and placing of Gabions/ or wire crates.

3) Measurement for payment for the filling with boulders will be of the volume of placed gabions. No deduction will be made for voids. Payment will be made at the Unit Price per cubic meter entered in the Bill of Quantities which shall include all labour, equipment, materials, required for furnishing, handling, transportation, and placing of rocks and boulders.

17.4.3.1. POLYMER ROPE GABIONS:

Measurement and payment for furnishing and placing the polypropylene rope gabions shall be in numbers of specified size as mentioned in relevant clause and Payment will be made at the Unit Price per nos. entered in the Bill of Quantities. The above unit price includes entire cost of supply & storage of polypropylene rope gabions, filling of boulders/rock fragments and placing with the help of crane or cast in situ as the case may be.

17.4.4. WET RANDOM RUBBLE MASONRY WALLS

1) Measurement for payment for the wet masonry walls will be of the volume of walls, placed to the lines and thicknesses shown on the Construction Drawings or those determined by the Engineer. Payment will be made at the Unit Price per cubic meter entered in the Bill of Quantities, which shall include for the cost of furnishing, handling, transportation, and placing of rocks, mortar, capping concrete and drainage and filter layers.

2) Foundation excavation, blinding concrete and weep holes will be measured for payment separately and paid for at the appropriate Unit Prices provided in other Sections of these Specifications.

17.4.5. DRY RANDOM RUBBLE MASONRY WALLS

1) Measurement for payment for the dry masonry walls will be of the volume of masonry placed. Payment shall be made at unit price per cum entered in the Bill of Quantities.

17.4.6. PRECAST CONCRETE BLOCKS

1) Measurement for payment of precast concrete blocks will be made of the volume of concrete placed in the moulds/form for production of the concrete block.

2) Payment shall be made at the unit price per cum entered in the Bill of Quantities which shall include the manufacturer cost inclusive of material, labour, equipment etc. required for production, handling transportation and placing of precast concrete blocks. The reinforcement, if any, will be measured for payment

separately and paid for under the item "Reinforcement". However, the formwork shall be deemed to be included in the unit rates for precast concrete blocks.

17.4.7. ROCK FALL PROTECTION BARRIERS

1) Measurement for payment will be made of the length of barriers shown on the Construction Drawings or those determined by the Engineer.

2) Payment shall be made at the unit price per running meters entered in the Bill of Quantities, which shall include the cost of labour, material including supply, tests, handling, transportation, and storage and placing complete in all respects.

17.4.8. SLOPE PROTECTION NETTING

1) Measurement for payment will be made of the area of protection netting shown on the Construction Drawings or those determined by the Engineer.

2) Payment shall be made at the unit price per square meter entered in the Bill of Quantities, which shall include the cost of labour, material including supply, tests, handling, transportation, and storage and placing complete in all respects.

17.4.9. WATTLING TRENCHES

1) Measurement for payment will be made of the length of trenches dug up to the lines and arrangements shown on the Construction Drawings or those determined by the Engineer.

2) Payment shall be made at the unit price per running meters entered in the Bill of Quantities, which shall include the cost of labour, material including handling, transportation, and storage and placing complete in all respects.

17.4.10. MULCHING/ PLANTATION OF GRASS/SHRUBS

Measurement for payment for the Mulching/ Plantation of grass/shrubs will be of the area treated in situ. Payment will be made at the Unit Price per square meter entered in the Bill of Quantities which shall include all labour and materials including handling, transportation, and placing complete in all respects.

17.4.11. JUTE GEO-TEXTILE

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Measurement for payment for the Jute Geo-textile will be of the area treated in situ. Payment will be made at the Unit Price per square meter entered in the Bill of Quantities which shall include all labour and materials including handling, transportation, and placing complete in all respects.

17.4.12. BALLEY BENCHING

1) Measurement for payment will be made of the number of posts driven in ground to the lines and arrangements shown on the ~~Construction Drawings~~ or those determined by the Engineer.

2) Payment shall be made at the unit price per number entered in the Bill of Quantities, which shall include the cost of labour, material including handling, transportation, storage and placing complete in all respects.

17.4.13. BAMBOO PILING

1) Measurement for payment will be made of the Numbers of posts driven in ground to the lines and arrangements shown on the ~~Construction Drawings~~ or those determined by the Engineer.

2) Payment shall be made at the unit price per number entered in the Bill of Quantities, which shall include the cost of labour, material including handling, transportation storage and placing complete in all respects.

17.4.14. EXCLUSIONS

1) No separate measurement and payment shall be made for the wire crates/Gabions laid by the contractor at access roads to quarries and borrow areas, for the installation of contractor's stationary plants and other infrastructural establishment and the cost thereof is deemed to be included in the respective unit rates.

2) No separate measurement and payment shall be made for the Rock paving, concrete blocks and /or Masonry walls constructed by the contractor at access roads to quarries and borrow areas, for the installation of contractor's stationary plants and other infrastructural establishment and the cost thereof is deemed to be included in the respective unit rates.

END OF SECTION B.17

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18. MONITORING INSTRUMENTS

18.1. SCOPE OF WORK

18.1.1. GENERAL

1) The Contractor shall supply, install, calibrate, test, survey and maintain instrumentation in the structures as specified in this Section or as directed by the Engineer. He shall supply and install all ancillary measuring equipment and construct terminal structures, protective surrounds for instruments, excavate pits and trenches, drill holes, install pipes and fittings, and cast concrete where required.

2) The extent, type, and location of the individual instruments are shown on the Drawings. The number and location of the instruments may be altered by the Engineer during the construction period, according to the requirements.

3) The Contract Documents give only the numbers, general type, and general arrangement of the instruments to be supplied by the Contractor.

4) The instrumentation shall be of high quality, realized according to the best practice and according to international standards. It shall be manufactured by well-known reputable company, with consolidated experience in monitoring of large dams instrumentation. The instrumentation shall be preferably vibrating wire type. All instrumentation operating on electrical or hydraulic systems shall be accompanied by individual test certificates, and shall be tested in the presence of the Engineer at their arrival at the site. The verification of the material shall be in accordance with the manufacture's specifications, unless specifically stated otherwise.

5) Acceptance of the instrumentation devices (sensors, cabling and communication facilities) after installation, shall derive from special procedures to be defined by the manufacturer/supplier and agreed with the Contractor and the Engineer. The proper functioning of every instrument, and satisfactory cabling and all connections to junction boxes, data loggers, computers and relevant identifications, shall be checked carefully. In case of malfunctioning, the faulty instrument or connection shall be replaced.

6) All instruments shall be installed to the lines and elevations shown on the Construction Drawings or as established by the Engineer as the work progresses during construction.

7) The installation of instruments may interfere with the overall construction progress. The Contractor shall make provision for any such interference in his construction planning. He will not be entitled to any compensation or extension of the Time for Completion by reason of any such delays, including repair and replacement of damaged instruments.

8) No instruments or any of their components shall be purchased prior to Engineer's approval on the manufacturer's name and model number of the offered instrument. However, approval by the Engineer of the Contractor's proposals and drawings or data shall not relieve the Contractor from his sole responsibility to meet all the requirements under this Contract.

9) All instruments shall be guaranteed against defect in installation/manufacturing for at least 18 months from the date of supply or 12 months from the date of embedment/installation whichever is later. All defective instruments during the period of guarantee shall be replaced by the contractor at no cost to THE EMPOYER. However, the buried defective instruments shall not be returned to the contractor.

10) . All instruments and equipment shall be accompanied by at least 3 copies of documents providing the following information:

Technical documentation (purpose of instrument, principle of measurement, general characteristics and performances in terms of accuracy, sensitivity, range, etc., in compliance with the Designer's Requirements).

Procedures for the installation and use (list of materials and tools required for installation, detailed procedure of installation, calibration, use of the instrument and results interpretation, measurement forms and files, etc.).

Calculations and interpretation of the measured data (calibration curve, calculation formula and form, example of calculation).

Acceptance testing procedure and maintenance manuals (detailed procedures for the instrument's acceptance, calibration and tests procedures, frequency of calibration where necessary, list of recommended spare, identification and description of possible failures, breakdown indicators, etc.).

18.1.2. MEASURING DEVICES

1) Instrumentation and monitoring for Dam, abutments, foundation, drifts, etc. includes the following:

a) Joint meters – linear and triaxial
b) Thermocouples
c) Single and multipoint borehole extensometers
d) Uplift measuring device (stand pipe piezometers)
e) Pore pressure gauges (vibrating wire piezometers)
f) Group of strain gauges
g) No-stress strain meter
h) Stressmeter
i) Direct pendulum

j) Inverted pendulum
k) Water level measuring automatic and gauge-mechanical type
l) Seepage measuring system – mechanical type
m) Strong motion accelerograph
n) Weather station
o) Topographical markers
p) Tilt meter
q) Microseismograph

2) for underground works includes the following:
a) Load cells
b) Single and multipoint borehole extensometers
c) Convergence measurement including optical techniques

18.2. SUBMITTALS

1) The contractor shall submit with his bid general information on the instrumentation he proposes to install, manufacturer's name and model number including additional equipment, read out units or probes which may be necessary for the instruments he proposes to use.

2) Within 112 days after the day of receipt of the Notification of Award, the Contractor shall submit details of the instruments (manufacturer's name and model number) proposed for the installation. These shall be consistent with the general information on the instrumentation submitted by the Contractor with his Tender as well as with any modifications subsequently agreed to by the Engineer and the Contractor, and shall include:
a) Detailed description of all instrumentation, cabling and accessories including any ancillary measuring equipment he proposes to install
b) Evidence of the successful performance of the instrumentation proposed for installation
c) Manufacturer's instructions for the installation, testing and operation of the instruments
d) Schedule of monitoring of instruments.

3) During the execution of the Works, the Contractor shall submit any further details regarding the instrumentation required by the Engineer. The Contractor shall prepare surveys and furnish "as-built" drawings for all installed instruments.

18.3. SKILLED PERSONNEL

1) The whole of the instrumentation work shall be carried out under the direct supervision of the manufacturer's Resident Engineer, approved by the Engineer, and employed by the Instrument manufacturer reporting to the Contractor's Site Manager. The Resident Engineer employed by the instrument manufacturer

shall be the one who is well experienced in all types of instrumentation and installation work and who understands the purpose and function of all instruments being installed. He shall be posted at site during the entire period of construction.

2) Installation and calibration of measurement instrumentation shall be carried out by the Resident Engineer or manufacturer's other skilled technicians, acceptable to the Engineer, well experienced in the installation of instruments and who have a thorough understanding of the purpose and function of the particular instruments being installed.

18.4. INSTALLATION

1) The Contractor shall get the instruments installed and calibrated by the manufacturer's skilled technicians in conformance to the manufacturer's instructions and shall, where necessary, expose all partially installed instruments, cables and tubes to continue their installation, including carrying out all survey work required to locate such instruments. Every precaution shall be taken to ensure that installation is correct and that the various instrumentation components are in no way damaged. The Resident Engineer employed by the instrument manufacturer shall be present during the entire process of construction. The contractor shall submit a certificate issued by the manufacturer regarding the installation of instruments as per the instrument's manual, to the Engineer. The Contractor shall tag all cables and tubes with identification tags approved by the Engineer to provide continuous identification.

2) Instrumentation shall be installed and calibrated in the presence of the Engineer, and when he considers it desirable, instruments shall be installed only during daylight hours. At all times, the Contractor shall ensure that adequate lighting is available, whether by natural or artificial means, to ensure proper execution of the work.

3) Cables and tubes shall be installed in the maximum lengths practicable. Splicing and coupling, if essential, shall be performed in accordance with the manufacturer's recommendations. Calibration readings shall be taken prior to and immediately after splicing. Open ends of all incomplete lines of tubing and casing shall be kept plugged or sealed and the Contractor shall at all times during installation keep the insides of casings and tubes free from foreign matter. The Contractor shall protect all instruments and relevant connections/cabling from damage and displacement during the progress of the work providing markers and protections Cables and tubes shall be identified by suitable tags fastened at regular intervals throughout their length. Cables and tubes shall be protected from mechanical damage and their tags preserved throughout the construction process by the Contractor.

4) Instruments shall be provided, where necessary, with protective devices against lightning and associated overvoltage

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5) The instruments shall be put in operation at the earliest possible period during construction in order to obtain information pertaining to the performance of the dam, its foundation, abutments and underground caverns.

18.5. CARE OF INSTRUMENTATION

1) The Contractor shall protect all instruments and connections from damage and displacement during the progress of the work. If damage or displacement of the instruments or connections occurs during the progress of the work, they shall be repaired or replaced immediately by the Contractor.

2) The Contractor shall be fully responsible for the maintenance and repair of all instrumentation for the duration of the contract period.

3) The contractor shall recalibrate instruments at the frequency/ period as specified by manufacturer/ or Engineer.

18.6. READING INSTRUMENTS

1) An initial set of readings on all instruments installed at any particular elevation will be taken prior to and immediately after their installation, and the Contractor shall not place concrete over the instruments or tubes or cables at this location until these readings have been taken and found to be in order.

2) The Contractor, after consultation with the Engineer, shall program his work and make all necessary arrangements to record the reading of instruments as soon as possible after their installation. Such arrangements shall include, where necessary, the provision of temporary read out points.

18.7. INSTRUMENTATION SPECIFICATIONS

18.7.1. GENERAL

1) The Contractor shall supply, install and maintain the measuring devices, carry out additional excavation, drilling, construct concrete or mortar pads, backfilling with concrete, perform the measurement, and record the readings at frequency/ period specified by Engineer for the all the instruments listed in par. 18.1.2., including the following:

a) Alarms
b) Sensor networking system
c) Cables

d) Cable slicing kit
e) Readout unit for electrical instruments
f) Readout unit for strain cable
g) Data acquisition system

2) The measuring devices to be provided shall be manufactured by a reputed international manufacturer with proven record and acceptable to the Engineer.

3) Investigations listed elsewhere in this section shall be carried out during excavation work at the locations and time intervals as directed by the Engineer. Contractor's personnel experienced and trained in rock mechanics testing and recording the readings shall perform the testing. All testing to be undertaken shall be done under direct supervision of the Engineer, who will interpret the results. Should the Contractor not have the persons required on his staff, he shall engage a specialised geotechnical firm as his subcontractor, subject to approval by the Engineer.

4) The Contractor shall take utmost care in preserving the factor and initial reading of each instrument and in the recording and analysis of the subsequent readings and prevent mixing of readings from different instruments.

5) During execution of the works, the contractor shall observe, record and submit readings of all the instruments in specified format along with analysis of observed data and at specified frequency/ period to the Engineer.

6) The Contractor shall make provisions in his planned excavation activities to enable the performance of the rock mechanics testing to be carried out concurrently with the underground excavation without disruption or delay. No extension of time for the Completion of Works will be granted to the Contractor due to the performance of such testing.

18.7.2. LOAD CELLS AND TOTAL PRESSURE CELLS

1) Toroidal Cells for tie roads are generically used for measuring the stress state of tie rods and reinforcing bars.
Load cells of vibrating wire type shall be installed to monitor the behavior of rock bolts installed.
The circular toroidal-shaped stainless steel cell is equipped with strain gauge sensor fixed internally to the longitudinal part.
The load on the cell deforms its longitudinal body, the strain is perceived by the sensor and measured and data provided as a variation of resistance.

2) The load cells shall have the following characteristics:

Measuring Range	300KN (or as specified on relevant drawing and/or BoQ)
Accuracy	1 % FS
Operation Temperature	-20…..+70 °C
Maximum overload allowable	150 % f.s.
Failure Load	>300 % f.s.
Material	Stainless Steel
Sealing	Hermetically sealed by welding
Rod Φ	up to 36 mm
Readings	Portable electrical and automatic unit

3) At the beginning, the readings shall be taken daily. Later, weekly readings shall be taken till the cessation of any movement or until the Engineer permits termination.

Total pressure cells are used for checking the stress state in earthfill embankments and for the control of the pressure of earth on structure and foundations.

The instrument is generally formed of two thin discs of stainless steel welded together and filled with oil, linked through a thin tube sealed to a vibrating wire gauge. The hydraulic pressure induced in the cell corresponds to the pressure transmitted from the ground and is measured by the vibrating wire sensor.

To obtain a measure with the maximum sensitivity, the cell is very thin with respect to the surface and the instrument has the main surfaces free as the measuring transducer is separate.

Accuracy	±0.1 % FS
Resolution	0.02% f.s
Linearity	<0.4%fs
Drift in temperature	0.025% fs per °C
Material	Stainless steel
Sealing	Hermetically sealed by welding.

18.7.3. CONVERGENCE MEASUREMENT INCLUDING OPTICAL TECHNIQUES

1) Convergence measurement shall be performed in underground excavation works to determine the relative displacement of opposite measuring points placed around the excavation perimeter.

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2) The measuring points shall consist of the convergence bolts made of stainless steel pins mounted on a short reinforcing bar grouted into predrilled hole.

3) The distance changes between the opposite convergences bolts shall be measured by means of tape extensometer connected to the bolts and tensioned between them. Change of length shall be read on a digital gauge. Accuracy of the measurement shall be 1mm.

4) The convergence bolts shall be installed within the heading zone after the installation of supports. At the beginning, the measurement shall be carried out daily. Later, weekly readings shall be taken for several months up to the cessation of any movement but latest when the placing of the concrete lining commences.

5) Convergence measuring tape: It is required for measuring distance for "Convergence measuring points. It shall be temperature resistant, water resistant and tear resistant, length not less than 30 meter, and 0.01 mm of accuracy.
The digital gauge shall be calibrated on their corresponding calibration devices before and after each measurement. Digital readout shall be in metric unit and the readings shall be displayed in 5-digit LCD .

6) Optical Targets: Optical Methods of convergence monitoring comprises of optical bi-reflex targets. A convergence bolt of 170 mm length and 10-12 mm OD with 3/8" pipe thread stud shall be securely attached to the exposed rock or shotcrete surface. The bolt shall be provided with a plastic cap with a breaking point serving as an adapter for the mounting of a reflector with a marked center point. This device shall be designed for high precision measurements with two axes of rotation and to be observable from both sides. The manufacturing accuracy of the fully machined bireflex target must be so as to achieve an overall accuracy of ± 1 mm within the measuring section. The targets must be replaceable without loss of accuracy The optical targets shall be monitored by the Contractor's precision Total Station for any convergence within the tunnel.

7) Wireless Sensors: The use of sensors is steadily increasing within the field of deformation monitoring. A system of sensors has the advantage of lowering or completely removing the need for measurement personnel in the tunnel at each measurement occasion, allowing for them to be more frequent. Digital tri axis inclination sensors with micro-radian precision can efficiently be used for monitoring movements in large engineering structures, some sensors are additionally capable of measuring distance from the sensor to a point to which the sensor laser is aimed. Recent progress in wireless telecommunication and specifically wireless networks has provided structural deformation monitoring with even more efficient tools. Instead of having to connect sensors with wires and having to visit the tunnel for collecting data, wireless technology can be used to send the data to a central storage. If internet connection can be provided inside the tunnel, the data can be accessed anywhere there is internet access.

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18.7.4. JOINT METERS – LINEAR AND TRIAXIAL

Vibrating wire joint meter suitable for remote reading, scanning and data logging shall be supplied complete with a socket assembly to facilitate installation in the two blocks. The instrument shall have long term stability and shall be water proof and corrosion resistant.

Joint meters are used to measure the relative displacement of two adjacent surfaces in three orthogonal directions.
Otherwise the automatic joint deformometers shall be used as a baseline with manual comparators to manually measure relative displacement across the structural joints in three orthogonal directions.
The range of the manual triaxial joint meters shall be ± 15 mm in the XYZ directions. The displacement to be measured by a micrometer depth gauge with a minimum range of 30 mm and resolution of 0.01 mm.

The joint deformometers will consist of:

- Sensors (vibrating wire or fiber optic) for displacement measurements
- Reference surface located on the opposite side of the joint.
- The sensor shall be encased in a rubber and water-resistant enclosure.
- The 3D sensor will allow simultaneous measurements in three orthogonal places.

The supply shall include two portable readout instruments which will allow the measurement during construction.

The specifications are as follows:

Range	50 mm
Sensitivity	0.1 mm
Accuracy	+ 0.5 % full scale
Material	Stainless Steel
Operating temperature	-10 to 80°C

The joint meter shall be provided with over voltage surge arrestor to protect vibrating wire gauge against damage from lightning. A 3,000 Ohm (25°C) R-T matched thermistor to be incorporated in the sensor for temperature sensing and for temperature - zero reading correlation.

Triaxial (perimetric) joint meters are required to measure relative movements between two blocks of the dam in three orthogonal directions. They will be located in the galleries and if required, also on the surface of the structure.

18.7.5. THERMOCOUPLES

1) Thermocouples will be embedded in the concrete, they should be used to measure and datalogging of local temperatures in the dam body at the locations shown on the drawings or identified by the Engineer.
Thermocouples are metal resistance thermometers that change their electrical resistance depending on the temperature, they are constituted by two conductors of suitable material, welded together at one end and which produce between the two free ends, a voltage which is a function of the temperature of the welded point.
They are widely used in RCC dams, directly embedded in the concrete.
Thermocouple Sensor shall be type " K" or "T", for general purpose and heavy duty probe.
A portable Data Acquisition Unit shall be supplied together with the Thermocouples to allow measurement directly at the end of the connecting cables, to record measurements also during construction.

Measurements requirements:
Range : -25° C / +80° C
Resolution up to 0.2°C

18.7.6. SINGLE AND MULTIPOINT BOREHOLE EXTENSOMETERS

1)These extensometers shall be installed in surface/underground excavation to measure displacements in the rock mass surrounding the excavation.

2) The extensometers shall be installed in the boreholes drilled radially on a plane perpendicular to the centerline of the underground structure. For dam installation, boreholes shall be drilled with the inclination indicated in the Drawings or as instructed by the Engineer. The exact location of each installation will be shown in the relevant drawings.

3) The borehole extensometer is composed of:
- Anchors (single or multiple points)
- Extension rods (fiber glass with protective tube)
- Head for automatic or manual measurements
- Vibrating wire sensors for automatic readings
- Depth gauge for manual readings
- Temperature correction system

4) The extensometers to be installed shall be of single point or three-point type with fiber glass rods. Boreholes diameter shall be:
- Underground works

- Single Point extensometer 50 mm
- Three-point extensometer 76 mm

- Dam
  - Single Point extensometer 90 mm
  - Three-point extensometer 125 mm

5) Single point extensometers will generally have a length of 6 to 10m, on average 8m. Three point extensometers will have a typical rod length of 4, 7 and 10m or 5, 10 and 15m. However, different rod lengths may have to be supplied to suit specific site conditions as specified in the Bill of Quantities.

6) Reading of the extensometer shall be done with electrical vibrating wire type sensors. At the beginning, the readings shall be taken daily. Later, weekly readings shall be taken till the cessation of any movement or until the Engineer permits termination but latest when the placing of the concrete lining commences. The readings so taken along with report (comprising of data observed, analysis of data etc.) shall be reported to the Engineer.

Measurements requirements:
Range: 0-50 mm
Accuracy: 5 % of full scale

18.7.7. UPLIFT MEASURING DEVICES

1) Mechanical type Uplift measuring devices shall be installed on top of open stand pipe piezometers or drain pipes.

2) Each group shall consist of the following three components:

- the measuring instruments,
- the shutoff valve,
- the tubes connected to the borehole or the drain pipes.

The shutoff valve shall permit the inclusion or exclusion of the measuring instrument. The measuring instrument shall be a stainless teel spring manometer, Bourdon type in glycerine.
Ranges are 0…100 m.
Accuracy: 0.5 % of range, or better
It shall be equipped with fitting and accessories for an easy connection and with a vibrating wire sensor for automatic measurement.

18.7.8. PORE PRESSURE GAUGES (PIEZOMETERS)

1) Pore pressure gauges shall measure the pore water pressures in the locations shown on the Drawings or as directed by the Engineer.

2) Pore pressure cells gauges shall be vibrating wire piezometer, as approved by the Engineer. The vibrating wire sensing element should be enclosed in a protected stainless steel housing properly hermetically sealed.

The pressure cell shall be protected from surrounding material with a specific porous filter.

All the parts of the sensing element, other than the wire, shall be made of stainless steel.

The VW piezometer shall be fitted with a surge protector and resistant to electrical and radio frequency interferences.

3) The pore pressure gauges shall have the following characteristics:

Measuring range	0 - 1.5 Mpa (150 m water pressure)
Accuracy	± 0.5 % of full scale

4) The cells shall be installed in boreholes at elevations as shown in the Drawings.

5) Pore pressure meters shall be provided with over voltage surge arrestor to protect the vibrating wire gauge against damage from lightning.

6) In one bore hole, only one pore pressure cell shall be installed. After the hole has been prepared, the cell shall be placed and embedded with grouting using an appropriate grout mix in consultation with engineer.

7) The end of the cables shall be kept during construction in protective boxes and later permanently installed in the terminal structures or switchboxes.

8) For tunnels, pore pressure gauges generally as per above specifications shall be installed in boreholes behind shotcrete or concrete lining or where directed by the Engineer.

9) At the beginning, the reading shall be taken daily. Later, weekly readings shall be taken till the cessation of any movement or until the Engineer permits termination.

18.7.9. GROUP OF STRAIN GAUGES

The main purpose of a strain gauge is to indirectly determine stress and its variation with time, quantitatively. Change in stress is determined by multiplying the measured strain by the modulus of elasticity.

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Group of six strain gauges to be mounted at different locations of the concrete structure to measure internal strain and thus indirectly determine three dimensional stress. Four strain gauges to be mounted at angles of 0°, 45°, 90°, 135° in one plane and one strain gauge at 90° to this plane. The system to consist of the following items:

Vibrating wire strain gauges suitable for remote reading, scanning and data logging should be of the following specifications:

Measuring range	± 1500 micro strain
Gauge length	About140 mm
Operating temperature	-10 to 80° C
Accuracy	± 0.5% fs
Sensitivity	1 micro strain with read-out unit
Magnet assembly	Integral part of the sensor (not as a separate assembly)
Enclosure	Stainless steel, hermetically sealed

Strain gauge spider: Precision machined to permit precise and accurate installation in the concrete structure of four strain gauges, on the spider roads, at angles of 0°, 45°, 90°, 135° in one plane and one strain gauge at 90° to this plane.

Junction box: Six to one polyester cable box with cable glands for six input cables and one twenty-core jelly filled output cable and requisite quantity of cable jointing compound.

18.7.10. NO-STRESS STRAIN METERS

No-Stress -Strain Meter is installed in conjunction with group of strain meters in mass concrete in a special container where no external force is acting on strain gauge embedded in concrete. The data of No Stress-Strain meter is required to evaluate the strain gauge data to find out true strain.

Range:	±1500micro strain
Resolution:	1 micro strain
Material:	Stainless steel
Operating temperature:	-10 to 800C
Thermistor:	YSI 44055 or equivalent, 3K at 25°C

18.7.11. STRESSMETER

A stress meter is an embedded geotechnical instrument installed within a dam body to measure in-situ stresses in concrete. It typically consists of a sensing element (hydraulic, vibrating wire, or electrical resistance type) that responds to stress changes and converts them into measurable signals. Stressmeters are used to monitor

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stress distribution, verify design assumptions, and assess the structural behavior and safety of the dam over time.

Stressmeter:

Range:	-3 MPa to + 25MPa
Resolution	10 kPa
Accuracy	±0.25% F.S.
Temperature Range	-20 to +80°C

Thermistor:

Range:	-80 to 150°C
Accuracy:	±0.5 °C

18.7.12. DIRECT PENDULUM

Measures and records of relative internal horizontal displacement of points along a true vertical line, for the dam body.

An assembly of direct pendulum shall be supplied and installed in concrete dam at the locations shown on the drawings for monitoring the displacement /tilt between top and the base of the dam. The contractor shall install pendulum in a hole of 300 mm diameter in the dam body.

The DIRECT pendulum shall be realized with a 1- 1.5 mm2 stainless steel wire suspended from the upper point and a reading station fixed to the structure at the lower point. The wire shall be tensioned by a suspended weight (30-50 kg) submerged in a damper tank.

For DIRECT pendulum that has more than 100m of length, the area of the stainless-steel wire shall be 2.0 mm2 and the suspended weight shall be at least 100 kg.

Pendulum system shall have long-term stability and all its components shall be robust and protected against corrosion.

The reading of the wire position for direct pendulums shall be possible both manually and automatically

Each pendulum shall be provided with an automatic and direct visual reading system installed on independent supporting structure to allow crosscheck measurement with the coordinometers.

The system shall have the following specifications:

Measurement method Automatic and Manual

Automatic Coordinometer:

Type	electrical type for automatic monitoring
Measuring Range	100 mm on the x-axis 50 mm on the y-axis
Accuracy	± 0.1 mm
Resolution	± 0.02% of full scale for the measuring groups

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Mobile Manual Coordinometer

Type: electro-optical module and electronic control, rechargeable unit, or power supply with UPS backup, with a three hour autonomy

Stainless steel wire	2 mm^2 area
Wire suspension	Collet on a rectangular bar grouted at the top
Suspension weight	30-100 kg
Oil tank	Stainless steel ;
Damping	oil S.A.E. 50-90

18.7.13. INVERTED PENDULUM

Measures and records of relative internal horizontal displacement of points along a true vertical line, for the dam foundation.

An assembly of inverted pendulum shall be supplied and installed in concrete dam foundation at the location shown on the drawings for monitoring the displacement between the base of the dam and the rock foundation.

The contractor shall install the pendulum in a predrilled hole. of 400 mm minimum hole diameter about 50 m installation depth (diameter and installation depth to be confirmed in drawings).

Inverted pendulum system shall have long-term stability and all its components shall be robust and protected against corrosion.

The reading of the wire position for all inverted pendulums shall be possible both manually and automatically.

Each pendulum shall be provided with an automatic and direct visual reading system installed on independent supporting structure to allow crosscheck measurement with the coordinometers.

The system shall have the following specifications:

Measurement method Group type for automatic and manual monitoring

Automatic Coordinometer:

Measuring Range	100 mm on the x-axis 50 mm on the y-axis
Accuracy	± 0.1 mm
Resolution	± 0.02% of full scale for measuring groups

Mobile Manual Coordinometer

Type: electro-optical module and electroniccontrol, rechargeable, or power supply with UPS backup, unit with a three hours autonomy

Range of measurement: +- 25 mm

Resolution: 0.01 mm

Accuracy: 0.1 mm

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Stainless steel wire 1 mm diameter

Wire suspension Collet on hollow float in tank filled with SAE 50-90 oil or similar

Anchoring weight 35kg

Tank (Stainless steel) 650-800 mm Φ x 500 mm height

Float material Stainless steel

18.7.14. WATER LEVEL MEASURING AUTOMATIC AND GAUGE-MECHANICAL TYPE

1) RESERVOIR and TAILWATER automatic level recorder shall be installed to record the reservoir and tail water levels during impounding and operation (between the minimum and the maximum operating levels of the reservoir).

A water level indicators & datalogger is proposed, however alternative equivalent solutions (vibrating wire piezometers) can be proposed and adopted by the Contractor.
The data logger shall be installed, according to the drawings, in suitable device to guarantee protection from debris and accessibility for possible replacement operation. The instrument shall have a pressure balance system with automatic reading.
The level recorder shall be located in places where water movement does not affect the level and where they can be easy read.
The level recorder and relevant cables shall be encased in suitable sleeve pipe to protect them against possible damages.

2) The Contractor shall supply and install water level measuring gauges, at locations shown on the relevant drawings.This instrument is aimed at indicating the water levels by means of elevation direct reading on a sign.

3) The height range to be covered by the gauges shall be 125 meters or as specified in the Bill of Quantities.

4) The gauges shall be of powder coated stainless steel 180 x 1000 mm (combined and disposed to record the total depth of the reservoir and the river tail water level) and shall be subject to the approval of the Engineer. The principal division shall be in meters above sea level, which will be further divided into centimeters. The elevation character shall be of powder will be 400 x 800 mm. with 100 mm resolution in height, and elevation marking each 2 m of elevation.

5) The Contractor shall set the gauges by accurate levelling from a designated benchmark. The gauges shall be fixed to the concrete walls by means of stainless-steel expansion bolts (e.g. Nelson or Hilti).

18.7.15. SEEPAGE MEASURING SYSTEM - MECHANICAL TYPE

Seepage measurement system shall be designed to measure a flow rate of around 0-20 litre/second or as given in the Bill of Quantities. The seepage water would be collected in a concrete reservoir by civil contractor with suitable filters to make the flow as nearly streamline as possible and made to flow over a thin stainless steel plate V-notch weir.

Graduated stainless still gauge staff is installed u/s, at least four time H far, the V-notch for water level measurements, the staff shall allow the reading of the water level with ±1 millimeter accuracy.

The flow, in terms of liter/second, calculated from the u/s level reading, shall be graduated directly on the V-notch weir.

The V-notch weir is composed by a movable sharp-edged stainless-steel plate (about 450 x 600 mm or as indicated in detailed drawings) provided with a 30° or 90° triangular opening for low and medium flows, or with an upper rectangular opening for large flows. The plate slides into a milled guide, which is anchored by bolts to the drain gutter walls with the interposition of a rubber gasket to make the coupling watertight.

Otherwise, a steel frame is bolted to the drain gutter walls. On its upstream side, the frame is coupled with a rubber gasket: the plate is juxtaposed to the frame and water tightly anchored by clamps.

The V notch shall be removable, being equipped with a steel handle. According to the measurement volume it shall be possible to change the V-notch type (30° triangular shape, 90° triangular shape, rectangular shape) inserting it in the milled guide.

18.7.16. STRONG MOTION ACCELEROGRAPH

1) Strong motion accelerographs shall be supplied and installed by the contractor at locations indicated on the drawings or as determined by the Engineer to record the response of the structure. Generally the instruments shall be located one on the left or right flank of the dam (free field) one over the darrage and one inside the dam body (in the lower gallery). These instruments will record events of all ground acceleration above an adjustable threshold limit based upon STA/LTA (to be provided by Engineer).

2) Each set of shall comprises of 3 no. triaxial sensors with digitizers and 1 no. common data acquisition system

The sensor (accelerometer) is a wafer stack composed of four individual wafers bonded together. Within the inner two wafer of the stack, and suspended by silicon springs, is a moving structure, proof-mass, that forms a differential variable capacitance between the surfaces of the moving proof-mass and the fixed caps. As the accelerometer is subjected to vibration, the proof-mass moves between the fixed plates which, in turn, causes a change in the differential capacitance.

Accelerometers units shall be properly fixed and provided with cast aluminum sealed access cover, in number and location as indicated in the design drawings The system must have long term stability, and proven reliability. The digital acquisition unit it shall be connected via cable to a desktop computer for data processing, or remotely via 3G or 4G modem , fiber optic or WiFi.

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3) Short haul modem pairs, or similar wireless connection, with suitable length of unshielded pair of twisted telephone cable for connection between the modems to be provided if distance between any accelerometer and data acquisition and storage module exceeds the allowable limit.

4) Suitable software for PC shall be supplied for retrieving data from the seismic data acquisition module, plotting the data on display screen as well as providing a hard copy record.

Strong motion accelerograph system should meet the following specifications:

a) Triaxial strong motion sensor with digitizer (3 no.)

Sensor system type 3-axis (orthogonal) strong motion force feedback Accelerometer.

Bandwidth DC to 100 Hz (-3 dB). The frequency response curve should not show any spurious response within the specified bandwidth. Triaxial force Force Balance Accelerometer: +-2g,

Dynamic Range:165 dB (per bin rel. full range), 156 dB (per bin rel. full scale rms), 134 dB (0.02 - 50 Hz)

Integrated nonlinearity: < 0.1 %

Accuracy: ± 0.4 dB max over the bandwidth

Cross Axis Sensitivity: < 0.5 %

Bandwidth: DC to 200 Hz

Damping: 0.7±0.1 critical

Offset Drift: 0.0005 g / °C

Span drift: 200 ppm / °C

Full Scale output: 0±10 V differential (20 Vpp)

Hysteresis: < 0.001 % of full scale Sensitivity: 2.5 to 20 V/g

Output impedance:100 ohms

System Power supply 10-28 V DC either directly or through a suitable power supply adaptor from 230 V, 50 Hz AC mains.

Materials Hard anodized aluminium case
Mil –spec connectors

Housing Weatherproof housing suitable for outdoor installation.

b) Seismic Data Acquisition and Processing System (1 no)

Communication technologies supported RS 232,RS 422,
PCMIC Amodem, Ethernet (10BaseT/100BaseT), Wireless LAN (802, 11b)

Internet technologies supported TCP/IP
PPP

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	HTTP,HTTPS server
Form factors	Stand –alone-3 ports
Port types	Data in/out, modem, console (user – configurable)
Flash memory	512Mb
On board disk type	USB
Filing system	Hot – swappable, journalling, Windows FAT 32 compatible
Direct disk recording formats	GCF, miniSEED
External storage	USB storage with 15 GB USB stick
Operating temperature range	-40 to 60 °C with managed disk heating
System power supply	10-35 V DC either directly or through a suitable power supply adaptor from 230 V, 50 Hz AC mains.
Power consumption	<0.75W + power pass – through

18.7.17. MICROSEISMOGRAPH

Seismographs can be used to measure local small earthquakes and determine whether or not reservoir induced seismicity is occurring at the dam area. The triggering of such seismic phenomena is linked to the effects of applying the weight of reservoir and the diffusion of increased pore pressures due the impounding.

Technical Specifications:

Sensor: Over damped geophone

Number of axis: 3, orthogonally oriented

Frequency Range: selectable, 1-80 Hz or 1-315 Hz

Dynamic Range:> 125 dB

Linearity:± 0.05 % of full scale

maximumCross Axis Sensitivity:± 1 % typical, 3 % maximum

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Temperature : 20°C to +60°C

Full Scale Output: ± 10 V differential (optional ± 5 V pseudo-differential)

18.7.18. WEATHER STATION

A weather station should be installed, in an area free form obstacles and interferences, on one of the abutments of the dam at the crest elevation. The installation of the weather sensors it makes possible to correlate structural data with environmental data. Environmental phenomena are often at the origin of geological changes and structural problems.
The weather system shall monitor:

barometric pressure,
temperature,
humidity,
rainfall depth and intensity,
evapotranspiration,
wind speed and direction,
Solar Radiation.

The station shall be able to operate autonomously (standalone) or connected via modem to processing units.
The data shall be stored in an internal static memory, that will retain data even in the absence of power.
The instrument shall consist of receiver with configurable channels, a sensors suite, and mounting hardware.
Electronic components must be housed in a weather-resistant shelter.
Sensor suite must be solar powered.
The weather sensors should meet the following specification or similar:

Rain Gauge (Rainfall monitoring)

- Transducer: Oscillating motion
- Collection Surface: 400 – 1000 cm^2
- Range: 0 – 200 mm/h
- Accuracy: 2 %
- Sensitivity: 0.2 mm

Barometer (Atmospheric pressure monitoring)

- Transducer: Semiconduttor
- Range: 700 mB – 1100 mB
- Accuracy: ± 0.5 mB

- Sensitivity: 0.1 mB

Thermometer (Environmental Temperature)

- Transducer: PT100 thermoresistances
- Range: -40 °C / +60 °C
- Accuracy: ± 0.1 °C
- Sensitivity: 0.01 °C

Higrometer (Ambient Umidity)

- Transducer: Capacitive
- Range: 0 – 100 %
- Accuracy: ± 2 % FS
- Sensitivity: ± 0.5 %

Anemometer (Wind velocity)

- Transducer: three cups with toroidal magnet and hall effect probe
- Range: 0 – 50 m/s
- Accuracy: ± 0.1 m/s in the wind range 0 – 30 m/s, ± 0.7 m/s over 30 m/s
- Sensitivity: < ± 0.25 m/s

Anemometer (Wind direction)

- Transducer: vane with potentiometer sensor
- Range: 0 – 360 °
- Accuracy: ± 0.1 °
- Sensitivity: < ± 0.1 °

Evatorimeter (water evaporation)

- Tank material Stainless Steel
- Tank diameter 1200 mm
- Transducer: LVDT
- Range: ± 25 mm
- Accuracy: ± 0.5 % FS
- Sensitivity: ± 0.1 mm

Global Solar Radiation (pyramometer)

- Transducer: Electronical

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- Range: 0 – 2000 W/m^2
- Sensitivity: 10 μV / m^2

18.7.19. TOPOGRAPHICAL MARKERS

1) The Contractor shall supply, install, and survey studs, base plates, observation pillars and survey targets along with accessories; as shown on the Drawings for Precision Surveying. Base plates and levelling studs shall be used to measure the vertical movements of the dam top of parapet wall & other concrete structures. Survey targets and observation pillars shall be used for measuring horizontal movement or deflection of the dam blocks. Observation pillars shall be installed on the downstream side banks and targets mounted on the downstream face of the dam at various elevations as shown on the construction drawings and /or as directed by Engineer.

2) Survey targets shall be made of stainless steel of about 15mm dia on top and 250 mm long. Its top there will be an engraved cross mark 1mm thick and 1 mm deep. Levelling studs/base plates shall be installed as soon as possible after placement of concrete at the locations where required. The base plate shall be 100x100x3 mm stainless steel plates. The top surface of the plate shall be a perfect plane.

3) The contractor may suggest some different type of targets also for approval of the Engineer.

4) Immediately after installation of any studs/base plates, its position and level shall be precisely surveyed. The level and coordinates shall be computed and submitted in writing to the Engineer within 48 hours of installation.

18.7.20. TILT METER

In place Mems Tilt Meter shall be supplied and installed by the contractor at locations indicated on the drawings to monitoring the behavior of the concrete face slabs.

The tilt meter consists of MEMS sensor housed in a compact, waterproof enclosure.
The tiltmeter mounting surface shall be horizontal and flat, a horizontal mounting shelf shall be constructed.
Two anchors are installed in the structure and the tiltmeter is fastened to the anchors.
The instruments shall be placed in instrumented section as shown in the drawings.

Measurements requirements:

Range: +- 15°
Resolution: ± 0.0001°
Accuracy: < 0.02 % (FS)

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Op. Temperature: -30 °C + 70 °C

18.7.21. ALARMS

Alarms shall be provided with:

- fixing and anchoring devices, as per manufacturer's instruction
- power and connection cables from the measuring point (that is usually an open- closed type breaker) up to each of the alarm point foreseen in the design drawings.
- Alarm shall be given with both audio and visual signals, as described hereinafter:

VISUAL and AUDIO ALARM:

Visual and audio signal alarm shall be located:

- internally, near the place where the event to be signaled occur.
- externally, in a visible location (near gallery accesses or at Dam control building).

Lamp intensity, given in effective candela, measured in use at the source, shall be of minimum 75 candela. Flash rate cycles between one and three Hertz (flashes per second).

VISUAL signal - or its reflection from adjacent walls and ceiling - must be of an intensity that will raise the overall light level sharply, but not so intense as to be unsafe for direct sight at a specified installation height. Strobes-whether projected from a wall or suspended from the ceiling - must be a minimum of 15 cm below the ceiling to avoid smoke obscuration in the event of a fire. To comply with provisions covering protruding objects, alarm devices must be at least 200 cm above the finished floor.

The AUDIO alarm shall have following minimum characteristics: 105 dB at 10 cm ~ 2400 Hz intermittent (5/sec).

The above specifications can be subject to modifications, according to the manufacturer's instruction, in function of the location of installation, if necessary. In any case the alarm volume shall allow to receipt the audio signal in the surrounding area of the alarm point.

18.7.22. SENSOR NETWORKING SYSTEM

All instruments or sensors shall maintain the ability to be read manually or by portable data Acquisition Units before entering the network.

Sensor networking shall be accomplished by using bus multiplexer system such that cumbersome handling of heavy cables leading to the DAS is avoided.

Accordingly, cabling shall be done based on the following practices with detailed cable routing drawings prepared by the designer/instrumentation supplier and approved by the Engineer:

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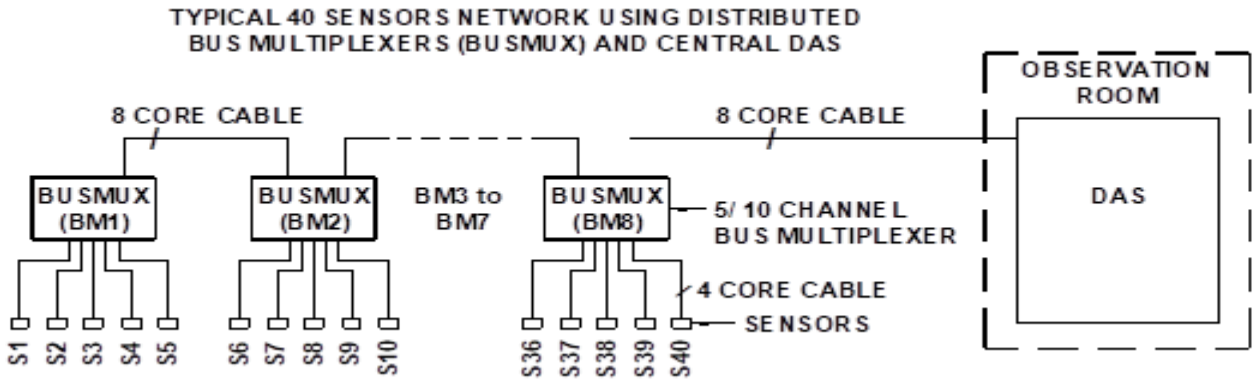
Bus Multiplexer System: Cluster of sensors shall be connected to individual bus multiplexers placed near the sensors. Several bus multiplexers shall in turn be connected to the Data Acquisition System through a single 8-wire bus cable (8-core cable with water blocking compound). A typical arrangement in which 40 sensors are connected to the DAS through a single 8 core cable is shown here:



18.7.23. CABLES

1) Cables shall be generally be of following types

a) 4 core cable- It shall have 7/0.25 annealed tinned copper, twisted pairs in red/black, green/white, with water blocking aluminium foil, 0.3 mm galvanized iron wire braid armoured, overall polythene sheathed, overall diameter of around 11 mm and weight of around 0.12 kg/m.

b) 6 core cable- It shall have 7/0.25 annealed tinned copper, twisted pairs in red/black, green/white, blue/grey with water blocking aluminium foil, 0.3 mm galvanized iron wire braid armoured, overall polythene sheathed, overall diameter of around 11.5 mm and weight of around 0.14 kg/m.

c) 8 core cable- It shall have 7/0.25 annealed tinned copper, twisted pairs with water blocking aluminium foil, 0.3 mm galvanized iron wire braid armoured, overall polythene sheathed, overall diameter of around 12.5 mm and weight of around 0.16 kg/m.

d) 10 core cable- It shall have 7/0.25 annealed tinned copper, twisted pairs with water blocking aluminium foil, 0.3 mm galvanized iron wire braid armoured, overall polythene sheathed, overall diameter of around 12.5 mm and weight of around 0.16 kg/m.

e) 12 core cable- It shall have 7/0.25 annealed tinned copper, twisted pairs with water blocking aluminium foil, 0.3 mm galvanized iron wire braid armoured, overall polythene sheathed, overall diameter of around 14 mm and weight of around 0.40 kg/m.

f) 20 core cable- It shall have 7/0.25 annealed tinned copper, twisted pairs with water blocking aluminium foil, 0.3 mm galvanized iron wire braid armoured, overall polythene sheathed, overall diameter of around 16 mm and weight of around 0.30 kg/m.

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g) 40 core cable- It shall have 7/0.25 annealed tinned copper, twisted pairs with water blocking aluminium foil, 0.3 mm galvanized iron wire braid armoured, overall polythene sheathed, overall diameter of around 19.8 mm and weight of around 0.60 kg/m.

2) Special cables, where required, for various gauges shall be of standard market quality, as approved by the Engineer.

18.7.24. CABLE SPLICING KIT

For joining two ends of same core cables, cable splicing kit shall be used. It shall be of material-AISI 304 stainless steel and suitable to make a water resistance sealed heavy duty joint between the two cables. It shall be supplied with requisite amount of cable jointing compound.

For joining different core cable, a suitable junction box (LB) shall be used. It shall be of material-aluminium with powder coating and shall have a suitable PCB with screwed terminals. It shall be filled with cable sealing compound to be supplied along with the JB.

18.7.25. READOUT UNIT FOR ELECTRICAL INSTRUMENTS

1) For all electrical instruments, the Contractor shall supply portable readout units suitable to read digitally in engineering units all cabled instruments and store data with time and date. The readout units should be light, robust and durable.

2) Detailed specifications of read out units for vibrating wire sensors should be as follows:

Type	Portable, microprocessor based, programmable battery operated digital indicator.
Suitable	For all types of vibrating wire sensors and 3K thermistors.
Display	In time period and also in engineering units (like μ strain, kg/cm^2, mm, kgf, tf, deg., ^{o}C etc.). In the engineering mode display, the read-out should be capable of being set to a resolution of up to two decimal points.
Calibration coefficients	The digital indicator should be capable of storing the calibration coefficients of around two hundred fifty vibrating wire transducers by an internal non-volatile RAM.
Data Entry	Shall be through a sealed membrane key-pad
Data download to computer	A RS-232C port for down loading data to a computer or a printer to be provided.

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Data Storage	The vibrating wire transducers indicator should have an internal non-volatile memory with sufficient capacity to store around 4,500 date and time stamped readings from around 500 programmed transducers in any combination.
Non-linearity corrections	The indicator should have the capability of storing three polynomial coefficients of each sensor for applying non-linearity corrections.
Enclosure	The indicator should be suitable for field use and housed in a sturdy portable enclosure.
Power	An internal rechargeable sealed maintenance free battery to be used to provide power to the indicator. A fully charged new battery should provide more than 40 hours of operation on a single charge
Battery Charger	To be provided to charge the internal battery from 230 V AC mains.

3) Detailed specifications of read out unit for strain gauge based Load Cells shall be as under:

Type	Portable, microprocessor based, programmable battery operated digital indicator.
Display	In engineering units (mm). In the engineering mode display, the read-out should be capable of being set to a resolution of up to two decimal points.
Calibration coefficients	The digital indicator should be capable of storing the calibration coefficients of around hundred transducers by an internal non-volatile RAM.
Data Entry	Shall be through a sealed membrane key-pad
Data download to computer	A RS-232C port for down loading data to a computer or a printer to be provided.
Data Storage	The read-out unit should have an internal non-volatile memory with sufficient capacity to store around 720 date and time stamped readings from around 100 programmed transducers in any combination.
Enclosure	The indicator should be suitable for field use and housed in a sturdy portable enclosure.
Power	An internal rechargeable sealed maintenance free battery to be used to provide power to the indicator. A fully charged new battery should provide more than 40 hours of operation on a single charge.
Battery Charger	To be provided to charge the internal battery from 230 V AC mains.

18.7.26. REAOUT UNIT FOR FIBER OPTIC TEMPERATURE AND STRAIN CABLE

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The DCU is a readout unit for a laser-based measurement system using an optical scattering measurement principle within the sensing fiber (Stimulated Brillouin Scattering). It can store information from dedicated fibers and cables as sensing element. Stimulated Brillouin Scattering is an intrinsic physical property of the fiber material and provides information about the strain and temperature distribution actually experienced by the sensing fiber.
It should be possible to connect multiple fibers to each unit through an integrated optical switch.
The final number, number of channels, cabling route and details will be defined with relevant supplier.

The unit should include an internal hard-disk storage, allowing great versatility in terms of connections.
The system should operate interactively or in automatic mode, gathering data according to a schedule, and must be able to communicate with the ADAS system located in the control room.

Thanks to a special software to be installed in the ADAS, it should be possible to visualize the data collected and to remotely control the system and act on the units to manage the automatic data acquisition settings without having to go to the units themselves.

The unit should meet the following specifications:

Distance range (per channel):	60 km (120km max. total fiber loop distance)
Spatial resolution:	1 m to 20 m (by increment of 0.1 m)
Sampling resolution:	0.25 m (1 m at max. distance range)
Acquisition time:	1-5 minutes typical, 5 -15 minutes for high resolution measurements
Measurement range:	Temperature : 0.1 °C ; Range from -150 °C to +1000 °C (fiber dependent)
	Strain: 2 με ; Range > 5%
Operating temperature:	0°C to 45°C

The Contractor shall supply, also, a portable readout unit, to be used during construction or till the final system enter into operation, suitable to read fiber optic cables and store data with time and date. The readout unit should be light, robust and durable.

18.7.27. DATA ACQUISITION SYSTEM AND WEB BASED DATA MONITORING SERVICES

A stand alone Data Acquisition System (DAS) shall be provided for real time on line and automatic scanning and recording of all electronic sensors. The DAS shall be complete with all required hardware and software components including power supply units, control and communication modules, input cards signal conditioners, interface devices, surge protector. All the DAS hardware components shall be housed in a cabinet. The system shall be suitable for unattended continuous operation in harsh environment. One number PC based

operator cum engineering station shall be provided by the contractor along with 0.5 KVA UPS with battery backup.

The scan rate shall be programmable from few times a second to once every few hours. The system shall have memory to store at least 3,000,000 data points. The measurement and control module shall provide sensor measurement, communication, data reduction, data/program storage and control functions. It shall have a battery backed clock. The system should have provision that data can be down loaded through an appropriate software to any standard PC or a laptop. It shall have powerful instruction set, in standard software to enable the system for generation of math functions, max., min., average, histograms etc. The software shall enable display of sections of the structure showing location of instruments along with instrument tag no or identification no. such that when the particular instrument on a section on which it is installed is clicked, data recorded for the instrument is displayed on the screen.

The contractor shall be responsible for data management and presentation till the end of his defect liability period for the project. For this purpose, the instrumentation manufacturer shall provide Web Based Data Monitoring Service (WDMS). The user shall be able to interact with the software using their web browser, when connected to the internet, from anywhere in the world. It should allow multiple authorized users at different locations to view any data, graphs or reports from the same project site simultaneously using a popular web browser like Microsoft internet explorer or Mozilla Fire fox amongst others.

18.8. MEASUREMENT AND PAYMENT

18.8.1. GENERAL

1) The drill holes, where required for installation of instrumentation shall be measured and paid separately under the section "Drilling, Grouting & Pressure Relief holes"

2) Unless otherwise specified, the Unit Prices for instrumentation entered in the Bill of Quantities shall include the supply, installation, calibration, testing, surveying, repairing and maintaining of all instruments, ancillary, read out equipment, including protective steel covers, tubes and tube protections, required to perform the specified measurements.

3) The Unit Prices shall also include for forming all necessary recesses in concrete, all necessary trench and pit excavation, foundation preparation, temporary and permanent protection of instruments and ancillary equipment by surrounding with selected material or by other approved method, and maintaining easy access to all readout points. No deduction will be made for the volume occupied by the instruments and instrument protection when measuring the embankment material for payment.

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4) The Contractor shall include in his Unit Prices any additional readout equipment, which may be necessary for reading the instruments he proposes to use.

5) The payment for the Web based Monitoring system shall be on lump sum basis as entered in the Bill of Quantities. This will include all the costs of software, hardware, any other item required for the transmitting the data through world wide web (www) on real time basis, imparting training to the owner's staff and demonstration at site and at owner's head office.

6) No extra payment will be made for rock sampling and testing. The related cost shall be deemed included in the appropriate items for underground excavation.

7) No extra payment will be made for Contractor's services rendered in connection with the tunnel mapping. The related cost shall be included in the appropriate items for underground excavation.

18.8.2. INSTRUMENTS

Measurement for payment and payment for the following instruments shall be made as per the unit prices entered in the bill of quantities:

a) Load cells and total pressure cells
b) Convergence measurement including optical techniques
c) Joint meters – linear and triaxial
d) Thermocouples
e) Single and multipoint borehole extensometers
f) Uplift measuring device (stand pipe piezometers)
g) Pore pressure gauges (vibrating wire piezometers)
h) Group of strain gauges
i) No-stress strain meters
j) Stressmeter
k) Direct pendulum
l) Inverted pendulum
m) Collimation system
n) Water level measuring automatic and gauge-mechanical type
o) Seepage measuring system – mechanical type
p) Strong motion accelerograph
q) Weather station
r) Topographical markers
s) Tilt meter

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t) Alarm

u) Readout unit for Electrical instruments e.g. extensometers, piezometers etc.

v) Acquisition unit for fiber-optic cable (DCU)

w) Data acquisition system and Web based data monitoring services (ADAS)

x) Microseismograph

y) Cables (including cable splicing kits, junction boxes, switch boxes, protection arrangements and other necessary accessories etc.)

18.8.3. EXCLUSIONS

The following shall not be paid extra and is deemed to be included in the unit price of various instrumentation items

a) Sensor networking Bus Multiplexer Systems.

b) Complete services of installation and monitoring like posting of one representative of the instrumentation manufacturer for the entire duration of contract including one year defect liability period.

END OF SECTION B.18

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19. SERVICE WATER SUPPLY, SEWERAGE SYSTEM AND SANITARY INSTALLATION

19.1. SCOPE OF WORK

1) The Contractor shall furnish all materials, equipment and supply all labour necessary for the complete installation, testing and operation of the plumbing and sanitary systems for the Dam control room in accordance with the Construction Drawings consisting of, but not limited to, the following:

a) Potable water systems including pumps, automatic pump, controls treatment plant etc.

b) All service water, plumbing and sanitary fixtures, fittings, trims and accessories,

c) Sewerage system, including sewage pump, automatic pump, controls, waste and vent pipe systems including sewage treatment plants,

d) Pipe hangers and inserts,

e) Painting of exposed pipes and appurtenances and asphalt protective coating and covering for all pipes laid underground

f) Any work involved in providing the complete operation of the domestic water supply system,

g) Supply of water for construction and testing purposes, and testing the installations.

2) The Construction Drawings do not indicate all pipes, fittings and valves. All such items, whether or not specifically mentioned or indicated, shall be furnished and installed if necessary to complete the system in accordance with the best practice of the plumbing trade and to the satisfaction of the Engineer.

3) All dimensional locations of fixtures, equipment and floor drains, risers and pipe chases shall be verified on the architectural drawings and manufacturers catalogues.

19.2. SUBMITTALS

1) The contractor shall propose in his bid, an experienced plumbing consulting engineer, who shall design water supply and sewage management system for Dam complex and shall assist the owner in the supervision of works to be extended by the contractor.

2) The Contractor shall submit for approval complete list of materials to be incorporated in the Works, samples of materials with specimen of workmanship, colour and finish, manufacturers catalogues at least 28 days prior to the date he wishes place or confirm orders.

3) The Contractor shall prepare all necessary shop and erection drawings and data covering equipment to be installed.

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4) In addition, he shall furnish the manufacturer's schematic diagrams and instructions for installation, servicing and repairs.

19.3. STANDARDS

The work is to be in full accordance with the requirements of all governmental agencies having jurisdiction thereof as well as of all relevant Indian Standards.

19.4. SYSTEM DESCRIPTION

19.4.1. WATER SUPPLY

1) The source of water needed for domestic purposes shall be surface water from the nearby streams (Nallah) as directed by Engineer. The water shall be diverted from the source by gravity or by pumping as the case may be. Intake works on the Nallahs shall be constructed as required. The water from the filter unit shall be stored in clear water tank from where it will be distributed at various levels in the control building by means of gravity.

2) The purification of water shall be carried out by means of sand/gravel filter plant or pressure filter which will remove the natural pollution as well as the mechanical pollution caused by oxidation and/or abrasion. Each filter shall have a capacity of 100% to ensure continuous operation of the water supply system during back flushing of one of the two filters.

3) After purification and before entering the tanks, the water shall be disinfected by means of a sodium hypochlorite dosing unit.

4) Water for domestic purposes will be disinfected again by means of a secondary dosing unit to compensate the evaporated chlorine. The second dosing unit will be connected to the system close to main distribution header.

5) Water for domestic purposes will be supplied to the toilets and washroom of the Dam control buildings by gravity. The water supply pipe line shall be directly connected to the natural source of water through providing a water tank of minimum capacity of 1000 litres.

6) Pressure reducing stations shall be provided where necessary for a proper and satisfactory operation of the systems.

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19.4.2. CHLORINATING EQUIPMENT

The chlorinating equipment shall be of the automatic and proportional type, operated by water pressure in the pipe line and controlled by water meter. The equipment shall be capable of injecting a quantity of hypochlorite into the main pipe line that is in direct proportion to the quantity of water flowing in the pipe line for all rates of flow from 10 l/min to 100 l/min and for all pressures in the pipeline. The equipment shall have a capacity of not less than 10 litres of hypochlorite solution per hour and shall be suitable for operation with a hypochlorite solution of 1% strength. The actual solution strength to be used will be determined from field tests after installation.

19.4.3. SEWAGE DRAINAGE

1) Sanitary sewage will be collected in the airtight collection tank in the Control Building and shall be pumped to the Fluidised Integrated Bio Reactors (FIBR) based sewage treatment and disposal plant. However, the Contractor may suggest any advanced alternate measures for approval by the Engineer.

2) Design data for sewerage system:
   a) No. of employees: 30 persons
   b) Sewage pp/day: 150 liters
   c) Retention time: 3 days

3) Sewage treatment plant (STP) and disposal plant will comprise the following:
   a) Collection tanks of adequate capacity of MS with inside epoxy coating. The collected sewage shall be pressurized by grinders and lifted to the digester tank through cast iron double flanged pipe of suitable diameter. The digested sewage from the digester tank shall be pumped into the outer shell of STP (Aeration tank). The biomass generated will be separated in the settling tank. The effluent from the outer shell of the reactor shall be passed through the chlorination units for disinfection and then shall be collected in the effluent collection tank. The effluent from the tank is then pumped to the multi grade filter units through filter feed pumps for reduction of dissolved and suspended solids to meet the disposal norms of Pollution Control Board. And finally the treated sewage shall be passed through post chlorination for final disinfection before disposal in river.
   b) All pipes, valves, pumps and all other associated mechanical, electrical and instrumentation items including panels etc. There shall be 100% standby and 100% backup for pumping units.
4) The Contractor shall design, supply and install septic tanks for sanitary sewage for the Dam at the location as shown on the drawings or as directed by Engineer
5) Septic tank shall be constructed of reinforced concrete class M25A20 to the dimensions shown on the drawings prepared by the Contractor and approved by the Engineer. An access manhole with removable cover shall be provided to each compartment of tank for inspection and cleaning.

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6) Backfill around the outdoor septic tank up to the required level shall be made in layers approximately of 200 mm thick and thoroughly tamped in a manner that will not produce undue strain on the tank

19.5. EQUIPMENT AND MATERIALS

19.5.1. IDENTIFICATION OF MATERIALS

1) Each length of pipe fitting, trap, fixture and device used in the plumbing system shall have cast, stamped or indelibly marked on it the manufacturer's trade or name, and the weight, type and class of product, when so required by the standards mentioned above.

2) All plumbing fixtures and fittings installed without the above trade marks shall be removed and replaced with properly marked fixtures and fittings by the Contractor.

19.5.2. TRANSPORTATION AND HANDLING

Any pipe and plumbing material damaged by improper handling and transportation shall be marked for identification. Rejected material shall be promptly removed from the work site and replaced by the Contractor.

19.5.3. MATERIAL STANDARDS

1) The principal basis for reference for the equipment, materials and labour employed in the construction, fabrication, delivery, installation and testing of the water supply and sewerage system shall be the appropriate Indian Standards.

2) General requirements for sanitary fixtures shall be the following:

a) Where required by the Engineer and at any time, a fixture sample of each type designated on the drawings shall be submitted for approval. The samples shall be completely fitted and set up at the building or in some other convenient approved place. All fixtures of poorer quality than the approved samples will be rejected.

b) Plumbing fixtures shall be of the best quality as fabricated by manufacturer of established reputation. All ceramic fixtures shall be best quality regular selection, white vitreous china thoroughly fused, producing a white material which, when fractured, shall show a homogeneous mass with close grain and free from pores. All surface coming in contact with walls, floors, or surfaces of other fixtures shall reasonably flat.

c) Enameled cast iron shall be the best quality and thickness necessary to form fixtures of the best commercial grade manufactured. Porcelain enamel coat on the surfaces required to be enameled shall be applied so that the enamel shall be smooth, of even thickness, white and free from craze,

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discoloration and chips. Exterior exposed surfaces not required to be enameled shall be treated with one coat of filler at the factories. The Contractor shall be responsible for any revisions of connections required to adapt the roughing sleeves and openings to the particular fixtures he proposed to use.

d) All fixtures shall have the manufacturer's guarantee label or trade mark indicating first quality.

e) All fixtures requiring hot and cold water shall have the cold water tap on the right hand side of the fixture and the hot water tap on the left hand side.

f) All fixtures shall be of the same manufacture, unless otherwise directed by the Engineer.

19.5.4. MATERIAL SCHEDULE

19.5.4.1. PIPING

1) Water supply main pipe and service connections to main pipe and pipes for water distribution:

a) All pipes for water supply shall be of Galvanized steel pipes conforming to IS 1239 (Part 1) for a nominal pressure of 10 bars (Heavy class).

b) Fittings for the steel pipes shall conform to IS 1239 (Part 2) and fixtures shall be made of chromium plated brass pipe or fitting. Suitable adapters shall be used where a change in materials is made.

2) Pipes for water distribution lines:

a) All water circulation piping within the buildings shall be galvanized steel pipes of standard weight.

b) Fillings shall be of malleable iron, except that exposed final connection at fixtures shall be made of chromium plated brass pipe or fitting. Suitable adapters shall be used where a change in materials is made.

3) Buried sewage piping:

All pipes and fittings shall be spigot and socket type with rubber ring sealing of diameter 150 to 300 mm.

4) Sanitary drainage system:

a) All pipes and fittings shall be HDPE pipe (class PN 10, conforming to IS14333) with maximum permissible working pressure 1.0MPa.

b) Short fixture connections and vent pipes shall be of polypropylene pipe spigot and socket type, sealed with rubber rings.

c) Adapters gaskets, etc. which come in contact with waste material shall be resistant to all commonly used acid, alkali, hydrocarbon, solvents and water.

19.5.4.2. WATER SUPPLY COMPONENTS, SANITARY FIXTURES

1) Globe valves made of cast brass, both ends female threaded, nominal pressure 16 bars, for domestic hot and cold water systems.

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2) Maintenance free globe valves, with soft seat, made of cast iron, nominal pressure 16 bars, suitable for domestic water systems.

3) Check valves, made of cast brass, hot pressed brass or bronze, swing type metal valves, suitable for domestic water systems, nominal pressure 25 bars, and both ends female threaded.

4) Bronze spring safety valves, enclosed type with steel spring, inlet connection male, outlet connection female taper, suitable for domestic water systems, made of brass, nominal pressure 16 bars.

5) Draw-off taps, made of brass, with loose handles and hose union, nominal pressure

6) Water closet units (Indian type) consisting of following components and accessories:

a) 1 WC bowl, made of vitreous china, colour white, size approx. 500x 600 mm, wash down type, mounted at floor level

b) 1 high hanging cistern, made of vitreous china, 15 litre content, incl. pull and chain as well as fixing material

c) 1 flush pipe Nominal Dia. 32mm, chromium plated brass

d) 1 chromium plated brass ball valve Nominal Dia. 15 mm, incl. chromium plated copper connecting pipe Nominal Dia. 15 mm

e) 1 set of connection unions escutcheons and sealing material

f) 1 PVC siphon Nominal Dia. 100mm

g) 1 ablution faucet, self closing flush type Nominal Dia. 15 mm, made of chromium plated brass, with 70 cm flexible chromium plated metal hose Nominal Dia. 15 mm and escutcheon

h) 1 chromium plated metal paper holder, incl. fastening material

i) 1 chromium plated double coat hook, incl. fastening material

j) 1 plastic closet brush set

k) 1 chromium plated metal hand bar approx. 30 mm Dia. incl. fastening material

7) Water closet units (western type) consisting of following components and accessories:

a) 1 WC bowl, made of vitreous china, colour white, wash down type, overall size approx. 600 x 350 mm, with integrated S-or P trap, floor standing

b) 1 low hanging cistern, made of vitreous china, content 9-11 litre, incl. fixing material

c) 1 chromium plated, metal flush pipe Nominal Dia. 32mm, incl. escutcheons and unions

d) 1 chromium plated brass ball valve Nominal Dia. 15 mm, incl. chromium plated copper connection pipe Nominal Dia. 15 mm and escutcheon

e) 1 heavy duty plastic seat with cover, colour black, incl. fixing material

f) 1 set of bowl fixing material

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g) 1 ablution faucet, self closing flush type Nominal Dia. 15 mm, made of chromium plated brass, with 70 cm flexible chromium plated metal hose Nominal Dia. 15 mm and escutcheon

h) 1 chromium plated metal paper holder, incl. fastening material

i) 1 chromium plated double coat hook, incl. fastening material

j) 1 plastic closet brush set

k) 1 chromium plated metal hand bar approx. 30 mm dia. incl. fastening material

8) Wash basin units consisting of following components and accessories:

a) 1 wash basin, made of vitreous china, overall size approx. 600 x 520 mm, colour white, with overflow and front spray edge

b) 1 water tap, made of chromium plated brass, Nominal Dia. 15 mm, with trecorn-deluxe handle, marked blue, swivel tube spout and jet regulator

c) 1 waste fitting, made of chromium plated brass, Nominal Dia. 32mm, with chain stay, chain and plug

d) 1 p-trap, made of chromium plated brass, Nominal Dia. 32mm, seal 75 mm, with adjustable inlet pipe and escutcheons

e) 1 angle stop valve, made of chromium plated brass, Nominal Dia. 15/10 mm, incl. chromium plated service copper pipe Nominal Dia. 10mm and escutcheon

f) 1 crystal-porcelain mirror, size 600 x 500 mm, incl. chromium plated clips and fixing material

g) 1 soap tray, made of chromium plated brass, incl. fixing material

h) 1 electric hand-dryer

9) Shower assemblies consisting of following components and accessories:

a) 1 shower basin, made of enameled steel, colour white, size 800 x 800mm, heavy quality, incl. supporting legs

b) 1 thermostatic mixing valve, made of chromium plated brass, Nominal Dia. 15 mm, outlet above, with stop valve Nominal Dia. 20 mm, trecorn-deluxe metal handles, scale handle with safety stop at 38 ^{0}C, built-in non return valves and dirt strainers, covered S-bend units Nominal Dia. 15 mm.

c) 1 jet shower unit heavy duty construction, with maintenance-free jet head with flow regulation, angle of jet 20 degree

d) 1 waste fitting, screen made of chromium plated brass, Nominal Dia. 40 mm (drainage via floor drain Nominal Dia. 50/40 mm)

e) 1 shower curtain, made of plastic, size approx. 1200 x 2000mm incl. hangers

f) 1 shower curtain rail, made of chromium plated brass, heavy solid construction, length approx. 1000 mm, incl. fixing material

g) 1 soap tray, made of chromium plated brass, incl. fixing material

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10) Service sink units consisting of following components:

a) 1 sink bowl, made of white fire clay, with hard wood pad at the front edge and stainless steel lift-up bucket grid

b) 1 wall tap Nominal Dia. 15, made of chromium plated brass, projection approx. 150 mm, with jet regulator, handle marked blue, incl. escutcheon

c) 1 wall tap as before, however handle marked red

d) 1 waste fitting Nominal Dia 40, screen type, made of chromium plated brass

e) 1 plastic P-trap Nominal Dia 50/40, with 75 mm seal and adjustable inlet pipe, colour white

f) 1 set of built-in cantilever brackets of white enameled cast iron and fixing material

11) Urinal unit consisting of following components:

a) 1 urinal bowl made of vitreous china, colour white, with integrated P- or S-trap, wash out type, wall hung, with semi concealed overflow

b) 1 flush valve Nominal Dia 15 made of chrome plated brass

c) 1 metal connection pipe Nominal Dia15, chromium plated with escutcheon

d) 1 connection piece Nominal Dia 50 to sewage pipe including;. escutcheon

e) 1 set of fastening material

12) Kitchen unit consisting of following components:

a) 1 top and sink unit made of stainless steel, with one bowl, incl. one-hole single lever sink mixer Nominal Dia 15 mm, with swivelling cast spout, projection 240 mm, cup strainer and trap Nominal Dia 40 mm, mixer, strainer and trap made of chromium plated brass, counter top with integral back splash

b) 1 15l capacity wall mounted electrical water heater (geyser) of reputed make, with cut-off function & outlet fitting Nominal Dia 15 mm, chromium plated.

c) 1 upper wall-mounted cabinet 1,050 x 600mm, made of sheet steel, finishing colour white, with 3 hinged doors, cabinet furnished with flush double bottoms

d) basic construction shall be made of 0.75mm sheet steel, door front, liners and shields shall be of min. 0.90mm sheet steel, internal gaskets and bracing shall be of 1.5mm sheet steel, finishing colour white

13) Strainer baskets flanged Nominal Dia 100, nominal pressure 16, consisting of flange body, stainless steel basket, grooved drive stud, hex. bolts and nuts.

14) Pump system, consisting of two centrifugal pumps (one standby), with incorporated suction strainer and check valve, with radial working impeller and motor including 1 set of level control devices for installation in the water tanks, complete with sub panel, for following functions:

a) High level: supply pump-stand-by

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b) Low level: supply pump-out, alarm

c) Lower level: pump protection alarm

d) 1 control panel with change: over automatic in case of pump failure and interval change over.

e) Design: squirrel-case motor

f) Voltage: 415 V 3-phase

g) Frequency: 50 Hz

h) Q each pump: 4.5 m^3/h

i) Pumping head: 7.0 bar

15) One pressure filter plant of sand/gravel filters with automatic de-aeration, consisting of:

a) 2 filter tanks of welded sheet steel, inside and outside sand blasted, inside coated, outside with zinc-chrome primer, complete with all required equipment as manhole, nozzle floor, connecting sleeves, internal water distribution system and steel feet as well as a complete filter charge

Flow rate: 5 m^3/h (each)

Diameter: 200 mm

Total height of plant: approx. 1200 mm

Required room height: 2000 mm

Max. Pressure: 6 bar

Connections: Nominal Dia 50mm

Filter speed: approx. 16 m/hr

b) 1 complete piping arrangement of galvanized steel, including all necessary fittings and valves, Nominal Dia 50mm.

16) Sodium hypochlorite dosing unit shall be quantity proportional operated dosing unit, flow rate up to 1.0 l/h, against a max. working pressure of 10 bar, consisting of:

a) Dosing pump with electric control devices, suitable for control via contact water meter, adjustment of required flow rate via infinitely adjustable stroke limit, electronic function indicator by green LED indicator, emptiness signal and disturbance indication by red pressure valve in double ball design, suction height of pump 1.0 m, direct solenoid driven, 240 V, 50 Hz, 57 W, 1.0 A, reversible on internal pulsar, pump ready mounted on contact water meter.

b) 1 Contact water meter with reed contacts

Q average: 4.0 m^3/h

Q peak: 10.0 m^3/h

connection: DN 20

c) 1 Complete set of suction fittings with non-return valve, level switch, incl. cable and plug type connection

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d) 1 Injection piece R 1/2" with reinforced PVC-connecting hose, incl. valve and check valve (spring type).

17) Set of level control equipment for water tanks for following functions:

a) High level: pressure boosting plants-stand-by

b) Low level: pressure boosting plants-out-alarm

18) Electrical panel for function and control of all equipment necessary for water supply and water treatment, incl. all necessary wiring between panel and the various equipment, for proper and satisfactory operation of plant, with control equipment and transformers for:

a) Water supply pumps

b) Double filter unit

c) Dosing units

d) Level control equipment

e) AC input 3 Ph 415 V, 50 Hz.

19) Label plates machine engraved, letters of min. 6 mm height, black lettering on a white background size 100 x 40 mm, incl. all necessary supporting material.

19.6. EXECUTION

19.6.1. GENERAL

1) All installation work shall be performed in a first-class, neat and workmanlike manner by personnel skilled in their trades to the satisfaction of the Engineer.

2) Following piping systems shall be installed:

a) Domestic water supply system,

b) Sanitary waste and vent system.

19.6.2. EXCAVATION, PIPE LAYING AND BACKFILLING

1) All trenches shall be kept free of water, where dimensions of trenches are not shown on the Construction Drawings; trenches for pipes shall be excavated to a minimum width as follows:

a) Trenches up to 2.0m in depth, 60 cm wide or pipe diameter plus 30 cm, whichever is greater,

b) Trenches exceeding 2.0m in depth, 1.0m wide or pipe diameter plus 60 cm, whichever is greater,

c) Where more than one pipe is to be laid in a trench, the trench width shall be calculated on the basis of the largest pipe.

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2) Trenches shall be excavated to the general alignment and levels indicated on the Construction Drawings or as directed by the Engineer. Any unsound material occurring in the bottom of trenches shall be removed and replaced with compacted gravely sand.

3) Trenches shall not be excavated to a greater depth than indicated without the consent of the Engineer. Additional excavation carried out without such specific consent will not be recognised and where directed by the Engineer shall be filled in to the required level with compacted gravely sand.

4) After excavation, the trench shall be carefully graded in such a manner as to provide an even support for the pipe throughout its length. Compacted gravely sand shall be used to make up depressions.

5) Bed holes shall be cut in the bottom of trenches as necessary and of such size and depth as to allow the joints to be properly made, and to ensure that the body of the pipe rests evenly on the bed.

6) When the trench is ready as specified, pipes shall be cleaned internally of all mud and any foreign matter, lowered into their final position and joined as specified.

7) Gravely sand shall be placed between the pipe and the sides of the trench and well rammed with hand rammers until it is level with the top of the pipe. Thereafter, a layer 200 mm thick of similar material shall be placed over the pipe to the full width of the trench and well rammed with hand rammers other than directly above the pipe.

8) After the protective layer has been placed to a level of 20 cm above the pipes, the remainder of the backfill shall be completed with natural spoil from the trench, large stones being removed. The spoil is to be placed and well compacted in layers approximately 200 mm thick.

9) Where trenches are in hard material, the depth of trench shall be increased by a minimum of 100 mm. After excavation, a layer of gravely sand not less than 100 mm thick shall be placed in the bottom and the trench bed prepared for the reception of pipes. Backfilling shall be carried out as described above.

10) No portion of the pipe work or any other work shall be covered without the consent of the Engineer.

11) At the end of the each days laying and whenever a length of jointed pipeline is to be left for any period, the ends shall be closed by means of a suitable cap or plug to keep out all dirt and foreign bodies.

12) Water supply and sewer pipes shall be laid in separate trenches.

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19.6.3. ANCHOR BLOCKS

All movement of pressure pipeline must be prevented by concrete anchor blocks. The Contractor shall design, supply and construct all necessary anchor blocks for all branches, caps, tapers, bends, reducers, valves etc. Anchor blocks shall be located in such a manner to allow easy access for removal of valves and fittings etc.

19.6.4. CONCRETE PROTECTION

Pipelines running under drain channels, streams or roads shall be encased in the reinforced concrete class M25/40 full length, if not otherwise prescribed. Before the concrete is placed, the pipe and all fittings shall receive a double wrapping of bituminous felt. The thickness of the concrete encasement around the pipeline shall be one quarter of the pipe diameter, but at least 15 0 mm. The concrete reinforcement shall be determined by the Contractor and approved by the Engineer.

19.6.5. PROTECTION

1) All openings left in floors or walls for the passage of pipes shall be covered and protected with suitable coverings and all open ends of pipes and traps shall be closed with plugs or caps to prevent the ingress of dirt of damage.

2) New, permanent water closets and other new plumbing fixtures are not to be used during the progress of the work.

3) New, permanent and floor drains are not to be used for the drainage of waste cement mixes during the progress of the work.

4) As soon as installed, all metal fixture trimmings shall be covered with non-corrosive and non-staining grease and maintained until construction work is completed.

19.6.6. CUTTING AND REPAIRING

1) The work shall be laid out in advance and any cutting out of already completed construction work shall be done with the permission of the Engineer. Roughing-in for fixtures shall be carried out along with the building construction.

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2) Openings shall be left in walls and floors of proper sizes, correctly located for the pipes, and the Contractor shall do any additional cutting needed in case of error or omission and shall properly replace any concrete work or flashing around the pipe as may be required.

19.6.7. GENERAL PIPE INSTALLATION

1) The arrangement, positions and connections, of pipes, fixtures, drains, valves, and the like shall be as shown on the Construction Drawings and or as directed by the Engineer. Pipes shall be laid or fixed in as straight and direct lines as possible, forming right angles or parallel with building walls and other pipes, and neatly spaced. Pipe risers shall be erected plumb and true.

2) All horizontal runs of piping, except where concealed in partitions, shall be kept as high as possible and close to walls. A minimum slope of 1% shall be maintained on all sewage, waste and drain lines.

3) Pipes or other apparatus shall not be installed in a manner which interferes with the full swing of the doors or windows.

4) All screwed pipe shall be reamed smooth before installation. Pipes shall not be bent, flattened, split or injured in any way.

5) Unless otherwise approved in special cases, reducing fittings shall be used in making reductions in sizes of pipes. Bushing will not be allowed without the consent of the Engineer.

6) Friction type wrenches and vices shall be used on all copper tubing and brass piping. Pipe showing tool marks shall be removed and replaced with new materials. Where chrome plated piping is installed, the pipe shall be cut and threaded so that no un-plated pipe threads are visible when the work is completed.

7) Fixture connections, concealed in building construction, shall be carried to points above floor, broken out close to the underside of fixture and risen, exposed, to the fixture.

8) Protective pans shall be provided under and over individual pipes passing high voltage electrical bus ducts or switchgear equipment.

9) Exterior piping shall not be installed in water or when trench or weather conditions are unsuitable for the work.

19.6.8. INSTALLATION OF WATER SUPPLY PIPES AND FITTINGS

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1) The piping shall be extended to all fixtures, outlets and equipment. The cold water piping shall be installed with a fall toward a drain down point situated on the downstream side of the main shut-off valve. The ends of pipes and outlets shall be capped or plugged and left ready for future connections.

2) The branch cold water piping to the various fixtures shall not be less than stated below:

Water closet tank	10 mm dia.
Urinals, flush-o-meter type	15 mm dia.
Service sink	15 mm dia.
Lavatories	10 mm dia.
Shower	15 mm dia.
Hose bib	15 mm dia.

3) Cast bronze union shall be installed at the connection to all equipment so that they may be conveniently disassembled.

4) All individual branches to fixtures and/or equipment shall be provided with air chamber shock absorbers.

5) Upon completion of the water system, all lines and valve seats shall be flushed out to clear the system of particles and dirt.

19.6.9. JOINTS AND CONNECTIONS

1) Fixture connections:
   a) Where space does not permit the use of standard fittings in conjunction with cast-iron flanges, special short-radius fittings shall be provided,
   b) Connections between fixtures and flanges on soil pipes shall be made absolutely air and watertight with an approved sealing compound; rubber gaskets or putty will not be permitted for these connections,
   c) Fixtures without outlet flanges shall be set at the proper distance from floor or wall to make first class joint with the use of closet-setting compound or gasket,
   d) No fixtures shall be set in place until the Engineer has examined and approved the setting.

2) Accessible contraction-expansion joints in piping shall be provided where necessary. Horizontal runs of pipe over 15 m in length shall be anchored midway along the run to force expansion and contraction equally towards the ends.

19.6.10. SLEEVES

1) Sleeves shall be provided for all pipes passing through floors, walls and concrete pits.

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2) Sleeves shall have an internal diameter at least 25 mm larger than the external diameter of the pipe being sleeved. Pipe insulation must be continuous through the sleeve. Sleeves shall be installed as construction progresses and secured in place during pouring of concrete.

3) Pipes passing through membrane waterproofed floor and roof slabs shall be flashed, and roof couplings provided at a suitable level above the roof slabs to terminate flashings.

19.6.11. FIXTURE AND EQUIPMENT SUPPORTS AND FASTENINGS

1) All fixtures and equipment shall be supported and fastened in a safe and satisfactory manner.

2) Inserts shall be securely anchored and the anchors shall be properly set in mortar. Inserts shall be installed flush with the finished wall and shall be completely concealed when the fixtures are installed.

3) Where through bolts are used, they shall be provided with plates or washers at the back and set so that heads, nuts and washers will be concealed by plaster. Exposed bolts, nuts, cap nuts and screws shall of the chromium plated brass.

4) All plumbing fixtures and accessories shall be installed so as to afford access for cleaning. All brackets, cleats, plates and anchors required to support the fixtures shall be fixed rigidly in place. Water closets shall be set on Bol-wax.

5) All installed plumbing fixtures and accessories shall be kept clean and in working order and be adequately protected. The Contractor shall not make use of the installed facilities without approval of the Engineer.

6) All fixtures shall be provided with individual control stops so that each fixture may be separately controlled without affecting any other fixture. All flush valves shall be equipped with vacuum breaking devices.

7) All surface mounted soap dispensers shall be installed with a 100 mm minimum clearance above the unit for filling.

19.6.12. HANGERS, ANCHORS, GUIDES IN BUILDINGS

1) All piping shall be rigidly supported by means of approved hangers and supports, to support and maintain the pipe in the required position and to prevent vibration. Supports shall be positioned to allow for expansion and contraction.

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2) Horizontal runs of pipe shall be supported on adjustable wrought iron or malleable iron pipe hangers spaced one pipe length, but not exceeding 3.50 m apart. Vertical runs of pipe shall be supported by wrought-iron clamps or collars.

3) Pipe hangers for water pipes 62 mm diameter and larger and for vent pipes shall consist of clamps formed out of 6 x 25 mm flat mild steel. Hangers for water pipes 50 mm and smaller shall be the split-ring type with 9 mm iron rods. Pipe hangers shall be thoroughly cleaned and painted with one coat of asphalt varnish.

4) Pipe hangers shall be fixed to concrete or masonry with approved steel fixings of the expanding anchor type or steel inserts cast into place. Expanding anchor type fixings shall be installed to develop their full strength. Inserts shall be cast steel and shall be of a type to receive a machine bolt or nut after installation. Inserts shall permit adjustment of the bolt and shall be installed before the concrete is poured.

5) Chromium-plated pipes shall have a clearance of not less than 18 mm or more than 25 mm where run on the face of plaster and shall be supported where required by cast-brass supports finished to match the pipe.

19.6.13. FLOOR, WALL AND CEILING PLATES

Where uncovered, exposed pipes other than ferrous pass through floors, finished walls or finished ceilings shall be fitted with chromium-plated plates. Ferrous pipes shall be fitted with cast-iron or steel plates. Plates shall be large enough to completely cover the hole around the pipe and shall be square, octagonal or round, with the least dimension not less than 37 mm larger than the diameter of the pipe.

19.6.14. CLEANING AND PAINTING

1) Prior to painting, all exposed metal surfaces shall be free from grease, dirt or other foreign material. Chrome or nickel-plated pipes and fittings shall be polished upon completion.

2) Pipe hangers, supports and all other iron-work in concealed spaces shall be painted with one coat of red lead and a finish coat of oil enamel paint.

3) All exposed soil, waste and vent piping or cast-iron works that are asphalt or tar-coated shall be given two coats of shellac and two coats of oil based paint.

4) All exposed pipes shall be adequately and durably identified by distinctive coloured paints as follows:

a) Cold Water PipeBlue
b) Hot Water Pipe Red
c) Vent PipeGreen

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d) Fire line Red

19.6.15. EARTHING OF METAL PARTS

The Contractor shall ensure electrical continuity of all pipeline network and all metal appliances, installed by him and to which all other metal parts of the installation have be connected.

19.6.16. METAL TAPES

Non-metallic pipelines shall be laid with a continuous metallic tape for easy detection after installation. The tape (or wire) shall be of corrosion resistant metal and shall be placed on the top of the pipeline.

19.6.17. MARKING ON PIPE MATERIAL

1) The following indications have to be marked on all pieces and on the pipes at 1.00 m distance from the socket or joints:

a) quality indication
b) manufacturing marks, brand name or trademark
c) nominal diameter
d) year of manufacture
e) corresponding number of the schedule

2) In case of spigot pipes, the spigot end has to show the control marks for connection.

19.7. TESTING ON INSTALLATION

19.7.1. GENERAL

1) The test programme shall include a complete visual inspection of the whole plumbing and fire fighting system and verification or performance as stipulated in the material specification and of correct functioning of the electrical and control systems.

2) All supply documents, operating instructions, acceptance documentation and maintenance regulations shall be checked to ensure that they correspond with equipment described and also all certificates such as that of the inspection authorities, test certificates and data about quality, temperature and pressure shall be submitted.

19.7.2. FIXTURES AND FITTINGS

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1) The type and the catalogue number of the sanitary fixtures shall be checked.

2) All equipment in general including the accessories shall be checked for service ability, correct operation and freedom from damage.

3) The flow and water capacity shall be checked on the full connection of lavatories, showers, WC's etc. and also the draining capacity shall be measured at the same time.

19.7.3. WATER SUPPLY SYSTEM

1) Visual inspections shall be made of the entire network for the water systems with regard to laying, fixing, suspension of pipes and fixtures, particularly the arrangements of the fixed points and the separation of the individual connections in the various parts of the system. The laying and sealing the water connections lines to the buildings and through walls shall be checked.

2) The satisfactory function of all dirt traps, valves, aeration and venting valves, check-valves, compensators, pressure gauges, pressure reducers, thermostats, thermometers, level controls, protective filters, pumps, etc., shall be checked.

3) The test programme shall also cover:

a) Checking of type, thickness and professional laying of the piping insulation,
b) Checking number, form and inscription of the equipment labelling,
c) Checking of all pipe and flanged connections to supply tanks, devices, distributors, water-heaters, air-conditioning devices, drainage and vents for symmetry and lack of strain,
d) Performance of pressure test for the entire network, including fixtures,
e) Checking of the filter medium in all filters for kind and quantity,
f) Checking of water quality with the aid of chemical analysis and bacteriological test results.

4) On completion of the pipe work installation or sections thereof as required, pressure test shall be made before the application of insulation. The pressure tests shall be taken by sectors. All equipment and accessories shall be provided and the Engineer shall be given notice that the work is ready for testing. Pipes shall be filled slowly with potable water to exclude all air. Tests shall be made by pumping up the system to the required pressure then closing the valves between the pump and the section under test. The valve shall remain closed for the duration of the test and pump shall be disconnected. Test pressure of maximum working pressure plus 50% shall be applied as detailed for a period of hours or longer, at the discretion of the Engineer. There must be no measurable loss of pressure for at least 30 minutes. If, at the end of period, there is no drop in pressure and no evidence of leak or other faults, the test will be considered satisfactory. Should any fault be revealed

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by the test, leaks are to be recorded. Faults shall be made good and the pipe work retested as many times as necessary until satisfactory results are obtained.

19.7.4. DRAINAGE SYSTEM

1) The entire system of waste, drain and vent pipes shall be checked and tested with water whenever possible, otherwise with air. Wooden plugs shall not be permitted for tests. The following will be covered:

a) Check the piping by means of the separation system, in relation to the specified capacity,

b) Check each connection for dimensions and draining capacity,

c) Check the drain line for laying, fixing, compliance with specification,

d) Check the practical arrangement of the fixtures, fixing points, suspensions, cleaning openings, vents, pit covers and ground inlets,

e) Check all the covers and openings, paying special attention to the separation system for waste/sewage and the storm water,

f) Generally clean water and apparatus shall be provided for testing.

2) The following test methods shall be used:

a) Air testing:

All open ends of pipe work shall be plugged and water seals of all sanitary appliances fully charged. Tee piece shall be connected to the installation by a flexible tube passed through a water seal, or by fitting to a test plug. Tee piece shall have cock on each branch, one branch connected to manometer. Air or smoke shall be introduced through other branch until a pressure equal to 38 mm water gauge register on the manometer scale. A period for temperature stabilisation to be allowed after which pressure has to be maintained without loss shall be not less than three minutes.

b) Water testing:

All the openings in the piping system shall be tightly closed by inserting testing plug so that heavy rubber gasket fits snugly all around the opening. The highest point will be left open to supply water and may be raised if necessary by temporary jointing, develop a minimum static head of 0.5 bar for of water at each section of the system. Water is filled to the point of overflow and any drop in the level of water will indicate a leak that will be found by inspection. The water level will be checked for no drop for at least 15 to 30 minutes. Higher stacks will be tested in sections, starting from the top section and then connecting top section to next lower section.

3) Testing shall be carried out as soon as practicable after completion of each drainage stack. All concealed work shall be tested before being finally enclosed.

19.7.5. DEFECTIVE WORKS

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1) If inspection or test shows, any defect, such defective work or material shall be replaced and the inspection and tests repeated until satisfactory to the Engineer.

2) All repairs to piping shall be made with new materials at the expense of the Contractor. No caulking of screwed joints or holes will be accepted.

19.7.6. WATER TREATMENT PLANT

1) The Contractor shall test the equipment in accordance with manufacturer's instructions to determine that it operates properly.

2) The testing shall consist of operating the chlorinating equipment under manual and automatic start-stop control, with the stroke adjustment set in at least five positions of solution feed between minimum and maximum strokes. The chlorine residual at several points in the treated water system shall be determined for each setting of the stroke by means of the compactor furnished with the chlorinating equipment. Final adjustment shall be made to produce a residual of between 0.20 and 0.50 ppm of chlorine in the treated water system. The tests shall be made with the pressure tank and pressure filter in operation.

3) The pressure tank and controls tests shall include any necessary adjusting of the air control valves, float switch, pressure switch. Air-pressure regulating valve and other accessories.

4) The pressure sand filter test shall include the operation of the multi-port valves through the stages of backwash, rewash and filtration and observing the operation to see that the filter unit is properly performing the desired function at each stage.

19.7.7. DISINFECTION

1) The entire water system shall be thoroughly flushed and disinfected with liquid chlorine or hypochlorite before it is placed in operation. Chlorinating agents shall be introduced into the water lines in a manner approved by the Engineer.

2) The chlorine dosage shall be such as to provide no less than fifty parts per million (50 ppm) of available chlorine. Following a mixing period of not less than 16 hours, the heavily chlorinated water shall be flushed from the system with clean water until the residual chlorine content is not greater than 0.2 ppm.

3) All valves in water lines being sterilised shall be opened and closed several times during the 16-hour chlorinating period.

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19.8. MEASUREMENT AND PAYMENT

No separate measurement for payment and payment shall be made for plumbing and sanitary fittings required in the Dam Control Building. The same shall be dealt as per Section B.15 "Building and Architectural works" of Technical Specifications

19.8.1. PIPE WORK

1) Measurement for payment for the supply and installation of the various sizes of pipes for water supply and sewerage system including insulations if any of the pipes will be of the length of pipeline of 25 mm diameter and above actually installed.

2) Payment will be made at the appropriate Unit Price per linear meter entered in the Bill of Quantities, which shall also include all fittings, fixings, valves, joint treatment and testing and commissioning of pipeline.

3) Pipe below 25mm diameter are included in the section B.15 "Building and Architectural works" of Technical Specifications.

4) The excavation, concrete and backfilling of the trenches required for pipes will be paid separately at the Unit Prices applicable for such work.

19.8.2. WATER TREATMENT PLANT AND PUMPS FOR THE WATER SUPPLY AND SEWERAGE TREATMENT PLANT SYSTEM

1) Measurement for payment for supply and installation of pumps and their other components for the water supply will be of the number of the particular items installed as specified in Bill of Quantities.

2) Payment will be made at the Unit Price per piece entered in the Bill of Quantities, which shall include all cost of labour and materials for the supply, and installation.

3) Payment for the water treatment plant consisting of the filtration and chlorination unit, all as specified, shall be quoted for on a lump sum per unit entered in the Bill of Quantities and paid for accordingly. This payment shall include all costs towards planning and designing the plant, costs of labour and materials for the supply and complete installation.

4) Payment for the sewerage treatment plant consisting of collection tank, FIBR based sewage treatment plant including filtration and chlorination unit, pumps including standby units, pipes, fittings, electrical /mechanical equipments including panels and all other material required for the successful operation of the

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plant shall be quoted for on a lump sum per unit entered in the Bill of Quantities and paid for accordingly. This payment shall also include all costs towards planning and designing the plant, all labour and materials for the supply and complete installation.

5) All plumbing, sanitary facilities and ancillary works such as control room for sewage treatment plant, as described in this and other Sections of the specifications, except as specified herein, shall not be paid separately and shall be included in the Lump Sum quoted under "Buildings and Architectural works".

6) Reinforced cement concrete required for the water treatment/sewage treatment plant shall be paid as per the relevant items of BOQ provided elsewhere in the technical specifications.

END OF SECTION B.19

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ANNEXURE-1

SEPTIC TANK

Septic tank should be located at a place open to sky, as far away as possible from the exterior of the wall of building and should not be located in swampy areas or areas prone to flooding. It should also be accessible for cleaning.

The Contractor shall design, supply and install septic tanks for sanitary sewage for the control building of Dam top and DG room, at the location as shown on the drawings or as directed by Engineer.

Dimensions of Septic Tank

Septic tank shall have minimum width of 750 mm, minimum depth of one metre below water level and a minimum liquid capacity of 1000 litres.

For rectangular septic tanks, the length of the tank shall be 2 to 4 times the width. Suitable sizes of septic tanks

For circular tanks the minimum diameter shall not be less than 1.35 m and operating depth shall not be less than 1.0 m

Inlet - The design of septic tank inlets shall be such as to introduce the crude sewage with the least possible distrurbance of the settled sludge or the surface scum. For tanks not more than 1200 mm wide, T-shaped dip-pipe not less than the nominal bore of incoming drain may be provided. The pipe shall be fixed inside the tank, with top limb rising above scum level and the bottom limb extending about 300 mm below the top water level. For tanks in excess of 1200 mm in width, two or more submerged inlets are preferable. One method of providing such inlets is by the use of submerged bends of the same nominal bore (not less than 100 mm) set as closely together as practical in a shallow sump formed within a small benched chamber

It is important that the invert of the benched channel be 58 mm above the top water level and the inlet ends of the submerged bends should be set flush with the floor of the sump which should be not less than 75 mm below top water level.

The sump may be the full width of the chamber, but should not exceed 1.5 times the nominal bore of the inlet bends in other direction.

The inverts of the outlet ends of these bends should be between 300 and 525 mm below top water level in the tank. A baffle should be provided 150 mm from the inlet end of the tank, extending 150 mm below the invert of the inlet pipes and 150 mm above the top water level

Outlet –

The final outlet for tanks which are less than 1200 mm wide should be by 100 mm nominal bore dip-pipe fixed inside the tank with a top limb rising above scum level and the bottom limb extending to about 1/3 of the liquid depth below top water level.

The invert of the outlet pipe shall be 50 mm below the invert of the inlet pipe. For wider tanks, it is necessary to use a weir outlet extending the full width of the tank and protected by a scum board fixed 15~ lmn from the weir and extending 150 mm above and 1/3 of liquid depth below the top water level. A deflector should

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be formed either in the structure 'of the end (outlet) wall or by a purpose-made deflector to prevent rising particles from reaching the outlet weir. This deflector should be located 150 mm below the base of the scum board and protrude 150 mm into the tank

Partition

Where the capacity of a septic tank exceeds 2000 litres, the tank may be divided into two chambers by means of a fixed durable partition. The partition shall be located so that the capacity of the first chamber is twice that of the second chamber. Suitable openings rectangular or circular with minimum dia 100 mm and maximum 150 mm shall be provided in the partition at approximately 300 mm below TWL.

Free-Board - A minimum free board of 300 mm should be provided.

Access Openings and Cover - Each compartment of a septic tank shall be provided with a rectangular access opening measuring, not less 455 x 610 mm or a circular opening 500 mm diameter. The cover to access openings shall be of reinforced concrete or of cast iron. A cover shall incorporate a suitable lifting device and when in place after installation of the septic tank shall fit neatly and be sealed to prevent the ingress of water.

Ventilating Pipe - Every septic trank shall be provided with ventilating pipe of at least 50 mm diameter. The top of the pipe shall be provided with a suitable cage of mosquito proof mesh. The ventilating pipe shall extend to a height which would cause no smell nuisance to any building in the area. Generally the ventilating pipe may extend to a height of about 2 m when the septic tank is at least 20 m away from the nearest building and to a height of 2 m above the top of the building when it is located closer than 20 metres. The ventilating pipe may also be connected to the normal soil ventilating system of the building where so desired.

SEPTIC TANK CONSTRUCTION

It is essential that the floor of the tank be water tight and of adequate strength to resist earth movement and to support the weight of the tank ,walls and contents.

The floor may be of cement concrete of minimum M 15 grade (IS : 456) and a minimum slope of 1 : 10 may be provided towards the sludge outlet to facilitate desludging.

Walls - The walls should be of such thickness as to provide adequate strength and water tightness. Walls built out of brick should not be less than 200 mm thick and should be plastered to a minimum thickness of 12 mm inside and outside with cement mortar not weaker than 1 : 3; where they are built out of the stone masonry. They should have a minimum thickness of 370 mm.

Backfill around the outdoor septic tank up to the required level shall be made in layers approximately of 200 mm thick and thoroughly tamped in a manner that will not produce undue strain on the tank

SLUDGE WITHDRAWAL

A portion of sludge not less than 25 mm in depth should be left behind in the tank bottom which acts as the seeding material for the fresh deposits.

The digested sludge should be withdrawn through a dip pipe of not less than 150 mm dia under a hydrostatic pressure of at least 450 mm. The sludge pipe shall deliver the sludge to the sump and be provided with a delivery valve to draw the sludge as required. Portable pumps may also be used for desludging in which case there will be no need for sludge pipe or sludge pump. Manual handling of sludge should be avoided.

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When removal of the sludge is carried out the scum in the first tank should not be disturbed more than necessary, their scum is needed to ensure efficient operation.

Sludge from septic tanks may be delivered into covered pits or into a suitable vehicle for removal from the site. Spreading of sludge on the ground in the vicinity should not be allowed

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ANNEXURE -1 – SEMI-ADIABATIC TEST PROTOCOL

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20. ROLLER-COMPACTED CONCRETE

20.1. SCOPE OF WORK

1) The Work under this section includes all labor, material, equipment, testing and services related to the RCC work to be carried out by the Contractor under this contract.

2) The RCC work shall be performed to the dimensions as shown in the drawing or otherwise directed by the Engineer. Lift drawings shall be prepared by the Contractor in accordance with the Engineer.

3) The Contractor shall co-operate with other Contractors related to permanent works with whom the interfacing with RCC works is involved.

4) Formwork, Reinforcement, Water stops, Joints, Instruments, Grouting & Conventional Concrete etc. are covered separately in other sections of these specifications.

5) The approval given by the Engineer to the Contractor's plants and equipment of their operation or of any construction methods shall not relieve the Contractor of his full responsibility for the proper safe execution of RCC work or any obligations under this contract.

20.2. APPLICABLE CODES AND STANDARDS

The following specifications, standards and codes including all official amendments/revisions and other specifications and codes referred to therein, should be considered a part of this specification. In all cases, the latest issue/edition/revision shall apply. In case of discrepancy between this specification and those referred to herein below or other specifications forming a part of this bid document, this specification shall govern.

a) Materials

1.	IS: 269	Ordinary Portland cement – Specification
2.	IS: 1489 (Part-1)	Portland Pozzolana Cement –Specification
3.	IS: 16415	Composite Cement – Specification
4.	IS: 3812 (part 1)	Pulverized Fly Ash, Specification Part 1 for use as pozzolana in cement, cement mortar and concrete
5.	IS: 383	Coarse and fine aggregate for concrete - Specification
6.	IS: 9103	Concrete admixtures - Specification
7.	IS: 2645	Integral waterproofing compounds for cement mortar and concrete – Specification
8.	IS: 1786	High strength deformed steel bars and wires for concrete reinforcement –

Specification

b) Material Testing

1.	IS: 4031 (part 1)	Methods of physical tests for hydraulic cement, Part 1: determination of fineness by dry sieving
2.	IS: 4031 (part 1)	Methods of physical tests for hydraulic cement, Part 2: determination of fineness by Blaine air permeability method
3.	IS: 4032	Methods of chemical analysis of hydraulic cement
4.	IS: 650	Standard sand for testing cement - Specification
5.	IS: 2430	Methods for sampling of aggregates for concrete
6.	IS: 2386 (part 1)	Methods of tests for aggregates for concrete, Part 1: particle size and shape
7.	IS: 2386 (part 2)	Methods of tests for aggregates for concrete, Part 2: Estimation of deleterious materials and organic impurities
8.	IS: 2386 (part 3)	Methods of tests for aggregates for concrete, Part 3: Specific gravity, density, voids, absorption and bulking
9.	IS: 2386 (part 4)	Methods of tests for aggregates for concrete, Part 4: Mechanical properties
10.	IS: 2386 (part 5)	Methods of tests for aggregates for concrete, Part 5: Soundness
11.	IS: 2386 (part 6)	Methods of tests for aggregates for concrete, Part 6: Measuring mortar making properties of fine aggregate
12.	IS: 2386 (part 7)	Methods of tests for aggregates for concrete, Part 7: Alkali aggregate reactivity
13.	IS: 2386 (part 8)	Methods of tests for aggregates for concrete, Part 8: Petrographic examination
14.	IS: 1199 (part 1)	Fresh concrete - Methods of sampling, testing and analysis Part 1: Sampling of fresh concrete
15.	IS: 1199 (part 2)	Fresh concrete - Methods of sampling, testing and analysis Part 2: Determination of consistency of fresh concrete
16.	IS: 1199 (part 3)	Fresh concrete - Methods of sampling, testing and analysis Part 3: Determination of density of fresh concrete
17.	IS: 1199 (part 4)	Fresh concrete – Methods of sampling, testing and analysis Part 4: Determination of air content of fresh concrete
18.	IS: 1199 (part 5)	Fresh concrete - Methods of sampling, testing and analysis Part 5: Making and curing of test specimens
19.	IS: 1199 (part 6)	Fresh concrete - Methods of sampling, testing and analysis Part 6: Tests on fresh self-compacting concrete
20.	IS: 1199 (part 7)	Fresh concrete - Methods of sampling, testing and analysis Part 7: Determination of setting time of concrete by penetration resistance

21.	IS: 516 (part 1)	Hardened concrete – Method of test, Part 1: Testing of strength of hardened concrete
22.	IS: 516 (part 2)	Hardened concrete – Method of test, Part 2: Properties of hardened concrete other than strength
23.	IS: 3025	Methods of sampling and test (physical and chemical) for water and wastewater
24.	IS: 6925	Methods of test for determination of water-soluble chlorides in concrete admixtures
25.	IS: 1727	Methods of test for pozzolanic materials
26.	ASTM C1170	Test Methods for Determining Consistency and Density of Roller Compacted Concrete Using a Vibrating Table;
27.	ASTM C1435	Standard Practice for Molding Roller Compacted Concrete in Cylinder Molds Using a Vibrating Hammer;
28.	ASTM C1176	Standard practice for making RCC in cylinder moulds using a vibrating table
29.	ASTM C403	Standard test method for time of setting of concrete mixtures by penetration resistance.
30.	ASTM C494	Materials for use as chemical admixtures in concrete
31.	ASTM C1040	Test Methods for density by Nuclear methods
32.	ASTM C1079	Testing Method for Moisture Content in fresh RCC

c) Material storage

1.	IS: 4082	Stacking and storage of construction materials and components at site – Recommendations

d) Equipment

1.	IS: 4925	Concrete batching and mixing plant - Specification

e) Code of practice/ Standards

1.	IS: 456	Plain and reinforced concrete – Code of Practice
2.	IS: 457	Code of practice for general construction of plain and reinforced concrete for dams and other massive structures
3.	IS: 7861 (part 1)	Code of practice for extreme weather concreting, Part 1: Recommended practice for hot weather concreting
4.	IS: 7861 (part 2)	Code of practice for extreme weather concreting, Part 2: Recommended practice for cold weather concreting
5.	IS: 1893	Criteria for earthquake resistant design of structures
6.	ACI 207.5R	Roller Compacted Mass Concrete

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7.	USACE EM 1110-2-2006	Roller Compacted Concrete
8.	ICOLD Bulletin 177	Roller Compacted Concrete Dams (2020)
9.	ICOLD Bulletin 126	Roller Compacted Concrete Dams (2003)
10.	BS 1881: Part 104: 1983	Ve Be Apparatus
11.	ASTM C94: Annex A1	Concrete Uniformity Test
12.	ASTM C1079	Testing Method for Moisture Content in fresh RCC
13.	ASTM C 1040	Test Methods for density by Nuclear methods
14.	ASTM C 494	Type F - Superplasticizers

f) Measurement

IS: 1200 (part 2) Method of measurement of building and Engineering works, Part 2: concrete works

20.3. ROLLER-COMPACTED CONCRETE

20.3.1. GENERAL

1) The Roller Compacted Concrete (RCC) describes a material (a concrete mixture) and a construction process characterized principally by the use of rollers for its compaction. Materials used for RCC include cementitious materials (Portland cement and supplementary cementitious material such as fly ash, Granulated blast furnace slag etc.), aggregates, filler, water and admixtures. The concrete mix is spread in thin layers over the length of the dam, enabling concrete to proceed very quickly.

2) The RCC has a no slump consistency and is densified by combined effect of vibrations and external loading of the vibratory rollers. This requires much lower water content that gives higher strength as compared to the conventionally placed concrete and provides the ability to support compaction of spreading equipment.

3) RCC shall be placed and compacted to the lines and grade shown on the drawings, as specified herein, and as directed by the Engineer. For matters not covered in this section the standard specifications for Concrete (Section B.9.) given separately shall be followed.

4) This Specification assumes that the RCC dam is zoned, with higher cementitious content mixes in the upstream part of the dam (to meet permeability requirements and tensile strength under dynamic loads) and at the downstream (for compressive strength requirements) and lower cementitious content mixes in the central part of the dam.

5) The cementitious materials to be used in RCC will generally be Portland Composite Cement. The total quantity of cementitious materials to be used and the respective proportions in the different zones of the dam should be as per RCC mix design approved by the Engineer.

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20.3.2. DEFINITIONS

The terms used in this specification shall have the meanings as defined below:

- Fine aggregate: Fine aggregate is defined as the material smaller than 75 microns.
- Cementitious Paste: The Cementitious Paste fraction of RCC is defined as the absolute volume of cementitious materials, liquid admixtures, air and free water.
- Coarse Aggregate: The term coarse aggregate defines the aggregate of which at least 90 % by mass is coarser than 4.75 mm.
- Crack Inducer: The term "Crack Inducer" is defined as the system incorporated into the upstream (and downstream) face concrete to induce shrinkage cracking in the facing concrete on the alignment of a joint in the RCC.
- Crack Director: The term "Crack Director" is defined as the system incorporated into the RCC layers to induce thermal shrinkage cracking on the alignment of a joint
- Conventional vibrated concrete (CVC): Conventional vibrated concrete is defined as mass concrete compacted with an immersion vibrator.
- Facing (or Skin) Concrete: Facing (or Skin) Concrete is a relatively impermeable mass concrete placed against formwork, or other surface forming the external face of the RCC body.
- Filler Concrete: Filler Concrete or dental concrete is mass concrete placed generally around items built into the interior of an RCC structure, or to prepare the foundation for acceptance of RCC.
- Fines: The Fines are defined as the total volume of material in the RCC mix smaller than 75 microns (cementitious, pozzolan & non-plastic aggregate fines).
- Full-Scale Trial (FST): The Full-Scale Trial is an embankment constructed in RCC for the purpose of testing plant, mixes, procedures and various other aspects of RCC construction in advance of the main dam wall.
- Grout Enriched RCC (GE-RCC): GE-RCC is Grout Enriched RCC is RCC to which an additional cementitious grout is added at the top of the layer before spreading the RCC and which is compacted by immersion vibrator. This concrete may be used where rollers cannot reach, around reinforcement, as well as against formwork.
- Grout Enriched Vibrated RCC (GEVR): GEVR is a RCC to which an additional cementitious grout is added at the bottom of the layer before spreading the RCC and which is compacted by immersion vibrator. This concrete may be used where rollers cannot reach, around reinforcement, as well as against formwork.
- Immersion Vibrated RCC (IVRCC): IVRCC is is a RCC mix proportioned with a consistency that allows compaction by immersion vibrator.
- Mortar: The Mortar fraction of the RCC mix is defined as the absolute volume of the paste and the fine aggregate (passing 4.75 mm sieve).
- Paste/Mortar Ratio: The paste / mortar (p/m) ratio of RCC is defined as the respective absolute volume of paste / mortar.

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- Foundation Bedding: The Foundation Bedding is a workable mortar, or highly sanded concrete placed on the prepared foundation to receive fresh RCC.
- RCC Bedding Grout: The RCC Bedding grout is a workable grout placed on a prepared compacted RCC surface, to receive fresh RCC.
- Roller Compacted Concrete (RCC): RCC is a zero-slump concrete designed to be transported by high-capacity equipment, spread by bulldozer and compacted by vibratory roller in layers.
- Sand/Aggregate Ratio: The sand / aggregate (s/a) ratio of RCC is defined as the weight of fine aggregate (<4.75 mm) / the total aggregate weight.
- Specified Strength: The design RCC strength, representing the compressive crushing strength of a 150 mm cube after curing in a bath of water at a constant temperature of between 22 and 25 °C for 365 days since mixing.
- Supplementary Cementitious Non-cement cementitious (SCM) materials (fly ash, Granulated blast furnace slag, natural pozzolans, etc).
- Total Paste: The Total Paste fraction of RCC is defined as the Cementitious Paste + the absolute volume on non-plastic aggregate fines (< 75 microns).
- Void Ratio in Fine Aggregate: Volume of voids determined in the compacted bulk density test of fine aggregate using the tamping rod procedure.

20.3.3. CONTRACTOR'S PLANT, EQUIPMENT AND CONSTRUCTION PROCEDURES

1) The contractor shall select the type of plant to be used for RCC. The contractor's plant shall be located in the contractor's work area at suitable location.

2) The Engineer shall have the right at all times to inspect all operations including the sources of materials, procurement, layout and storage of materials, the concrete batching and mixing equipment and the quality control system. Such an inspection shall be arranged and the Engineer's approval shall be obtained prior to starting of concrete work. This shall, however, not relieve contractor of any of his responsibilities.

20.3.4. MIX DESIGN

1) Within 18 months from the date of LOA, the Contractor will complete a mix design study, including results of accelerated cure than will indicate 1-year strengths, in order to define mix proportions for different mixes to be used in the dam and the expected time dependent and load dependent properties of each mix.

2) The Contractor shall be responsible for the design of the RCC mixes and for ensuring that all concrete placed in the Works meets the requirements of the Technical Specification.

3) The Contractor shall use different RCC mixes in different areas of the dam, as defined in Drawings. The Contractor shall conduct mix verifications testing in the laboratory. The mix design for each type of RCC

mix shall be approved by the Engineer. The Contractor shall adjust the precise limits and types of mixes for each part of the dam based on results of mix verification tests that use site specific materials prior to construction and, if appropriate, during construction.

4) The selected mixes, as approved by the Engineer, shall be transferred to the concrete plants to be prepared for the work. However, minor adjustments in exact proportions such as the added moisture required to obtain optimum compaction during cold/damp weather as compared to warm/wet weather may be carried out or admixture dosage to achieve the required initial setting time. Continual visual monitoring of the behavior of the mix at the time of placement shall be used as the basis for immediate adjustments, with records being kept that document the precise mix proportions for RCC placed in every part of the dam.

5) The RCC mix design shall be aimed generally:
   a. To achieve adequate strength (compressive and tensile), density, permeability and porosity;
   b. To minimize internal heat rise from hydration and the subsequently developed stress or crack potential;
   c. To ensure appropriate bond between successive layers without joint treatment. The RCC mix shall be designed by the Contractor with a sufficiently delayed set to allow the placement of a new layer before the initial set of the surface of the receiving layer beneath. For this purpose, the Contractor shall use set retarding agents that have been properly tested and approved.
   d. To achieve a workable mix;
   e. To confirm the mixes cement/fillers/sand/aggregates are not alkali reactive;
   f. To define relation Setting Time vs. Temperature and in-situ conditions;

6) A Trial Mix program shall be conceived to produce trial mixtures over a range of cementitious contents, SCM contents and coarse and fine aggregate blends, admixture type and dosages, other material sources, etc.

   Testing of the various mixes shall include:
   - Aggregate specific gravity and absorption
   - Aggregate gradings and moisture content
   - VeBe Workability
   - Air content
   - Unit weight
   - Specimens:
     - Time of Setting
     - Compressive strength
     - Direct Tensile strength
     - Splitting Tensile strength
     - Young's Modulus

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- Aggregate specific heat
- Coefficient of thermal expansion
- Diffusivity
- Creep
- Adiabatic Temperature Rise
- Tensile strain capacity

The RCC mixes shall only be finalized on successful testing of the Full-Scale Trial placement.

20.3.5. TEST SECTION

1) Placement of test section is aimed at pre-qualification of equipment, training of personnel, establishment of construction procedures and quality control tests. The test section is not for the commissioning of equipment, the contractor shall commission all the equipment well before the start of the trial.
   The RCC shall be produced by the final RCC plant, completely installed and tested, using equipment representing the equipment to be used in the dam, demonstrating the batching & mixing capability and to pre-qualify the type of equipment for transporting, placing and compacting. It will also serve as a practice area for inspection.

2) Prior to placing RCC in the Dam, the contractor shall complete an acceptable RCC trial placement, at location approved by the Engineer to demonstrate the batching & mixing capability and to pre-qualify the type of equipment for transporting, placing and compacting. The contractor shall place at least 8 lifts 300 mm high (approximately 14 x 25 m) for an overall volume of at least 840 m3 of RCC for each mix to be used in the dam. If the Engineer is not satisfied with the placement, the contractor shall continue the placement of RCC in test section until RCC is satisfactorily placed in accordance with these specifications for 3-consecutive lifts to the satisfaction of Engineer without any additional cost to the Employer. The cost of placing RCC test section shall be on lump sum basis.

3) The material, composition, mixing, placing, compacting, formwork, curing and testing of the test section shall be in accordance with clauses 22.5 to 22.21 given below.

4) Placement of test section in the field is planned to achieve the following:
   a. Adjustment required, if any, for field RCC mix proportion.
   b. Confirmation of no. of passes of vibratory roller for desired compaction.
   c. Determination of modified maturity factor for RCC Joints
   d. Determination of cutoff rainfall intensity for placement of RCC
   e. Confirmation of suitability of contractor's equipment.
   f. Confirmation of contractor's way and sequence of RCC layer placement.

5) Contractor shall ensure suitable arrangement to simulate rainfall intensity of 2 mm per hour to 10 mm per hour with a least count of 0.25 mm per hour while placing of RCC in test section.

6) The Contractor shall submit a dedicated Method Statement for the test section at least 2 months in advance before starting of the trial including the list of tests to be carried out, techniques and materials that will be used in construction of the dams such as precast panels, joint cleaning, compaction, density testing, bedding, GERCC/GEVR, waterstop installation, etc. The Contractor shall also excavate a trench through the RCC test section to allow visual inspection of the RCC lifts and recover a sufficient number of 150 mm cores to enable the qualitative and quantitative evaluation of all aspects tested.

7) Core drilling and testing shall be sufficient to provide a statistically based confirmation of compressive, tensile and shear strengths, Poisson's ratio and permeability, both of the parent RCC and of the various different joint preparations at the various different joint maturities applicable.

8) The Engineer will require minimum 105 days after placement to fully evaluate the test placement before the placement is accepted. The contractor shall assist the Engineer in this evaluation.

20.4. SUBMITTALS

20.4.1. SUBMITTALS BEFORE CONSTRUCTION

1) Submittals listed herein are related to items, which require the consent of the Engineer and are to be submitted by the Contractor before the appropriate work may proceed.

2) Within 28 days from the date of issue of 'Notice to Commence', but before procuring or mobilizing at site the equipment, the contractor shall submit to the Engineer updated and detailed plans and descriptions, consistent with those submitted with his Tender and any subsequent amendments and additions agreed to by the Engineer and the contractor, of the following:

   a. Transport and Storage of Cement
      - Full details of methods of transportation including intermediate transshipment of cement in bulk tankers and/or other suitable methods during normal & peak RCC placement.
      - Full details of storage and handling of bulk cement at project site and other transshipment location such as railway siding etc.

   b. Aggregates Processing Plant

Description, flow diagrams and drawings in sufficient details to indicate layout, type and capacity of crushing, screening, washing, conveying and other aggregate processing and handling equipment.

c. Batching and Mixing Plants
Description, flow diagrams, and drawings of the plants, and details of the equipment the contractor intends to use to determine and control the amount of each separate RCC ingredient and mixing thereof into uniform mixture.

d. Concrete Cooling Plant
Details of refrigeration and ice plants and methods, which the Contractor proposes to use to comply with, concrete temperature requirements.

e. Transport and Placing of RCC
Full details of the equipment and methods for transporting the concrete from the concrete plant to the final point of placing, including numbers, type and capacity of transport vehicles, concrete chutes, immersion vibrators, vibratory rollers, joint cutters, vibro-compactors, bulldozers etc. and details of standby plants to be installed.

f. Mode and methodology of concrete compaction and concrete curing.

g. Sampling and Testing of Materials
List and details of equipment for sampling and testing, detailed program for quality control of RCC work and qualification and experience of the proposed personnel.

h. Foundation and surface preparation equipment.

3) At least 56 days in advance of any RCC work being carried out at the site, the Contractor shall submit to the Engineer following notifications based on the results of the preliminary material testing:
   a. Notification of quantity requirement of cement and SCM
   b. Notification of transportation of cement and SCM from Owner's store to the work site.
   c. Notification of source, analysis, method of delivery, and storage of water for RCC manufacturing.
   d. Notification of any admixtures which the contractor proposes to use, manufacturers thereof, and information about the chemical names of the principal ingredients and the effects of under or over dosage.

4) At least 28 days prior to procuring or dispatch to the site of the particular item of work to which the submittal relates, the contractor shall submit to the Engineer the following:
   a. Details of curing compounds, if any.

b. Details of epoxy mortar for concrete repair.

5) The Contractor shall submit a layout and schematic drawing with a narrative description of his planned aggregate production and equipment, locations and sizes of stockpiles, transportation methods, and storage procedures. Anticipated peak production capacity, the estimated amounts of any waste material, normal operational rates, and anticipated hours of production, storage areas, and storage volumes vs. time of use shall be indicated. The submittal shall be provided at least 90 days prior to the start of aggregate production.

6) The Contractor shall submit at least six months before the start of the RCC works a detailed method statement and equipment list for handling, hauling, and depositing RCC, including anticipated production rates, power requirements, how the delivery system will reach every portion of the dam, and a detailed schedule of the expected elevation vs. calendar date.

20.4.2. SUBMITTALS DURING CONSTRUCTION

1) Contractor shall provide the Engineer with a weekly placing schedule giving the details of RCC placement. This weekly program shall be submitted to the Engineer for his acceptance at least 2-days prior to the commencement of the week.

2) Before commencement of the RCC placement, the Contractor shall prepare a checklist regarding all preparations for the specified work such as rock surfaces and foundation, cleaning, formwork, reinforcement, embedment, instruments, placement equipment and submit this list to the Engineer, who after his satisfaction about the work preparations will permit the contractor in writing to commence concrete placement.

3) The Contractor shall keep and make available to the Engineer records of the date, amount, and storage location of each delivery of cement and SCM of the part of the works in which it was used and shall provide facilities for checking the stock of cement & SCM.

4) During the performance of the RCC work, the Contractor shall keep a diary where he shall record the construction procedures related to RCC works. This diary shall be made available to the Engineer upon request. The records shall contain at least the following:
   a. Commencement and termination of RCC placement.
   b. Quantity and quality of aggregates, cement and SCM provided and the storage from which they were drawn.
   c. Temperature of air, water, cementitious material, aggregates and concrete.
   d. Meteorological conditions and humidity of air.

e. Sampling and testing performed and summary of results.
f. Personnel employed during various stages of the concreting operation and name of the responsible inspector or foreman.
g. Equipment used.
h. Directives received from the Engineer.
i. Any special material or procedures employed.

5) The Engineer reserves the right to require any additional information deemed necessary to be included in the submitted documents.

20.5. MATERIALS

20.5.1. GENERAL

1) Materials shall be so selected that they can satisfy the design requirements of strength, serviceability, safety, durability and finish with due regards to the functional requirements and the environmental conditions to which the structure will be subjected. Materials complying with codes/standards shall generally be used. Other materials may be used after approval of the Engineer and after establishing their performance suitability based on previous data, experience or tests.

2) Main stock of cement (located in the aggregate treatment plant area) must guarantee at least 10-days of peak RCC production to complete the placement without hindrance due to lack of it. Adequate surge stocks of cement close to the batching & mixing plants shall be maintained all the time.
As far as the aggregate is concerned, it is required a stock for 7-days of peak RCC production for all the aggregate classes in the aggregate treatment plant area. Adequate surge stocks for each aggregate class are foreseen close to the batching & mixing plants.

3) For the purpose of this specification, cementitious materials shall be interpreted to mean Portland Composite Cement. However, in case of exigency, if required, the Contractor shall investigate mix design, using other cement such as Portland Pozzolana Cement and use the same in works with the approval of Engineer-in-charge provided that the mix design so obtained meet all the technical specifications of fresh and hardened concrete including thermal requirements. The use of mix design with other cement shall be at no additional cost to the Owner.

4) All the materials required for RCC shall be supplied by the contractor. The Percentage of fly ash shall not be less than 15% in PPC. The total SCM content in PCC shall not be less than 35% whereas the content of fly ash shall not be less than 15%.

5) Cementitious materials shall be free from lumps and other deleterious matter and shall be otherwise undamaged when used.

6) Separate facilities shall be provided for unloading, transporting, storing, and handling each type of cement. Different fitting connections shall be used to pump into the cement and SCM silos to avoid the possibility of cross contamination.

7) Transportation from the place of manufacture to the batching plant shall be by means, which will protect the cementitious materials completely from exposure to moisture. Immediately upon receipt at the job site, bulk cementitious materials shall be stored in dry, watertight, properly ventilated and painted in a reflective color bins/silos, until the materials are batched.

8) The bins/silos shall be emptied and cleaned by the contractor when so directed by the Engineer.

9) All storage facilities shall be subject to approval by the Engineer and shall be constructed to permit easy access for inspection.

20.5.2. CEMENT

1) Cement shall be Composite Cement conforming to IS:16415. The cement shall be procured from the cement sources/plants approved by the Engineer-in-Charge. At least two sources/plants shall be selected out of those intimated by the Contractor so that one is standby for any eventualities.
Preference shall be given to the use of cement with a total alkali content, expressed as the sodium oxide (Na2O) equivalent, not exceeding 0,6 %, where:
% Na2O equivalent = % (Na2O + 0.658 x % K2O).

Cement shall have a heat of hydration at 28 days preferably in the range of 220-230 KJ/Kg. However, the heat of hydration of cement at 28 days shall not exceed 260 KJ/Kg in any case.

2) Cement which does not comply with relevant IS Code or is damaged in consignment; handling or storage shall be promptly removed from the Site.

3) All facilities for transport and storage of cement shall be subject to approval of the Engineer-in-Charge and shall be such that easy access for inspection is assured.

4) Bulk cement shall be transported from the port or mill to the Site in adequately designed weather-tight trucks, or other means where cement will be protected from exposure to moisture. All carriers shall be clean and dry prior to loading with cement and shall be equipped with weatherproof closure on all opening.

Immediately upon receipt at the Site, cement shall be stored in a dry, weather-tight and properly ventilated structure with adequate provisions for the prevention of absorption of moisture and constructed in such a way that there will be no dead storage. The vents of the bins and silos shall be equipped with dust collectors to reduce loss of cement during handling and inconvenience to the personnel.

5) Cement bags shall be stored in weatherproof buildings with a raised, well-ventilated wooden floor, and placed so that each consignment can be segregated if required and used in order of its age. Bags shall not be stacked more than 2.5 m high. Cement shall not be stored out of doors, except for immediate use, and in such event shall be protected during storage and handling by waterproof covers and a raised floor. Unused cement bags shall be placed back into the storage buildings.

6) Cement shall be used on a "first supplied", "first used" basis.

7) Bulk storage bins or silos shall be emptied completely and cleaned of all cement accumulations every 3 months.

8) Arrangements shall be made such that stocks of cement are adequate to meet the programme of work at all times. The program shall allow time for testing and approval of each consignment before such cement is incorporated in work. Cement shall be preferably used in same order in which it has been received at the Site. Storage of cement shall be limited to 90 days in bags and 150 days in bulk. Cement that has been in storage for longer than these periods or which may have absorbed moisture shall not be used unless it has been re-tested by the Contractor and approved by the Engineer-in-charge. Cement that has become lumpy shall not be used. The cements coming from different mills or of different makes shall be stored separately.

9) The temperature of cement upon arrival to the Site shall not exceed 70°C and when entering the mixers shall not exceed 50°C unless otherwise approved.

10) The testing of cement shall be as per section B.9 of these Technical Specifications.

11) The Contractor shall submit test certificates relating to each consignment of cement from the factory; each certificate shall show that a sample of the consignment has been tested by the manufacturer or by an approved laboratory and that it complies in all respects with the requirements of the Specification.

12) Contractor shall maintain a record of the locations of the concrete made from each consignment.

13) In case a new source of cement is proposed during the course of the works, the performances of the mix should be checked with this new cement.

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14) In no case it will be allowed to store in the same silo two cements of different origin.

15) The Contractor shall submit to the Engineer-in-charge the manufacturer's certificate of chemical and physical properties including heat of hydration at 7 days according to Langavant method for each shipping, delivery and every 5000 ton.

16) The following Verification "check" tests shall be conducted by the Contractor on samples obtained at the jobsite from each shipment or at least every 5,000 tons:
- Setting time according to ASTM C-191 or international equivalent;
- 2, 7 and 28 days strength according to ASTM C-109 or international equivalent;
- False set according to ASTM C-451 or international equivalent.

20.5.3. AGGREGATES

20.5.3.1. GENERAL

1) Unless otherwise specified, concrete aggregates shall conform to the requirements of IS: 456 and IS: 383. They shall be tested in accordance with the provisions of IS: 2386.

2) Sufficient storage and/or stockpiling facility shall be provided in the close vicinity of batching plant to meet the programme of work at all times.

3) Aggregates shall consist of clean, hard, dense, durable and uncoated materials, and shall have stable moisture content and grading when delivered to the batching plant. Aggregates shall not contain substances which may impair the quality of the concrete, attack reinforcing steel or reduce bond. The following substances are regarded as being harmful: loam, clay, pieces with large cavities, foam-like or vitreous pieces, and organic materials such as topsoil, roots, wood, coal, lignite, etc. In doubtful cases the effects of harmful substances shall be established by tests.

4) Use of aggregates containing minerals which can cause alkali reactivity shall not be permitted. Presence of such minerals in the stones to be used as aggregates shall be determined by testing.

5) The Flakiness and elongation indices of aggregate as determined in accordance with IS: 2386 shall not exceed 25% individually and the combined flakiness and elongation indices shall not exceed 40%. Rock which breaks down into such shape, regardless of the type of processing equipment used, will not be approved for use in the production of aggregates.

6) The Contractor shall make provisions for crushing and processing of material in accordance with recommendations contained in IS: 383 to meet the gradation and other requirements of these Specifications, in order to obtain the total amount of aggregate required for RCC manufacture. Crushing, screening and washing operations, benefaction of aggregates, and blending of crushed and natural aggregates shall at all time be subject to the consent of the Engineer.

7) The contractor's aggregate storage facility shall not allow contamination of the aggregates. In case, Engineer determines contamination of aggregate the contaminated portion shall be removed from the storage and disposed off at no cost to the Owner.

8) The optimum proportion of crushed to natural aggregate, and in particular the possibility to use crushed sand, shall be determined at trial mix stage.

9) Natural and crushed aggregates shall be stockpiled and batched separately.

10) The handling, transporting, and stockpiling of aggregates shall be such that there will be a minimum amount of fines resulting from breakage and abrasion of material resulting from free fall and improper handling. Excess in any of fine or coarse aggregate sizes shall be disposed of in approved manner.

11) The Contractor shall remove all rejected aggregate from the Site.

20.5.3.2. SOURCE

1) Coarse and fine aggregates shall be produced from suitable material obtained from required excavation for Permanent and Temporary Works and from the approved quarry and borrow areas shown on the Drawings, or from other sources as may be designated or approved in the course of the work.

2) The Contractor shall carefully clear the area from which aggregates are to be produced of unsuitable materials and other objectionable matter. The area shall be operated so as not to detract from the usefulness of the area. All materials removed from the area and not used in the work shall be disposed of as directed.

3) Alternative sources developed by the Contractor shall be subjected to approval by the Engineer. The Contractor shall carry out tests to furnish satisfactory evidence that aggregates from such alternative sources comply with the requirements of this Section.

4) The aggregate source shall be subject to the approval of the Engineer. However, such approval of source shall not be construed as acceptance of all materials to be taken from that source. The Engineer reserves

the right to reject certain localized areas, strata, or channels within the approved areas and zones, when the material is unsatisfactory for use.

20.5.3.3. FINE AGGREGATES

1) The percentage of deleterious substance in the fine aggregate shall conform to IS: 383, except that the fine aggregate shall contain no more than 0.1% by weight of deleterious (reactive) ferrous sulphide. The sum of the percentages of all deleterious substances in aggregate, as delivered to the mixer shall not exceed 2 % by weight.

2) Fine aggregate having specific gravity of less than 2.6 shall be rejected. Fine aggregates, when subjected to soundness test with a solution of sodium sulphate, after five cycles of tests, shall not suffer a loss of weight in excess of 10 per cent.

3) Fine aggregate, upon delivery to the batching plant, shall have uniform and stable moisture content. The amount of moisture shall be less than 6% by weight, and shall not vary by more than 0.5% per hour.

4) The plasticity index shall not exceed 15 and the liquid limit shall not exceed 25 as determined on crushed sand materials according to IS 2720 (part 5).

20.5.3.4. COARSE AGGREGATES

1) Coarse aggregates shall be stored separately in stockpiles or bins in such a manner to avoid intermixing of different size of aggregates. The storing shall be done in following sizes:
   - 6 mm to 25 mm
   - 25 mm to 50 mm

2) The percentage of deleterious substance in the coarse aggregate shall conform to IS: 383, except that the coarse aggregate shall contain no more than 0.3% by weight of deleterious (reactive) ferrous sulphide.

3) When subjected to following tests as specified in IS: 2386 (Part IV), the coarse aggregate shall comply with following requirements.

Aggregate Crushing Value	Less than 45%
Aggregate Impact Value	Less than 45%
Los Angeles Abrasion value	Less than 40%

4) When subjected to sodium sulphate soundness test, coarse aggregate shall not suffer a loss of weight in excess of 12% after five cycles.

5) Coarse aggregate shall be hard, dense, durable, uncoated rock fragments. Rock having absorption greater than 2% or specific gravity less than 2.5 shall not be used.

6) Aggregate delivered to the batching plant shall have uniform and stable moisture content.

7) The gradation of the combined aggregates shall be within the limits shown below and will have the same basic graphed shape as indicated by the graphed gradation band. However, the gradation will not be allowed to go from near the maximum amount allowed on one sieve size to near the minimum amount allowed on the subsequent sieve, or vice versa. The gradation of each class of aggregate shall be such as to be capable of being proportioned at relatively constant ratios to provide the required final combined gradation.

Table 22.5.1 Gradation of Aggregates

Sieve (ASTM serie)	Fine Aggregate	Gravel 6-25 mm	Gravel 25-50 mm	Combined Gradation
mm	(% passing)	(% passing)	(% passing)	(% passing)
63				100
50			90-100	98 - 100
37.5			75-90	92 - 100
25		95-100	15-35	76 - 88
19		78-90	0-5	65 - 79
12.5		45-60		53 - 67
9.5		26-41		47 - 59
4.75	95-100	0-7		36 - 47
2.36	75-85			28 - 38
1.18	53-68			20 - 30
0.600	41-51			15 - 23
0.300	26-36			10 - 16
0.150	16-25			6 – 11

20.5.3.5. AGGREGATE STORAGE

1) Aggregates shall be stored in a manner so that each size of aggregate is stored separately in free-draining piles in a manner that reduces breakage, deterioration, contamination and segregation to a minimum. Storage arrangements shall be subject to acceptance by the Engineer.

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2) The Contractor shall complete the stockpiling of at least 30-50% of total weight of aggregate foreseen for the overall RCC works at the Site before start of placement to permit continuous placement of RCC in accordance with the contractual time schedule. A minimum stock of aggregates shall be ensured by the Contractor in silos close to the batching plant at all time during the construction. Storage facilities and arrangements shall be configured to prevent contamination between different aggregate sizes.

3) The moisture content of aggregates shall be controlled as far as practicable, by wetting the stockpiles and by adequate drainage. The sand stockpile must be protected and covered adequately to prevent excessive moisture increase during rainy period.

4) The preparation of stockpile areas, the storage of processed aggregates and the disposal of any rejected material shall at all times be subject to the approval by the Engineer.

5) Materials shall be removed from stockpiles by methods, which minimize contamination, segregation and crushing. No fine aggregate from the bottom 500 mm of the stockpile shall be used for mixing RCC.

6) Conveyors used to transport aggregate to the RCC mixing plant shall be covered for protection from rain and sun. They also shall be equipped with misting nozzles to maintain the moist and evaporative condition of the aggregates. The spray shall be used and adjusted if necessary to maintain reasonably uniform moisture as the aggregates enter the mixer plant bins.

7) At the Batching Plant the moisture content of the sand and of the smallest size group of coarse aggregate shall be controlled so that not to exceed 6% by weight of the SSD.

20.5.3.6. ADMIXTURES

1) Admixtures shall be proposed by the Contractor and shall be used only upon written approval of the Engineer. Only admixtures that have been commercially used with satisfactory service in a similar type of RCC work shall be considered for approval. All admixtures shall be manufactured by a reputable company, supported by a fully staffed technical service organization and research group.

2) The contractor will use a set-retarding water-reducing admixtures conforming to IS: 9103 (3). Only admixtures that can delay the initial set for 16 to 24 hours (and keep the final set within the range of 30 to 45 hours) and reasonable dosages will be accepted.

3) It is possible that the use of high mineral admixture contents has sufficient retardation without the need for retarder. The choice of any admixture shall be confirmed by laboratory trial mixes and full-scale test results.

4) Admixtures to be used for concrete production shall be tested for their suitability with the cement and other materials under actual working conditions. Each shipment of admixtures shall be tested for density and dry extract.

5) Admixtures older than 12 months, after their manufacturing, shall be tested for deterioration.

6) Shipment of which the tested sample has not pass the criteria shall be rejected

7) Admixtures shall be stored and handled so as to avoid contamination or damage to their properties by temperature or moisture changes or other influences.

8) The quantity of admixture used and the method of mixing shall be strictly in accordance with the manufacturer's printed instructions, or as required to produce specified results and approved by the Engineer.

9) The contractor shall be held liable for any damages and difficulties resulting from the selection and use of admixtures such as delay in concrete placing or damage to concrete during forms removal and shall not be entitled to any time extension or claims resulting here from.

20.6. ROLLER COMPACTED CONCRETE COMPOSITION

20.6.1. GENERAL

RCC shall be composed of cementitious materials, crushed fine aggregate, coarse aggregate, water and retarding admixtures as specified; all well mixed and brought to the proper consistency.

20.6.2. MIX PROPORTIONS

1) The Contractor shall be responsible for the design of the RCC mixes and for ensuring that all concrete placed in the Works meets the requirements of the Technical Specification.

2) Mix proportions for RCC shall be within the range given in the following Table. The trials on mixes shall be conducted in the laboratory based on standard mix proportions under the supervision of Engineer.

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Nominal Maximum Size of Aggregate	(mm)	50
Total cementitious material	(kg/m^3)	120 – 180
Fine aggregate, percentage of tot. aggregate	(%)	40-45

- *% are given by weight*

3) Mix proportions of various ingredients shall be decided, considering results of mix proportioning tests within the above range.

4) The contractor shall make adjustments as directed by the Engineer to obtain RCC mix having suitable workability, consistency, impermeability, strength and durability without the use of excessive cementitious materials in accordance with project requirements.

5) Suitable compressive strength for RCC will be that which will assure that 80% of all test cubes exceed the values specified in drawings at 365 days.

6) The mix design will be adjusted as directed by the Engineer during the progress of the work whenever the need for such adjustment is indicated by results of testing of the aggregates and the RCC. The Contractor shall not be entitled to any additional allowance above the prices bid in the schedule because of such adjustments of the mix proportions.

20.6.3. FIELD MIX PROPORTIONS

Field mixture proportions shall be decided by Engineer considering results of mix proportioning tests based on the above range, full scale test and climatic conditions of work execution.

20.6.4. CONSISTENCY OF RCC

1) The consistency of the RCC under working circumstances will be closely monitored and optimized during the construction of the Full-Scale Trial based on the requirements necessary for adequate hauling, spreading and compacting. Changes will be directed based on visual examination of the RCC during the spreading and compaction process. Changes will also be instructed should the modified VeBe time vary outside the range considered ideal for compaction, as well as when the in-situ density falls below the allowable minimum.

2) The consistency of RCC will be determined using the Loaded VeBe test using VeBe apparatus in accordance with BS 1881: Part 104: 1983 or any other equivalent International standard

3) The allowable range in consistency will be determined by the Engineer based on the experience with construction of the pre-qualification test section and later, the dam itself. RCC exceeding the allowable range at the time of compaction shall be removed by the contractor at his own expense.

4) Uniformity in RCC consistency from batch to batch will be required. To maintain RCC at the proper consistency, the amount of water and fine aggregates batched for RCC shall be adjusted to compensate for variation in the moisture content or/and grading of the aggregates as they enter the mixer.

5) Addition of water to compensate for stiffening of the RCC after mixing, defined as, 're-tempering' will not be permitted.

20.7. PLANTS

1) The Contractor shall submit a layout and schematic drawings of the RCC plants together with a narrative of layout, anticipated methods of handling aggregates, equipment for mixing, transporting, placing, compacting, curing, protecting, and cleaning RCC. The Contractor shall inform the Employer's Representative 60 days prior to placing orders to suppliers.

2) The contractor shall provide equipment and shall maintain and operate the equipment to accurately determine and control the prescribed amounts of the various materials in RCC. The amounts of cement, SCM and each size of coarse and fine aggregates entering each batch of concrete shall be determined by individual weighing. Fine and coarse aggregate may be weighed with separate scales and hoppers or cumulatively with one scale and hopper. The batch plant shall be equipped with automatic interlocking sequential batching controls and shall be as specified in para 22.7.1.

3) All plant shall be maintained in good working order and shall be of adequate capacity to comfortably meet the requirements of peak production on a sustained basis.

4) All RCC batching, mixing, placement and compaction plant and equipment shall be in place and ready at least 28 days before initiation of the construction of the RCC Full-Scale Trial.

5) The proposed batching plant is conceived with a double line for RCC and CVC production. RCC line will have two mixers with a 6 m^3 plate capacity and CVC will have four mixers with a 4 m^3 plate capacity, allowing a peak production rate of 360 m^3/h and 480 m^3/h respectively. The system has the flexibility to produce only RCC or CVC with both the lines, if needed. The indicated production capacities and plant configurations are to be considered as preliminary and indicative only. They shall be subject to confirmation and possible revision based on the results of the RCC mix design development and full-scale trials, as well as on the detailed construction programme. The final configuration of the batching and mixing plants,

including number of units, layout and production capacity, may be optimized by the Contractor in order to meet the required placing rates, taking into account site-specific conditions, logistics, and construction sequencing.

20.7.1. BATCHING EQUIPMENT

1) Concrete batching and mixing plant shall be as per IS: 4925. In case of any discrepancy between this and the specification given below the latter will govern. The Engineer's decision in this regard will be final and binding on the contractor.

2) Batch plants shall be computerized and shall be equipped with printers, which list the quantities of individual materials, measured for each batch and a summary of material batched at the end of each shift or day. The contractor shall provide the Engineer with a continuous record of these measured batch quantities as batched in Excel spreadsheet format as hard as well as soft copy. The continuous printer shall be located in the contractors furnished enclosed building, adjacent to the batching and mixing plant in an enclosed area isolated from vibrations and dust.

3) The computer shall have the capabilities of storing each concrete mix to be used and of adjusting each mix for moisture control without interfering with batching. It shall be capable of storing a minimum of 20 mixes. The plant shall be capable of switching from one pre-calibrated mix design to another within reasonable time while maintaining the specified tolerance and uniformity requirements. The maximum "switching time" will be of about 45 seconds. The control panel shall display the designed formula values and the instantaneous percentage values, or actual measured masses, for each ingredient and shall record the values at a present time interval.

4) All weighing equipment shall be accurate to 0.40 percent over the working range. The contractor shall schedule and perform monthly tests to assure that the operating performance of each scale and measuring device is within the 0.40 percent accuracy and shall provide standard test weights and any other equipment necessary to conduct these tests. The tests shall be made in the presence of the Engineer and shall be subject to his approval. In addition to monthly tests, the contractor shall perform additional tests when requested by the Engineer. The contractor shall make such adjustments, repairs or replacements as may be necessary to meet the specified requirements for accuracy of measurement.

5) Each weighing unit shall be spring less and shall visibly register the actual weights during the weighing operation and not just indicate when a prescribed weight has been obtained. The display shall indicate increments not greater than 1kg of water and cementitious materials and not more than 5kg for aggregate for each cubic meter normally batched. Batching controls shall be interlocked so that a new batch cannot

be started until the weighing hoppers have been completely emptied of the last batch and the scales register zero weight.

6) The equipment shall be capable of controlling the delivery of material so that the combined inaccuracies in feeding and measuring during normal operation will not exceed the allowable limit as given below:

Calibration of Batching Plant

S. No.		Interval	Allowance
1.	Water	Once a week	±1.0%
2.	Chemical agent	Once a week	±3.0%
3.	Cement	Once a week	±2.0%
4.	Fine Aggregate	Once a month	±2.0%
5.	Coarse Aggregate	Once a month	±2.0%

The weighing hoppers shall be constructed so as to permit the convenient removal of materials batched in excess of the prescribed mix design and the above tolerances.

7) Measuring devices for chemical admixtures shall have sufficient capacity to measure at one time the full quantity of properly diluted solution required for each batch and shall be maintained in a clean and freely operating condition. If admixtures are measured by a method other than direct weighing, equipment shall be designed for confirmation of the accuracy of each batch quantity by use of visual mechanical gauges readily visible from the batch plant operator's station. Admixture batching equipment shall be so constructed that the required batch quantity can only be added once to each batch, and so that each admixture is discharged separately into the batched mixing water as it is being discharged in the mixer.
Volumetric dispensers shall be used only for liquid admixture and each plant shall be equipped with the necessary calibrated devices that will permit convenient checking of the accuracy of the dispensed volume of the admixture. The batching or dispensing devices shall be capable of repetitively controlling the batching of the admixture to the accuracy specified. Piping for liquid admixtures shall be free from leaks and properly valved to prevent backflow or siphoning. The dispensing system shall include a device or devices which shall either detect and indicate the presence or absence of flow of the admixture or provide a convenient means of visually observing the admixture in the process of being batched or discharged. Each system shall be capable of ready adjustment to permit variations of the quantity of admixture to be batched.
Each dispenser shall be interlocked with the batching and discharge operations so that each liquid admixture is added separately to the batch in solution in a separate portion of the mixing water, in a manner that ensures uniform distribution of the admixtures throughout the batch during the required mixing period. The nozzles of admixture dispensers shall be maintained in a clean and fully operational condition at all times.

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8) Equipment for conveying batched materials from weighing hoppers into the mixer shall be constructed, maintained and operated so as to prevent spillage of the batched materials and overlap of batches.

9) Equipment for handling cementitious materials in the batching plant shall be constructed and operated so as to prevent noticeable dust during the measuring and discharging of each batch of materials.

10) The plant shall be capable to discharge the load of any mixer, away from the conveyor system delivering RCC on to the dam.

11) Aggregate batch bins shall be so constructed as to be self-cleaning during draw down and be capable of handling the aggregate in a damp condition without plugging or choking (aggregate bins shall have suitable designs with steep slopes, fillets in corners if necessary, and vibrators if necessary to eliminate the potential for plugging in the feed bins).

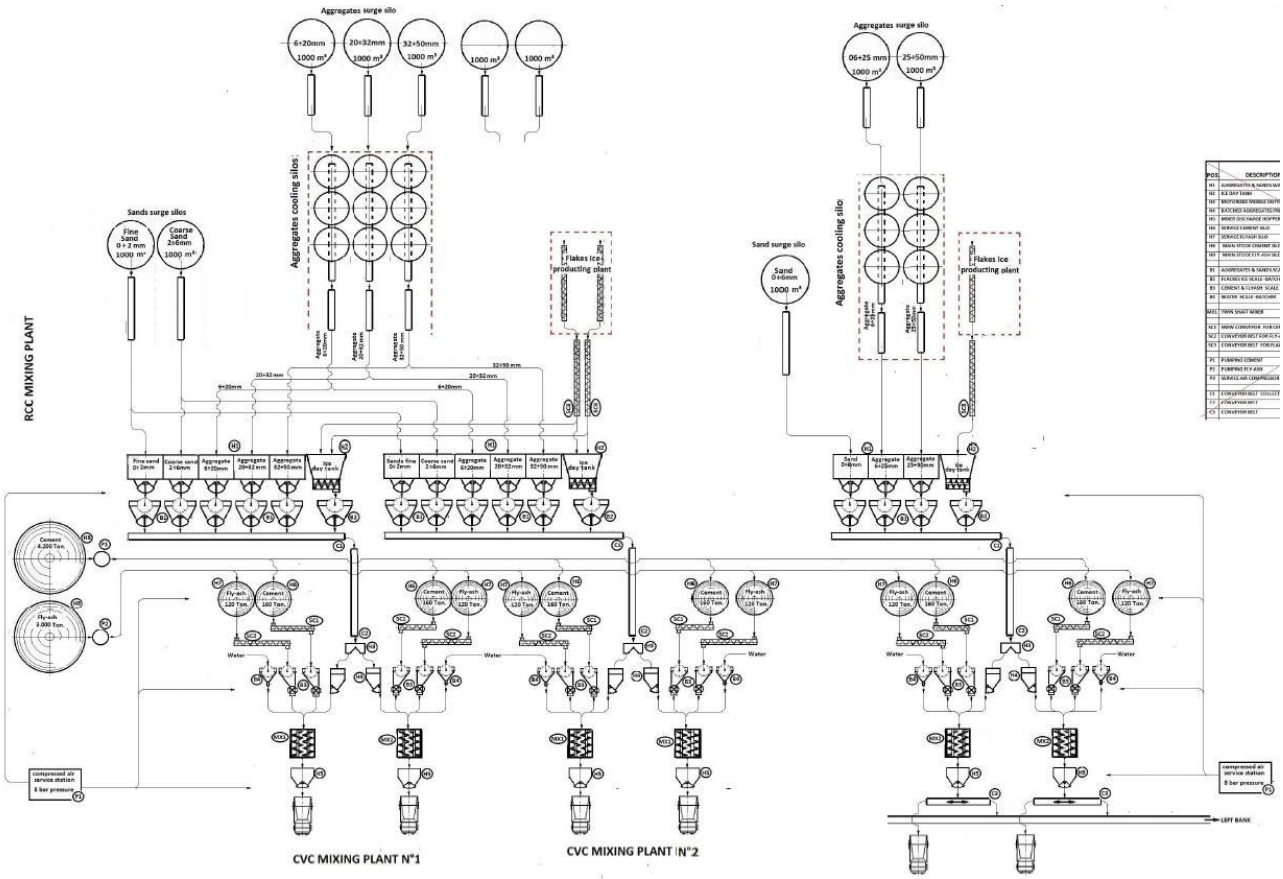
12) Convenient facilities shall be provided for readily and safely obtaining representative samples of cementitious materials, admixtures, fine aggregate and each size of coarse aggregate from the discharge stream between batch bins and the weighing hoppers or between the batch hopper and the mixer.

13) The water-batching device shall be constructed so that the water will discharge quickly and freely into the mixer without objectionable dribble from the end of the discharge pipe and shall be such that leakage will not occur when the valves are closed. In addition, equipment shall be capable of adjusting batch water by as little as 1.0 kg/m^3 and there shall be a means for accurately introducing small increments of water into each mixer after batching for occasional final tempering of the concrete. The meter may be an in-line volumetrically activated flow meter. It shall be capable of reading or converting the amount of water being added to kg per cubic meter of concrete. Water tank shall be protected from the sun.

14) The contractor shall inform the Engineer prior to and after changes and adjustments in batching equipment and control instrumentation.

20.7.2. MIXING

1) In the following scheme, a typical flow sheet for CVC and RCC batching plants is indicated.



2) RCC shall be thoroughly mixed to become uniform; the order of introduction of materials shall be investigated during concrete uniformity tests.

3) It shall be necessary to thoroughly clean the mixer before and after mixing of concrete and in case of suspending work due to reasons such as equipment trouble.

4) The period of suspension requiring cleaning shall be around 120 minutes as a standard, but at times when air temperatures are high such as in summer, it shall be 60 minutes.

5) The concrete, as discharged from the mixing plant, shall be uniform in composition and consistency from batch to batch. Mixers will be examined regularly by the contractor for changes in condition due to accumulation of hardened concrete or mortar or to wear of blades. The adequacy of the mixing will be determined by the contractor in accordance with the concrete uniformity requirements to the satisfaction of Engineer. Samples of concrete for such tests will be taken from any size batch, which is commonly mixed during concrete production. For testing purposes, the contractor shall mix, in the mixers to be tested, the size of the batch directed by the Engineer at the batch plant, and shall assist in collection of required samples from that batch.

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6) Any mixer that at any time produces unsatisfactory results shall not be used until repaired. If repair attempts are unsuccessful, a defective mixer shall be replaced.

7) Water shall be admitted prior to and during charging of the mixer with all other concrete ingredients. After all the materials are in the mixer, each batch shall be mixed for not less than the time specified by the Engineer based on the concrete uniformity tests.

8) The mixing equipment shall conform to the following additional requirements:
   a. Plant configuration shall be such that the mixing action of each mixer can be observed from a safe location, which can be easily reached from the control station. Provisions shall also be made so that the operator can observe the concrete in the receiving hopper or buckets as it is being dumped from the mixers.
   b. Each mixer shall be controlled with a timing device, which will indicate the mixing period and assure completion of the required mixing period.
   c. The batch plant shall be equipped with an interlocking mechanism, which will prevent concrete batches from entering mixers, which are not empty.

20.8. TRANSPORTATION

1) RCC shall be conveyed from the mixing plant to the placement as rapidly as practical, by a combined conveyor belts delivery system plus trucks with enough capacity to meet project requirements. All transportation equipment shall be designed so that segregation is minimized. The conveyors and transfer sections will be covered to avoid material to lie exposed to drying by wind and/or sun, or from over-wetting by rain and shall be protected against sun.

2) In order to allow continuous RCC production without delays to the schedule, the conveyor system must be capable of accommodating possible developments where the Contractor requires the dam to be constructed in monolith blocks or groups of blocks rather than by placement from abutment to abutment. Two independent systems are envisaged, one for the right and one for the left bank.

3) The equipment shall be designed for low maintenance continuous operation with clean return belt surfaces.

4) The conveyor system shall be installed and fully operational at least 30 days prior to the start of planned RCC placement in the dam.

5) Crawler mounted belt placers shall be equipped with flat steel street pads or hard rubber pads that minimize damage to the compacted RCC lift surfaces. Crawler mounted belt placers shall be sufficiently powered to

climb over the edge of the thickest lift used in the placement. They shall be capable of manoeuvring into, out of, and within the placement areas without external assistance or tow cables.

6) If necessary, the Contractor shall provide baffles at the end of conveyors and within hoppers to limit free falls, and at other locations that otherwise cause excessive segregation. Suitable vibrators or other methods shall be used if necessary to prevent plugging at transfer locations including belt transfers and any interim bins or hoppers.

7) No vehicles shall be allowed to travel on the dam unless they are free of deleterious substances as listed in 20.15.3, which may contaminate the lift surface. This may require the undercarriage and tyres or tracks of the vehicles to be cleaned off all such substances.

8) When delivering concrete by dump truck, the truck shall not be driven in a manner so as to adversely affect the surface of concrete such as abruptly turning or braking.

9) Dump trucks shall not be permitted to travel on the surface of un-compacted concrete.

10) The total length of time from the start of mixing until completion of compaction of RCC shall not exceed the time fixed during Full Scale Trial, unless further full-scale tests, show that a relaxation is technically acceptable for the exact mix, cement, water content, and temperatures in question.

11) Interim storage at gob hoppers shall be provided when direct conveyor systems do not provide continuous unsegregated delivery to the final placement location.

12) The gob hoppers shall be constructed with enough capacity so that mixing is not stopped or slowed during production. Gob hoppers shall be constructed with steep smooth side slopes and fast opening/closing gates (typically air operated) that allow for the free flow of RCC without segregation or choking. Gob hoppers shall be protected from sun and rain.

13) Telephone or radio communication shall be provided between remote gob hoppers, the batch plant, and the placement site.

14) If more than one RCC mix is used, gob hoppers shall be emptied of all of one mix before being filled with a mix of a different design.

20.9. PLACEMENT

20.9.1. GENERAL

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The contractor shall notify the Engineer before batching begins for placement of RCC. Unless inspection is waived for that specific placement, batching and placing shall be performed only in the presence of the Engineer. Placement shall not begin until after all preparations are complete and the Engineer has approved completion of all preparation for that placement.

20.9.2. PREPARATION FOR PLACEMENT

Prior to beginning RCC placement, the contractor shall have a sufficient number of properly operating vibratory rollers, power tampers and equipment operators, ready for operation. Moreover, the contractor shall have available at all times, one additional item of each piece of plant available that could be used to replace any equipment should it become defective during the progress of the placement. The Engineer may require that the contractor delay the start of the RCC placement or adjust the placement rate until the number of properly operating rollers and tampers available are accepted.

20.9.3. PLACING PLAN

The Contractor shall define a detailed daily program of work for the placement of RCC. The Contractor shall define and submit weekly to the Engineer a detailed 2 weeks rolling program of work for the placement of RCC. The 2 weeks rolling program will be updated every week. Every day the Contractor will issue and submit a detailed daily program of the works. The Engineer may ask for modifications in the detailed daily and weekly programme to meet the requirements of work.

20.9.4. DEPOSITING AND SPREADING

1) Prior to spreading of concrete, loose aggregate particles at the horizontal construction joint shall be removed and water sprinkled. Spreading dozers shall be equipped with rubber treads or pads. dozers shall provide initial compaction and leveling by "tracking" over the mix as it is spread. Dozers shall have hydraulic tilt and angle capability of the blade and laser-controlled blades. The laser may be used as a check and for final grading, or it may be used for continuous grade control during rough spreading as well as final trimming.

2) The dam shall be raised at essentially the same level within each placing area or isolated monolith or group of monoliths (between formed vertical joints).

3) Belts shall discharge in a "windrow" fashion that does not cause unacceptable segregation, moving the advancing edge forward. The conveyor will not be allowed to pile the RCC in heaps. Windrows shall be placed adjacent to each other, with an overlap that is half the height of the windrow. No "fill-in" will be allowed between windrows.

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4) Where trucks will be used, fresh RCC shall be dumped on roughly spread but uncompacted materials or on mortar/bedding mix if the preceding layer is covered with mortar/bedding mix. If segregation occurs, the segregated parts shall be removed by dozer spreading and remixing and, in extreme cases, should be removed by hand flat shovel and cast onto the top or sides of the pile so that it can be pushed into the pile and remixed as the RCC is spread forward. Pushing a pile shall be done by a dozer of suitable dimensions and power and at least three laborers shall be always present and available for shoveling any segregation at the edges of piles.

5) RCC shall always be dumped on uncompacted layer of RCC. The height of the pile shall be less than 750 mm. Spreading will not be permitted with rubber-tyred equipment. All equipment shall be maintained in good operating condition so that it does not leak or drip oil, grease, or other visible contamination on to the RCC. Maintenance or servicing of equipment will not be permitted on the RCC.

6) As placement of a lift progresses, exposed edges shall be kept "live" by progressively placing out from them. Whenever a cold joint at any edge of any lift does occur, it shall be located at least 3 m from the location of other cold joints that may have previously occurred in the same direction. The joint edge shall be prepared as required for cold joints prior to resumption of RCC placement. Together with the daily program of RCC placing, the Contractor shall submit a sketch showing firstly the tentative development/progress of the works and secondly the possible exposed edges that may become cold joints.

7) In general, no cold joint shall be allowed along the edge of a lift in the upstream / downstream direction for more than one-half of the upstream/downstream dimension of the dam at that elevation. No cold joint of edge of a lift shall be planned at the one-half upstream dimension of the dam.

8) Sloping layer method is an acceptable procedure to construct lift of multiple layers. The primary goal of this method is to minimize the exposure of fresh RCC until it is covered by the next sloping layer. The inclination of the layer will be defined/adjusted according to effective delivery of materials on the layer within the maximum time exposure of fresh RCC and according to the stability of equipment in motion on the layer. If this method is used the Contractor must submit relevant Method Statement at least one month prior to its application for the approval of the Engineer.

9) RCC shall be spread into an even layer with an action that minimizes segregation, contamination, or deterioration of previously placed RCC, with the thickness of the loose RCC as it is deposited on the construction joint approximately 340mm which will be determined during tests. It shall be spread into an even layer that will be, after compaction, 300mm thick. Layer thicker than 300 mm may be used with the approval of Engineer provided the Contractor shall demonstrate that such a layer can be spread and compacted within the allowed time limits without segregation and with a consistent average density similar to that achieved for the 300 mm thickness layer.

10) Where RCC is spread onto or into bedding mix, the RCC mix shall be spread and compacted no later than 15 minutes after placement of the bedding mix and at no time later than the time the bedding mix begins to set or dry from exposure.

11) The transportation, depositing and spreading of RCC shall be completed within 60 minutes after the mix water combines with the cementitious materials.

12) Since there is a risk of coarse aggregate being concentrated between placement lanes (furrows), spreading shall be done in a manner that furrows will not be formed as far as possible or that coarse aggregate will not be concentrated at furrows.

13) During and after spreading and before compaction is completed, care should be taken not to drive on the uncompacted RCC with equipment other than that required for spreading and compacting this area of RCC. This is to minimize pre-compaction and the possible bridging by the compaction equipment that may result.

14) RCC shall not be placed when grout is worked up to the surface of the RCC by rollers and wheels or when rollers cause depressions greater than 25mm in the compacted RCC. Causes of this include improper mix proportions, excessive water due to curing or a rain. If the grout is worked up to the surface by compaction, all compacted RCC mix shall be removed and the surface of previous lift shall be prepared to the satisfaction of the Engineer as specified in these specifications to receive fresh RCC

15) Heavy rainfall can negatively impact the RCC construction by reducing tensile and shear strength properties of the lift joints. Generally, RCC placement shall be stopped when the rainfall intensity exceeds 2.5 mm per hour. However, placement of RCC during higher rainfall intensity may be done with approval of Engineer provided the contractor demonstrates through laboratory test in the test section prior to full scale placement that the higher intensity rainfall does not have adverse effect on lift joint tensile and shear strength. A meteorological radar will be installed on site to allow short-term forecast of rainy events. In case of incoming rain, the RCC can be promptly stopped and the already places RCC protected by quick rolling and or using protective sheets or other method proposed by the Contractor.
The radar must be suitable for real-time monitoring of weather in areas with complex topography with the following minimum characteristics:

- transmitter/receiver
  - Operating frequency 9410 MHz
  - Peak Power 10 Kw
  - Pulse width 0.3-1.2 μS
  - Repetition Frequency 500-1600 Hz

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- Transmitter — magnetron type, horizontal polarization
- Receiver — logarithmic

- Antenna
  - type — parabolic prime focus reflector
  - horiz. Lobe width — < 3°
  - vert. lobe width — < 3°
  - gain — > 35 db
  - scan mode — continuous azimuth scan with elevation of 0.1° in the 0° to 180° range

- Processor
  - type — digital processing on PC and DSP
  - parameter — horizontal reflectivity in dBz
  - sensitivity — 9.4 dBz @ 25 km, 22 dBz @ 100 km
  - range — 20 – 100 km
  - range resolution — 30 – 60 m

Rain gauge shall be installed in the laboratory near the batching plant. If the rain intensity exceeds the threshold values established by test sections, placing operations shall be suspended; however, RCC, that has been deposited and spread shall be compacted before operations are suspended.
After the RCC has hardened sufficiently to allow equipment and workers on the surface (as determined by the Engineer, but no sooner than 3 hours after RCC compaction), the RCC surface shall be cleaned of all loose material and water ponds, and if required and as directed by the Employer shall be washed to break up laitance and/or mud like coatings on the surface. The washing shall not undercut any coarse size aggregate. Pickup of the wash debris shall be accomplished with a truck mounted vacuum or other approved system. The washing action is critical in order to remove coatings formed during light rains that, if left in place, would act as bond breakers between each lift. Sufficient pieces of equipment of adequate size shall be provided so as not to slow the regular placement and compaction of RCC.

During period of lesser rainfall, placement of RCC shall continue if the Contractor can meet the minimum requirements of a saturated surface onto which RCC is placed, free of ponds of water and clean.

20.10. COMPACTION OF RCC

20.10.1. GENERAL

1) RCC compaction shall be completed within 60 minutes of the completion of mixing. Each layer of RCC shall be compacted with the number and type of passes to achieve the required density as determined by the Full Scale Trials and approved by the Engineer. Typically, the sequence of passes of a vibratory roller shall

be in the range of (1- static) + (~ 4 - Vibration) + (1- static), the number of vibration passes shall be determined in full scale trails.

The number of passes required for completion may be increased or decreased by the Engineer due to changes in the workability of the RCC, at no additional cost to the Employer. In addition, vibratory rollers will be checked at regular intervals, as determined by the Engineer to assure that complete compaction is being maintained.

2) Compaction by vibratory roller shall be done with overlapping of about 20 cm with the adjacent lane.

3) Rollers shall not be operated in the vibratory mode until they are moving. Small walk behind vibratory rollers and/or hand-guided power tampers shall be used for compaction at the abutments and in any areas that cannot be reached with the drum of a large vibratory roller.

4) When the RCC is wetted by rain or dried so that the moisture content exceeds the tolerances in para 22.10.4 below, the entire layer affected, as determined by the Engineer and in consideration of the dam zone, shall be removed and shall be replaced in accordance with these specifications at the expense of the contractor. The RCC shall be compacted uniformly throughout the entire lift. The surface of the compacted RCC shall be dense and sealed with exposed aggregate held firmly in the place by paste. The compacted surface shall be free of undulations, tracks or roller marks greater than 25mm.

5) The edge of all compacted layers against which adjacent RCC is not placed within 30 minutes shall be trimmed to a straight line, with minimal ramping and no feather-edging, and rolled so that the edge is thoroughly compacted and does not contain loose segregated aggregate.

6) The largest equipment specified below capable of physical and practical operation in the area to be compacted shall be used. In general, large width, self-propelled, single-drum vibratory rollers shall be used in open areas; small vibratory rollers shall be used in areas inaccessible by large roller; and hand guided power tampers shall be used for compacting areas that cannot be reached by either of the rollers mentioned above.

7) Because of the wide variation in compaction effort achieved by individual vibratory rollers, all vibratory rollers shall be approved by the Engineer prior to use on the dam. All compaction, vibrating, and consolidation equipment will be subject to testing during the Full-Scale Trial.

8) All vibratory rollers shall be properly maintained to ensure the maximum compaction effort of each roller is being achieved. All vibratory rollers operating on each lift of RCC shall be of same make.

20.10.2. VIBRATORY ROLLERS

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a. Large Self-propelled Vibratory Rollers

1) The large self-propelled dual-drive single-drum or dual-drum vibratory rollers shall transmit a dynamic impact to the surface through a smooth steel drum by means of revolving weights, eccentric shafts, or other equivalent methods. The roller shall have a gross weight of not less than 12 tons and shall produce a minimum dynamic force of at least 6.5 kg/mm of drum width at the operating frequency which is used during construction.
The roller shall have variable amplitude and a minimum vibrating frequency of at least 25 Hz. The roller drum shall be between 1.2 m and 2.0 m in diameter and 1.5 m to 2.5 m in width. The engine driving the eccentric mass shall have a rating of not less than 70 kW. The roller shall be operated at speeds not exceeding 2.5 km/hr. Within the range of the operational capability of the equipment, the Engineer may direct or allow variations to the frequency and speed of operation that result in maximum density at the fastest production rate. At least two operating (and one standby) large self-propelled vibratory rollers in good operating condition and meeting these requirements shall be maintained on the placement area at all times. The large self-propelled vibratory rollers on the placement shall all be the same make, model and size, and they shall all be operated in the same manner.

2) The rollers shall not remain stationary on the RCC with the vibratory mechanism operating.

b. Power Tampers and Small Compactor.

1) Power tampers, rammers, and small vibratory rollers which can operate within a few centimeters of a vertical face shall be used to compact the RCC adjacent to form work, near the abutment face, up to the downstream face, and at other areas where the large vibratory rollers specified above cannot maneuver.
The dynamic force produced by small rollers shall be at least 3.5 kg/mm of drum width for each drum of a double drum unit and at least 5.3 kg/mm of drum width for a single-drum unit. Rollers shall operate at a minimum of 1,500 VPM.
Rammers shall operate at a minimum of 700 blows per minute and develop a force of at least 800 kg/blow with at least 1.7 kg/cm2 area.
Vibratory plate compactors shall be used to finish the compaction of the RCC surfaces along the abutment slopes, along the upstream and downstream formwork and other areas where the small vibratory rollers specified above cannot maneuver. They shall have an operating weight between 60 and 150 kilograms, and a minimum vibrating frequency of 60 Hz.

2) The number of passes and layer thickness required shall be whatever is necessary for the particular equipment to provide the same degree of compaction as would be attained with the large self-propelled vibratory roller. The power tampers, rammers and small on the placement shall be the same make, model and size and they shall be operated in the same manner.

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c. Immersion Vibrators

GEVR, GE-RCC or IVRCC shall be used in narrow areas of the layer of difficult access for the small rollers. GE-RCC/GEVR/IVRCC shall be consolidated by immersion vibrators. The head diameter, frequency (measured immersed) and average amplitude (measured in air) of the vibrators shall conform to the following requirements:

a.	Head Diameter	(mm)	65-100
b.	Frequency	(cycles per minute)	7000-10500
c.	Amplitude	(mm)	0.75-1.5

Vibration shall be systematic, with emphasis on closely spaced insertions. The duration shall be sufficient to produce good consolidation. There shall be adequate air pressure available for air vibrators and adequate voltage for electric vibrators. At least three immersion vibrators shall be kept in operation at the point of facing concrete placement to ensure that facing concrete is compacted with minimum delay. Spare vibrators shall be available to maintain production in the event of a breakdown.
In addition, a backhoe mounted at the front with a gang of hydraulically operated vibrators shall be used to consolidate the concrete by immersion vibration against the formed faces and against the abutments. The capacity of the hydraulic engine of the backhoe will be enough to operate at the same time at least 4 vibrators of the specifications mentioned above.

20.10.3. DENSITY CONTROL

1) Control of the compacted RCC shall be such that the density of the compacted RCC as determined by tests performed by the contractor shall conform to the following limits to the satisfaction of Engineer.

2) The wet density at each location will be recorded as the wet density measured at a depth of 250mm. Control of the compacted RCC shall be such that the density of the compacted RCC, as measured by the nuclear densimeter, shall conform to the following limits:
   a. The average of all the measurements in-place of the wet density of each layer shall be higher than 98.0% of the t.f.d (theoretical field density).;
   b. The final wet density at a single location shall not be less than 98% of the t.f.d;

   The t.f.d. will be calculated based on the daily unit weight tests of each RCC mix proportioned as approved by the batching plant.
   Daily wet density readings shall be adjusted per the daily RCC calibration using the nuclear gauge RCC calibration area.

The location of the density measurement will be at 10 m x 10 m grid points on the dam surface as shown on the drawings.

Where density tests result in additional compaction and retest, the retest shall be undertaken within 1m of the location of the failed test or in a similar location to the test that failed. Tests shall be carried out within 30 minutes of the completion of compaction.

Material not reaching the above values will be re-rolled if compaction can be achieved within 30 minutes after spreading. If this cannot be achieved, the rejected RCC will be removed.

3) A nuclear density meter should be available at the laboratory and at site and shall be calibrated daily. It should be placed in a locked container and training course set up for contractor's and the Employer's staff by the manufacturer. The staff using the densimeter shall wear the proper uniforms and badges.

4) Laboratory density shall be measured once a week taking average of 3-samples of the day and compact them to refusal by vibrating table.

5) The contractor will inform the Engineer when placement of RCC is near or exceeds the limits of uniformity specified above, and the contractor shall immediately make adjustments in procedures as necessary to maintain the placement density within the specified limits.

20.10.4. MOISTURE CONTROL

1) During the compaction of RCC the in-place moisture content shall be maintained so that the W/(C+F) - water to cementitious materials ratio, by weight is within 2% of its design W/(C+F).

2) To determine whether the moisture content of the RCC is being met, the contractor will conduct field and laboratory tests on samples close to grid location of densiometer tests (number of samples will be in the range of ½ the number of grids). The result of completed tests will always be available in the laboratory. RCC not meeting the moisture content requirements specified below shall be removed. The contractor shall be entitled to no additional allowance above the price bid in the Schedule by reason of any work required to achieve the placement moisture content. The contractor shall not supply any additional moisture to the RCC after the completion of mixing.

Moisture content of the RCC will be measured by in-place testing within 30 minutes of compaction being completed using the calibrated nuclear moisture - density gauge, and also by either microwave and/or conventional oven drying of RCC samples taken either from sand replacement density testing or at any time following mixing of the RCC and up to 30 minutes after completing the compaction.

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3) The moisture content of the RCC prior to and during compaction shall be distributed uniformly throughout each layer of RCC. The moisture content of compacted RCC, as determined by tests performed by the contractor shall be within the following limits:

   a. Material represented by the samples tested having moisture content more than 5% wet or dry of the design moisture content shall be removed.
   b. Within the above limits and based on a continuous record of tests made by the contractor on previously placed and accepted RCC, the uniformity of placement moisture shall be such that:
      i. No more than 20% of 10 consecutive samples of accepted RCC shall be 3% wetter or drier than the design moisture content.
      ii. The average moisture content of 10 consecutive tests of accepted RCC shall be within 2.5% of the specified optimum design water content.

   c. The difference in moisture content between mixing and placing of RCC shall be no more than 5% of the moisture content of RCC determined immediately after mixing.

4) The contractor will inform the Engineer when the moisture content is near or exceeds the limits of uniformity specified above, and the contractor shall immediately make adjustments in procedures as necessary to maintain the design optimum moisture content.

5) Adjustments to maintain proper moisture content include but are not limited to the following:
   a. Discontinuance of placing RCC.
   b. Covering the un-compacted RCC and RCC in hauling vehicles.
   c. Compacting RCC immediately after spreading.
   d. Making necessary adjustments in the stockpiling.
   e. Adjustments in handling, batching and mixing operations of RCC.

20.11. CURING

1) RCC shall be continuously moist cured and curing shall begin immediately after compacting. The RCC surfaces shall be treated as specified to prevent loss of moisture from the RCC until the required curing period has elapsed or until immediately prior to placement of other concrete, other RCC, or backfill against those surfaces. Only sufficient time to prepare construction joint surfaces or lift surfaces and to bring them to a moist, clean condition shall be allowed between discontinuance of curing and placement of adjacent RCC or concrete. Improperly cured RCC will be considered defective and shall be removed. Engineer reserves the right to delay RCC placements due to improper curing procedures until the contractor implements proper curing procedures which are approved by the Engineer.

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2) The top surface of all RCC layers upon which subsequent concrete will be placed shall be kept continuously moist cured (and curing shall begin immediately after compacting) until 28 days or until it is covered with the next layer.

   Water used for curing shall meet the requirements specified in Section B.9. On no account shall the Contractor be allowed to use curing compounds on surfaces that are to receive RCC or other concrete.

   Subject to tests the surface about 20 m in front of the placement might be allowed to dry back to a condition that is just less than saturated surface dry (SSD). That is, the surface has turned a lighter color gray and has no surface water, but the RCC scratched just below the surface is still darker coloured and damp. This condition allows for up to about 30 minutes prior to placing RCC over the surface. It allows more efficient cleaning of the lift surface just in front of the placement by blowing with air, and it does not reduce bond strength at the lift joint. Drying and blowing is especially effective at removing dust and loose small sand grains.

3) The RCC surfaces to be cured shall be kept moist by moisture application methods that will keep all exposed surfaces continuously moist and do not damage the fresh surface of the RCC. Suitable methods may be using a system of perforated pipes, hand-held hoses, stationery or portable sprinklers, fogging or by other approved methods that meet the 2 criteria above.

4) U/S & D/S faces shall be cured for minimum 28-days. Faces of the dam can be cured with pigmented curing membrane.

5) At least one person 24 hours per day, seven days a week shall be on duty on the placement with the sole responsibility of operating the water system to maintain the entire surface moist but not over watered. He may be allowed to perform routine maintenance of nozzles and move hoses only if these activities do not prevent him from fully accomplishing his responsibility of keeping the entire exposed surface in a continuously damp condition.

6) The final top surface of RCC at the top of the dam or at the top of a monolith left uncompleted for more than 21 days shall be continuously moist cured for at least 45 days.

7) When necessary or as directed for hot-weather protection, provisions for windbreaks, shading, fog spraying, ponding or wet covering with a light-coloured material shall be made in advance of placement, and such protective measures shall be taken as quickly as concrete hardening and finishing operations will allow.

8) The cost of curing including membrane is included in the price of RCC entered in the Schedule, which shall include the cost of furnishing of all materials hauling, storing and performing all works for curing.

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20.12. INTERFACE CONCRETE AND FOUNDATION PREPARATION

20.12.1. GENERAL

1) Prior to placing roller compacted concrete on the foundation and against abutments, the exposed foundation material shall be cleaned, filled with levelling/dental concrete (if necessary), shaped (if necessary), and prepared. The surfaces against which RCC, GEVR/GERCC IVRCC or bedding mortar is to be placed shall be clean and damp. No foundation shall be covered by concrete until the Engineer has inspected and commented the foundation preparation. For leveling/ dental concrete, refer section B.9.

2) After cleaning of the foundation, some lean concrete (CVC) with same strength characteristics of RCC could be applied with 0.5m thickness to achieve a levelled surface to receive RCC. The CVC should have sufficient workability to allow immersion vibration.

3) A bedding mix consisting of a lean conventional wet mix shall be placed at the interface between the rock foundation or hardened conventional concrete and RCC mixes.

20.12.2. FOUNDATION SHAPING AND CLEAN-UP

1) Shaping by minor rock excavation (trimming) of obtrusive high points and overhangs, and by filling with conventional dental fill concrete of depressions into which RCC cannot be thoroughly compacted, shall be required.

2) Depending on the location, size, shape, and rock quality, trimming may necessitate any one or a combination of the following methods:
   - mechanical ripping;
   - scaling by hand or by bars;
   - jackhammers;
   - surface charges;
   - small shots of stemmed dynamite in drilled holes.

3) If any large areas or volumes of unacceptable quality or shape rock are encountered, they shall be treated as rock excavation before receiving the foundation preparation required herein. Dental fill concrete may require rough face forming.

4) Prior to placing any concrete or bedding mix, the surface shall be cleaned of loose, unkeyed, and deteriorated rock; all mud, silt accumulations, vegetation, grease and spilled oils; and frozen materials,

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accumulations of gravels, sands, and loose rock fragments; laitance that may have accumulated on dental concrete, and any other detrimental material.

5) It is expected that most of this can be accomplished with air blowing, high-volume water washing, large truck vacuum, and/or air-water jetting using equipment normally designed for this purpose and used in large scale foundation clean-ups.

6) No foundation shall be covered by concrete until the Engineering has given his authorization.

7) All surfaces upon which RCC or any bedding mix is placed shall be damp. The Contractor shall have available adequate equipment for necessary air, air/water, and pressure water jetting of the foundation.

20.12.3. FOUNDATION BEDDING MIX

1) The foundation bedding mix shall be provided between the foundation or abutment and the RCC.

2) The bedding mix shall be retarded so that its initial set time exceeds 3 hours at 35 °C.

3) The bedding mix shall be spread so that all of the surface to receive bedding is covered with some material, and so that the average thickness over rock foundations does not exceed about 50 mm.

4) The RCC shall be spread over the bedding and compacted into it before it reaches its initial set and within 30 minutes of when it was discharged.

5) The exact mix proportions shall be developed by the Contractor. Materials used in the tests shall be representative of those to be used in the dam. The mix design shall be within the following general guidelines:

- Slump: 150 - 250 mm
- Maximum aggregate size: 5 - 10 mm
- Air Content: 0 % - 10 %
- Water reducing admixture: As required
- Minimum cement content: 300 kg/m^3
- Design characteristic strength at 90 days: 25 MPa (to be coordinated with RCC strength)
- Retarder: As required to achieve specified delayed set.

6) Admixtures may be reintroduced into the mix to maintain its workability. The mix should be a very workable and highly sanded mix with some coarse aggregate. It shall be proportioned so that it does not segregate.

20.12.4. RCC BEDDING MIX

1) The RCC bedding mix shall be between the RCC lift joints.

2) The bedding mix shall be retarded, if necessary, so that its initial set time exceeds 30 minutes at 35 °C.

3) The bedding mix shall be spread so that the average thickness over RCC surfaces is at least 6 mm.

4) The RCC shall be spread over the bedding with 10 minutes of placement.

5) The exact mix proportions shall be developed by the Contractor. Materials used in the tests shall be representative of those to be used in the dam. The mix design shall be within the following general guidelines:
   - Grout Flow (cone with 12 mm orifice): 10-14 seconds
   - Maximum aggregate size: None
   - Air Content: Not measured
   - Water reducing admixture: As required
   - Water/cement ratio: 0.50
   - Design characteristic strength at 90 days: 25 MPa
   - Retarder: As required to achieve specified delayed set.

20.13. FORMATION OF FACES OF DAM

1) Faces of dam shall be formed with Grout Enriched RCC. Grout enriched RCC has used various names to imply different processes or procedures for adding grout to an RCC mixture at the placement location (GEVR / GERCC).
   The distribution of the grout to the point of placement will be made in the bucket of a front-end loader, directly by pipes, small buckets or conveyed by some other approved means.
   The grout mixes shall be developed by the Contractor through the site laboratory, trials shall be also performed on site. For all of them details shall, should be submitted as well as tests results. For reference purposes it can be considered a cement grout with water-cement ratio of 0.55 to 0.65 and a consumption of grout of about 8 litres/m against formwork and 15 litres/m against rock surface.

2) The Contractor shall select the detailed method for making and consolidating Grout enriched RCC and he shall be responsible for achieving acceptable results. The procedure shall be demonstrated in a full-scale test section. The Contractor shall provide the necessary support for evaluation of the test including coring, pressure testing, saw cutting and destructive inspection by excavating into the Grout enriched RCC.

3) After grouting, the Grout enriched RCC shall be vibrated with large mass immersion concrete vibrators, suitable for the aggregate size and stiff mix. The vibrators shall be ganged and inserted from the boom of a small excavator or tractor, supplemented, if necessary, by hand held vibrators. Concurrently, the RCC shall be rolled as close as possible to the Grout enriched RCC, preferably overlapping slightly onto it. Follow-up compaction with a plate vibrator and some hand work may be necessary to leave a suitable final lift surface.

4) Prior to placing conventional concrete facing in the spillway, laitance of the horizontal and vertical downstream faces of the steps and poorly vibrated concrete and/or GE-RCC and segregated area shall be removed with air water jet at a minimum pressure of 1 MPa, chipping and high-pressure water jetting as necessary.

20.14. ACCEPTANCE CRITERIA

1) All RCC work shall satisfy the requirements given below for it to be acceptable:

a. Properties of constituent materials
b. Characteristic compressive strength
c. Specified mix proportions
d. Minimum cement content
e. Maximum free water/cementitious material ratio
f. Workability
g. Temperature of fresh concrete
h. Curing
i. Tolerances in dimensions
j. Tolerances in levels
k. Durability
l. Surface finishes
m. Special requirements such as:
    iii. Water tightness
    iv. Resistance to aggressive chemicals
    v. Resistance to freezing and thawing
    vi. Strength
    vii. Fire resistance
    viii. Wear resistance
    ix. Resistance to early thermal cracking

2) The Engineer's decision as to the acceptability or otherwise of any RCC work shall be final and binding on the contractor.

3) For work not accepted, the Engineer may review and decide whether remedial measures are feasible so as to render the work acceptable. The Engineer shall in that case direct the contractor to undertake and execute the remedial measures. These shall be expeditiously and effectively implemented by the contractor. Nothing extra shall become payable to the contractor by the Employer for executing these remedial measures.

20.15. JOINTS

20.15.1. GENERAL

1) Each RCC layer placed between horizontal joints shall be so placed that the layers harden into one monolithic block, minimizing as far as possible the occurrence of horizontal discontinuities between successive placement layers and lifts.

2) The interval between placements of successive layers of RCC, which can be tolerated, will depend on temperature, cleanliness and surface moisture.

3) Portable high-pressure washers shall be used for washing and cleaning the RCC layer and lift surfaces, as required during the RCC placement. The units shall facilitate the removal (without damaging or undercutting coarse size aggregates) of all laitance, surface mortar coatings, grime, dirt, oil, or any hard packed or loose contaminants from the RCC surface during all weather conditions expected at the project site. The portable high-pressure washers shall have a nozzle gun and hose capable of easily being handled by one man. The washer shall be capable of developing a working pressure of not less than 400 bars at the nozzle.

4) A vacuum cleaner shall be used to clean the RCC surfaces. The equipment shall have a suction capacity in excess of 250 m3/minute, must be capable of sucking stone up to 75 mm in size and weighing up to 1 kg and the tank for the detritus shall have a capacity of more than 4 m3. The vacuum truck will be provided with a 2.5 m wide bottom suction unit and a rear suction trunk of at least 150 mm in diameter. Cleaning with the vacuum truck shall be carried out in a manner that will not cause deterioration of the RCC surface.

5) A rotating highway-type brush, carried by a front-end loader, 15-20 ton operating weight or similar equipment shall be used for lift surface clean up and horizontal joint preparation. Different types of brush (nylon, steel) materials shall be used, depending on the operation.

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20.15.2. HORIZONTAL JOINT

1) The top surface of each layer shall be flat without large irregularities, and laitance and loose aggregate particles shall be removed at a suitable time when concrete placed will not be damaged.

2) Rainwater, curing water, and cleaning water shall be handled in a manner so as not to run on to adjacent areas of placement, and measures shall be taken such as to provide sumps in order for pump-up of the water to be done prior to placing.

20.15.3. JOINT PREPARATION & TREATMENT

1) No RCC shall be placed until previously placed RCC has been thoroughly compacted and the surfaces to receive fresh RCC have been approved.

2) Before RCC is placed, surfaces shall be free from any deleterious substances. Deleterious substances include un-compacted, loose, deteriorated, or improperly cured RCC material, laitance or any material other than RCC including but not limited to dirt, petroleum products, curing compound, free surface water from any source, remaining concrete materials from removed RCC or concrete lifts.

3) Before concrete spreading, the surfaces of the underlying RCC layer shall be treated as specified below for each type of joint. The Contractor shall receive no separate payment for any horizontal joint treatment defined below.

4) The maximum length of time between placements of successive layers of RCC is dependent upon cleanliness and surface moisture, as well as maturity of the lift surface (surface temperature x elapsed time since rolling). The time or maturity limits shall be considered preliminary and the final ones for each joint treatment will be defined during the full-scale trial.

5) When the time or maturity limits between successive placements of RCC layers exceeds those described below, a joint condition will be considered to have occurred, and the procedures described below for joint treatment shall be followed.

6) In general terms, three definitions of maturity shall be defined:
    a. a layer surface shall be considered to be a "Hot" joint before initial set of the surface of the RCC of the compacted layer beneath has occurred as measured according to ASTM C403, or as established by the Engineer during the full-scale demonstration;
    b. a layer surface shall be considered to be a "Warm" joint for the duration of the period between initial set of the RCC and the time at which the joint is considered to be "Cold";

c. a layer surface shall be considered to be a "Cold" joint when it is judged that one of the following conditions are met:

(c1) little or no penetration of the aggregate from the new layer into the previously compacted layer will occur, or

(c2) the final set of the RCC of the compacted layer beneath has occurred as measured according to ASTM C403, or

(c3) a modified maturity factor as established during the full-scale demonstration has been exceeded. The modified maturity factor is the product of the exposure time (or time between the placements of the successive layers of RCC) in hours and the average ambient temperature in ºC at the placement, modified by adding 12ºC.

7) Maturity limits for hot, warm and cold joints (and methods to establish them) shall be demonstrated by the Contractor for the approval of the Engineer during the construction of the Full- Scale Trial.

8) Based on test results for site specific mixes and materials additional qualities of cold joint may be developed by the Contractor

9) A set retarder admixture will be used to significantly extend the time of initial set and accordingly the period during which a layer joint remains "Hot". The respective maturation characteristics of the RCC and the associated requirements for bonding fresh RCC to old will be analysed during the Full-Scale Trial construction. In principle, the treatment measures necessary for the three categories of layer surface maturity are defined below.

a. Hot Joints

The lift surface must be maintained moist without pooling water. The surface of all hot joints shall be thoroughly cleaned prior to the placement of the next layer to remove all loose materials, pools of water or other foreign matter to the satisfaction of the Engineer. The method to be used shall have the approval of the Engineer and may include blowing off carefully with compressed air, compressed air/water and/or the use of a vacuum cleaner. Cleaning shall be carried out in a manner that will not cause deterioration to the RCC surface.

b. Warm Joints

In addition to the measures applicable for a hot joint the treatment of a warm joint shall be to cover the specified surface area of the warm joint with a layer of RCC bedding mix.

c. Cold Joints

"Cold" layer joints shall be prepared for the placement of the subsequent RCC layer in the following manner:

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i. Maintain 100 % of the lift surface continuously moist, without pooling water;
ii. Remove the surface mortar, laitance and contaminants by high pressure washing up to 400 bars until coarse aggregate has been slightly exposed. If the treatment is made while the surface is still green, medium pressure washing might be sufficient to achieve the same surface finish;
iii. Clean the surface, to remove all loose material, dust and dirt using an approved method, such as labour or high-pressure water and air washing and vacuum debris removal. This green-cutting procedure shall expose but not undercut any coarse aggregate; and
iv. On resumption of RCC placement, ensure that the surface is free from debris and contaminants and cover the specified surface area of the "Cold" joint with a layer of grout, as directed by the Engineer.
v. The bedding grout shall not be exposed for a period of longer than 10 minutes before being covered by the RCC of the subsequent placement layer.

At all times throughout the above procedures, the old RCC surface shall be maintained in a damp condition until covered by the next layer.
The use of high-pressure water shall be delayed until the concrete is sufficiently hard so that only the surface mortar coating is removed and there is no undercutting of coarse aggregate particles.

d. Damaged and Contaminated Joints
All joint surfaces that have been, as determined by the Engineer, contaminated, and damaged such that more extensive clean-up is required, shall be classified as a 'damaged' joint and shall be prepared in the same fashion as a cold joint.

20.15.4. CONTRACTION JOINT

1) Crack Inducers are used in the surface zone (GE-RCC, GEVR) to ensure the correct alignment of the crack with isolation waterstops and chamfers on the dam face. Crack Directors are used to establish the alignment of contraction cracks through the body of the RCC. The crack inducer and director systems proposed by the Contractor shall be proved to the satisfaction of the Engineer during trials on the Full-Scale Trial

2) A hydraulically powered plate driver attached to a wheeled, or rubber-tracked excavator, or modified front-end loader shall be used to create vertical slots in the freshly compacted RCC into which approved de-bonding systems shall be inserted to create transverse induced joints with the geometry indicated in drawings.

Contraction Joint may be also formed with formworks, depending on construction schedule, as approved by the Engineer. In this case the same procedure used for U/S facing will be adopted.

3) The crack inducing system shall be manufactured in suitable material, in accordance with drawings and installed in such a manner that ensures that the inducing plates are firmly in contact with the waterstops and the formed drain hole and aligned such that the plate is exactly on the line of the centrebulb of the waterstop and on the alignment of the chamfer on the dam face (if present).
   The accurate installation of this system must be rigorously enforced, and the Contractor's quality control system must allow the Engineer to be completely certain that the crack inducer system is accurately and correctly installed.
   A suitably robust framework shall be manufactured and used to hold the waterstop, the drain-hole former and the joint-inducer plates firmly in their vertical position during the placement and compaction of GERCC/ GEVR and RCC around and in the vicinity of the induced joint.
   Should the alignment of the components within an installed crack inducer system, or the alignment of the crack inducer system itself ever be found to fall outside the indicated tolerances, corrective action should be immediately taken.

4) Measurement and payment for contraction joints in RCC dam shall be as per Section B.12.

20.16. WATER STOP

1) The Contractor shall design a support system for waterstops, crack inducers and void formers at the faces where installation of these systems is indicated on the drawings. The system will be applied to ensure the accurate fixing and alignment of the inducing system and waterstops and shall be capable of keeping all items completely taut and rigid in their correct locations above the RCC layer in such a manner that they will not be disturbed to any extent during the placement or compaction of the surrounding concrete. The design of the system shall be submitted to the Engineer for approval.

2) Waterstops forming a seal with the foundation rock, shall be anchored into pre-formed pockets excavated into competent rock. The pockets shall be thoroughly cleaned and backfilled by with a non-shrink cementitious grout immediately before the waterstop is inserted.

3) Specification of waterstop shall be as mentioned in Section B.12 and as shown in the respective Drawings.

4) Measurement and payment of water stop work shall be as per Section B.12.

20.17. UPSTREAM SPRAYED MEMBRANE

1) A two-component sprayed polyurea membrane, to be approved by the Engineer, shall be applied on the upstream face of the dam. The sprayed membrane shall be 100% pure polyurea conforming to EN 1504 part 2.

   The sprayed polyurea shall adhere intimately to the GEVR/GERCC surface overlapping with an external free-to-deform thermo-plastic elastomer previously installed in correspondence to the dam contraction joints, creating a continuous composite impervious element.

2) GEVR/GERCC surface shall be prepared before the application of the sprayed membrane by removing any laitance, surface staining, mortar drops, curing compound (if required), etc. by means of high-pressure water jets or equivalent method without damaging the GEVR/GERCC surface. Possible honeycomb and/or other defects of GEVR/GERCC surface shall be repaired before the application of the membrane.

3) An epoxy cementitious primer shall be sprayed/applied on the surface before the application of the membrane. This primer must be applied in 1-2 coats to give a 150-200 microns minimum wet film thickness. Light broadcast on the wet primer of 0.3-0.8 mm quartz sand at a rate of about 1 kg/m2 shall be done to increase the adhesion with the sprayed membrane (quartz sand may be directly mixed with the primer before its application of the GEVR/GERCC surface, to be verified with relevant supplier). Application must be done by specialist applicator, fully familiar with the operation of the required heated, high pressure, plural component spray equipment. Primer shall be colored to be clearly visible once applied over the GEVR/GERCC surface. The minimum bond strength with the substrate shall be 1.5 MPa, measured according to EN 1542 (failure of substrate).

4) If required by the Engineer, the Contractor must apply a levelling mortar for filling GEVR/GERCC surface imperfections prior to the application of the epoxy cementitious primer. This levelling mortar must be a three-part epoxy modified cementitious fine textured mortar conforming to EN 1504 part 2 and 3 with a minimum tensile adhesion strength on the substrate of 4 MPa measured according to EN 1542 (failure of substrate).

5) The waterproofing two-parts polyurea membrane shall be sprayed over the surface previously treated with the primer using a suitable two-components pump in subsequent layers of about 1 mm thickness, creating a continuous surface with a minimum overall guaranteed thickness of 4 mm. The membrane must be applied by specialist applicator, fully familiar with the operation of the required heated, high pressure, plural component spray equipment. Minimum requirements include:
   - Tensile strength 20 MPa (according to DIN 53504 or ISO37)
   - Static Crack Bridging A5 class (EN 1062-7 (A))
   - Elongation at Break > 300% (DIN 53504 or ISO37)
   - Adhesion to concrete > 3 MPa (EN 1542)

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- No changes in the behavior after artificial weathering (EN 1062-11)

Polyurea membrane above EL. 795.0M which may get exposed to sunlight after filling of reservoir shall be provided with a top coat. The top coat should have good adhesion to the Poly urea Substrate and should have high solar reflective Index and also should have good hydrolysis stability. Mix density of product should be 1.2 g/cm3 and solid content should be more than 70 % and should be confirming to the sustainable building protocol LEED v4.1.

6) The membrane shall be sprayed also on the external thermo-plastic elastomer (TPE) previously installed, in correspondence to the dam contraction joints. The external elastomer shall be minimum 60 cm wide with a minimum thickness of 2 mm and shall be installed using epoxy resin or mechanical system using a debonding sheet in correspondence of the joints to create a free-to deform system. The external surface of the elastomer shall be suitably treated with quartz sand to increase the bonding with the sprayed membrane. Minimum requirements include:
   - Tensile strength 8 (longitudinal) / 6 (transversal) MPa (according to EN 12311-2)
   - Elongation at Break > 300% (DIN 53504 or ISO37)
   - UV resistant (EN 1297)

7) All the materials of the system (levelling mortar, epoxy primer, sprayed polyurea, thermos-plastic elastomer, epoxy resin) must be from the same reputed manufacturer and shall demonstrate fully compatibility with each other.

8) The Contractor shall submit a detailed Method Statement two months before the application of the sprayed membrane and shall apply an on-site a complete mock-up (including cleaning of surface, primer application, sprayed membrane application) over a minimum area of 20 m (width) x 3 m (height) including at least one contraction joint to prove the efficacy and performance of the application system, prior to starting work on site. On site testing shall include:
   - material gel /setting times
   - Adhesion to substrate in accordance with EN 13596 or ASTM D 7234.
   - Shore Hardness development in accordance with DIN 53 505 or ASTM D 2240.
   - Thickness using metal plate with calipers or ultrasonic equipment

20.18. TEMPERATURE OF RCC

1) Cooling plants and methods implemented by Contractor shall allow the placement of RCC at temperature not more than 15 °C and not less than 7 °C at full production.

2) The maximum allowable weighted average placing temperature, as defined here below, shall be indicated in the drawings.
   Weighted average placing temperature is the value given by the ratio between the sum of the products of RCC volumes placed each hour by the mix placing temperatures for each hour and the total volume for the time period, according to the formula:

$$\frac{\Sigma\,[(\text{Volume of RCC placed each hour}) \times (\text{Mix placing temperature for the hour})]}{(\text{Total Volume for the time period})}$$

   Placing temperature is the temperature of the mix after being delivered and spread, but before compaction, determined by inserting a probe thermometer into the mix from the surface.
   The Contractor will record the data which will be always available on site to the Employer's Representative at any time.

3) After depositing and prior to compaction, the temperature will be determined by placing a thermometer in the RCC immediately after sampling at the placement site. The temperature of the RCC at batch plant shall be adjusted to assure that the specified RCC temperature is attained at the placement.

4) The temperature rise in the RCC shall be monitored and recorded for a minimum period of 180 days with a frequency of at least one reading every day. Temperature monitoring system shall consist of T-Copper and Constantan type thermocouples as temperature sensors, which are to be installed in the dam body at locations specified in the drawings. The connecting cables from the thermocouples from various groups will be terminated in separate junction box. The junction box shall be installed at accessible location in the gallery or at other locations as decided by the Engineer.

5) In addition to the control for RCC, conventional concrete (if used) and any mass conventional concrete at the foundation or base of any monolith block shall have a placing temperature that should not exceed the prescription reported in Section B09. Conventional dental fill concrete below any RCC shall be placed at such a temperature that no cracking can be observed.

20.19. INSPECTION

All materials, workmanship and finished construction shall be subject to continuous inspection and approval of Engineer. Materials rejected by Engineer shall be expressly removed from site to disposal area and shall be replaced by contractor immediately at no extra cost to the Employer.

20.20. PROTECTION

1) The contractor shall protect RCC against damage until final acceptance by the Engineer at the termination of the contract. In addition, compacted lift surfaces shall be protected until the lift surface is covered by the subsequent lift placement. Equipment and vehicles shall be operated in a manner, which precludes tight turns; sudden stops, spinning wheels or other procedures that damage previously placed RCC.

2) Un-compacted RCC and fresh RCC shall be protected from rain or hail. The contractor shall provide such protection to prevent erosion of RCC whenever such precipitation either periodic or sustaining, is imminent or occurring.

3) When such a precipitation appears imminent, the contractor shall immediately make ready at the placement site all materials, which may be required for protection of RCC. The Engineer may delay placement of RCC until adequate provisions for protection are made.

4) The contractor shall provide a recording thermometer to provide hourly temperature readings for determining the mean hourly temperature.

5) The cost of furnishing all materials and performing all work for protection of RCC shall deemed to be included in the price of RCC in Schedule.

20.21. CLEAN UP

Upon the completion of RCC work, all equipment, construction tools, protective coverings etc. resulting from the work shall be removed and the surfaces left clean.

20.22. FORMWORK

1) All formworks shall be designed and constructed in such a manner to ensure that the concrete can be placed and compacted to the required shapes, finishes, positions, levels and dimensions as shown on the drawings. The formwork shall be capable of resisting all dead and live loads to which it is subjected and shall be maintained rigidly in position. Special attention shall be given to the design of the formwork and the anchoring system when the RCC set time is retarded. The formwork shall be specially designed to allow a continuous placement of RCC without interruptions. All formworks shall be designed for the specific characteristics of the RCC/GEVR/GERCC, as applicable, and the placement methods and rates applied.

2) The types of ties used and their spacing shall be such that the required finish is achieved and will not be marred by the subsequent corrosion of ties. The formwork and the formwork joints shall be sufficiently tight to prevent any loss of mortar.

3) Removal of forms shall be done after concrete surrounding she-bolts has hardened and the required strength has been attained. Concrete placement in the RCC method is done in layers and placements will necessarily have short intervals and are seemingly continuous. Consequently, removal of forms will be required to be done rapidly.

4) The time of removal of forms will differ depending on the various conditions affecting strength of young concrete such as mixture proportions and air temperature. This will be decided by the Engineer after evaluating the performance of test section in the field.

5) Recesses resulting from removal of form ties shall be patched using a method and materials to be approved by the Engineer.

6) The formwork for RCC dam shall be measured and paid separately.

20.23. QUALITY CONTROL

20.23.1. GENERAL

1) The Contractor shall establish and maintain an effective quality control program for RCC, ensuring compliance with the Contract requirements and maintaining records of control, including tests and inspections, their findings, and remedial actions taken when necessary.

2) With regard to concrete materials, various items shall be tested and comparisons made with design values. In the event of occurrence of a difference with the design value, mixture proportions shall be changed or other appropriate measures shall be taken as directed by the Engineer.

3) Standard values and sampling frequency for quality control of concrete shall be as designated by the Engineer.

4) When required by the Engineer the records of quality control shall be submitted by the contractor without delay.

20.23.2. RCC QUALITY CONTROL PROGRAM

1) The contractor shall be completely responsible for performing detailed quality control program during the execution of work in accordance with the following:

   a. Quality control measures

      The contractor shall be responsible for taking quality control measures to ensure compliance of the RCC with the contract requirements.

   b. Quality assurance program

      The contractor will conduct a RCC quality assurance programme incorporating the tests at his own test facilities. The tests shall be conducted to the extent and frequency necessary to ascertain that the RCC constituents, as well as fresh and hardened RCC, meet the specified qualities. The quality assurance program shall be subject to inspection and checking by the Engineer.

2) RCC Quality Assurance and Control shall focus on the implementation of appropriate measures, procedures, systems and checks with the objective of eliminating the occurrence of strength and other test failures. As a consequence of the difficulties associated with recreating representative construction compaction conditions in a laboratory cube, RCC cube/cylinder crushing tests shall be viewed as indicative and primarily of use as a part of the quality assurance and confirmation programme.
   The process of sampling and testing RCC cores reflects the real characteristics of the material built into the dam and core tests are accordingly seen as providing the primary measure of the quality control achieved in the RCC construction, as well as providing a definitive record of the important properties of the concrete in the dam. Despite this fact, sampling and testing of RCC cubes shall not be neglected. All cube/cylinder test results shall be statistically assessed.

3) Aside from the contractor's testing program, the Engineer will make control test to the extent, as he deems necessary. The contractor shall give all required assistance in sampling and provide for the proper storage and transport of the specimens to be tested by the Engineer.

4) Effective programs for quality assurance and control shall be established and maintained for all RCC construction and these shall be the means by which compliance with the contract requirements is assured and control records are maintained. The Quality Assurance Program of the Contractor will serve to ensure that all controls are effective and are effectively enforced and observed. The program shall further ensure that problems and/or quality variations are identified and rectified before these might affect the works. The Quality Assurance Program shall include, inter alia, the following aspects: monitoring aggregate manufacture and gradations, moisture, batching requirements and mix proportions at the batch plant, ensuring adequate materials availability, that embedded items are properly installed, that insulation is installed, that joint treatment is correctly carried out and that all other tests and inspections required by this specification are correctly completed. The Contractor shall plan and document his Quality Assurance

and Quality Control Programs, and these shall be approved by the Engineer before the main construction activities are initiated and shall be maintained as a "live" document for the duration of construction.

The final acceptance will take into account the reliability and variability of RCC sample testing, as compared to typical equivalent core results, and will develop secondary checks to estimate the relevance of test criteria failures.

Qualified personnel, equipment and supplies that are necessary to ensure the effective testing and fulfilment of the quality control program shall be provided by the Contractor. No concrete placement or aggregate production will be allowed until the Engineers's approval of the quality control program has been granted. The tests described in 20.23.8**Error! Reference source not found.** shall be performed and, based upon the results of these inspections and tests, the action required in 20.24.3 shall be taken.

20.23.3. RCC CORE PROGRAMME

1) The records of greatest value that define the actual quality achieved in the dam construction, are those derived as part of the RCC core recovery and testing program. A core drilling program will be required for the main dam. At least 60 days after first RCC placement, a core drilling program shall be initiated (so that cores can be tested at 90 days) and one 150 mm diameter diamond core drills shall be active on virtually a continuous basis. Drilling shall follow a pre-defined program compiled by the Contractor and approved by the Engineer. RCC cores shall be stored in a water curing bath at a constant temperature of between 22°C and 25 °C until tested.

   Accurate records and logs of the recovered cores shall be maintained, including position of extraction, angle of drilling and depth of each section of the core. Only drilled RCC older than 70 days shall be taken for testing. Cores shall be tested at ages of 90, 180 and 365 days

2) At least one core every 100’000 m3 of RCC shall be extracted from the dam for inspection and testing. The average length of these cores shall be 15 m. Testing will be accomplished by drilling from a lift surface, the gallery floor, or the top of the dam, using diamond core holes with a minimum diameter of 150 mm. The location of each core will be selected by the Engineer to provide a representative view of the in-situ properties of the RCC placed in the dam and to investigate specific areas as indicated by the Engineer.

3) Extracted cores shall be tested for at least compression, direct tension, splitting tension, hear strength, permeability and elastic modulus, density and Poisson's ratio in the parent material and across layer and lift joints under the supervision of the representatives of the Engineer.

4) The holes created during the core drilling program on the dam, or alternatively additional holes of 75 mm in diameter, shall be used to test the permeability of the RCC. Permeability shall be tested using packers in accordance with the procedures set out in the Section B.7,”Drilling and Grouting” with a pressure equal

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to 110% of the reservoir head for the zone being tested. In general testing will be done in packered length 3 m long (10 layers of RCC).

If the average permeability, after maintaining constant pressure for 15 minutes, is less than 10^{-8} m/second, the test shall be considered acceptable. If the average permeability is greater than 10^{-8} m/second for the length of hole, the length of packered hole shall be reduced to 1 m.

If the average permeability is less than 10^{-7} m/second for each meter tested, the result shall be considered acceptable. For GERCC a lower permeability shall be defined, not higher than 10^{-9} m/s.

Additional RCC Permeability tests will be carried out in the drainage holes drilled from dam upstream galleries. At least one drainage hole for each dam block will be tested, from the lower pair of galleries up to the upper pair of galleries. Permeability tests will be either falling head or pressure tests, as prescribed by the Engineer.

Attention shall be paid during execution of water test campaign to the observation of leakages on the upstream face of the dam. When sign of leakages or wet areas are observed on the dam upstream face, detailed survey of such areas shall be carried out and recorded.

No individual lift shall have a permeability greater than 10^{-6} m/second. If a test fails these criteria, the Contractor shall propose remedial measures to rectify the situation for the approval of the Engineer. The Engineer may direct additional remedial measures also. Any such remedial measure shall be executed to the satisfaction of the Engineer at no cost to the Employer.

5) The drilling shall be paid separately under relevant items in Schedule. The cost of testing is included in the cost of RCC. Filling of the hole with cement mortar & retesting shall be at contractor's cost.

20.23.4. RCC SEMI-ADIABATIC TEST PROGRAMME

The contractor shall carry out semi-adiabatic test for all the approved RCC mixes as per protocol as per annexure to section B.20 of these Technical Specification.

20.23.5. TEST FACILITIES AND SAMPLING EQUIPMENT

1) The contractor shall provide sampling equipment and testing facilities at each batching plant:

   a. An enclosed building of not less that 100m^2 area adjacent to the batching and mixing plants, free from plant vibration and excessive plant noises and furnished with all necessary utilities including computer, lights, compressed air, water, room temperature control and electrical power to monitor various activities. An additional covered area of 70 to 75 m^2 shall be provided to house the curing baths and at least one office shall be provided for the use of the Engineer

b. Mechanical sampling devices for safely procuring and handling representative test samples of aggregates and other concrete materials during batching and for obtaining representative concrete samples from a point in the discharge stream as the concrete is discharged from the mixers. In addition, some facilities for testing of the hardened RCC, water intake test to decide the permeability of concrete shall be included.

c. Ample and protected working space near the placement site and a means for safely procuring and handling representative concrete samples.

d. The laboratory equipment must include all equipment required for conducting quality control tests such as:

- A cube press capable of crushing 150 mm square RCC cubes of 60 MPa strength.
- Two sets of grading screens each for the coarse and fine aggregates.
- A large capacity microwave and convection oven.
- Running water and electric power supply.
- A scale accurate to 10 g, with a capacity of 250 kg.
- A scale accurate to 1 g, with a capacity of 12 kg.
- A nuclear density measurement device, capable of measurement at 300 mm depth.
- Two modified Vebe apparatus
- Vibrating table capable of compacting > 12Nº 150-mm cubes/cylinders at the same time
- PC for data recording and processing of mix design variation.
- Concrete thermometers.
- A laboratory pan concrete mixer (vertical axis) capable of mixing at least 150l of zero-slump RCC
- Cubic 150 mm metal moulds (No. 100)
- Cylindrical metal moulds, 150 mm in diameter and 300 mm in length, complying with ASTM C470M-09 (No. 30)
- Curing baths, with a water temperature thermostatically controlled to between 22 and 25 °C, of an adequate capacity to store 1400 No. 150 mm concrete cubes and core segments.
- A slump cone with a rod.
- Penetrometer (as described in ASTM C403).
- 15 No. 150 x 150 x 300 mm steel moulds for mortar samples used in the setting time tests.
- Mechanical sieve of large capacity for sieving 5-mm mortar out of the RCC mix.
- Two galvanised curing tanks fitted with thermostatically controlled temperature to maintain curing water up to 90ºC (accelerated curing). The tanks shall be capable of storing each 16Nº cubes 150 mm size.
- Direct tensile testing machine for 150mm-diameter RCC cylinders of 4 MPa strength.
- Efflux Index testing apparatus in accordance with EN 933-6.

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- Apparatus for Sand Equivalent test in accordance with EN 933-8.
- A set of aggregate flakiness and elongation measurement templates
- Apparatus for Methylene Blues test in accordance with EN 933-9.
- Any additional equipment required to meet test program.

2) The Contractor shall ensure that all equipment is properly maintained in a fully functional and accurate condition for the duration of construction and that all necessary calibrations are regularly completed in accordance with the relevant standards. A copy of the full range of specified testing procedures shall be kept in the laboratory at all times.

3) After tests are completed, the contractor's furnished test facilities shall remain the property of the contractor and shall be removed from the work site.

20.23.6. DRAWINGS AND DATA

1) The contractor shall submit drawings and data to the Engineer for approval showing locations and descriptions of contractor furnished test facilities and sampling equipment for testing of concrete and concrete materials not less than 30 days prior to start of installation of the contractor's plants and equipment for processing, handling, transporting, storing and proportioning concrete ingredients and for mixing, transporting and placing concrete. The drawings and data shall provide a description in sufficient detail for an adequate review of the facilities and equipment the contractor proposes to provide the Employer Ltd. for use in the Employer's concrete quality assurance program.

20.23.7. COST

The cost of furnishing drawings and data, sampling equipment, testing facilities and activities shall deemed to be included in the unit price of other items entered in the Schedule.

20.23.8. INSPECTION DETAILS AND FREQUENCY OF TESTING

1) Aggregate Properties

At least once during each shift that concrete is placed, or that aggregates are produced, gradations shall be checked for each aggregate size, including calculation of the fineness modulus and the compacted void content of the fine aggregate. The locations from which samples are taken may be selected by the Contractor provided that they give an accurate indication of gradations of materials as they enter the mixer. In addition, the following tests shall be determined according to the respective Standards and with a frequency of at least 1 test/week during aggregate production and RCC placement:

a. specific gravity and absorption of all aggregate sizes,

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b. elongation and flakiness indices of coarse aggregates (BS BS812 Part 105),
c. abrasion test (Los Angeles) for the coarse aggregate sizes
d. loss by washing (particles <0.075mm) of the coarse aggregate sizes,
e. compacted (rod) void ratio of the fine aggregate, the fine aggregate with the < 0,075 mm particles removed and the full combination of aggregate sizes in the proportions that are used in the RCC mix,
f. if required by the Engineer, plasticity index of the sands (sample passing 0,420mm sieve) and determination of deleterious clay content of the fines in aggregate (methylene blue),
g. determination of sand geometrical properties, in accordance with EN 933-6.

During each day of placement for each aggregate size, the moisture content shall be determined at intervals not exceeding 4 hours. The location from which the sample is selected may be determined by the Contractor provided that it is typical of materials entering the mixer.

2) RCC Plant Control

When the concrete plant is operating, a daily report shall be prepared indicating the type and source of cement and pozzolan used during the day, aggregate size groups used, required mix proportions per m³ for each mix design used, the amount of water as free moisture in each size of aggregate, and the aggregate and water weights per m3 for each mix design of concrete made during plant operation.

In addition to the standard control and certificates issued by the cement supplier, samples of the cementitious materials shall be taken from the plant silos with a frequency of 1 sample/10'000 m3 of RCC and the standard tests as described in EN 12620:2002+A1:2008 1491 (part 1 or 2 as applicable) for pozzolanic material shall be checked.

A sample shall be taken from the water tank feeding the RCC plant every week during and RCC placement and the parameters required for mixing water for concrete in accordance with Section B09 shall be checked.

Admixtures used in the RCC mix shall be checked on a weekly basis during RCC placement and in particular the density of the retarder admixture. The uniformity of the admixture is checked as part of the standard testing procedure of the RCC (setting time and strength). In addition, the effect in both parameters of an overdosage of admixture by 50% and 100% shall be checked and the results compared with those investigated during the mix design stage.

The scales shall be checked and calibrated by a recognised authority across the full range of operation and a certificate of calibration shall be issued. Calibration shall occur before start-up of concrete operations and at quarterly intervals during operation thereafter, and/or as required by the Employer.

The accuracy of each batching device shall be routinely checked during a weighing operation by noting and recording the required weight and the weight actually batched. Rechecks shall be made at least every 40 shifts of operation and whenever variations in the properties of the RCC mix are apparent.

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3) Accelerated curing

Accelerated RCC test curing involves 4 days of conventional curing, 1 day of raising the temperature to 90°C, 4, 7, or 14 days of curing at 90°C, 1 day of cooling to 22°C and 1 day at 22°C. With total test durations of 11, 14 and 21 days, accelerated curing will allow a prediction of the ultimate concrete strengths and an approximate estimate of the 1-year concrete strengths, which can be calibrated against the normal cure 1-year strengths. During construction, accelerated curing can be used to very rapidly test the impact of any apparent variations in moisture content, admixtures and/or aggregates, etc. as well as to monitor concrete strength consistency.

4) Testing RCC

a. General

Fresh concrete shall be sampled and tested for compliance with the specifications and for additional information as required by the Engineer. Samples for testing shall be taken at the placing location at the time of placement but may also be taken at the batch plant as directed by the Engineer.

b. Mixer Performance

A complete mixer performance test of three different batches of concrete shall be made on each mixer in accordance with the requirements of 20.7.2 prior to the start of concrete placing. Whenever mixer adjustments are necessary as a consequence of specification non-compliance, the mixer shall be re-tested after adjustment. Performance tests shall be completed routinely on each mixer at least once every month.

c. Temperature

RCC temperatures (for each mix placed) shall be determined every hour during the placing of RCC by means of a digital type immersion thermometer. RCC temperatures shall be measured at the mixer, when heaped for spreading and in the spread state immediately prior to compaction. The temperature of a heap of discharged RCC at the site of placing shall be measured at a penetration depth of not less than 300 mm from the surface of the heap. At the same time as the placement temperature is recorded, the ambient air temperature shall also be recorded by means of the mercury thermometer. The reading shall be taken in the shade as close as possible to the position of the RCC placement.

Additional tests shall be made when rapid set time or workability loss is reported, or when cold weather problems occur.

The Contractor shall record the following information:

- the temperatures of the RCC at the mixer, in the heap before spreading and in the spread layer;

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- the ambient air temperature;
- the time of day (hour); and
- the position of the RCC in the works, i.e. the reference level of the RCC layer and the block number of the structure (where applicable) as shown on the drawings.

The method of taking the temperatures shall be subject to the approval of the Engineer. The readings shall be taken by a suitably trained person.

d. Moisture Content

At least once during each 4 hours of production placement at the batch plant, a RCC sample shall be micro-dried for moisture content. At least once every 2 hours at the placement site (immediately after compaction) the moisture content shall be determined on the RCC mix using a nuclear gauge in the direct transmission mode. The probe shall be driven to a depth of 250 mm for each reading. The gauge shall be calibrated against oven-dry samples of each mix design used. After consistent moisture control is achieved, the rate of testing may be decreased to one test per 8 hours at the plant and one test per 4 hours at the placement. At least three tests shall be made in different areas of each layer of RCC placed.

e. Preparation for Concrete Placement

Foundations, lift surfaces, construction joints, formwork, and embedded items shall be inspected in sufficient time prior to each concrete placement in order to certify that the area is ready to receive concrete. Formwork shall be checked closely for condition, support, alignment, and dimensions. The results of inspections shall be reported in writing as a part of the quality control reports. The placing foreman shall supervise all placing operations, he shall determine that the correct mix design of concrete is placed in each location as directed by the Engineer and shall be responsible for measuring and recording concrete temperatures, ambient air temperature, weather conditions, time of placement, volume placed, and method of placement. The placing foreman shall not permit placing to begin until he has verified that an adequate number of vibratory rollers and spreading equipment of the correct size, in working order, and with competent operators is available. He shall further ensure that all required joint treatments have been effectively accomplished.

f. Dumping and Spreading

The placing foreman or other designated representative shall continually observe and monitor dumping and spreading operations to ensure that operations are appropriate to minimise segregation and to avoid excessive spreading after dumping. Each layer of RCC shall be routinely checked in its spread un-compacted condition for evenness and correct thickness

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that will result in a smooth, even, compacted layer within the thickness tolerances specified and having an average thickness as required. A laser shall be used in conjunction with hand-carried vertical rods to determine the elevation (and subsequently the thickness) of each layer. The laser shall be of the type that emits a rotating or constant light beam in a fixed plane.

g. Compaction Equipment

Before any compactor is used in RCC construction, it shall be checked for correct dimensions, weight, and vibratory capacity. At least once per 12 shifts of use, a spot recheck of frequency shall be made. At least once per placement shift for the first 5 days of operation by any new operator, performance shall be spot checked for the correct number of passes, correct spread, coverage of the area being rolled, and good rolling practice. Thereafter spot checks shall be made on each operator at least weekly.

h. RCC Consistency and fresh density (VeBe density)

Consistency of RCC shall be measured using the VeBe apparatus as described in EN 12350-3: 2009 to the procedure described in ASTM C1170M Procedure B. The following information shall be included in the report:

- Date of test,
- Identification of sample i.e. point of sampling and approximate location when placed in terms of chainage and offset,
- Loaded VeBe time (in seconds), and
- Time of concrete mixing and time of the test.

An additional test of fresh RCC density (VeBe density) may follow using the same sample. The procedure is as follows:

- Continue vibration so that the total vibration time is 30 seco nds,
- Clean off the transparent disc so that all the ingredients of the concrete are in the container,
- Weigh the container and concrete,
- Fill the container, still containing concrete, with water until it is completely full,
- Weigh the container, concrete and water,
- Calculate the fresh compacted density by:

$$\text{density} = \frac{W_c - W_o}{V_o - (W_w - W_c)} \times 10^3 \ (kg/m^3)$$

where:

V_o = volume of container (litres)

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W_o = weight of container (kg)

W_c = weight of container and concrete (kg)

W_w = weight of container, concrete and water (kg)

i. Air Content

Measurement of air content in fresh RCC will be performed using the pressure method (ASTM C 231).

Unit weight of RCC will be also calculated as part of measuring air content of RCC using a pressure meter. The measurement of air content of RCC shall be carried out with a frequency of at least twice per placing shift.

j. Concrete Specimens for Compressive and Tensile Strength Tests

RCC shall be sampled at position of placement and cubes and cylinders shall be manufactured, cured and tested for compressive strength and tensile test, respectively.

All sampling, preparation and testing shall be in accordance with EN 12620:2002+A1:2008.

The specimens shall be manufactured using a vibrating table. Each set of cubes shall comprise 12 specimens, unless otherwise indicated; with 2 cubes each tested at 7, 28, 56, 90, 180 and 365 days in compression.

For every 5 sets of cubes made, an additional set of 12 No. cylinders 150mm diameter shall be manufactured using the same procedure with 3 cylinders each tested at 28, 90, 180 and 365 days in direct tensile. These series might be different in the case of the Full-Scale Trial and in the process of establishing control for the main dam construction.

Test specimens shall be compacted to the same density as applicable for the wet density of the compacted RCC on the dam wall close to the point of sampling. At least 98 % of the cubes shall indicate densities of within 50 kg/m^3 of the measured wet density of the RCC close to the point of sampling.

All cubes and cylinders shall be clearly marked with adequate information to allow precise identification, accurate tracing and full correlation and evaluation of the results at any stage.

The following regularity of cube sampling shall apply:

i. Full-Scale Trial

A minimum of one set of 150 mm cubes shall be made for every half layer of RCC mixed. A minimum of one set of 150 mm cylinders shall be made per layer of RCC placed.

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ii. During Initial RCC Placement

A minimum of one set of cubes of 150 mm dimension shall be manufactured every shift during RCC placement. The cubes shall be tested in compression at the ages specified above. In addition, one set of 150 mm cylinder shall be made and tested as specified above for every 5000 m^3 of RCC placed. This procedure shall be maintained until the Engineer is satisfied that adequate control over batching and mixing activities has been achieved.

iii. During RCC Placement Once an Adequate Level of Control has been Achieved

A total of one set of cubes of 150 mm dimension shall be manufactured using RCC sampled from 3 separate batches at intervals evenly spread throughout each day of placement. For every 5 sets of cubes sampled, one set of cylinders shall be manufactured from the representative daily samples and tested for tensile strength at the ages specified above.

k. Density

i. Quality control density tests will be used to determine whether the optimum compaction density has been achieved and to determine when additional RCC compaction or other actions are necessary. Density readings at different locations and depths shall be made during compaction. Density readings shall be taken on a regular basis after compaction has been fully completed.

Readings will be scheduled so as not to disrupt or delay any of the other ongoing RCC operations.

ii. Frequency and test results of compacted RCC shall meet the requirements specified in 20.10.320.23.8. If compaction cannot be achieved within 30 minutes after spreading the rejected RCC shall be removed.

iii. The in-situ density will be determined by a nuclear densitometer. A nuclear densitometer will be placed at laboratory and at site and calibrated every week. Before arriving on site, the densitometer shall be calibrated and a certificate provided. It should be placed in a locked container and a training course set up for personnel. The staff using the densitometer will be wearing the uniforms and badges.

iv. The laboratory density will be measured once a week taking an average of 3 samples (taken throughout the day) and compacted on the vibrating table.

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v. During the course of all RCC placement, a running cumulative average of RCC densities will be maintained on a bar graph (or other approved form) and will consist of all valid readings, starting after all major mix design field adjustments have been completed for the Full-Scale Trial.

vi. Moisture contents of the in-situ RCC shall be measured by nuclear methods will be made at the same time and frequency as the nuclear density measurements.

l. Notification

Notification will be given when placement of RCC is near or exceeds the limits specified above, and actions will be immediately taken to make adjustments in procedures as necessary to maintain the placement density within the specified limits. This will be addressed in the Contractor's Quality Control Procedures.

20.24. TOLERANCES

20.24.1. GENERAL

1) Tolerances are defined as allowable variations from specified lines, grades and dimensions and as the allowable magnitude of the surface irregularities. Allowable variations from specified lines, grades and dimensions are listed under specific requirements vide paragraph 20.24.2.

2) Concrete shall be within all stated tolerances even though more than one tolerance may be specified for a particular concrete structure; provided that the specified variation for one element of a structure shall not apply when it will permit another element of the structure to exceed its allowable variation. Where tolerances are not specified or shown on the drawings for a particular structure, tolerances shall be those specified for similar works. The contractor shall be responsible for finishing the concrete and for setting and maintaining concrete forms within the limits necessary to ensure that the completed work shall be within the tolerance limits specified. Concrete work that exceeds the tolerance limits specified shall be remedied in accordance with para 20.24.3.

3) Hardened concrete shall be checked by the contractor and will be subject to such inspection and measurement as needed to determine that the structures are within specified limits.

4) Variation is defined as the distance between the actual position of the structure or any element of the structure and the specified position in plan for the structure or the particular element. Plus or minus variations, shown as ±, indicate a permitted actual position up or down and in or out from the specified position in plan. Variations not designated as plus or minus indicate the maximum deviation permitted between designated successive points on the completed element of construction.

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5) The Engineer reserves the right to diminish the tolerances set forth herein if such tolerances impair the structural action, operation function, or architectural appearance of a structure or portion thereof.

20.24.2. SPECIFIC REQUIREMENT

1) Offsets of adjacent precast segments or panels shall not exceed 10 mm.

2) The elevation of the surfaces of roller compacted concrete layers upon which subsequent concrete is placed shall not vary by more than 125mm from the design elevation, except that the elevation of the top three lifts shall be within 50mm of that shown on the drawings.

3) The thickness of individual compacted layers of RCC shall be within ±30mm for 300mm thick lift.

4) Depressions, or irregularities in the surface of a "Hot" joint when receiving the spread RCC layer above shall not exceed 75 mm.

5) The alignment of all waterstops shall not deviate more than ±50 mm from the line specified on the drawings.

6) The alignment of the induced contraction joints, crack inducers and crack directors shall not deviate more than ±50 mm from the line specified on the drawings.

7) The alignment of the components within a crack inducer system should not deviate more than ±3 mm from the lines specified on the drawings.

20.24.3. REMEDIAL MEASURES

1) Hardened concrete, which is not within specified tolerances or as otherwise approved by the Engineer shall be repaired to bring it to within those tolerances. Such repairs shall be accomplished in a manner approved by the Engineer. Concrete repair to bring concrete within tolerances shall be done only after consultation with Engineer regarding the method of repair. The Engineer shall be notified as to the time when repair is to be performed.

2) Concrete, which will be exposed to public view, shall be repaired in a manner, which will result in a concrete surface with a uniform appearance as demonstrated and approved in the test section. Concrete surfaces of lesser quality than approved shall without exception, be repaired as necessary in a manner approved by the Engineer to bring surfaces within specified tolerances.

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20.25. MEASUREMENT AND PAYMENT

20.25.1. TEST SECTION

1) Measurement for payment for test section shall be made at the lump sum price bid in the schedule.
2) The lump sum price bid in the Schedule shall include the cost of all materials, labour, equipment, test, sampling and testing etc. & performing all works to the satisfaction of Engineer.
3) The lump sum price bid in the schedule shall include all activities and cost towards pre-qualification of equipment demonstration, material selection and training of personnel etc.

20.25.2. RCC

1) Measurement for payment of RCC shall be made of the in situ volume placed in cubic meters as shown on drawings.

2) Payment for RCC will be made at the Unit Price entered in the Schedule, which shall include, but not be limited to, the following:

    a. Excavation, loading, transportation, crushing, screening, washing, blending, and storage of aggregates.
    b. Provision, delivery, transportation, storage and mixing of cement at nominal content) and complying with all requirements specified.
    c. Cooling, Batching, supply of mixing water and admixtures, mixing, transportation, placing, and compacting the RCC.
    d. Labour, tools and equipment for cleaning, and preparing surfaces prior to roller compacted concreting.
    e. Forming and treatment of construction joints and dam faces.
    f. Forming RCC Contraction Joints and void formers.
    g. Attaining the concrete temperature as specified, and hot and/or cold weather precautions.
    h. Protection and curing of RCC.
    i. Repair of defective RCC and removal of rejected RCC.
    j. Communication system connecting the points of placing RCC with the relevant mixing plant or delivery equipment.
    k. Furnishing the trial bays and panels, provision of material samples and all activities required in connection with the performance of the tests including their transportation to the testing laboratory.
    l. All the instruments and accessories required for testing of RCC.

3) The unit price of RCC per m³ entered in the Schedule will be based on the cost of 150 kg of nominal cement content. The amount of cement required per cubic meter of concrete of each RCC class will be established

at trial mix stage or the approved modifications thereof as established by the Engineer in the course of RCC work. Any increase or decrease in the cement content in the mix proportion per m³ shall be measured for payment/ recovery. Payment for increase or recovery for decrease shall be made at the unit price per kg entered in the Schedule, which shall include the cost of supply, handling, transportation and storage and use to work of cement.

4) 2% of the amount towards payment for RCC will be withheld from each R.A. bill, till the completion of dam construction. This accumulated amount will be released only after first filling of dam and after ascertaining the impermeability of RCC concrete. The contractor will be responsible to do necessary grouting at his own cost to achieve desired level of minimum acceptable leakage, through joint/ body of the dam before release of said payment.

5) Where access ramps onto the dam are used the ramp re-fill concrete shall be placed to grade. The cost of such re-filling is deemed to be included in the unit price of RCC.

6) Measurement for payment and payment for reinforcing steel, pre cast concrete etc. are stipulated in other sections of these specifications.

20.25.3. GEVR / GE-RCC

1) Measurement for payment of GEVR / GE-RCC in RCC dam will be made to the volume placed within the lines & grades shown on the drawings.

2) Payment for GEVR / GE-RCC will be made at the unit price entered in the Schedule which shall include the cost of furnishing of all materials including cement and fly ash but excluding chemical admixtures, hauling, storing and performing all works required to get the finished faces of dam.

3) Variation of cement shall be paid/ recovered as per clause 20.25.2 (3).

20.25.4. ADMIXTURES

1) Measurement for payment for set retarding water reducing admixtures actually used in RCC, will be of the weight of the agreed dosages established at trial mix stages or the approved modifications thereof and computed on the basis of the number of cubic meters of RCC measured and approved for payment.

2) Payment will be made at the applicable Unit Price per kilogram as entered in the Schedule which shall include the entire cost of supply, handling, storage, and dispersing.

3) No extra payment will be made for other kinds of admixtures such as non-shrink agents.

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4) No payment will be made for admixtures used for Contractor's convenience only.

20.25.5. U/S SPRAYED MEMBRANE

1) Measurement for payment for sprayed epoxy cementitious primer with quartz to be applied over the upstream face of the dam before the application of membrane, including preparation of the surface by means of high-pressure water jets to remove any laitance, surface staining, mortar drops, curing compound (if required). Payment will be made at the applicable Unit Price per metric ton as entered in the Schedule which shall include the entire cost of supply, handling, storage, application.

2) Measurement for payment for a two-component sprayed polyurea membrane applied on the upstream face of the dam. The membrane shall be sprayed over the surface previously treated with the primer using a suitable two-components pump in subsequent layers of about 1 mm thickness, creating a continuous surface with a minimum overall guaranteed thickness of 4 mm.
   The sprayed polyurea shall adhere intimately to the GEVR/GERCC surface overlapping with an external free-to-deform thermo-plastic elastomer previously installed in correspondence to the dam contraction joints, creating a continuous composite impervious element). Payment will be made at the applicable Unit Price per metric ton as entered in the Schedule which shall include the entire cost of supply, handling, storage, application including top coat.

3) Measurement for payment for external thermo-plastic elastomer installed, in correspondence to the dam contraction joints. The external elastomer shall be minimum 60 cm wide and shall be installed using epoxy resin or mechanical system using a debonding sheet in correspondence of the joints to create a free-to deform system. The external surface of the elastomer shall be suitably treated with quartz sand to increase the bonding with the sprayed membrane. Payment will be made at the applicable Unit Price per meter as entered in the Schedule which shall include the entire cost of supply, handling, storage, application, anchoring system, quartz sand.

20.25.6. EXCLUSIONS

20.25.6.1. RCC / GEVR / GE-RCC

No extra measurement for payment or payment will be made for the following:

1) Any defective and wasted concrete; concrete which has to be removed and replaced due to Contractor's non-compliance with the Specifications or Engineer's directions, and all related cost shall be at the contractor's expense.

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2) Any concrete which the contractor places or uses for his own installations or for his own convenience.

3) Developing alternative sources of aggregates by the Contractor and the resulting additional material testing.

4) Any pre-cast concrete units damaged by improper storing, handling or transportation.

5) Any pipe work or material incorporated into the work to aid in placement of concrete.

6) Backfill concrete in over break in surface excavation except geologically approved over break.

7) Curing, including curing compound on dam faces.

20.25.6.2. TESTS

1) All cost associated with testing as described in this Section shall be borne by the Contractor, who shall make allowance for such expense in the Unit Prices for the concrete work. These shall include, but not be limited to, the following:

   a. Routine tests for quality control during the execution of the RCC work carried out by the Contractor as specified herein and as directed.

   b. Other tests required during execution of the work to be carried out by an approved test laboratory.

   c. Preparation, storage, handling, curing and delivery of samples to a laboratory designated by the Engineer, if so required for additional independent testing.

2) Should the contractor fail to adhere to his testing program, all test deemed necessary by the Engineer to check RCC work will be performed by the Engineer or a laboratory assigned by him, at Contractor's expense.

END OF SECTION B.20

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ANNEXURE-1

SEMI-ADIABATIC TEST PROTOCOL

SCOPE

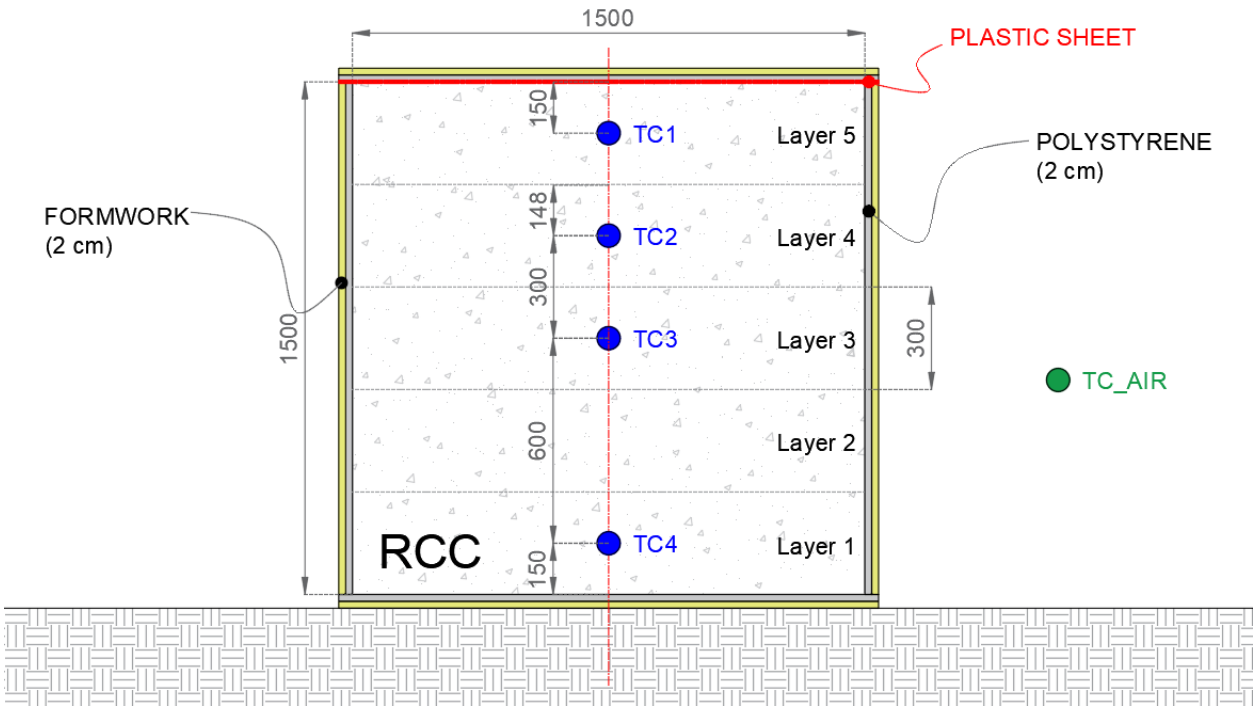
Hydration heat is emitted during the chemical reaction between minerals contained in the cementitious material and the mixing water. In general, the rate of hydration heat production is temporally variable.

The method herewith proposed covers a procedure for determining the temperature rise in the most relevant RCC mix to be used for Dorjilung Dam construction under semi-adiabatic conditions, primarily due to heat liberated on hydration of cement.

TEST LAYOUT AND EQUIPMENT

The test shall be carried out on a RCC sample **block of dimension 1.5 x 1.5 x 1.5 m**, with the following insulation system on the exposed surfaces (refer to the figure below):

- **PLASTIC SHEET** (on the upper face of the block)
- **POLYSTYRENE** (2 cm)
- **FORMWORK** (2 cm)



Semi-adiabatic test layout and equipment (dimensions in mm)

In order to monitor the temperature rise in concrete after casting, **no. 4 thermocouples shall be installed** within the block (namely TC1, TC2, TC3 and TC4), located along the vertical central axis of the block in the positions indicated in the above figure (blue dots).

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TEST SETUP

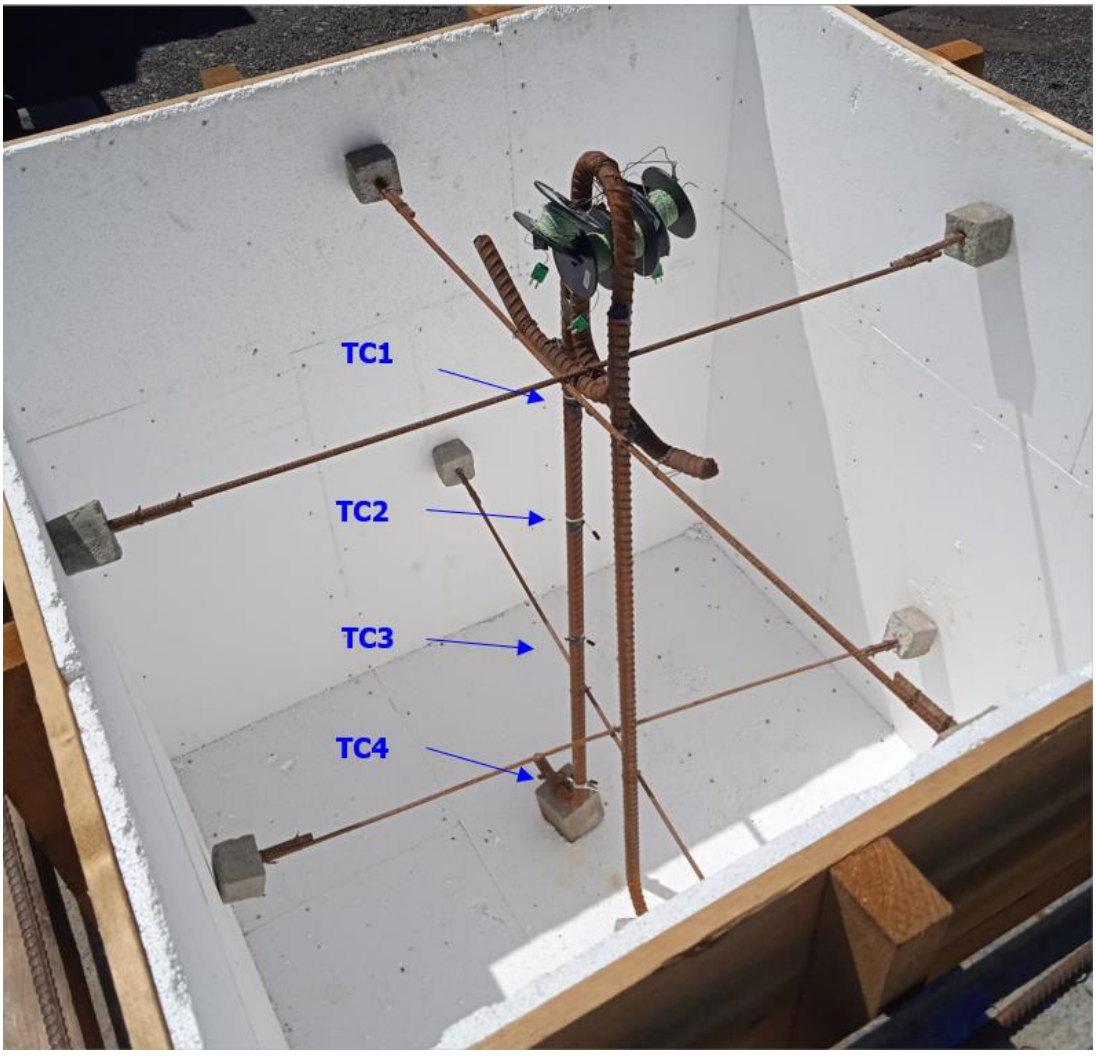
The testing setup procedure is summarized as follows (the next figures have been taken from semi-adiabatic test carried out on concrete for Koysha Project, but the procedure is the same):

STEP 1 Predisposition of the formworks and polystyrene on the bottom and lateral surfaces, and positioning of the thermocouples

STEP 2 RCC Casting (layers 30 cm compacted by power tamper)

STEP 3 Application of the plastic sheet on the upper face of the block

STEP 4 Application of the polystyrene and formwork on the top of the block, above the plastic sheet



STEP 1, Predisposition of polystyrene, formworks and thermocouples (ref Koysha Project)

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STEP 2, Concrete pouring (ref Koysha Project)

STEP 3, Application of the plastic sheet on the top of the block (ref Koysha Project)

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STEP 4, Application of Polystyrene and formwork above the plastic sheet (ref Koysha Project)

AMBIENT CONDITIONS

In order to assure the best thermal insulation of the block during the test, **the test shall be carried out in a closed environment**, where the contribution of the heat due to solar radiation is approximately zero.

The environmental air temperature shall be constantly monitored and recorded for the entire duration of the test with appropriate tools (thermometers, thermohygrometers, thermocouple, etc.), as indicated in Figure 1 (green dot). It shall be recorded also during the testing setup procedure, as it may affect the concrete placing temperature.

TEMPERATURE RECORDINGS

After the concrete pouring, the temperatures measured by the thermocouples shall be recorded with the following frequencies:

- **HOURLY basis until the temperature peak is recorded**
- **DAILY basis for 10 days after the temperature peak is reached**

The temperature recordings shall be put into an excel file reporting the following information:

- Date and Time of the recording
- Elapsed time since the concrete casting
- Temperature recording for each thermocouple installed in the block (TC1, TC2, TC3 and TC4)
- Air temperature recording (TC_AIR)

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21. ADDITIONAL INVESTIGATIONS

21.1. GENERAL

The contractor shall conduct the additional geotechnical and geophysical investigations, field and laboratory tests as specified herein or as required by the Engineer during the course of the execution of the works and submit the reports to the Engineer.

The investigation reports shall include all the relevant information with respect to the conducted investigation/test, but not limited to the following:.

GEOTECHNICAL IN SITU TESTS

- Detailed description of the activities
- Timing and personnel
- Equipment
- International Standards adopted,
- Plate load in situ readings and results
- Goodman jack in situ readings and results
- Flat jack in situ readings and results
- Shear test in situ readings and results

GEOPHYSICAL INVESTIGATIONS

- Detailed description of the activities
- Survey location
- Timing and personnel
- Equipment and software
- Indian/International standards adopted
- Description of the interpretation method adopted
- Illustration of the results obtained for each performed tests, described in the next sections.
- Raw geophysical data in appropriate format to Engineer-in-charge as per the requirement.

The detailed description of the expected results for each test is shown in the following sections of this document.

Before submission of the final report of each investigation/test performed by the contractor, the results from each investigation (field raw data and photos) shall be submitted to the Engineer, for his review and comments, in both digital and printed format. The comments/observations/suggestions of the Engineer shall be included by the contractor in the final report. The format of the report shall be as per the international practices as agreed mutually by the Contractor and the Engineer.

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21.2. PLATE LOAD TEST

The contractor shall conduct Plate load tests determine the deformability characteristics of the rock mass as per the requirements of the Engineer at the location decided by the Engineer.

The test shall be carried out according to IS: 1888, or one the following standards:

- ASTM D 4394 (Reapproved 1998) – "Standard Test Method for Determining the In Situ Modulus of Deformation of Rock Mass Using the Rigid Plate Loading Method",
- ASTM D 4395 (Reapproved 1998) – "Standard Test Method for Determining the In Situ Modulus of Deformation of Rock Mass Using the Flexible Plate Loading Method",
- IRSM "Suggested Methods for Determining In Situ Deformability of Rock".

The documentation submitted to the Engineer-in-Charge shall contain the following information:

- General information (project, worksite, location, date, operator name);
- Number of test,
- testing procedure,
- tests position,
- tables with displacements values measured by 6-bases extensometer and the instruments positioned around the loading area in function of the applied stress, the time, as well with the average values of the instruments positioned around the loading area,
- diagrams stress-displacement measured at the depth of 0 m, 0.25 m, 0.50 m, 0.75 m, 1.00 m and, if meaningful, of 2.00 m from loading area,
- diagrams of the average values of the displacements measured around the loading area in function of the applied stress,
- diagrams of the total (comprehensive of the testing phase at constant stress) and of the reversible displacements in function of the applied stress levels,
- tables with the secant deformability and elastic moduli,
- diagrams with the values of secant deformability and elastic moduli in function of depth,
- diagrams of the displacements of the head of the boreholes with reference to the deepest anchor (3.00 m), of the applied stress and of the temperature in function of time.

21.3. FLAT JACK

The test shall be carried out according to IS: 13946 (Part-4), or the following standards:
ASTM D 4729 (Reapproved 1997) - Standard Test Method for In Situ Stress and Modulus of Deformation Using the Flatjack Method
The documentation submitted to the Engineer shall contain the following information:

- General information (project, worksite, location, date, operator name);
- Number of test;
- Adit name and chainage;

- Adit side,
- In situ readings;
- Load-settlements graphs;
- Calculated Young's modulus;
- Updated calibration certificates each 6 months.

21.4. GOODMAN JACK

Tests will be performed according to relevant IS, where available, or adopting ASTM D 4971-08.

Test Report documentation shall include:

- general site information (site name, location, date, operator name);
- name of the adit
- adit chainage
- name of the tested drilled hole;
- test depth and elevation;
- on site data readings;
- data processing;
- calibration certificate;
- notes and observations.

21.5. SHEAR STRENGTH TEST

The test has to be carried out according to relevant part of IS: 2720, or to the "ISRM Suggested methods for Determining Shear Strength" standard.

The documentation submitted to the Engineer-in-Charge shall contain the following information:

- General information (project, worksite, location, date, operator name);
- Name of specimen,
- testing procedure,
- tests position,
- field collected data
- photograph and detailed description of test equipment and a description of methods used for specimen preparation and testing.
- For each specimen a full geological description of the intact rock, sheared surface, filling and debris preferably accompanied by relevant index test data (c.g-roughness profiles: Atterberg limits, water content and grain size distribution of filling materials)

- Photographs of each sheared surface together with diagrams giving the location, dimensions, area, dip and dip direction and showing the directions of shearing and any peculiarities of the blocks.
- Detailed digital surface model, result of the photogrammetric survey,
- For each test block a set of data tables, a consolidation graph and graphs of shear stress and normal displacement vs. shear displacement,
- For each test peak and residual friction angle.

21.6. HIGH RESOLUTION SEISMIC SURVEY

The Geophysical survey programs will include:

- Seismic Refraction Tomography (SRT) survey into adits
- Direct Wave Seismic Tomography (DWS) survey between adits
- Cross-hole Seismic Tomography (CST) survey between drill holes

The quantity of the tomographic seismic line, and the Direct Wave Tomography (DWT) between adits is shown in drawings.
The location, type and the length of tests shall be adjusted as per the instruction of the Engineer at site as per availability of ground stretch and resolution requirements, following the results obtained from first tests.

Geophysical survey will be carried out in compliance with IS-15681:2006 / ASTM D5777 concerning Geological exploration by Seismic refraction method.

STAFF AND EQUIPMENT

The survey will be carried out by teams including, at least, the following specialized workers:

- 1 Senior Geophysicist
- 2 Surveyor
- Local workers to be utilized during field work.

The senior Geophysicist shall have at least ten years of experience in similar works, to be proved by means of a CV with references, upon request of the Engineer, while the surveyors shall have at least five years of specific experience. Whether the qualifications of the personnel proposed might not be adequate, the Engineer might request replacement at no additional cost for the Client.
The following (minimal) instruments and accessories will be deployed at survey site by the Contractor, including:

- Seismograph for refraction and Cross-hole Seismic Tomography, (24/48 channel – 24 bit)
- 24 numbers verticalgeophones + spare, 24 numbers of omnidirectional geophones + spare
- 2 numbers seismic cables with 12 takeout each at 5 m interval + spare cable
- 2 numbers Geophone extension cables + spare

- Trigger cable/wire of adequate legth
- Hammer (10kg) + spare
- Nylon/acrelic plate for Hammer impact
- Cross-hole Seismic Tomography unit (including Sparker source and Hydrophone chain)

SPECIFICATIONS FOR SEISMIC REFRACTION TOMOGRAPHY (SRT) AND DIRECT WAVE TOMOGRAPHY (DWT) AND CROSS-HOLE SEISMIC TOMOGRAPHY (CST)

The related geophysical survey program will be focused on the following points:

- Geophysical characteristics (P wave Velocity) of the rocks into the adits;
- Seismic tomographic reconstruction of one or both adit wall and drill holes as per requirement;
- Direct Wave Tomography (DWT) between the adits
- Data processing and editing of the obtained results;
- Interpretation of the results and editing the technical report.

DATA COLLECTION FOR SEISMIC REFRACTION TOMOGRAPHY (SRT) AND DIRECT WAVE TOMOGRAPHY (DWT) AND CROSS-HOLE SEISMIC TOMOGRAPHY (CST)

The seismic data for the tomography will be collected by the seismograph with the following settings. These settings may vary as per actual site conditions with the agreement of Engineer:

- 0.5 m to 5.0 m of geophone spacing as per site requirements;
- Shot interval: Preferebly between each geophones in case of SRT and 0.5m to 1.0 m in case of DWT
- Sampling interval: 0.025 milliseconds (ms) to 0.25 ms (As per site requirement)
- 24 to 48 channel recording (depending on the Survey line lengths);
- 12 channel recording in case of CST
- Record length: Between 50 to 500 ms (As per sampling interval)
- 1 ms pretrigger (If required)
- Application of filtering if necessary;
- Data file stored in SEG2 or SEGY standard.

DATA PROCESSING

The data processing sequence will be the following:

- To analyse the seismograms, filtering and picking the first arrival times with the use a specific software. The picking data must be included in the final report.
- To produce the Tomographic sections between the adit and drill holes as the case may be

21.7. LABORATORY TESTS

Laboratory tests to be carried out on samples retrieved from boreholes include the following:

- UCS in dry and wet condition

- UCS with measurement of young's modulus
- Specific gravity
- Determination of density (Dry & Saturated)
- Triaxial tests
- Direct shear on natural and levelled joints (DST)
- Tensile strength tests
- Los Angeles Abrasion test (LAA)

Tests shall be carried out according to relevant part of IS: 2720, or other international standards such as ISRM and ASTM.

21.8. MEASUREMENT AND PAYMENT

21.8.1. GENERAL

Measurement for payment for the following investigations shall be made as per the unit prices entered in the bill of quantities:

- PLATE LOAD TEST
- FLAT JACK TEST
- GOODMAN JACK TEST
- SHEAR STRENGTH TEST IN ROCK MASS
- SHEAR STRENGTH TEST FOR CONCRETE ROCK CONTACT
- SEISMIC REFRACTION TOMOGRAPHY (SRT)
- DIRECT WAVE TOMOGRAPHY (DWT)
- CROSS HOLE TOMOGRAPHY (CHT)
- UCS IN DRY AND WET CONDITION
- UCS WITH MEASUREMENT OF YOUNG'S MODULUS
- DETERMINATION OF DENSITY (DRY & SATURATED)
- TENSILE STRENGTH TEST
- LOS ANGELES ABRASION TEST (LAA)
- TRIAXIAL TEST
- DIRECT SHEAR TEST

Measurement for payment and Payment for drilling, concreteing, excavavation, backfill, rockbolts, reinforcement etc. required in connection with the geological and geotechnical investigations shall be made as per relevant sections of these specifications.

21.8.2. EXCLUSIONS

The following shall not be paid extra and is deemed to be included in the unit price of various instrumentation items:

a) Calibration of instruments, all accessories, cables, tools,

b) Complete services for the execution of the investigations, including topographical survey works, installation works, preparation of the test area, power and lightning, etc.

c) Factual data report

d) Interpretative Data report

END OF SECTION B.21

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22. HSS EQUIPMENT – GENERAL AND PARTICULAR TECHNICAL SPECIFICATIONS

I. GENERAL TECHNICAL SPECIFICATIONS

22.1. GENERAL DESCRIPTION

22.1.1. THE DOCUMENT

The Contractor shall strictly observe this General Technical Specification in conjunction with the Particular Technical Specifications. He shall carry out all work in a skilled and workman like manner in compliance with modern methods of engineering. All design calculations, materials, works, manufacture and testing shall conform to the latest applicable standards.

In addition, the Contractor shall conform to all applicable regulations regarding the execution of construction and installation work, and shall follow all instructions issued by the competent Authorities, and the Engineer.

The Particular Technical Specifications shall take precedence over the General Technical Specifications in case of any contradiction.

Grouting works are within the Civil Contractor's scope; however, required material strength (kPa/N/mm²) shall be specified by the H&M Contractor to ensure proper interfacing during execution.

Clause number cross-references refer to the volume in which they occur unless stated otherwise.

22.1.2. SCOPE OF WORK

It is not the intention of these specifications to specify the complete details of equipment; however the contractor shall supply the equipment, which will meet in all respect, the requirements of the owner in regard to performance, durability and satisfactory operations. All the equipment supplied shall conform to the relevant Indian Standards. Wherever the Indian Standards are not existent or silent, relevant ASTM, DIN, Japanese Industrial Standards (JIS) or BS standard shall be adopted.

The broad scope of the work for the equipment as specified in the following paragraphs shall include the fabrication design (shop drawings), procurement, fabrication/manufacturing, inspection, shop assembly, testing, painting, transportation, site storage & site erection, testing and commissioning including provision for all the required labour, plant & material for the above, handing over to owner, supply of necessary spares parts and their operating systems for the following items:

- Six (6) Sets of Spillway gates;
- One (1) Set of Spillway stoplogs;
- One (1) Spillway gantry travelling crane;
- One (1) Auxiliary Spillway service gate;
- One (1) Auxiliary Spillway maintenance gate;
- Eight (8) Sets of Trashrack;

- One (1) Trashrack cleaning machine;
- Two (2) Intake service gates;
- Two (2) Intake maintenance gates;
- Two (2) Fixed Wire rope Hoists;
- One (1) door for Adit-1;
- Steel Liner in Spillway Glacis, Piers and Breast wall;
- Environmental Flow System Release.

The detailed design shall be carried out by the Main Design Consultant (DC).
Supply and installation of all incidentals not specified but necessary for the proper completion and satisfactory functioning of works and guarantee of the permanent equipment, along with all auxiliary equipment in the designated location of the project as specified in the following sections of technical specifications, shall also be in the scope of work.

22.1.2.1. SPARES

Mandatory spare parts as per PTS.

22.1.2.2. DESIGN/Drawings and Operation and Maintenance Manuals

The scope of work shall also include submission of following documents:

- Fabrication Design and shop Drawings
  1. Two (02) sets of all approved design and 6 prints each of all approved drawings and 6 prints each of all approved “As Built Drawing” properly bound & placed in folder.
  2. 2 Soft copies of all designs & 4 soft copies of all drawings on good quality DVD/Pen drive suitable for editing and printing.

- Operation and Maintenance Manual
  3. 8 sets of operation and maintenance manual containing drawings, all related catalogues and brochures for plants and machinery, handling procedures for assemblies & sub-assemblies of all equipment covered under this specification properly bound & placed in folder.
  4. 2 Soft copies of above manuals on good quality DVD/Pen drive suitable for editing and printing.

22.2. STANDARDS

Latest Indian Standards for design, testing, workmanship, material and Works have been selected mostly in these specifications as a basis of reference. Except where modified by this specification, works and materials shall be in accordance with INDIAN STANDARD. If relevant Indian Standards are not available in any case or cases, then relevant International Standards shall be proposed by the Contractor for approval by the Engineer.
When IEC or ISO Recommendations or other Standards are referred to, the edition shall be that current at the time of issue of Tender Documents, together with any amendments issued to that date.

If requested by the Engineer, the Contractor shall supply at his own expense three copies in English of latest edition and one in the original language of any national standards, which are applicable to the Contract.

22.2.1. STANDARDS FOR GENERAL APPLICATIONS

Standard publications issued by the following organizations of standardization are considered being approved standards for the works with a priority to use Indian standards.

- BIS : Bureau of Indian Standards.
- ASTM : American society for testing & material.
- ASME : American society of mechanical Engineers.
- DIN : Deutsches Institut fur Normung.
- BS : British standard.
- IEC : International electromechanical Commission.
- JIS : Japanese Industrial Standard.
- EN : European standard

22.2.2. STANDARDS for Design & Testing

Latest Edition of following is the list of Indian Standard Specifications, which shall be followed wherever the detailed requirements have not been outlined in these specifications:

S. No	**Description**	**Number**
1.	Recommendation of structural design of gates	IS: 9349 and DIN 19704
2.	Code of practice for design of rope drum and chain hoists for hydraulic gates.	IS: 6938
3.	Code of practice for design manufacture erection & testing of cranes & hoists.	IS: 807
4.	Code of practice for use of structural steel in general building construction.	IS: 800
5.	Approval test for welding procedures	IS: 7307 (Part I)
6.	Approval testing of welders working to approved welding procedures (Part I).	IS: 7310(Part I)
7.	Approval tests for welders when welding procedures approval is not required.	IS: 7318

8.	Code of practice for liquid penetrant flow detector.	IS: 3658
9.	Code of practice for Ultrasonic tube echo testing by contact and immersion methods.	IS: 3664
10.	Code of practice for magnetic flow detector.	IS: 3703
11.	Code of practice for radiographic testing.	IS: 2595

Reference should be made only to the relevant Indian Standard Specification. However, where such code is silent on certain specific provision, reference may be made to other appropriate & relevant ASTM, ASME, DIN, JIS or BS. Standards other than those stipulated in the Bid documents shall be acceptable after scrutiny provided they ensure equal or higher quality than those specified in the specifications. The contractor shall submit for approval the detailed standards, which he proposes to use.

It shall be confirmed by the contractor that in case the standards proposed by him are not found acceptable by owner during engineering, conformance of the offered equipment to the respective standards as specified in the bid documents shall be ensured by him at no extra cost to the owner.

If these specifications conflict in any way with any of the above standards or codes, these specifications and drawings shall take precedence.

22.2.3. MATERIAL STANDARD

All material used for the fabrication of the equipment shall conform to relevant Indian standard or equivalent International standard as DIN, ASTM, or BS unless otherwise specified.

A) Materials for gates and Embedded Parts.

S. No	Component Part	Recommended Material / Make	Code reference
i. a.	Structural parts of gate leaf including skin plate, steel liner, stiffeners, horizontal girders, diaphragms, track base, seal base, seal seat base, liners, seal clamp,lifting lugs, guide, anchor bolts, anchors, etc.	Structural steel	IS 2062
ii. a	Wheels	Cast steel / forged steel/Carbon Steel	IS 1030/ IS 2004/ IS 1570 P-II
b.	Self-aligning spherical roller bearings/ antifriction bearings	SKF, FAG, INA, NTN	

c.	Wheel pins	Corrosion resistant steel	IS 1570 (Part V) Gr.20 Cr.13
d.	Retainers	Structural steel	IS 2062
e.	Sleeves for pin (Distant piece)	Corrosion resistant steel	IS 1570 (Part - V) Gr.04Cr19Ni9
iii. a	Guide roller	Cast steel/Forged steel	IS 1030/ IS 2004
b.	Guide roller pin	Stainless steel	IS: 1570 (Part-V) Gr.20 Cr.13 / AISI 420
c.	Bushing	i) Self-lubricating bush ii) Al.Bronze	Tenmat/NTN/FAG/SKF IS: 305,Gr-AB-2 IS: 318,Gr-LTB-1
iv.	Seals	Rubber	IS: 11855
v.	Track	Corrosion resistant steel	IS: 1570 (Part-V) Gr.20 Cr.13/ Gr.30Cr.13
vi.	Seals seat	Stainless steel	IS 1570 Gr. 04 Cr. 19 Ni9
vii.	Seal fasteners	Stainless steel	IS 1570 Gr. 04 Cr. 19 Ni9

B) Material for components of Hoist Bridge, Hoist Support, Walkways, Railing, Dogging Devices etc.

i)	Base plate, anchors, stiffeners, bracings, lugs, etc.	Structural steel	IS: 2062 Rolled sections IS:808

ii)	Walkway	Chequered Plate	Standard or IS3502
iii)	Bridge bearings	Neoprene or Plate bronze	Standard IS 305/IS 318
iv)	Handrails & Posts		IS 1239 MS Black Medium duty

C) Materials for wire rope Hoists

i)	Wire rope	Steel Improved plow	IS:2266 (6x37 fibre core)
ii)	Drums	Cast steel/ M.S.	IS: 1030/IS: 2062

	a) Gears	Cast steel/	IS:1030
		Structural steel	IS: 2062/ IS:2707
	b) Pinions	Carbon steel	IS: 1570C40
		Structural steel	IS: 2062
		Forged Steel	IS: 2004 Cl. IV
iii)	Sheaves and pulleys	Cast steel	IS:1030
iv)	Shafts	Forged steel	IS:2004Cl.IV
		Carbon steel	IS: 1570 C 40
v)	Speed reducer, Motors, Electromagnetic, Thruster brakes, Plummer blocks with bearings, Switches, Control equipment, Electrical bought out items etc.		Standard reputed
vi)	Pins	Forged steel/ Carbon steel	IS 2004/ IS 1570-C40
vii)	Bushing	Bronze/Al-Bronze	IS: 305/ IS:318
viii)	Steel for shrunk fit gear rims	Forged steel/ Carbon steel/ Structural steel	IS: 2004 IS:1570-C40 IS: 2062
xi)	Threaded fasteners	IS: 1363	IS: 1367

22.2.3.1. SUBSTITUTE Material

In case the material specifications of any component(s) proposed by the contractor is not in accordance with the technical specification, data in respect of those materials shall be submitted for assessing the suitability of the same. However, the bidder shall confirm that in case the materials proposed by him are not found acceptable, he shall abide by the materials specified in the specifications without any extra financial implications to the owner.

22.3. TECHNICAL DOCUMENTS

22.3.1. GENERAL

This Chapter specifies the general scope and gives a definition of the documents which, together with those listed in the Particular Specifications, shall be delivered by the Contractor to the Engineer within the periods, and in a number and quality as specified in the General and Special Conditions.

The Engineer reserves the right to request the Contractor additional documents as may be required for proper understanding and definition of constructional, operational, co-ordination or other matters.

The Contractor shall co-operate with other Contractors in the exchange of drawings, dimensions, data and all other information required to ensure proper co-ordination of the work. All documents to be supplied shall be submitted in accordance with the agreed program so that any comment and change requested by the Engineer can be taken into account before starting of the manufacturing in the workshop and/or erection or installation at the Site.

If the Contractor fails to submit such documents, then the later execution of changes requested by the Engineer and the resulting additional cost and/or delays shall be the Contractor's liability. The contractor shall not be released of his responsibility and guarantee after drawings and computations have been approved by the Engineer.

The preparation of drawings, computations or other technical documents shall not be subcontracted by the Contractor without the written authorization of the Engineer. In such a case of subcontracting the Contractor shall be fully responsible for such drawings, computations and other technical documents as if they were done by him.

If required for proper understanding of the documents, additional descriptions/explanations shall be given on these documents or on separate sheets.

All symbols, marks, abbreviations, etc., appearing on any document shall clearly be explained by a legend on the same document or on an attached sheet.

Each device appearing on any document (drawing, diagram, list, etc.) shall clearly be designated. The abbreviation mark used for an individual device shall be identical throughout the complete documentation so as to avoid confusion. All documents shall have a uniform title-block as outlined in the specification. Beginning with the very first submittal to the Engineer, the Contractor's drawings shall bear a serial number.

Revised technical documents replacing previously submitted documents shall be marked accordingly. Also, the revised part in the Document itself shall be marked clearly. The documents required to be supplied shall be clearly marked as regard to their status namely "FOR APPROVAL" (A), or "FOR INFORMATION" (I), respectively.

Any comment given by the Engineer on "I" type drawing shall have the same effect as if it were given on "A" type drawing.

22.3.2. DESIGN & DRAWING

The Contractor shall submit details of estimated machinery imposed loads on concrete structures, location of anchors, groove details and checks in structures constructed by others within 60 days of award of Contract for interfacing with civil works.

Manufacturer shall submit the fabrication design computations and shop drawings to the Engineer for approval/information (as per requirement listed under para (3.3), which shall include in sufficient detail to show:

- Design fabrication calculation for all components and parts in accordance with design criteria & specification to prove their adequacy supported by catalogues / technical literature of all bought out components with selection criteria & characteristics.
- Kinematic details in the form of line diagram/sketches/data of gate and hoist establishing and describing the position of gate either fully closed and in gate fully open position etc.
- General assembly and sub-assembly arrangement and detailed dimensions of the parts of the equipment to be supplied under the contract.

- Blockout drawings dimensioning locations of anchors and Ist stage concrete outlines.
- Material lists covering specifications, sizes, quantities, and weight of each component.
- For all larger pieces of works which, due to their dimensions and/ or weight and transport limitations, will require special means for their transportation, the contractor shall submit binding loading drawings indicating dimensions weights, etc. of the respective pieces of works and the necessary trailer for its transportation to the site.
- Weld details.
- Machining and assembly tolerances and fits.

Diagrams:

- The circuit diagrams shall show the power circuits in all phases with the main apparatus as well as the pilot circuits (measuring and control circuits). It shall show in full the functioning of part or all installations, works or circuits with all required technical information. This shall show all technical blocks control cubicle, cable details, cable tracks etc.
- Electrical wiring diagrams of hoist, cable lay out drawings, performance curves, specifications and catalogue numbers of all motor control centres, control panels, motors and accessories.
- Automatic or manual lubrication system, controls, control panels, motors and accessories.
- All handling attachment for site assembly.
- Control & Indicators.

All drawings shall be carefully checked by Manufacturer for accuracy, completeness and clarity before submission to the Engineer. Manufacturer shall be responsible for correctness and adequacy of the design in relationship to the specifications.

The approval of drawings or design shall not relieve or absolve the contractor of his responsibilities regarding adequacy of design / drawings and correctness of design/drawings.

The Engineer shall have the right to ask the contractor to make any change in the designs and drawings, which may be necessary in the opinion of the Engineer to make the equipment conform to the provisions and intent of those specifications without additional cost to the purchaser.

The requirements of any such alterations requested by Engineer shall not be construed to mean that the drawings have been checked in detail. It shall not be accepted as justification for an extension of time and shall not relieve Manufacturer from responsibility for the adequacy of the designs and correctness of the drawing.

The Contractor shall carry out and be responsible for the fabrication design of works. Design shall be prepared by qualified designers who are engineers or other professionals and have experience and capability necessary for the design. The contractor undertakes that the designers shall be available to attend discussions with the Engineers at all reasonable times until the date of relevant Defect notification period.

The Contractor shall prepare all Contractors' Documents, and shall also prepare any other documents necessary to instruct the Contractor's Personnel. The Employer's Personnel shall have the right to inspect the preparation of all these documents, wherever they are being prepared.

Any approval or consent, or any review shall not relieve the Contractor from any obligation or responsibility.

22.3.3. SUBMISSIONS

The documents/design computations/drawings required to be submitted to the owner for approval or information is broadly listed hereunder:

1. Design

a) Gates and stoplogs

For approval	For information
Fabrication design of Gate with lifting attachments, Wheel Assembly / Wheel Track, Connection details (weld/bolt), Dogging device, Hoist capacity calculations and embedded parts design, Shop Assembly Procedure	Guide rollers, wheels, bumper arrangement and other components.

b) Trashrack and TRCM

For approval	For information
Fabrication design of panel with lifting attachments, Connection details (weld/bolt), Dogging device, Hoist capacity calculations and embedded parts design, Shop Assembly Procedure	Guides, bumper arrangement and other components. Pulleys/ sheaves & attachments, overload/slack rope mechanism, limit switches, power supply arrangement, Turn buckles, Walkway, ladders, handrails, grating/ chequered plate/hatch covers, other components, rope clamps, couplings, Plummer blocks etc.

c) Cranes, hoists & Supporting Structures

For approval	For information
Fabrication Design/ Selection of Ropes, Reduction gearing, Shafts, Wire rope and attachments, Motors, Brakes, hoist Supporting structure, Shop Assembly and Load Testing Procedure & Schematic drgs.	Pulleys/sheaves & attachments, , overload/slack rope mechanism, limit switches, power supply arrangement, Turn buckles, Walkway, ladders, handrails, grating/ chequered plate/hatch covers, other components, rope clamps, couplings, Plummer blocks etc.

2. Drawings

I. Gates and stoplogs

For approval	For information

• General arrangement drawing of gates/stoplogs • Block out & Ist & 2nd stage embedded parts details • Detail of gate	All types of sub-assembly drawings including wheel assembly, etc. & detailed drawings of all components.

II. Trashrack and TRCM

For approval	For information
• General arrangement drawing • TRCM operating and standby position • Block out & Ist & 2nd stage embedded parts details • Detail of trashrack panels and of TRCM	All types of sub-assembly drawings including wheels, etc. & detailed drawings of all components. Structural details of TRCM

d) Cranes, hoists & Supporting Structures

For approval	For information
• General arrangement with gate & hoist (lifting & sitting position) with technical particulars • General arrangement drawings of Hoist • G.A. drawings of structure along with connection details.	Drum Assembly, End gear assembly, central drive unit assembly, Plummer blocks, Shafts, Gears, Couplings, Structural detailed drawings, All components drawings, Structural sub-assembly drawings etc.

22.3.4. INSTALLATION AND COMMISSIONING PROCEDURES

22.3.4.1. INSTALLATION PROCEDURES

The installations procedures shall describe in sequential steps the erection of major equipment and shall contain sufficient details such as equipment preparation on erection bay, handling of large and heavy pieces, leveling, anchoring, site welding, site painting, erection checks, alignment and run out checks to allow the engineer to plan and supervise the Works at site. The contractor may submit his proposals for such installation but shall have to obtain the approval of the purchaser before acting. Detailed instruction to the installation of the gates shall be given by the purchaser or his authorized representatives at site and shall be binding on the contractor.

22.3.4.2. COMMISSIONING PROCEDURES

The commissioning procedures shall sequentially and in sufficient detail describe activities and tests for all systems covered by the Contract Document.

22.3.5. OPERATION AND MAINTENANCE MANUALS

The operation and maintenance manual shall be prepared and provided by the contractor and shall contain following information in sufficient detail to enable the employer to maintain dismantle, reassemble, adjust and operate the works with all its works and installation.

The manuals shall include a separate and complete section describing the following:

- Description of works & equipment.
- Operating principle & characteristics.
- Operating instruction (For normal & emergency operation.)
- Testing & adjustments.
- Maintenance instructions.
- As Built drawings.
- Catalogue of bought-out items
- Spare parts.

The manuals shall describe and illustrate the procedure for assembling, adjusting, operating and dismantling of each component and control system. The maintenance of each component shall be described, including the recommended frequency of inspection and lubrication.

Three (3) copies of the manuals shall be submitted in English in draft for approval of the Engineer within 3 months after the final approval of the equipment. Eight

(08) sets of copies properly bound and placed in folder shall be provided to Engineer along with soft copies on good quality DVD/ pen drive (two sets) suitable for editing and printing of the text & drawings not later than 30 days after receipt of approval.

If revision of the manuals becomes necessary, as a result of information gained during installation and initial operation, Manufacturer shall make the necessary revisions and furnish eight (08) copies of the revised section sheets with the revision symbols along with DVD/ pen drive of the same.

The manuals shall include a complete list of all drawings prepared by Manufacturer, a list of spare parts and a list of parts for each component or item of equipment. The parts list shall include manufacturer's name and serial numbers. The manual shall include data, literature and catalogues of bought out items.

Manufacturer shall ensure that his installation supervisor has a copy of all approved drawings and the manuals in his site office.

22.3.6. PROGRESS REPORTS

22.3.6.1. PROGRESS REPORTS DURING DESIGN AND MANUFACTURING

The Contractor shall monthly submit four (4) copies of the progress reports in a format acceptable to the Engineer, detailing the progress of the work during the preceding period. The report shall contain (but not be limited to) the following information:

- A general description of the Works performed during the reporting period on each main activity.

- Overall percentages of the works completed, with reference to the CPM programme.
- The percentages of each main work activity completed during the reported month with reference versus the scheduled programme.
- A list of activities scheduled to be started within the next period of three (3) months, with expected starting and completion dates. Any notable problems, differences, comments with reference to the schedule may be supported with appropriate documents.

22.3.6.2. PROGRESS REPORTS DURING INSTALLATION AT SITE

During erection the Contractor shall, before the tenth (10th) day of each calendar month, submit four (4) copies of the monthly progress reports in a format acceptable to the Engineer, detailing the progress of the work during the preceding month. The report shall include, but not be limited to, the following information:A general description of the Works performed during the reporting period on each main activity.

- The total overall percentages of erection works completed, with reference to the CPM program.
- The percentages of each main work activity completed during the reported month with reference versus the scheduled program.
- A list of all activities of scheduled and actual progress during the reporting period including actual starting dates versus scheduled starting dates; and actual completion dates versus scheduled completion dates for each activity.
- A list of activities scheduled to be started within the next period of two (2) months, with expected starting and completion dates. If the expected starting and/or completion dates are different from those shown on the CPM program, an explanation shall be given.
- Contractor shall also briefly report the manpower strength and expatriate personnel employed equipment etc. deployed during the reporting period.
- A statement concerning potential problems and recommendations on how they could be resolved.

22.4. SPARE PARTS AND TOOLS

22.4.1. SPARE PARTS

All spare parts to be supplied shall be interchangeable with the corresponding parts of all the Works supplied under these Specifications and shall be of the same material and workmanship. They shall be replaceable without cutting or destruction of adjacent components. Before issue of the Installation Certificate the spare parts shall be checked and tested at the Site by the Contractor in presence of the Engineer. Acceptance of any spare parts will not take place before the Contractor has submitted the complete final detailed list of all spare parts and tools.

All spare parts shall be protected against corrosion and shall be marked with identification labels in the Ruling Language. The identification shall be in accordance with the agreed Works Identification System.

All spare parts, tools and materials shall be delivered in marked boxes of sufficient sturdy construction to withstand long term storage.

The scope of work shall include all special tools, as well as all special devices including lifting devices, ropes, etc. necessary for total assembly and disassembly of all parts of the supplied facilities.

22.4.1.1. MANDATORY SPARE PARTS

The required Mandatory spare parts are listed separately in the Particular Technical Specifications. The price for each listed special spare part shall be quoted individually in the Price List; the total price shall be included in the Total Tender Price.

If any additional spare parts are recommended by the tenderer for satisfactory operation of Plant & Equipment after commissioning, these shall be stated in quantity and description for each item. The prices for that may be indicated in separate price schedule. This may not be treated as the part of price schedule.

22.5. DESIGN AND MANUFACTURE

22.5.1. DESIGN AND CONSTRUCTION REQUIREMENTS

The following directions, information and technical requirements for layout, design and erection shall be observed as far as they are applicable to the Works to be offered. The technical requirements of the General Technical Specifications are valid for all parts of the Works except where they are varied by additional and/or special requirements, specified in the Particular Technical Specifications.

Whenever a Tenderer deviates from these Specifications, he shall furnish the data called for in the Technical Data Schedules and give a summary of and the reasons for all deviations in the "List of Technical Deviations from Specifications". Failure to accomplish this may cause the elimination of his Tender, especially when a major deviation is involved. Any changes of the design of any part of the Works, which may become necessary after signing the Contract, have to be submitted in writing to the Engineer for approval, being sufficiently substantiated and justified.

Additional cost can only be accepted in case of a basic design change by the Engineer after award of Contract.

The Works shall be designed, manufactured, arranged and installed to provide functional design and neat appearance. All parts of the Works shall be arranged to facilitate surveillance, maintenance and operation. All control sequences shall be simple and rational.

The parts of the Works shall be designed and arranged so that they can be easily inspected, cleaned, erected and dismantled without involving large scale dismantling of other parts of the Works. They shall be designed, and manufactured in accordance with the latest recognized rules of workmanship and modern engineering practice.

The regulations, standards and guidelines listed in these Specifications shall be observed in the design, calculation and manufacture of the Works.

All parts of the Works shall be suitable in every respect for continuous operation at maximum output under the climatic conditions and operating conditions prevailing at the Site.

Special attention shall be given to Works, parts of which are delivered by different manufacturers. Problems arising in this conjunction shall be solved by the Contractor and be defined in writing.

For individual items of the Works, materials and design are to be selected which are best suited for the operating conditions to which the parts in question will be subjected. Only such design and types of Works shall be offered which has confirmed its reliability in long-term continuous operation. Innovations cannot be accepted for the Main Tender but can be offered as an alternative proposal.

All live, moving and rotating parts shall be adequately secured in order to avoid danger to the operating staff. All electrical components shall be electrically earthed as per the latest practice.

Manufacturers shall take appropriate measure to prevent the ingress of dust into any Works (such as bearings, relays, control and measuring equipment etc.) which may be endangered thereby.

Suitable lifting eyes and backing-out bolts shall be provided where required or where they will be useful for erection and dismantling.

Pockets and depressions likely to hold water shall be avoided, and if not avoidable they shall be properly drained.

Parts of the Works principally intended for standby purposes shall be protected from corrosion by careful choice of material and if necessary, by additional means these should not reduce their continuous standby readiness.

All design details and layout matters shall be discussed in periodic meetings with the Engineer. The first design meeting between the Contractor and the Engineer shall take place within 28 days after the Date of Commencement. Further design meetings shall take place as agreed between the participants until the design work is completed.

Lettering of the drawing shall be at least 3 mm high in block capitals. The sizes of Manufacturers drawings shall conform to International Organisation for Standardization (ISO) sizes. All drawings shall bear the mutually agreed title block, and drawing number as per the coding and pattern available with the employer. All drawings shall be drawn in accordance with Indian Standards, to scale, and shall be legible. Wording on drawings shall be in English. Symbols shall be in accordance with Indian Standards. Manufacturer shall submit to the Engineer 4 prints each of all documents / drawings for approval/ information. If revisions are required after a drawing has been submitted, manufacturer shall resubmit 4 additional prints for approval after incorporating the comments. Fabrication shall not commence until Engineer has approved drawings and thereafter no change shall be made on any drawing without the approval of the Engineer.

After designs and drawings are completed and approved, the manufacturer shall supply 2 prints of all the design and 6 prints of drawings including 6 prints each of all approved “As Built Drawings”. However, prior to completion of contract manufacturer shall supply 2 sets of design & 4 sets of drawings (soft copy) on good quality DVD/ pen drive suitable for editing and printing.

Drawings shall be submitted to Engineers for approval sufficiently in advance prior to the date on which they will be required to ensure that the work is carried out in compliance with approved schedule of work.

22.5.2. DESIGN CRITERIA

The Works shall be designed for the worst possible combination of the following loading conditions:

- All static and dynamic hydraulic loads,
- All loads due to dead weight and frictional forces,
- Seismic or wind loads, and
- Other loads

The full reservoir level, maximum water level, minimum drawdown level sill elevation and design criteria are described in particular specification required for the design.

The basic wind load of 600 N/ sq. m. shall be applied on the vertical projected area of exposed equipment, multiplied by the form factors for the different type of structures in accordance with IS: 875.

The wind load for the stability check of equipment etc. shall be 600 N/ sq. m while operating and 1500 N/ sq. m when out of service.

Load on the footpath, balcony floor and platform: 5000 N/m2

Vertical load on steel roof structures: 2500 N/m2

Vertical load on each part of ladder: 1800 N/m2

22.5.3. TOLERANCE AND CLEARANCE

The following design clearance shall be submitted to the Engineer for approval:

- Clearance between end of main Roller housing (side of gate) and gate guide.
- Clearance between moving gate components with respect to face of concrete/steel lined grooves.

22.5.3.1. GENERAL CLEARANCES

Side guide to guide track	6 mm in any direction.
pre-compression of side and top seals	4 mm
Pre-compression of bottom wedge type seal	5 mm
Minimum clearance between gate/stoplog platform (whichever is higher)	300 mm Bottom face to dogging or deck/maintenance
Minimum clearance from extreme top part of gate /stoplog to crane/hoist	300 mm
Minimum recess from concrete face to extreme part of gate / stoplog	100 mm

22.5.3.2. FABRICATION TOLERANCES

All components shall be fabricated in accordance with IS 4622 except as noted below:

a. All dimensions under 400 mm shall be ± 0.8 mm unless otherwise specified and are non-cumulative. All other dimensions shall be ± 1.5 mm.

b. The machined sealing surface of the sill and lintel beams and side guides shall be straight within 0.5 mm and level within 1.0mm over the whole length with a straight edge.

c. The roller path below the lintel shall be straight within 0.4 mm in any 3 m length and within 0.8 mm over the whole length and shall not deviate from a vertical line in any direction by more than 1.0 mm. Roller path faces for the same gate shall be in the same plane within 1.0 mm.

d. The roller path above the lintel shall not deviate from a vertical line in any direction by more than 2 mm and shall be straight within 2 mm over the full length.

e. The side roller paths shall be straight within 1.0mm in any 3 m length and within 2mm over the full length. The side roller path shall not deviate from a vertical line in any direction by more than 2mm.

f. The distance between the side roller paths and the main roller paths shall not vary by more than 3mm.

g. Radial run out of assembled roller shall not exceed 0.025mm of total indicator reading measured at the roller tread.

h. The bearing surfaces of roller treads on an assembled gate section shall be straight within 0.1mm over the full height of the section. The roller axis shall be parallel to the machined top and side seal bases of the gate within 15 minutes.

i. Wheel treads, seal bases (top and side), bearing faces and seal faces (side and top) on an assembled gate should be in a true plane.

22.5.3.3. INSTALLATION TOLERANCES

Installation tolerances shall not exceed 1.5 times the corresponding fabrication tolerance or the tolerances specified in the relevant IS codes whichever is the more stringent. Design and fabrication of the gates, hoist and embedded parts shall be suitable for the achievement of such tolerances during installation.

22.5.4. STANDARDIZATION OF WORKS

Every effort shall be made to standardise parts and minimise costs throughout the Works in order to facilitate replacement, interchangeability, keeping stocks, maintenance etc.

The Engineer, therefore, reserves the right to request the different Contractors to use uniform types or makes of Works and materials. The Contractor shall not be entitled to claim extra payment due to this request. This request shall especially be applicable to small mechanical and electrical Works such as:

a. seals
b. fasteners
c. oils and lubricants
d. valves
e. thermometers
f. pressure gauges
g. flow meters
h. water level gauges
i. terminals and terminal racks
j. indicating instruments and meters
k. auxiliary relays
l. contactors, fuses
m. motor protection switches
n. control devices
o. lights, bulbs, plugs, sockets

The types or makes to be used shall be decided later by the Engineer. All instrument scales shall be written in the Ruling Language of the Contract.

22.5.5. QUALITY OF MATERIAL AND WORKMANSHIP

For general requirements concerning the quality of materials and Works refer to relevant section of these Technical Specifications..

All materials shall comply with the latest IS standards, or other Standards specified unless otherwise specified. The materials and workmanship throughout shall be the best of their respective kind and free from defects. The design of all equipment shall be such that installation, replacements and general maintenance may be undertaken with the minimum of time and expense. All fitted joints shall be machined and castings shall be spot faced for nuts. All components shall be built in accordance with approved drawings only. No patching plugging or other such means of overcoming defects, discrepancies or errors shall be done without written permission of Engineer.

No welding, burning, filling or plugging of defective castings or any other components shall be permitted without the Engineer's agreement in writing.

Where stainless steel cladding consists of plates welded to mild steel sections, the welds shall be adequate to ensure that the stainless steel is securely fixed for all conditions of load and wear. Generally, all stainless steel parts shall be welded with stainless electrodes. The thickness of the stainless steel cladding shall not be less than 3 mm. Similar parts shall be made to gauge where possible, to ensure that such parts are interchangeable one with the other.

The Contractor shall be responsible for the accurate manufacture and fabrication of equipment in accordance with the best modern practice in the manufacture and fabrication of materials of the types covered by these specifications not withstanding the minor errors or omission therefrom.

Dimensions shown on the drawings shall be adhered to closely and the work shall in all cases be of high grade and carefully performed to the satisfaction of the Engineer. The contractor shall warrant all materials and workmanship furnished by him to be free from injurious defects. He shall replace free of cost any defective materials or workmanship discovered during erection or in guarantee period and shall pay the actual cost of the correction on the field of any errors for which he is responsible.

The Contractor shall supervise the leveling and adjustment of all parts of the equipment on the foundations and after each item is set up and the Engineer's approval obtained, grouting or concreting will be carried out by the civil works contractor's and verified by the Contractor. The Contractor shall be responsible for ensuring that such work is carried out to his satisfaction and that levels and adjustments made by him are not disturbed by the grouting operation. The Contractor shall be responsible for ensuring that the positions, levels and dimensions of the Works are correct according to the drawings notwithstanding that he may have been assisted by the Engineer in setting out the said position, levels and dimensions.

22.5.6. WORKS IDENTIFICATION SYSTEM

An approved, uniform Works identification system shall be applied for all mechanical, electrical and Instrumentation and Control (I&C) Works to be agreed upon during detailed design.

22.5.7. IDENTIFICATION PLATES

22.5.7.1. GENERAL

Each important part to be delivered under this Contract shall be equipped with permanent identification plates in readily visible locations. Whether a part shall be considered as important in this respect shall be decided by the Engineer.

The identification plates shall be protected during erection and especially during painting. Damaged or illegible identification plates shall be replaced by new ones. The identification plates of non-corroding, non-disintegrating material (except manufacturer's nameplates of small standardized components) shall be inscribed in the Contractual language.

The inscription shall be printed, stenciled, or handwritten, but in any case water- proof, oil-proof and wear-resistant. Works (machines, transformers, etc.) nameplates shall be either of the enameled type or be of stainless steel covered after stamping with a transparent paint. Wording, size and material of all labels and plates shall be subject to the Engineer's approval.

22.5.7.2. MANUFACTURER'S NAMEPLATES

All equipment shall be provided by a securely fastened name plate showing the maker's name, model, serial numbers, year of manufacture, main characteristics data of the respective equipment and further relevant information specified in the applicable standards or necessary for the proper identification of the equipment involved.

22.5.7.3. INSTRUCTION PLATES

All plates showing designations or instructions for operation, safety, lubrication, etc., shall have a uniform design. Instruction plates, sequence diagrams or instruction to operating staff shall be displayed on the inside of the front door of the control panel/switch board. All works inside cubicles, panels, boxes etc. shall be properly labeled with their item numbers. This number shall be the same as indicated in the wiring diagrams works lists, operation and maintenance manual.

All instruction plates displayed on the sub-assemblies like servomotors, powerpack hoist etc. shall show operational parameters, safety, lubrication etc. which shall have a uniform format.

22.5.7.4. WARNING PLATES

Warning labels for safety of equipment as well as operating staff shall be provided and shall be of synthetic resin with letters engraved in the contract language.

22.5.8. FABRICATION OF STEEL WORKS

Roundings, Chamfers, Edges: The edges of surfaces to be painted shall be rounded (minimum radius 2 mm) or chamfered accordingly. This requirement must be stated in all shop drawings for the relevant parts.

Structural steel: Work shall conform to the requirement hereinafter specified, unless otherwise called for in these specifications or on the drawings. Finished members shall be free from twists, bends and open joints. Compression joints shall have surfaces truly faced so as to have full contact bearing when aligned and welded or bolted.

Straightening of materials: Before being laid off or worked, rolled material shall be straightened and shall be cleaned of all rust and dirt. If straightening is necessary, it shall be done by methods that will not be cause for rejection of the material.

Shearing and cutting: Shearing and cutting by torch shall be performed carefully and in all work which will be exposed to view after completing shall be finished neatly. Sheared or cut edges of plates more than 16mm thick which carry computed stresses shall be planned to a depth of 6mm. Re-entrant cuts shall be filleted before cutting.

Holes: Holes in structural steel members carrying calculated stresses shall be sub- punched to 3mm less than the nominal diameter and reamed to full size or drilled after assembly. All other members may be punched to full size. Main members shall be assembled in the shop prior to reaming or drilling holes for field connection.

Accuracy of punched holes: Holes shall be punched so accurately that after assembling the component parts of a member, a cylindrical pin 3mm smaller in diameter than the nominal diameter of the punched hole may be entered perpendicular to the face of the member, without drifting in not less than 75 per cent of any group of continuous holes in the same plane. All holes shall punch a pin 5 mm smaller in diameter than the nominal diameter of the holes.

Reaming: Reamed holes shall be cylindrical, perpendicular to the member, and not less than 1.5 mm nor more than 2.5 mm than the nominal diameter of the bolts. Built up members shall be assembled and firmly bolted together before any reaming is done. Reamed parts shall not be interchanged. Burrs and savings from reaming shall be removed and, if necessary, reamed pieces shall be taken apart before being joined and the shavings removed.

Drilling: Drilled holes shall be cylindrical perpendicular to the member and 1.5mm larger than the nominal diameter of the rivet.

Accuracy of reamed and drilled holes: Holes shall be drilled and reamed so accurately after assembly that not less than 85 per cent of any group of continuous holes in the same plane shall show no off-set greater than 0.8mm between adjacent thickness of metal.

Removal of burrs: Burrs resulting from reaming or drilling shall be removed with a tool making a 1.5mm level.

22.5.9. SURFACE FINISH

22.5.9.1. FINISHED SURFACES

Where the finish is not indicated or specified, the type of finish shall be that type which is most suitable for the surface to which it applies and shall be consistent with the class of fit required.

Surface finish shall be indicated on the shop drawings by symbols. Compliance with the specified surface shall be determined by the sense of feel and by visual inspection of the work compared to applicable "Standard Roughness Specimens", or with roughness feeler gauge instruments. Both "Standard Roughness Specimens" and feeler gauge instrument shall be provided by the Contractor at the request of the Engineer.

22.5.9.2. UNFINISHED SURFACES

As far as practicable, all work shall be laid out to secure proper matching of adjoining unfinished surfaces. Where there is a large discrepancy between adjoining unfinished surfaces, they shall be chipped and ground smooth, or machined to secure proper alignment.

Unfinished surfaces shall be true to the lines and dimensions shown on the drawings and shall be chipped or ground free of all projections and rough spots. Depressions or holes not affecting the strength or usefulness of the parts shall be filled in a manner approved by the Engineer.

22.5.9.3. PROTECTION OF FINISHED SURFACES

Finished surfaces shall be thoroughly cleaned of foreign matter. Finished surfaces of large parts and other surfaces shall be protected with wooden pads or other suitable means. Unassembled pins or bolts shall be oiled or greased and wrapped with moisture-resistant paper or protected by other approved means (like Tectyl 506 H, etc.).

22.5.10. FASTENERS

Bolts, Studs, Nuts and Screws : They shall have standard threads and be of high quality steel. All standard size bolts, studs, nuts and screws (including their washers) shall be heavily protected against corrosion or made of stainless steel if so specified in the technical Specifications. Nuts and bolts heads shall be hexagonal in shape & truly faced. Nuts & bolts and screws which might become loose during operation shall be locked in fastened position by means approved by the Engineer.

All bolts shall have unified threads. Bolts in tension shall have a net section at root of thread, 15 percent in excess of the net section required in tension.

Field Jointing: All fasteners for field joint shall be supplied 5 per cent in excess of actual requirements. This should be indicated in the drawings/bill of material.

22.5.11. WELDING

Members to be joined by welding shall be cut accurately to size, and where required, shall be rolled or pressed to proper curvature in accordance with the approved drawings. The dimensions and shape of edges to be joined shall be such as to allow thorough fusion and complete penetration and plates shall be planed if necessary, to accomplish this result. Members to be welded together shall be in sufficient intimate contact at the time of welding so that members will not be forced more closely together with the cooling of the weld, thus setting up additional strains and distortions in the weld and parent metal.

The cut surface shall be free from all visible defects such as lamination, surface defects caused due to shearing or cutting or flame cutting operations. The surfaces of plates to be welded shall be free from dust, grease and scale for a distance of 12mm from the welding edge at the time of welding. Flame cutting may be used in the preparation of the various members provided the operation is performed carefully and the edge so cut are cleaned thoroughly after being cut so as to expose clean metal. Any contour irregularities at points of critical stress shall be removed by grinding.

Procedures for welding and Non Destructive Tests (NDT) must be submitted before the start of the work. Copies of the following should be submitted:

- Procedure Qualification Record (PQR)
- Welding Procedure Specification (WPS)
- Welder Performance Qualification (WPQ)
- Welding sequences, repair procedures and welding rod control procedures.

Welding procedures shall be qualified in accordance with ASME/AWS or equivalent IS.

PQR and WPQ shall be witnessed by the Client. All welding shall be carried out using a suitable welding sequence/procedures approved by the Engineer and in such a way that harmful effects of welding are avoided.

When the welding process has been approved by the Engineer, the contractor shall produce a record drawing to show the approved process. The drawing shall include details such as the form of edges to be welded, electrodes and other welding materials, welding sequence etc. Changes in the welding process after the welding method has been approved shall require the consent of the Engineer.

Additional copies of all records of all welding procedures, including preheating and stress relieving, chemical analysis and physical properties, shall be made available to the Engineer upon request.

Unless otherwise allowed by the Engineer all welded parts to be welded shall be manufactured of steel produced by open hearth or electric furnace with carbon content not more than 0.20 % and a Phosphorous content not more than 0.05%.

A welding process approved by the Engineer generally in accordance with the standards specified in the Technical Specification shall be followed. Approval of the welding procedure shall not relieve the Contractor of his responsibility for correct welding and correct selection of electrodes and minimising of defects in the finished structure.

All welding shall be done by the electric arc method or by a process, which will exclude the atmosphere from the molten metal, except where otherwise specifically permitted. The welding electrodes shall be heavily coated type designed for all position welding. In assembling and during welding, the component parts of built up members shall be held in place by sufficient number of clamps or other adequate means to keep all parts in proper position.

The Contractor shall follow the steel manufacturers instructions/ recommendations concerning electrodes and other materials and post & preheat treatment. Notwithstanding the above, the suitability of electrodes to be used for welding for both shop and field welding shall be demonstrated by trials to the satisfaction of the Engineer.

The strength of welding of all equipment subject to high and/ or alternating stresses, vibrations etc. shall be at least equal to the strength of the parts being welded. Between plates and other sections where such stresses are to be transmitted only butt welds shall be permitted. At welded butt joints, where the weld material is required to be deposited on both sides of the joints, the weld shall be chipped thoroughly to obtain a clean surface prior to the application on the first head of the welding on the opposite side of the joint. Where fillet welds are used, the lapped sections shall fit closely and shall be held together during the welding operation. Surfaces to be welded shall be cleaned of loose scale, slag, rust, paint and other foreign matter, except that a thin coat of linseed oil need not be removed before welding. When weld metal is deposited in two or more layers, each layer shall be brushed with a wire brush or otherwise cleaned before subsequent layer is deposited. In welding precautions shall be taken to minimise stresses due to expansion or contraction by peening the welds while hot, or by other satisfactory methods. Correction of distortion by blows, after welding is completed and the place is cold, will not be permitted. Upon

completion, the welds shall be brushed with wire brushes and shall show uniform section, smoothness of weld metal, feather edges without excessive overlaps and freedom from porosity and clinkers. Visual inspection at edges and ends of fillets and butt joints welds shall indicate good fusion and penetration into base metals.

The specification regarding welding including the technique of welding employed, the appearance and quality of welds made, and the methods used in testing of the welds, and in correcting defective work shall conform to relevant Indian Standard or other standards specified.

All shop and field welding performed on the work shall be subject to inspection by Engineer when welding plates, of which one or both exceed 25mm in thickness. Continuous areas of plates around the welding operation shall be preheated to not less than 70°C and kept at a substantially uniform temperature throughout the process. The temperature shall be measured by Tempil sticks or other approved means. Low hydrogen electrodes shall be used everywhere. Peening of multiple pass welds to control distortion or to minimise residual stresses may be carried out with light blows from a power hammer using an elongated round nosed tool. Peening shall be done after the weld has cooled to a temperature warm to the hand. Care shall be exercised to prevent scaling, flaking or rupturing of weld and base metal from over peening. Neither the first nor the last pass of a multiple pass weld shall be peened.

All welds on stress-carrying members shall be done in Manufacturer's shop unless otherwise agreed by Engineer. In general, only non-load- carrying seal welds will be permitted in the field. All field welding shall have prior agreement of Engineer. Tack welds shall be permitted only as a temporary welds required for assembly purposes. The welding sequence shall be planned to control and minimise distortion and, where necessary, shall include stress relief to minimise residual stresses. Minimum stress-relieving requirements are specified in the appropriate sections of these specifications.

Welded components subject to vibration and stress reversals shall be fabricated with full-penetration welds.

For welding of principal stress carrying parts the standards of welding procedures, qualification of welders and welding accessories shall conform to relevant Indian Standards or equivalent to the requirements of the ASME Boiler and pressure vessel codes section VIII and IX, or DIN EN 287. All welders assigned to the work shall have passed a performance qualification test. If more than one year has elapsed since the welder passed his last test, then he shall be tested and qualified again.

Not withstand the above weld procedure for steel liner must conform to section IX of the ASME code or relevant clauses of IS:2825.

22.5.11.1. STRESS RELIEVING / POST WELD HEAT TREATMENT

All steel liners must be given a post weld heat treatment at temperatures not less than those specified in the ASME code, section VIII, division 1 (Table UCS-56, UCS-56.1, UHA-32, and UHT-56) when the nominal thickness of any welded joint in the penstock section or parts exceeds the limit in those tables or as per Table 6.3 of IS 2825.

All forgings shall be normalized and all castings shall be annealed

22.5.12. CORROSION PROTECTION

22.5.12.1. SURFACE TREATMENT AND PROTECTION

The manufacturer shall provide as part of his work/supply the surface treatment, priming, corrosion protection and painting of the equipment furnished. Such work shall include the coating and painting work at the workshop and at the site unto and including the finish painting. Unless otherwise specified the coating and painting shall be carried out in accordance with the latest Indian Standards or International standards.

All priming and painting material shall satisfactorily fulfil the requirements imposed by the site conditions, as well as the stresses to which the respective equipment is subjected during operation of the works. Shades of the finishing coatings shall be as approved by the Engineer.

Each coat of primer and paint shall be compatible with the previous and subsequent coats. All pigmented primers and paints which will be used for priming and painting at the site shall be delivered in original and sealed containers packed by the manufacturer bearing brand name, colour designation, storage and handling instructions.

The manufacturer shall supply full details regarding the extent to which sand-blasting, priming and paintings will be carried out in his workshops (or his contractors, as the case may be) at the site and after erection. A properly equipped paint shop shall be set up at the site using a specialist organisation, experienced and skilled in the preparation and application or protective coatings at the conditions prevailing at the site.

Each coat shall be free from runs, drops, pinholes, waves, laps, sags and unnecessary brush marks and shall be allowed to dry or to harden before the succeeding coat is applied.

Machinery paint may be thinned, if necessary to permit satisfactory application, but the amount of thinner shall be kept to a minimum.

For removing rust and mill scale from structural steel, plate sheets, piping and other steel surfaces, as well as from other parts blast cleaning shall be carried out to clean bare metal. The average surface roughness after sand blasting shall not exceed 40 microns. Parts which cannot be blast- cleaned shall be cleaned free from rust and scale by power tool cleaning to the highest possible degree.

Coal tar painted surface which is directly exposed to Ultra violet rays should be painted with aliphatic polyurethane having DFT of 75 microns in addition to total DFT mentioned as below:

All ferrous surfaces including non-mating finished surfaces exposed to atmosphere or water shall be given a coat of rust inhibitive phosphate wash by brush immediately following the cleaning operation. Proper reaction of the phosphate wash is indicated by a light grey film after drying. A dark sticky residue results if the reaction is not complete. This should be wiped off with dampened rags and area retreated. If the surface is very hot, it may be necessary to dilute the phosphate wash solution with water to obtain proper reaction. Within one hour after the rust inhibitive wash has dried thoroughly, one coat of priming paint shall be applied by brushing, without thinning.

Stainless steel and bronze surfaces shall only be cleaned but not painted. All surfaces of the embedded parts which are to come in contact with concrete shall be cleaned as mentioned above and given two coats of cement latex to prevent rusting during shipment and while awaiting installation. All finished surfaces of the gates and stoplogs that will be exposed to atmosphere during shipment or while awaiting installation shall be given a coat of gasoline soluble rust preventive compound. For preservation of hydraulic cylinders during shipment and while awaiting installation these shall be filled minimum 10%-15% with hydraulic oil suited to temperature range for the particular Project, and 2% VSI or equivalent corrosion inhibitor shall be added prior to dispatch to site . Exposed piston shall be protected by Tectyl 506 (or equivalent) and locked properly to avoid dislocation.

22.5.12.2. PAINTING SYSTEMS

GATES AND EMBEDDED PARTS

Perfect cleaning of all surfaces, which are not to be covered with concrete, shall be carried out by sand blasting to the requirements of Sa 2.5 of Swedish Standard (same IS 3073). Over the prepared surfaces one coat of inorganic zinc rich primer / 2 coat of Zinc rich primer by spray (preferably airless spray) should be applied giving a dry film thickness of 70 ± 5 microns.

The interval between surface preparation and painting shall be as short as practicable and in no case longer than 4 hours. Over the primer, two coats of solventless coaltar epoxy paint shall be provided at an interval of about 24 hours. Each coat shall give a dry film thickness of 150 microns. The total dry film thickness of all the coats shall not be less than 350 microns.

HOISTS

a. Structural components: Cleaning of all the surfaces shall be done by sand blasting to sa 2.1/2. In such areas where it is not possible the parts shall be cleaned by brushing and scraping.
   The parts after surface preparation shall be given two coat of inorganic zinc silicate / Zinc phosphate primer paint conforming to IS: 102 in the shop before dispatch. One further coat of primer shall be applied after erection. The primer coats shall give a minimum dry film thickness of 40 microns per coat. The finish paint shall consist of two coats of alkyd based micaceous iron oxide/ synthetic enamel of thickness 50 micron per coat or one coat of alkyd based micaceous iron oxide paint of thickness 65 microns followed by two coats of synthetic enamel paint of thickness 25 micron per coat. The interval between coats of micaceous iron oxide paint or synthetic enamel paint shall be 24 hours. The total dry film thickness should not be less than 175 microns.
b. Machinery: All surfaces of machinery (except machined surfaces) including motor, gearing, housing, shafting bearing pedestals shall be given one coat of Zinc Phosphate, of thickness 50 micron. The finish paint should consist of three coat of aluminium paint/ synthetic enamel of thickness 25 micron per coat. Total DFT of paint should not be less than 125 microns. Unfinished interior surfaces of oil reservoir and gearboxes and unfinished surfaces of gears which will run in oil need not be painted.

MACHINED SURFACES

Machined surfaces shall be protected with adhesive tapes/or other suitable means during the cleaning and painting operations. All machined surfaces of ferrous metal including screw threads, which will be exposed during shipment or while awaiting installation, shall be cleaned with solvent and coated with a gasoline soluble rust preventive compound.

22.5.12.3. COLOUR SCHEME

S.No.	Item	Colour/Scheme

1.	Gate, E.Parts, and other components immersed in water.	Black or Orange Orange coating shall be used only for hydraulic components (e.g., servomotors). Embedded/submerged parts shall have black tar epoxy or bituminous coating. To be clearly indicated in drawings/specifications.
2.	Super structure including columns, trestles, hoist platform, staircase etc.	Grey
3.	Hoist Machinery	Red
4.	Handrails	Black & white alternate

22.5.12.4. REPAIR OF PRIMER AND FINISH COATS

For touching up, the same paint shall be used as for the original painting work. Repaired finish coats shall be of identical appearance with the original and no difference in the colour shall occur. The Engineer may require severely damaged coatings to be removed and repainted.

22.5.12.5. QUALITY CONTROL

The minimum dry film thickness prescribed in these Specifications shall be observed. Of each 100 m sq. one area of 10m sq. will be measured for dry film thickness. No measured thickness shall be less than the specified thickness. Where the minimum thickness is not achieved, the coat shall be reapplied to reach the specified minimum dry film thickness.

The dry film thickness shall be measured by approved gauges, and the cost of two new electronic gauges shall be included in the Tender for the use of Engineer.

For checks on porosity, the Contractor shall furnish a D.C. variable high tension test instrument with built-in pore counter. The test voltage shall not exceed 2000 V. The tests shall not be performed within 0.5 m distance from uncovered, corrosion resistance surfaces.

Upon completion of each coat, the painter shall make a detailed inspection of the painting finish and shall remove from all adjoining works all splattering of paint material. He shall make good all damage that can be caused by such cleaning operations.

A detailed inspection of all painting work shall likewise be made, and all abraded, stained, or otherwise disfigured portions shall be touched up satisfactorily or refinished as required to produce a first-class job throughout and to leave the entire work clean and acceptable condition.

The adhesiveness of the paint shall be verified by cross cut testing in accordance with ISO 2409.

22.5.12.6. GALVANIZING

Parts to be galvanised shall be properly prepared and galavanised by hot dip galvanizing process in accordance with ASTM Specification A 123. All cutting, drilling and welding shall be done prior to galvanising.

22.5.13. METAL WORK

22.5.13.1. EMBEDDED METAL WORK

Unless otherwise specified, any foundations, wall and roof openings and coverings, concrete floor filling, sleeves in foundations and walls and trenches with floor plates for cables will be provided by the Contractor.

The Contractor shall supply all anchors, fasteners, embedded metalwork, piping, and sleeves associated with and required for the equipment to be installed under this Contract, except if otherwise mentioned in the Specifications.

As far as practicable, the supports shall be of consistent design throughout and preferably of an approved proprietary type.

Attachments to concrete shall wherever practicable be by means of embedded inserts of an approved proprietary type.

The Contractor shall be responsible for determining all loads and forces exerted by his equipment and transmitted to the foundations.

The Contractor shall indicate on his drawings the location and full details of all embedded components supplied under his scope of work, and shall be responsible for the completeness and accuracy of such drawings and of all information provided for coordination with the civil works.

Anchorages and embedded parts to be cast into primary concrete shall be installed as part of the civil works, based on the Contractor's drawings. The Contractor shall remain responsible for the adequacy and accuracy of the location of all embedded components supplied by him, regardless of whether they are installed by the civil works team or by the Contractor.

All adjustments to foundation levels, embedment, bedding and grouting of Works on foundations, as well as cementing into walls and floors, shall be performed within the civil works scope. However, all levelling and final adjustment of the Contractor's Works on foundations shall be executed by the Contractor.

Grouting operations shall be performed by the civil works team under the direction and supervision of the Contractor. The grout mix and grouting pressure shall be subject to the Contractor's approval. The Contractor shall ensure that all grouting works have been completed to his satisfaction.

Any steelwork to be built into concrete foundations shall not be painted or coated unless otherwise approved or specified.

22.5.13.2. MISCELLANEOUS METAL WORK

Except where otherwise indicated elsewhere in the Particular Technical Specifications, the Contractor shall supply the following:

All platforms, ladders, guards and handrails necessary for easy and safe access to Works are supplied under the Contract. Handrails shall be of tubular steel construction.

The use of ladders shall be kept to a practicable minimum. Where ladders are approved for use they shall be of steel, have an inclination of 70o to the horizontal and a minimum width of 450 mm.

Safety guards at each point where normal access provision would permit personnel to come within reach of any moving equipment to be provided under the Contract.

All covers for pipe and cable trenches, required for completing the floors around and over Works supplied under the Contract will be supplied and installed by the Contractor. Unless otherwise approved, floor plates shall be of an angular pattern.
Covers and curbing for dismantling hatches in main floors will be provided by the contractor.

22.6. FABRICATION

22.6.1. GATES

The gates shall be of welded steel construction with dimensions as shown in drawings. All parts of the gates shall be fabricated in strict accordance with the Standards as per specification. Special care shall be taken in fabrication of parts affecting the strength, rigidity or water tightness of the gates. Caulking of rolled edge plates will not be permitted. All pockets or depressions shall be provided with drain holes to prevent collection of water.
The structural members of gates shall be securely connected by welding or by fit bolts. Highly important joints and connections which will be heavily stressed under load shall be made without flaw. These joints shall include the connection between horizontal girders and end girder box, splicing joints in gates. For welding of such connection only, the approved qualified welders shall be assigned. The splicing arrangement shall be designed to allow flexibility in the gate assembly to facilitate installation. The lengths of the members shall be so selected to keep splice joints to a minimum subject to transportation limitations. All splices shall be designed with watertight sealing arrangement. The welding procedure for the gates body shall be planned to control and minimize distortion. All welded connections shall be fully welded.
Care shall be taken that the side seals of gate bear evenly and with uniform pressure throughout their length on the side seal seats embedded in the faces of the piers and that the bottom seals bear evenly on the bottom seal seat (sill) embedded in crest. The roller axle supports and lifting connection shall be accurately line bored so that the axis of all such holes be perpendicular to the vertical centre line of the gate and shall lie in a common plane which shall be parallel to the finished surface for the seal bases. The wheel pins shall be finished to required surface finish. The sealing faces for the vertical seals, bearing bars and lintel seal shall be finished to required surface finish. The bolt holes for guide rollers shall be accurately bored only after the gate has been completely field assembled and position of guide rollers.

22.6.2. EMBEDDED PARTS

All structures, parts of the gate frames anchorages shall be straight and free from twist. The bottom sill beam, seal seats etc., shall be fabricated as steel plates, structural sections and shall be provided with suitable anchorage for rigid connection to the crest and the piers.
Both faces of the track base flanges carrying the track shall be truly perpendicular to the web. The flange face shall be finished to provide a truly plane surface for the track. The faces of the seal seats shall be finished so as to lie in one place within permitted tolerances. The crowns of the track shall lie in a true vertical plane. The splice length for embedded parts such as seal seats, track paths, guides etc. shall not be less than 6.0m.

All structures, parts of the gate frames shall be straight and free from twist. The bottom sill beam, wall plates liners etc. shall be fabricated of steel plates, structural sections and shall be provided with suitable anchorages for rigid connection to the piers.

22.6.3. INSTALLATION

22.6.3.1. INSTALLATION OF GATES

The gates complete with the seal arrangement and guides shall be properly assembled and installed as per the drawings approved by the owner. All these assemblies and installations have to be done in the most workmen like manner, to the specifications and tolerances etc. indicated in the drawings. After installation, it shall be checked that all the parts are smooth with no wavy surface. Each gate leaf transported in sub-assemblies and seal sub-assemblies shall be assembled and erected in strict compliance with the details shown on the final approved shop drawing and with manufacturer's instructions, special precautions have to be taken to ensure joints are made water tight where required. The side, top and bottom shall be in true alignments so that rubber seals when installed shall have tight and even bearing on the sealing surface of embedded frame.

22.6.3.2. INSTALLATION OF FRAME, GUIDE AND TRACKS

Each set of frames, guides, tracks and seal seat arrangements shall be assembled within the respective blockouts, brought to line, grade and plumb within the erection tolerances, and secured in place by the required anchorages as shown on the drawings or as otherwise required by good modern practice to ensure proper performance of the units. The erection tolerances for frames and guides shall be as indicated on the drawings. Extreme care shall be exercised to ensure that all working surfaces lie in a true plane, within the specified tolerances, throughout their full length; otherwise, serious damage to the gate during operation may occur.

Assembly shall be carried out by bolting and welding, and all connections to embedded anchorages shall be adjusted and firmly tightened to maintain the correct position of frames and guides during placement of concrete in the blockouts.

First-stage inserts shall be embedded in the primary concrete as part of the civil works, unless otherwise specified. Erection supports shall be adequately braced so that activities such as chipping or dressing of the first-stage concrete, straightening of bent dowels, or second-stage concreting do not adversely affect alignment.

After the erection and installation of the second-stage embedded parts, there will be a period during which these parts remain unconcreted and may be susceptible to displacement or misalignment due to ongoing work in the vicinity. It shall be the responsibility of the Contractor (manufacturer) to ensure that the alignment of these embedded parts remains correct and that they are not displaced or disturbed by any surrounding activities. To ensure this, the Contractor may provide additional bracing or temporary steel supports as necessary. The cost of all labour, materials, tools and equipment required for this purpose shall be deemed included in the item rates for second-stage embedded parts in the Price Schedule.

22.6.3.3. PLACING CONCRETE IN BLOCKOUT

The concrete will be placed in the blocks by the contractor, who will provide a detailed schedule for fixing and aligning the parts incorporated for this purpose. Before placing the concrete in any one lift and between placements of successive lifts, alignment tolerances shall be checked and remedial action taken if any displacement has occurred. The block out concrete will conform to the grade M-40 unless otherwise specified on drawings.

22.6.3.4. HOISTS

Hoist bridge and hoist sub-assemblies shall be assembled and erected in strict compliance with the details shown in the final approved shop drawing and with manufacturer's instructions. Special precautions shall be taken to ensure perfect alignment between mating components and for placements of the hoist drums so as to match with the centre to centre of lifting lugs of the gates.

For hoist the contractor shall prepare a complete erection procedure which shall describe the sequence of operations to be carried out, the methods to be used, the measurements to be taken and the tolerances to be met, in the erection and alignment of the equipment.

22.6.4. SEALS

Rubber seals shall be of the moulded type only. The materials used for rubber seals shall be compound of natural rubber, a copolymer of butadiene and styrene, a blend of both or EPDM, and shall contain reinforcing carbon black, zinc oxide, accelerators, anti-oxidants, vulcanising agents and plasticizers. The contractor shall provide all seal with adequate temperature and age resistant properties which will provide, in the moulded form, suitable sealing properties. The shelf life of the seals shall be clearly mentioned on the products or declared with the manufacturer. The seals shall meet the properties as per IS: 11855.

All corners shall be remoulded and have a suitable radius on the inside edge. All joints, shop and field, shall be located at reasonable distance from the corners and shall meet the following requirements:

a. All shop joints shall be vulcanised. Joint geometry shall be such as to avoid feather edges on the sealing surfaces.
b. Field joints shall be kept to a minimum and shall be accurately machine cut and carefully butted during assembly to an interference fit. The field joints shall be held with double fasteners on each side of the joint.
c. Vulcanised joints shall not break on tear when bent 180 degrees around a mandrel of a diameter equal to the maximum cross section thickness of the seal.
d. The longitudinal strength in tension of vulcanised joints shall be not less than 71.4 kg/cm2 as verified by tests on a tensile specimen prepared from one joint in accordance with ASTM D15 Part C. The joint tested shall be located at the midpoint of the test specimen and its strength determined in accordance with ASTM D 412.
e. The joints in the rubber seal shall be vulcanised but joints and at right angle to the rubber seal. Oblique joints at the corner shall not be permitted in the rubber seal. Vertically placed strips of rubber seals shall be formed in one piece and no joints of any sort shall be permitted in them.
f. Sufficient quantity of seal jointing compound shall be supplied along with rubber seals for site requirements.

Joints shall be water tight and seal materials shall have following physical properties as determined by tests made in accordance with the relevant Standards.

Property	**Limits**
Tensile strength	14.5 Mpa minimum
Ultimate elongation	450% minimum
Durometer hardness (Shore, Type A)	60 - 70
Specific gravity	1.1 to 1.3
Water absorption (70^0C for 48 hours)	5%by weight (max.)
Compression set	30% maximum
Tensile strength after oxygen bomb ageing (48 hours at 70^0C)	80% (min.) of tensile strength before ageing

22.6.5. DRIVES AND GEARS

All moving parts of machinery including shafts, couplings, collars, projecting keyheads, gear wheels, rope/belt-drives shall be completely guarded to provide full protection. All set screws on revolving shafts shall be countersunk or suitably protected. The guards shall be of approved design and shall be fitted, where necessary, with inspection gates/openings. All guards shall be arranged so that they can be removed without disturbing the parts of the gears and Works, which they protect.

Gears shall be designed so that all stresses are within allowable limits when the maximum loads are being handled. All gears shall be designed and calculated in accordance with IS Standards or equivalent international standards, or widely approved methods and to the individual experience of the manufacturer. On request of the Engineer, the manufacturer shall submit the calculation of the gears.

Where worm gears are used as a direct drive, they shall have the same load and time rating as the motors driving them. The gears shall work in oil and the temperature rise of the oil bath shall not exceed 400C – 500C under normal working conditions at Site. The materials of the mating faces of worm wheel and worm shall be of a bronze/steel alloy.

Where practicable gear wheels shall be forced fit on the shaft and in addition, shall be keyed adequately to prevent any relative motion between the wheel and shaft. Where gears and couplings are secured in position by means of keys, they shall be easily accessible for tightening or removal. All keyways shall be machine cut. Couplings and collars shall be the shrouded or protected-type, free from projections of any kind.

All bearings shall be mounted in dustproof housings. Base of bearing supports shall be machined, and shall rest on machined-surfaces.

22.6.6. LUBRICATION, LUBRICANTS AND OILS

Efficient means of lubrication, suitable for use under Site conditions, shall be provided for all moving parts. Self-lubricating types of bearings shall be given preference, unless otherwise specified or practicable.

The contamination of the air, water and soil by lubricants and fuel shall by all means be avoided by applying an appropriate design and layout of the Works in conformity with the latest recognized standards for modern engineering practice.

The number of different lubricants, transformer oils, oils for pressure systems, etc. used in the items of Works throughout the Works shall be limited to a minimum in order to facilitate keeping stocks and maintenance.

Manufacturer shall be approved by the client and their clear specification shall be mentioned.

The Owner reserves the right to request the different Contractors to use certain types of lubricants, oils etc. The Contractor shall not be entitled to claim extra payment for this request. All different types of oils, lubricants, etc., shall be stated in the Tender and are subject to the written approval of the Engineer.

22.6.7. MECHANICAL INSTRUMENTS

All mechanical parts of instruments shall be suitably protected against shocks and vibrations, heat, humidity and splash water etc.

Pressures gauges shall be provided with a damping liquid, e.g., glycerine, to compensate vibrations. Pressure gauges without damping means are not permitted, unless approved by the Engineer.

22.7. ELECTRICAL WORKS

22.7.1. GENERAL

The electrical items of Works of any electrical or mechanical installation to be provided under this Contract according to the Particular Technical Specifications shall - if not stated otherwise therein-fulfil the requirements of this Section.

All components shall be of an approved and reliable design. The highest extent of uniformity and interchangeability shall be reached. The design shall facilitate maintenance and repair of the components.

The Works shall be pre-assembled to the highest possible extent in the Contractor's or Contractor's workshop, complete with all devices and wired up to common terminal blocks.

Unless otherwise agreed, ratings of main electrical Works (infeeds, bus-ties) as selected or proposed by the Contractor, whether originally specified or not, shall generally include a safety margin of 10% under consideration of the worst case to be met in service. Prior to approval of such basic characteristics, the Contractor shall submit all relevant information such as consumer lists, short circuit calculations, de- rating factors etc.

Short-circuit calculations shall be evaluated giving full evidence that every electrical component can withstand the maximum stresses under fault conditions, for fault levels and duration's obtained under the worst conditions, e.g., upon failure of the corresponding main protection device and time delayed fault clearing by the back- up protection device.

All Works shall be suitable for the prevailing climatic conditions.

Outdoor installations shall be protected against solar radiation by means of adequate covers, where required.

The Contractor shall ensure that all the supplied Works is insensitive to any signals emitted by wireless communication equipment.

22.7.2. LOCAL CONTROL PANEL

The local control panel shall be an Indoor/ outdoor type (degree of protection of enclosure type IP-65) made of steel sheet of thickness not less than 2.5mm, containing all necessary equipment for the control, protection/safety and supervisory elements as required and shall be completely painted and wired. The panel frame structure shall be self-supporting, free standing on floor or suitable for wall/vertical post mounting.

Cubicles and panels shall be vermin proof. Removable gland plates shall be supplied and located to provide adequate working clearance for the termination of cables. Under no circumstances shall the floor/ roof plate be used as a gland plate. The cables and wiring shall enter from bottom or top as approved by Engineer.

The cubicles and panels shall be adequately ventilated, if required, by vents or louvers, and shall be so placed as not to detract from the appearance. All ventilating openings shall be provided with corrosion resistant metal screens or a suitable filter to prevent entrance of insects or vermin. Space heating elements with thermostatic control shall be included in each panel.

Cubical/panel will be of sufficient size so as to neatly and methodically accommodate all the electrical power and control equipment. Indicating lamps, push buttons, all the necessary relays, starters, fuses, limit switches, selector switches, terminal blocks, circuit breakers, contactors, current transformers, protection gears, Inter locks, alarms, measuring instruments including all wiring and all other accessories necessary for safety, control and operation of the hoist.

The controls, indicating lamps, push button, selector switches etc. will be installed flush mounted on the out-side door of the control panel so as to give clear view of all the indicating lights, measuring instruments, position indicator so that the gate and hoist can be operated with the cabinet door closed. The remaining equipment will be installed inside the cabinet being accessible when the door is opened.

The panel door shall have close fitting, gasketted, hinged, swing off construction capable of being opened through 180 degree. The doors shall be provided with integral lock and master key. A mechanical interlock shall be provided so as to ensure de-energisation of the panel as soon as the door is opened. Suitable provision may, however, be made to bypass the above interlock under extraordinary requirements when manual energisation of panel is necessary under open condition. Panel shall be provided with door switch operated illumination.

All terminals will be of block type. Wiring inside the control panel is made at least with 650 Volt insulation grade, 1.0 sq. mm, 1.5 Sq.mm. and 2.5 sq.mm. Control cable and required size of power cable. All cables shall be brought at terminal blocks mounted inside the control panels to facilitate connection with the external cables. All the metallic parts of the switch- boards and all the earth wires of the circuits shall be connected with the Earthing bus of not less than 25 sq. mm. copper conductors. All control cables and components will be marked in a systematic manner on drawings on the accordingly tagged cables and components in the control panel. All necessary auxiliary devices for connection to limit switch shall also be provided. The control equipment shall generally meet the requirements of Clause 6.6 of IS: 6938-1989.

All panels cable schedule as built shall be provided to the client in 3 standard copies.

22.7.3. STANDARDS

The design, manufacture and testing of all Works and installations shall strictly comply with the latest edition of the relevant IEC publications.

22.7.4. COLOUR CODE

The manufacturer's painting systems shall be used to the maximum possible extent, but shall by all means be subject to the approval of the Engineer. Final coats of paint shall be matching adjacent installations, where required.

22.7.5. ELECTRIC MOTORS

22.7.5.1. GENERAL

All motors shall be of approved make and shall comply with the requirements of this Chapter. Motors of the same type and size shall be fully interchangeable and shall comply with Indian standard and to IEC standard motor dimensions.

The general construction shall be stiff and rigid, no light metal alloy casings will be accepted. All precautions shall be taken to avoid any type of corrosion.

All motors shall be fitted with approved types of lifting hooks or eye bolts as suitable.

AC motors shall have squirrel cage type rotors.

22.7.5.2. RATING

The rating of motor shall be adequate to meet the requirement of its associated equipment. The service factor, being the ratio of the installed motor output to the required power at the shaft of the driven machine at its expected maximum power demand, shall be applied as follows:

Power Demand of Driven Machine	**Service Factor**
Up to 5 kW	1.2
More than 5 kW	1.1

AC motors shall be capable of operating continuously under rated output conditions at any frequency between 95% and 105% of the rated frequency and/or with any voltage variation between 90% and 110% of the nominal voltage. A transient over voltage of 130% of the nominal voltage shall as well be sustained.

Further, the motors shall be capable of maintaining stable operation when running at 70% nominal voltage for a period of 10 seconds. The pull-out torque for motors shall not be less than 225% of the rated torque.

22.7.5.3. STARTING

A.C. motors shall be designed for direct on-line starting. They shall be capable of being switched on without damage to an infinite busbar at 110% of the nominal voltage with an inherent residual voltage of 100% even in phase opposition. For starting the motors from the individual main and auxiliary busbars, a momentary voltage drop of 20% referred to nominal voltage should be taken into consideration. With 85% of the nominal voltage applied to the motor terminals, each motor shall be capable of accelerating its associated load to full speed with a minimum accelerating torque of 5% of full load torque.

The maximum starting currents (without any tolerance) shall not exceed value 5 times of rated current for motors.

Generally, all motors shall be able to withstand three cold starts per hour, equally spaced. In addition, each motor shall be capable of enduring two successive starts with the motor initially at operating temperature under the same conditions or once every twenty minutes without detrimental heating.
Motors for frequent automatic starting shall have an adequate rating. In the motor list the Contractor shall state the frequency of starts permitted in compliance with the motor design.

22.7.5.4. WINDINGS AND INSULATION CLASS

The insulation of all motors shall be of class F but maintain in operation the temperature limits of class B materials. It shall be suitable for operation in damp locations, for occasional contact with corrosive gases and vapours and for considerable fluctuations in temperature.
The stator winding shall be suitably braced to withstand the forces due to thyristorised controlled/ direct-on-line starting and transfer conditions as mentioned before. The winding envelopment and tails shall be non-hygroscopic. The stator winding shall withstand the maximum fault current for the period determined by the associated protective devices.
The rotor winding (if applicable) shall be designed to give trouble-free continuous service including repeated thyristorised/direct-on-line starting. The rotor shall be subjected to a 120% over speed test for 2 minutes without showing any winding dislocation.

22.7.5.5. VENTILATION AND TYPE OF ENCLOSURE

All motors shall be of the totally enclosed fan-cooled type, protection class IP 54 according to IEC Recommendation 144. Cable terminal boxes shall be of class IP 55.
They shall have a closed internal cooling air circuit recooled by an external cooling air circuit drawn from the opposite side of the driving end.
Where motors are installed outdoors, a weather-proof design shall be chosen. Above shall be equipped with automatically controlled heating elements for protection against internal condensation of moisture during stand-still periods.
Motors installed outdoors and directly subjected to solar radiation shall be rated such as not to exceed a maximum metal temperature of 850C. Where necessary, such motors shall be provided with sun shields.
Vertical motors shall be provided with a top cover to prevent the ingress of dirt etc.

22.7.5.6. BEARINGS

As far as possible, the motors shall have sealed ball or roller bearings lubricated for life. All other motors with ratings of about 1 kW and above shall be equipped with lubricators permitting greasing while the motor is running and preventing over- lubrication. For water expose bearings calcium sulfonate specific grease should be considered. Additionally, the bearings shall be fitted with grease nipples permitting the use of a universal grease gun. Vertical motors shall have approved thrust bearings.
All bearings shall be easily controllable during operation or stand-still without dismantling the bearings. The bearings shall further be protected and sealed against dust penetration and oil leakage.
In case of independent bearings, motor and bearing pedestals shall be fitted on a common base plate.

Suitable packing/special bearing inserts shall be provided to prevent damage during transport of motors equipped with ball or roller bearings.

22.7.5.7. SHAFTS AND COUPLINGS

The motors shall be provided with a free shaft extension of cylindrical shape with key and keyway according to IEC Recommendation 72-1 and with the motorside- coupling, which shall be pressed on the motor shaft and be balanced together with it. A coupling guard shall be provided.
Shaft and coupling arrangement shall be easily accessible for maintenance purpose and 2 key system shall be provided .

22.7.5.8. TERMINAL BOXES AND EARTHING

The terminal leads, terminals, terminal boxes and associated equipment shall be suitable for terminating the respective type of cables as specified in these General Technical Specifications and in the Particular Technical Specifications.
The terminal boxes shall be of ample size to enable connections to be made in a satisfactory manner. Supports shall be provided at terminal boxes as required for proper guidance and fixing of the incoming cable.
The terminal boxes with the cables installed shall be suitable for connection to supply systems with the short-circuit current and the fault clearance time determined by the motor protective devices.
A permanently attached connection diagram shall be mounted inside the terminal box cover. If motors are provided for only one direction of rotation, this shall be clearly indicated.
Terminal boxes shall be totally enclosed and designed to prevent the ingress of moisture and dust. All joints shall be flanged with gaskets of neoprene or similar material. For motors above 1 kW, the terminal box shall be sealed from the internal air circuit of the motor.
Depending on the size, the terminal box of L.V. motors shall be fitted either with an approved cable sealing-end or with a gland plate drilled as required and provided with suitable fittings for cable fixing and sealing. Such openings shall be temporarily plugged or sealed during transportation.
Terminal boxes of M.V. motors shall be fitted with an approved cable sealing end and a pressure relief diaphragm suitably located. For plastic insulated and sheathed cables filling with compound is not required.
The three neutral ends of the windings of M.V. motors shall be brought out to a separate terminal box.
For earthing purposes, each motor shall have adequately sized bolts with washers at the lower part of the frame. In addition, each terminal box shall contain one earthing screw.

22.7.5.9. NOISE-LEVEL AND VIBRATIONS

Under all operating conditions, the noise level of motors shall not exceed 85 dB (A). In order to prevent undue and harmful vibrations, all motors shall be statically and dynamically balanced. Vibration displacements or velocity shall be measured in accordance with DIN 45 665 for IEC motor sizes 80 to 315. The results for all motors shall be within the "R" (reduced) limits.

22.7.5.10. TESTS

Each motor shall be factory tested and shall undergo a test at site. The following tests shall be performed under full responsibility of the Contractor.

Workshop Tests:

- Measurement of winding resistance
- No-load and short-circuit measurements
- Measurement of starting current and torque
- Efficiency measurement (type test)
- Heat test run
- Dielectric test
- Measurement of insulating resistance
- Over speed test Site Tests:
- Measurement of insulation resistance
- Measurement of motor vibrations
- Measurement of starting time

Type test reports as per IEC 60034 shall be submitted. The type test shall be for the same rating of motors and the type test shall not be older than five years. It shall be done from an accredited third-party laboratory.

22.7.6. AUXILIARY WORKS

22.7.6.1. AUXILIARY SWITCHES

Where appropriate, each item of Works shall be equipped with all necessary auxiliary switches, contactors and devices for indication, protection, metering, control, interlocking, supervision and other services. All auxiliary switches shall be wired up to terminal blocks on the fixed portion of the Works.

All auxiliary switches and mechanisms shall be mounted in approved accessible positions clear of the operating mechanism and are to be protected in an approved manner. The contacts of all auxiliary switches shall be strong and shall have a positive wiping action when closing.

22.7.6.2. CONTROL SWITCHES

Control switches for electrically operated circuit breakers shall be of the pistol grip or discrepancy type. They shall operate clockwise when closing the circuit breakers and anti-clockwise when opening them. The control switches shall be so designed as to prevent them from being operated inadvertently, and where switches of the discrepancy type are used they shall require two independent movements to effect operation. Control switches shall be so designed that when released by the operator, they return automatically to the neutral position after having been turned to the "closed" position and shall at the same time interrupt the control voltage supply to the operating mechanism of the circuit breaker.

Switches for other apparatus shall be operated by shrouded push buttons or have handles of the spade type, the pistol grip type shall be used for circuit breaker operation only.

Control, reversing, selector and test switches shall be so mounted, constructed and wired as to facilitate the maintenance of contacts without the necessity for disconnecting wiring.

22.7.6.3. ANTI-CONDENSATION HEATERS

Each individual enclosure accommodating electrical Works which is liable to suffer from internal condensation due to atmospheric or load variations shall be fitted with heating devices suitable for electrical operation at the specified standard A.C. voltage, being of sufficient capacity to raise the internal temperature by about 15□C above the ambient temperature. Heaters in motors and similar devices shall be switched on automatically upon opening of the motor starter, and vice-versa. Heaters in switchgear/MCC cubicles, control cubicles, panels, desks, etc., shall be controlled automatically by adjustable hydrostats (setting range about 50 - 100% relative humidity) The electrical apparatus so protected shall be of such design that the maximum permitted temperature is not exceeded if the heaters are energised while the apparatus is in operation.
Heaters shall be equipped with a suitable terminal box. All Works, whether fitted with a heating device or not, shall be provided with suitable drainage and be free from pockets in which moisture can collect.

22.7.6.4. PROTECTION DEVICES

The main parts of the Works shall be protected and interlocked so as to prevent malfunctions and other fault occurrences, and to maintain safety during all operation phases.
Electric protection relays shall be the standard product of an experienced and reliable protection relay manufacturer. They shall be of the static or mechanic/ magnetic, tropicalized type and be mounted in suitable dust proof and shock- absorbing casings. They shall not be affected by external magnetic fields or any other influence (radio, computer, signals, impulses, etc.) consistent with the place or method of mounting. Electro-magnetic relays shall have a transparent cover with appropriate seals.
The protection relays shall be equipped with all necessary auxiliaries such as tripping unit, time relay, external resetting device (hand reset flag with seal-in operation). The relays shall provide easy access for testing and setting purposes. All control and protective relays must be delivered to the customer, once final adjustment has been completed, accompanied by the appropriate documentation and in the presence of a witness.
Pre-warning alarms shall be initiated as early as possible before the protection system trips, in order to enable the operators to take precautions. Tripping of a protection system as well as the sources of the protective action shall be indicated and recorded as an alarm.
Unless otherwise required for special purposes, protection relays shall remain in the tripped position until the operator resets the relay manually. The protection and auxiliary relays shall be grouped and mounted on plug-in modules or stationary- mounted on swing frame with separate plugs and sockets to feature easy replacement and testing. The construction shall be sturdy and such that all parts are easily accessible for adjustment. Relays installed in switchboards shall be arranged in compartments separated from the switchgear.
Besides the mechanical-operated flag type indicator, all relays shall have sufficient contacts and/or auxiliary relay contacts to perform all the tripping, intertripping, interlocking, indication and alarm functions required. Spare contacts (1 N.O.1 N.C.) shall be provided for later use. The contacts shall be silver-plated or of the seal-in type

with the main contacts adjustable. The relay contact rating shall be for the specified standard voltage and for 200% of the nominal passing current. The relay coil shall be able to operate properly at voltage variations of -25% to +15%.

Relays shall be capable of withstanding at least one million operations without any defect.

Testing of the individual relays shall either be effected by stationary-mounted or portable testing devices.

22.7.7. TERMINAL POINTS

The owner will provide 33/0.415 kV distribution transformer which will be located within 400 m to 500 m from the tunnel portal. The contractor shall arrange all the necessary LT distribution board, TPN and associated CB, capacitor bank, lightening arrestor, treated earth pit, cables for extension/connections from the distribution transformer.

Upon work completion, the contractor should retain the power supply lines for the gate operation uninterrupted.

Limits of the supply

Voltage

a) Steady +5/-10% ±2%

b) Transient +30% ±10%

Limits of the frequency ±2% ±1%

22.7.8. CABLES

22.7.8.1. GENERAL

The Contractor shall provide the relevant design and engineering of the relevant cable systems and, in close co-operation with the Civil Contractor, prepare the cable installation drawings with cable routing, connection diagrams, and cable lists, details, etc.

The power cables and control cables shall be of copper as per Indian Standards or IEC publications and the power cables shall be of minimum size 16 mm2 and control cables shall be of minimum size 1.5 mm2.

All cables and accessories shall be suitable for installation under site conditions (e.g. aggressive soil conditions, etc.).

The Contractor shall select the most suitable cable routes and raceways ensuring a minimum of interference with other installations.

22.7.8.2. COLOUR CODE

Live parts of electrical connections shall be colour coded as follows.

Conductor Designation	**Coding Alphanumeric**	**Symbol**	**Colour**
A.C. network	phase 1	L1	red
	phase 2	L2	yellow
	phase3	L3	blue

	neutral	N	black
Protective earthed	neutral	PE/N	green/yellow
Earth	neutral	E	grey

Mimic diagrams to be arranged on switchgear cubicles, control panels/desks etc. shall be colour coded as bellow:
415 V white

22.7.8.3. ILLUMINATION SYSTEM

The contractor shall supply and install the lighting fixtures including high pressure mercury/sodium vapour lamps etc to provide proper illumination over and under all the hoist equipment to enable the operator and O&M crew to work on the equipment being supplied at any time during 24 hrs.

Interior lighting will be implemented using LED luminaires. Fixture selection will be tailored to the visual requirements of each area to ensure optimal illuminance. Specifications mandate a Color Rendering Index (CRI) of no less than 80 and a Correlated Color Temperature (CCT) not exceeding 4000K. Lighting intensity levels for normal and emergency operations are described in the subsequent sections.

For normal operation, the lighting intensities that will be required for various areas are shown in Table below.

Area / Application Task	**Illuminance (Lux)**	**Reference**
Operating floor (turbines, electrical floors, etc.)	**323 lx**	ANSI/RP-7-21
Control room	**538 lx**	Project requirement
Battery room	**323 (215) lx**	Project requirement
Circulation corridors	**54 lx**	ANSI/IES RP-10-20+E2
Janitor closet	**108 lx**	ANSI/IES RP-10-20+E2
Stairways	**215 lx**	ANSI/IES RP-10-20+E2
Toilets and locker rooms	**215 lx**	ANSI/IES RP-10-20+E2

Emergency lighting shall be provided for all egress routes, integrated with the DC and UPS systems. The system will meet or exceed NFPA 101 requirements, ensuring a minimum operation time of 90 minutes, with a project-specific target of two hours to maintain consistency with the UPS battery life. Emergency lighting intensities are summarized in the table below.

Illuminance (Lux)	Uniformity Ratio	Reference
11 lx	max/min 40:1	NFPA 101 / OSHA / Project requirement
108 lx	-	Project requirement

22.7.8.4. EARTHING SYSTEM

All electrical system shall be properly earthed as per the latest ruling practice for the safety of the equipment, operating staff as well as the system. All protection devices for the control equipments including grounding system/ pit wherever required shall be provided by the Contractor.

22.7.9. LABELS AND PLATES

22.7.9.1. GENERAL

Labels and data plates shall be provided in accordance with applicable standards and as detailed hereunder.
The proposed material of the labels, size, exact label lettering and proposals for the arrangement of the labels shall be submitted to the Engineer for approval.
Where applicable, designations in the selected local language shall appear above or to the right of the designation in the Contract language. The translations and writings in the local language shall be submitted for approval.

22.7.9.2. EQUIPMENT LABELS AND INSTRUCTION PLATES

Labels written in the Contract language shall be provided for all instruments, relays, control switches, push-buttons, indication lights, breakers, etc. In case of instruments, instrument switches and control switches, where the function is indicated on the device, no label is required. The label shall be fixed close to the devices in such a way that easy identification is possible. Fixing on the dial glass of instruments will not be accepted. The wording shall conform to the wording used in engineering documents.
Each separate construction unit (cubicle, panel, desk, box etc.) shall be identified by its Works identification number. Cubicles and similar units shall also bear this
identification number on the rear side if rear access is possible. The overall designation of each unit shall be given in the Contract language and - if required - also in a selected local language. These labels shall be made of anodised aluminium with black engraved inscriptions, arranged at the top section of the units. Manufacturer's trade labels shall - if desired - appear in the bottom section of the units.
All Works inside cubicles, panels, boxes, etc., shall be properly labelled with their item number. This number shall be the same as indicated in the pertaining documents (wiring diagrams, Works list etc.).
Instruction plates sequence diagrams or instructions for maintenance shall be fitted on the inside of the front door of the electrical switchboards. These shall be in the contract language and if required in the selected local language.

22.7.9.3. WARNING LABELS

Warning labels shall be made of synthetic resin with letters engraved in the Contract language and in particular cases, where required, in the selected local language.

For indoor circuit-breakers, starters etc. transparent plastic material with suitably contrasting colours and engraved lettering would be acceptable.

22.7.9.4. LABELS FOR CONDUITS ETC.

The material shall be non-corrosive and the description be done with 4 mm high letters/figures.

22.7.9.5. LABELS FOR CABLES

Each cable when completely installed shall have permanently attached to each end and at intermediate positions as may be considered necessary by the Engineer, non- corrosive labels detailing identification number of the cable, voltage, and conductor size.
The cable identification numbers shall comply with those of the cable list.
All cables in cable pits and at the entry to buildings shall be labelled utilising the aforementioned type of label.

22.7.9.6. RATING PLATES

Works (hoists, machines etc.) rating plates and other technical data/informative plates shall either be of the enamelled type or be of stainless steel suitably protected after engraving with a transparent paint resistant to aggressive atmosphere and solar radiation.

22.7.10. KEY SYSTEM FOR ELECTRIC BOARDS

The locks or padlocks shall be coordinated for the different applications and shall be supplied with three keys. A key cabinet at the end of each board (distribution board, MCC, control cubicles etc.) shall be provided for storing the keys of that board. For all locks supplied there shall be six master keys to open any lock or padlock supplied. Each key shall have one identification label fixed above the key hanging hook inside the cabinet.
The cabinet door keys shall be similar and shall be six (6) in number.

22.8. TRANSPORT AND STORAGE

22.8.1. GENERAL

Shipping, transportation, loading and storage shall be performed by or under the responsible direction of the Contractor. An appropriate period for transportation shall be considered.
The general co-ordination of storage and erection work as well as the civil engineering work on site will be done by the Engineer.
The delivery dates, transportation and erection periods indicated in the Contract Documents shall be strictly adhered to.
From the time of manufacturing until commissioning all parts shall be protected against damage of any kind. Parts, which are damaged during transport, shall be replaced at the Contractor's expense.
The Contractor shall provide the Engineer with complete packing lists of each performed shipment.
The Contractor shall have arrangements trailer and suitable cranes for multiple movement of material if in urgency required at the site.

The Contractor shall submit the storage and handling control plan of the equipment as per class of protection required.

22.8.2. PACKING

After the workshop assembly and shop inspection and tests including witness inspection by the Engineer or his authorised representative wherever specified and prior to dismantling for shipment to the Site, all items shall be carefully marked to facilitate site erection. Wherever applicable, these markings shall be punched or painted so they are clearly visible.

Dismantling shall be done into convenient sections, so that the weights and sizes are suitable for transport to Site and for handling on the Site under the special conditions of the Project.

All individual pieces shall be marked with the correct designation shown on the Contractor's detailed drawings and other documents (packing lists, spare part lists, in Operating and Maintenance Instructions etc.).

Marking shall be done preferably by punching the marks into the metal before painting, galvanising etc., and shall be clearly legible after painting, galvanising etc. In labelling, the Contractor shall endeavour to use as few designations as possible, and each part of identical size and detail shall have the same designation, regardless of its final position in the plant.

All parts of the Works shall be packed at the place of manufacture the packing shall be suitable for transportation to Site. Where necessary, double packing shall be used in order to prevent damage and corrosion during transportation, unloading, reloading or during intermediate storage.

All parts including electrical parts shall be suitably protected against corrosion, water, sand, heat, atmospheric conditions, shocks, impact, vibrations etc. by packing them into high pressure polyethylene foil.

The Engineer reserves the right to inspect and approve the packing before the items are despatched but the Contractor shall be entirely responsible for ensuring that the packing is suitable for transit and such inspection will not exonerate the Contractor from any loss or damage due to faulty packing.

All packing costs shall be included in the scope of Work.

22.8.3. MARKING

The Contractor shall mark all containers with the implementing document number pertinent to the transport. Each container shall also be clearly marked on at least two sides.

22.8.4. STORAGE

The Contractor shall inform himself fully as to all relevant transport facilities and requirements, loading gauges and other limitations and shall ensure that the equipment as prepared for transport shall conform to such limitations.

The Contractor shall also be responsible for obtaining from the railway or highway authorities any permit that may be required for the transport of loads exceeding the normal gauges.

The contractor shall be responsible for all Custom clearance of the consignments from the Indian port if by sea and or from airport if shipped as air cargo, local storage and further transportation to site.

The Contractor shall provide means for all unloading and reloading for all consignments of the plant, during transport to Site. Unloading on the Site will be provided for by the Contractor. Consignments shall be unloaded immediately on arrival at Site. The Contractor is required to take the necessary steps in order to provide the carriage, special supporting structures for heavy loads etc.

The contractor shall develop necessary storage facility for proper and safe storage of all the materials. The warehouses shall be waterproof, well ventilated and of designated floor etc.

If large parts are stored in the open air, they shall be provided with weather resistant and fire-resistant covers. Electrical parts which are not packed in heavy duty polyethylene foil and those so packed but whose packing has been damaged shall be kept in suitable places from the moment of storage to the moment of installation.

All insulation materials which will be taken from the warehouse for installation and which are stored temporarily in the station shall be protected from weather or humidity.

22.9. INSPECTIONS AND TESTS

22.9.1. GENERAL

In addition to the provisions established in the Conditions of Contract regarding general procedure of inspections and tests, terms and definitions, and time schedules for inspections and tests the following stipulations shall apply.

Approval of assemblies, tests, inspections, related procedures etc. and acceptance of pertinent test and inspection certificates, or waiving of inspections or tests, shall in no way relieve the Contractor of his contractual obligations for finishing the Works in accordance with the provisions of the Specifications.

Three (3) sets of all test records, test certificates, performance curves, tables etc. of all inspections and tests, whether or not attended by the Engineer shall be supplied soonest after performance of each inspection or test. After completion of all testing two (2) sets of the above mentioned documents shall be supplied properly bound in books.

All test certificates shall be endorsed with sufficient information for identification of the equipment and material to which the certificates refer.

In addition, the following references shall be entered in the top right-hand corner:

- Contractor's name
- Project title
- Plant's (stage's) name
- Contractor's drawing No.
- Date

Inspection and testing of equipment shall include all inspections, tests, checks etc., whether mechanical, hydraulic or electrical, as required to ensure that the equipment supplied meets the requirements of the Specifications. They shall comprise, but not be limited to the following:

- Chemical analysis of materials
- Destructive and non-destructive tests of materials
- Checks and examination of welds
- Checks of fits and assemblies
- Dimensional checks
- Balancing tests
- Inspection of paints and coatings (thickness and porosity)
- Hydrostatic pressure and tightness tests
- Electrical tests
- Running tests (incl. Measurement of sound level)
- Functional tests
- Performance tests
- Load and overload tests
- Type tests
- Acceptance Test

The technique, equipment and instrumentation to be used for these tests, checks, inspections, examinations, etc. shall be in accordance with the pertinent and internationally accepted Standards, rules or Codes, in particular these mentioned in the specifications.
If in the Employer's Representative opinion instruments apparatus, devices, etc, used by the Contractor (or his Subcontractor) need calibration or recalibration, then such instruments, apparatus, devices etc. shall be calibrated at the contractor's cost by an independent authority or institute subject to approval by the Employer's Representative.

All inspections and tests shall be carried out in accordance with the approved Quality Assurance Plan. The Contractor shall prepare separate Quality Assurance Plans for the different activities, including manufacturing and site works. Accordingly, separate Inspection and Test Plans (ITPs) shall be prepared for manufacturing works and site execution works.
Each ITP shall be submitted to the Engineer for review and approval before the relevant activities start.

The contractor shall be responsible to carry out and keep record of all inspection/tests during manufacture through his quality assurance group. This shall be supplemented by third party inspection by reputed Firms well versed in carrying out inspection activity in accordance with the approved Quality Assurance Plans namely Lloyds, Bureau Veritas, TUV, SWECO, DNV, SGS, Intertek, RINA, etc for all components under fabrication at manufacturer's/sub

contractor's works. In addition Owner's inspection representatives shall get associated for specific inspections as specified in the approved quality assurance plan.

The cost of third party inspection shall be deemed to be included in the respective costs of the items of supply in schedule of prices (No separate cost to be quoted).

In case these parties do not operate in the region of the manufacturer, he may propose suitable alternative Inspection agencies of international repute furnishing their detailed particulars, previous references etc. The owner reserves the right to reject any or all of such proposed agencies. Manufacturer shall arrange the third party inspection through one of the above named agencies or the alternative approved agency, without any financial implication for the owner.

The Contractor shall also be responsible for Implementation of quality assurance standards as per approved plans and procedures.

22.9.2. WORKSHOP INSPECTIONS AND TESTS

As far as practicable, quality of materials, workmanship and performance of all items of the Works to be furnished under this Contract shall be inspected at the places of manufacture.

When placing orders for major material and equipment with sub suppliers, the Contractor shall send unpriced copies of such orders in triplicate to the Engineer.

Where the Contractor desires to use stock material, not manufactured specifically for the Works, satisfactory evidence that such material conforms to the requirements of the Contract shall be submitted. Tests on these materials can be waived.

Arrangements shall be made for expediting the shop inspection by having all shop assemblies or pieces covering a single shipment ready at one time. Any painting work as well as transport to the site of the Works shall not be started before the approval of the Engineer has been obtained.

Free and unrestricted access to the Contractor's factory and shops (including those of his Subcontractors) shall be granted to the Engineer, and upon reasonable notice by the Engineer or others nominated by him if deemed necessary by the same for additional witnessing of assembly work or inspections and tests.

Should an agreed inspection not be carried out as proposed because of lack of preparation, obvious negligence or material and/or equipment being presented in a state, which does not correspond to the proposed procedure or is clearly not acceptable such an inspection shall be repeated. The cost incurred for all regular as well as repeated inspections shall be fully borne by the Contractor. The travel expenses for each additional or repeated inspection shall be borne by the contractor. Inspection at manufacturer's works/ vendor's works (for bought out items)

All the requirements of section 22.9.2.1 to 22.9.3.1 of the specifications shall be covered including the following

- Inspection of materials with material verification test certificate
- Inspection of bought out items/ components with manufacturer's test certificate.
- NDT for welding (Radiography, Ultrasonic, MPT, DPT)
- Inspection of shop assembly of embedded parts
- Inspection of shop assembly of gates

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- Inspection of shop assembly of hoist/ operating equipment including operational tests (Gate manufacturer works or vendor's works).
- Inspection of shop assembly of hoist supporting structure.

The above inspections shall also include dimensional accuracy checks, tolerance check for critical dimensions.

22.9.2.1. MATERIAL TESTS

Unless otherwise specified, the quality of materials shall be verified generally by:

- Chemical analysis
- Mechanical tests (yield point, tensile strength, elongation's, notch impact strength, etc.)
- Welding tests (welding procedure, welding material, welding tensile strength, welding bend test, welding reversed bend test, etc.)
- Non-destructive x-rays, ultrasonic, magnaflux, liquid penetration tests visual inspection, magnetic properties etc.)
- Electrical tests (voltage losses, tan-delta, insulation, magnetic properties)

Certified mill test reports of plates will be acceptable when these comply with the requirement for "Reports of Inspections and Tests" as stated in the Special Conditions. Test specimen and samples for analysis shall be plainly marked to indicate the materials they represent.

Castings and forgings shall be tested in the rough state in order to detect flaws in time thus avoiding delays. Magnetic particle inspection of important castings shall cover the whole surface of the casting. After partial machining further tests can be conducted. Important castings and forgings like Gate wheels, hoist drum gears, etc. shall be ultrasonically tested. The acceptable limit for ultrasonic testing of castings shall be level I of SA-603 of ASME Section-5 and that of forgings shall be as per SA

388 of ASME Section-5.Load tests on steel wire ropes, chains, etc. shall be considered as material tests.

22.9.2.2. CHECKING OF DIMENSIONS

The dimensions, especially clearances and fits, (ISO 286) which are essential for operation and efficiency shall be carefully checked in an approved manner, as for example:

- runout and roundness tolerances of shafts, pistons etc., to be measured on single parts as well as (wherever possible) on the assembled components.
- fits and clearances of gates, bearings, valves, guiding, distributing and actual actuating elements etc.
- accuracy, surface roughness and shape of sliding and guiding surfaces of seals, bearings, water passages in hydraulic machinery, valves etc.,
- dimensions of couplings or connections for assembly with other deliveries from the Contractor, Contractors or other contractors.

22.9.2.3. WORKSHOP ASSEMBLY

In addition to the quality and production control tests, the following shop assembly work and tests shall be made to check measurements, fitting and functioning.

Works to be furnished shall be shop assembled to a status sufficient to prove that the design and workmanship have been executed in accordance with the Specifications, that the delivery is complete, and that no work remains to be done at Site which reasonably can or should be done in the shop.

The metal work shall be shop-assembled to ensure that all parts are properly fitted and that the dimensional and tolerance requirements shown on the drawings have been obtained. All holes for field connections of parts furnished under these specifications shall be drilled or reamed as noted on the drawings, with the embedments so assembled. Members to be shop-bolted shall have all parts well pinned up and drawn together with bolts before bolting is commenced.

Gate shall be assembled in shop for checking all dimensions specifically critical dimensions as per final approved shop drawings and manufacturers instructions.

The Hoist shall be completely assembled in the shop to ensure that all parts are properly fitted. Surfaces of metal which will be in contact shall be cleaned before the parts are assembled. The parts shall be adjusted to line and fit and shall be well pinned and bolted so that the surfaces are in close contact before reaming, drilling, bolting or welding is commenced. The field connections shall be fitted and checked in the shop to assure proper fit during field erection.

After shop assembly the Hoist shall be tested at manufacturer's workshop for functional tests.

Where applicable each item of the works shall be assembled completely prior to painting.

Field joints shall be temporarily connected.

All parts shall be properly match marked, identified and doweled where practicable, to facilitate correct and quick field assembly and alignment. Where necessary, suitable dowels shall be provided for insertion after field assembly and drilling. The holes for any fitted bolt shall be accurately reamed.

During workshop assembly all instruments, control devices and piping shall be fitted.

If the assembly shows defects in the design or manufacture or unforeseen difficulties in assembling and dismantling, these shall be eliminated. If required, design alterations or corrective measures can be executed provided that reliability of operation or interchangeability are not reduced and provided that the agreement of the Engineer has been obtained.

If the corrections cannot be carried out in accordance with the terms mentioned above, the components concerned will be rejected. The decision on possible subsequent corrections is reserved exclusively to the Engineer. Faulty parts or Works shall by no means be delivered.

The assembled parts shall subsequently be subject to tests as per applicable standards or required by the Engineer.

22.9.2.4. FUNCTIONAL TESTS

Functional tests shall be defined as tests of the function of assemblies, sub- assemblies or parts of the Works under no load conditions. Functional tests shall be performed on all Works prior to the execution of operational tests.

22.9.2.5. OPERATIONAL TESTS

As far as practicable operational test shall be carried out on all Works, simulating operating conditions.

Parts to be delivered by sub suppliers shall be tested either at the premises of the sub supplier or of the Contractor, as agreed by the Engineer.

Before testing the Contractor shall submit a notice containing full information on the tests with detailed tables or graphs on the latest edition of the characteristic values of the Works to be tested and on the test facilities and equipment.

Operational tests of lifting equipment and other machinery shall include tests under following condition:

i. No load
ii. 5% of rated load
iii. 125 % of rated load

Unless otherwise specified. The deflection test shall be carried out with the safe working load at rest.

22.9.2.6. INSULATION TEST

The following tests shall be carried out at shop as well as at site after erection.

I. After erection but before the hoist is connected to the supply, the insulation of the electrical equipment shall be tested by a suitable instrument and any defects revealed shall be rectified. The voltage required for the insulation resistance test shall be d.c. voltage not less than twice the rated voltage.

II. Any reading less than 0.5 megaohm obtained with an insulation resistance tester of the un-regulated type shall be dis-regarded and the wiring under test shall be sub-divided until a reading higher than 0.5 megaohm is obtained. Failure to obtain a higher reading shows an unsatisfactory state of insulation. If an installation has been sub-divided for test purposes, each sub-division shall meet the requirement.

III. The insulation resistance of each wiring circuit exclusive of connected apparatus shall be not less than 2 megaohm, If necessary, it shall be permissible to disconnect individual items of equipment while making this test.

22.9.2.7. ELECTRICAL TESTS

Electrical Works shall be tested in accordance with applicable Standards and agreed test programs and procedures. Testing of the electrical Works shall be performed in accordance with applicable Standards, they shall include but not be limited to tests or heating, loading, overloading, losses. However before the complete installation is put to commercial service, tests shall be carried out to ascertain the following:

1) The satisfactory operation of each controller, switch, contactor, relay and other control devices and in particular the correct operation of all limit switches under the most unfavorable conditions.
   i. The correctness of all circuits and interlocks and sequence of operation.
   ii. Satisfactory operation of all protective devices.
   iii. The satisfactory operation of each motion of the hoist.
   iv. The compliance of the hoist with the specified performance requirement.

v. Tolerances on specified speeds on full load shall be within 10% The measurement shall not be taken on the first application of the load.

22.9.3. SITE INSPECTION AND TESTS

22.9.3.1. GENERAL

During erection, commissioning and trial operation the Contractor shall organize at suitable intervals all inspections and tests in the presence of the Engineer in order to prove the orderly execution of the works in accordance with the Contract.

Unless otherwise specified, all costs for testing at site and of the works and charges associated with it shall be borne by the Contractor. This includes the measuring devices, properly calibrated, and any pertinent accessories, which shall be made available by the Contractor for the entire duration of the tests. The Contractor shall delegate his experts to supervise the tests at site.

The tests, checks, examinations at site shall comprise but not be limited to:

- Checks and examinations of welds
- Hydrostatic pressure test
- Tightness tests
- Dielectric tests
- Functional checks (on all operating mechanism, on protective devices, automatic and manual controls, monitoring, supervisory equipment etc.)
- Running tests
- Overload tests (hoists)
- Reliability tests
- Performance tests and determination of characteristic data

All such tests and checks shall be performed in the presence of the Employer's Representative. If not satisfied with the performance of the tests and checks the Owner’s Representative shall have the liberty to ask for additional tests or repetition of same.

The testing at Site shall be complete in every respect to prove the successful performance and operation of all the works and Works supplied and erected under the Contract.

For the procedure of inspections and test at site, notice to the Engineer, reports, commissioning, trial runs and trial operation, and acceptance tests refer to General Conditions.

22.9.3.2. COMMISSIONING AND TRIAL RUN

After the contractor has notified the Owner’s Representative and received his agreement that the equipment is ready for the commissioning tests, the Contractor shall start with the Tests as stipulated in the Conditions of Contracts.

The tests shall comprise the following stages:

a) Pre-commissioning Tests

b) Commissioning Tests

c) Trial Operation

a) Pre-Commissioning Tests shall include the appropriate inspections and (dry or cold) functional tests to demonstrate that each item can safely undertake the next stage (b).

Stage inspection at site

* Requirement of IS 7718-1991 shall be covered. Inspection of embedded parts duly assembled/ erected in location, fully aligned and adjusted including installation of sill beam, side guide members, lintel members, sill seats/ tracks/ bearing pads and hoist supporting structure. This inspection involves measurement of critical dimensions, verticality, coplanerness of sealing/ bearing surfaces and dimensional accuracy within permissible erection tolerances.
* Prior to concreting, it shall be ensured that the embedded parts which have been erected/ aligned and inspected are supported by additional bracing etc. so that they do not get disturbed during concreting.
* After concreting, critical dimensions of embedded parts shall again be inspected for clearance of any excess concreting requiring chipping etc.
* Inspection of gate at site after its complete assembly and checking of dimensional accuracy, critical dimensions, coplanerness of skin plate and bearing / sealing faces.
* Inspection of structural components of hoist support, their dimensional accuracy, correct location and rigidity.
* Inspection of hoist for exact location of pulley block over the lifting point of the gate and for proper matching and connections.

Final Checking and Testing at Site General

After completion of various phases of works final checking of the entire work shall be done, by the contractor to ensure that all the equipments erection and wiring etc. have been done strictly according to the specification drawings and as approved by the Engineer. All the works shall be thoroughly inspected keeping in view the following main points:

* Check for completion of all works in accordance with specifications and drawings
* Checking of alignment of all mating components
* Checks for correctness of connections, continuity check, insulation resistance test
* Checks, adjustment and characteristic test of all controls/ protective equipment in accordance with manufacturers instructions.
* Checking of equipment for proper mechanical adjustment and proper operation.
* All routine and pre-commissioning tests and any other special tests required to be conducted at site on each and every equipment as per relevant standards and manufacturers instructions and recommendations.
* All other tests as specified under relevant standards and codes of practice but not mentioned here.

* Functional tests/ checks for various components.
* Tests & commissioning of control panels.

Proper record shall be maintained for all visual inspections, settings and checks carried out.

Hoists

* Ensuring completion of all component parts in accordance with the drawings.
* Ensuring proper lubrication of all components.
* Functional test of various assemblies of hoist.

Dry Testing of Gate & Hoist

The dry testing of the gate and hoist shall be carried out generally in accordance with Cl. 8.1, 8.2, 8.3 and 8.4 of IS 7718. The gate & hoist shall be functionally operated, fully closed, fully opened and it shall be ensured that there is no obstruction during the operation, the movements are smooth without any jerks and no undue effort is required for operation. Contact between gate seals and seal seats shall be checked and pre-compression ensured by viewing the contact surface against a light source. The operation of the hoist shall be smooth without any undue noise/ excessive friction and without excessive vibrations in the gate, hoist and supporting structure.

IMPORTANT: Any 'Dry' testing movements should have Rubber seals & seal faces lubricated with WATER. (Do not use grease/ oil) For Metal to Metal sealing/ bearing surfaces grease be used.

b) Commissioning Test, which shall include the specified operational tests to demonstrate that the works or section can be operated safely and as specified, under all available operating conditions; and shall include:

* Satisfactory operation of all equipment, after erection.
* Satisfactory vibration and noise level during entire cycle of operation
* The testing of gate and hoist for aspects as per Cl. 8.1 to 8.7 of IS: 7718 shall be performed with water pressure against the gate (preferably up to design head)
* Determination of leakage past gate seals under minimum and maximum available head and adjustment where necessary to meet the requirements of the specification.

Completion certificate shall be issued by the Engineer after successful commissioning of the facility as per above.

c) Trial Operation, After issue of completion certificate, trial operation shall commence which will demonstrate that the works or section perform safely & as specified with reliability during repeated operation and in accordance with the Contract.

During the trial operation period the Contractor may request any minor adjustments which do not in any way interfere with or prevent the use of the equipment by the Owner's or result in reducing the output or decreasing the efficiency.

If any failure or interruption occurs in any portion of the equipment covered by the Contract due to, or arising from, faulty design, materials, workmanship (but not otherwise sufficient to prevent full use of the equipment the trial operation period is to recommence after the Contractor has remedied the cause of defect.

A certificate of suitability for Operation shall be signed by an authorised representative of the Employer's Engineer and the Contractor.

This Certificate shall state:

* the conditions of commissioning
* the names of the participants
* the date of commencement of trial run
* the list of minor defects, if any

During the trial run the Contractor shall make familiar the Owner's personnel with the properties, the operation and maintenance of the Works and its auxiliaries to such extent that thereafter the duties can be assigned to the Owner's trained personnel.

The operation acceptance certificate shall be issued thereafter.

22.9.3.3. ACCEPTANCE

The installation testing of any part or section of the Permanent Works which can operate as an independent unit, shall be performed in accordance with the standards and regulations laid down in the "Particular Technical Specifications" and following the test procedure agreed upon between Engineer and Contractor.

Immediately upon termination of any such testing of a part or section of the permanent Works a "Protocol of Acceptance" shall be issued by the Engineer.

This document shall be signed by an authorised representative of the Owner's, the Engineer and the Contractor and shall form an integral part of the later "Taking- Over Certificate".

The acceptance of the equipment will be based upon:

- Mutual acceptance of results of test between the contractor and the purchaser
- Acceptance of Inspection and test records/ Test certificate carried out at "Works" and at "Site".

This "Protocol of Acceptance" shall state:

- The date of testing
- Statement of all minor defects and/or irregularities, which have to be corrected by the contractor.
- Confirmation that the guaranteed data have been proven
- Confirmation that all contractual documents have been submitted.
- Confirmation that the Owner's personnel has been familiarised with the Works and that they will be able to operate and maintain the Works.

If any test for the verification of the guaranteed data could not be performed for operational reasons beyond the Contractor's responsibility, this part of the acceptance shall be stated in the "Protocol of Acceptance" and be postponed for a mutually agreed period.

22.10. MISCELLANEOUS

Where ever the gate items are embedded, structural steel supports required to hold them in position and which are finally embedded in concrete shall be deemed to be included in the unit prices of various items mentioned. No

separate payment shall be made for such supports or any other type of temporary or permanent supports. The unit price accepted for the various items shall be considered to include cost of all materials, transport, plant and equipment, labour, tools and tackles, fabrication, erection, non-destructive tests (both at shop and field), surface preparation, painting, protective coating, wrapping, machining, supervision, Supply, installation, testing and commissioning of equipments, etc. complete as required for all the operations specified herein above in addition to those specifically so provided or otherwise so specifically directed for particular item of work.

II. PARTICULAR TECHNICAL SPECIFICATIONS

22.11. SPILLWAY EQUIPMENT

The bidder shall provide for all the equipment as per following description suitable for the operating duties as described and as per the requirement of civil and hydro mechanical design.

22.11.1. OBJECT AND LIMITS OF THE SUPPLY

The supply shall include the following equipment:

- six (6) spillway radial gates;
- six (6) sets of embedded parts for radial gates;
- six (6) hydraulic power units to operate the gates;
- six (6) local control panels to control the gates;
- two (2) sets of spillway stoplogs including lifting beam;
- six (6) sets of embedded parts for stoplogs;
- one (1) set of mandatory spare parts;
- Steel liner in Spillway Glacis, Piers and Breats wall for Spillway, as indicated in Drawings.

22.11.2. DESIGN DATA

Spillway radial gates design data:

Type of gate:	radial gate operated by oil pressure servomotors;
Number of openings	6
Number of gates	6
Dimensions of radial gate (w x h) clear opening	9.0 m x 15.1 m
Elevation of gate sill	795.0 m a.s.l.
Design water level	850.0 m.a.s.l.
Operation speed	0.3 m/min

Spillway stoplog design data:

Type of gate:	stoplog with wheels operated by spillway crane

Number of openings	6
Number of stoplog sets	1
Dimension of each sluice (w x h) clear opening	9.0 m x 21.5 m
Number of elements of each set	7
Sill elevation	795.0 m a.s.l.
Design water level	850.0 m.a.s.l.
Pressure balancing	by-pass valve on upper element

22.11.3. DESIGN CRITERIA

22.11.3.1. SPILLWAY RADIAL GATES

The gate shall consist of a curved steel skin plate that will be reinforced with structural members. Seals shall be placed along the bottom, top and both sides of the gate. The seals shall be attached in a manner to permit the replacement of the seals. The side, the top and the bottom sealing plates will be stainless steel. Each gate will be operated by two oil operated servomotors.

The gates shall be of sturdy construction, suitable to withstand bending and torsion due to unequal operation of the servomotors and shall be free from harmful vibrations at any degree of opening. The gates shall be kept in any position by the servomotors without the use of any mechanical device: an automatic restoring system shall be provided for compensating any oil leakage of the system.

The gates shall close under unbalance condition by their own weight, damped by their hydraulic cylinders.

The hydraulic cylinders and hydraulic power unit shall be approved by the Client.

The gate shall be provided with mechanical latching system to hold the gates in particular condition if required for long a period of time.

The spillway radial gates (mobile and fixed parts) shall be calculated according to DIN 19704 standard considering also the seismic effect in accordance with IS: 1893. The design shall be checked for additional forces due to horizontal and vertical earthquake acceleration of 0.141g and 0.094g respectively with increased stresses.

22.11.3.2. SPILLWAY STOPLOGS

The stoplogs are envisaged to carry out maintenance to the spillway radial gates.

The stoplogs shall be made of multiple elements. Each element shall be designed to be lowered and raised by suitable lifting beam of a self-latching and unlatching type by a suitable gantry crane.

Stoplogs will serve for maintenance purposes only and will always be operated under balanced pressure; to this end a by-pass valve will be provided to allow the filling of the vane in the upper element.

The gate shall be provided with horizontal girders, vertical stiffeners, side guide roller assemblies, bumpers, wheel assemblies etc. including bottom seal, top seal, side seal and lintel sealing elements.

Each element comprises of 4 wheels, 2 on each side. Wheels shall be provided with spherical roller bearings, which shall be protected from water by suitable sealing arrangements having rotary sealing rings and/ or oil seals/ rings. Wheel pins shall be provided with suitable eccentricity (minimum 5mm) between centers of pins and holes in end

girder plates to facilitate adjustment in wheel alignment to have proper contact with the roller path. Each unit shall have three horizontal girders. Suitable drain holes shall be provided on all horizontal girder webs and horizontal stiffeners except top most horizontal girder.

Each stoplog element shall be provided with guide rollers (minimum two guide rollers for each side) to check the side and lateral movement of the gate and to restrain the same within specified limits. The guide rollers should be adjustable (by providing shims). They shall travel on the embedded guides. The guide rollers shall be provided with self-lubricating bushes on fixed pins.

All elements of each spillway stoplog element is operated under balanced conditions.

To this end a by-pass valve will be incorporated in the upper stoplog element to allow the filling of the vane.

The stoplogs (mobile and fixed parts) shall be calculated according to DIN 19704 standard considering also the seismic effect in accordance with IS: 1893. The design shall be checked for additional forces due to horizontal and vertical earthquake acceleration of 0.141g and 0.094g respectively with increased stresses.

The relevant lifting equipment shall be calculated according to FEM rules.

The total number of stoplogs (2 sets) will allow the maintenance of two radial gates at the same time.

22.11.4. STRUCTURAL DETAILS

22.11.4.1. GATES

The gate body shall consist of a frame of steel structural shapes of sturdy construction supporting a skin plate placed upstream.

If for transportation the gate shall be divided into parts, such parts shall be assembled on site by welding.

A proper number of gauged bolts shall be anyway provided to ensure the correct geometrical assembly of the parts.

The skin plate shall have a minimum thickness of 10 mm. A 2 mm allowance for corrosion shall be considered in the calculation.

The lower part of the gate shall be shaped in such a way as to avoid turbulence and pressure pulsations.

The downpull effect, if any, shall not be considered in the calculation of the weight required for the gravity closure.

The connection with the stem shall be adequately strengthened.

22.11.4.2. SEALS

Seals shall be made of rubber with stainless steel clamping and adjusting bar and stainless steel or hot dip galvanized bolts.

The metal on the embedded parts shall be Stainless steel AISI 304 or AISI 316.

Appropriate welding procedures shall be adopted for welding of two different materials (stainless steel with carbon steel).

The rubber seals shall be molded rubber shapes clamped to the gate by means of steel sections and stainless steel or hot dip galvanized bolts, nuts and washers. These sections shall be adjustable and easily replaceable. Extruded seals will not be permitted.

The seals shall be made of synthetic rubber made of SBR (Styrene Butadiene Rubber) meeting the following requirements:

- Polymer Type: SBR
- Hardness Shore A 50 - 70
- Tensile strength [MPa] >21
- Elongation at break % >450
- Ozone resistance at 20 °C 25pphm 120 hr 20 % elong. no crack

For design purposes, the coefficient of friction shall be assumed in accordance to DIN 19704.
Where it is not possible to provide seals in one length, the separate component length shall be tight-butted in the workshop.
The facing ends shall be cut at right angles and dressed slightly longer than required to assure a tight joint.
After their inspection, for gates which need to be disassembled for shipment, the seals shall be match-marked with the gate before removal for packing and shipment to the Site; the seals shall be removed and packed separately.
Holes for seal bolts in the gate leaf and seal clamp bars shall be drilled in the workshop.
Adjustment of the seal shall be carried out with bolts on the downstream side of the gate.

22.11.4.3. GUIDES AND SEALING SURFACES

Gates and stoplogs shall be provided with lateral guides to limit the sideways displacement and to prevent vibrations during operation.
The fixed parts shall start at the sill level and shall reach the elevation of the operating level.
The guides and sealing surfaces shall be smooth, true to form and free from twists, warps and kinks. The surfaces to be in contact with rubber seals shall be lined with stainless steel sheets or sections to be welded to the steel structure.
The guides shall be supplied complete with stiffening bars; anchor plates and other accessories including the plates to be embedded in the first stage concrete.
Stud bolts to be welded to the above plates during erection shall be provided with double nuts and washers for a precise alignment of the guides.
The Contractor shall provide the steel beams to be embedded in the concrete of the sill.

22.11.4.4. STEEL LINER IN SPILLWAY GLACIS, PIERS, AND BREAST WALL FOR SPILLWAY

To safeguard the Spillway from damage due to high velocities, the steel liners in all six Nos. level spillways shall be designed, fabricated and installed as per indication in Drawings. However, the final layout and details shall be decided at the time of detailed design. The various items involved in the scope of work mentioned herein shall generally consist of the following but not necessarily be restricted to:

1. Six Nos. steel liners from u/s end of curve portion to centre line of trunnion pin of spillway

2. Six Nos. steel liners on both sides of the piers on u/s of the spillway openings including stoplog grooves
3. Six Nos. steel liners on both sides of the piers for full opening height of the spillways between stoplog grooves and radial gate wall plate
4. Six Nos. steel liners on both sides of the piers on d/s of the spillway openings/wall plate upto centre line of trunnion pin to suit the water nappe profile
5. Six Nos. steel liners on Breast wall of the spillway openings to suit its profile

22.11.5. OPERATING SYSTEM

The radial gates shall be operated by a hydraulic system with oil operated servomotors, as described hereafter.
The maintenance stoplogs shall be operated by a gantry crane described in a dedicated chapter.
The hydraulic power pack for the radial gate will be located at dam top.

22.11.5.1. GENERAL

The radial gates shall be operated by two servomotors. The operating system of the radial gates shall be equipped with an equalization system in order to ensure equal loading on the cylinders under all conditions, and prevent any undue loading, additionally a gasoline engine-operated portable power pack may be provided.
For maintenance purposes and for emergency, it shall be possible to have full oil pressure also in the upper servomotor chamber.
The hydraulic system for the gates shall be designed to maintain the servomotor filled when the gate is held in the open position.

22.11.5.2. HYDRAULIC SERVOMOTOR

The servomotor shall consist of a hydraulic cylinder and piston rod. The servomotor cylinder and covers shall be made of cast steel or welded steel plate stress-relieved prior to final machining.
The cylinder shall be accurately bored and shall be provided with fittings for connecting oil piping, and with suitable seals or packing boxes to prevent leakage of oil along the piston rod.
The servomotor piston shall be made of cast steel or steel plate and shall be fitted with not less than two piston rings suitably shaped to give closed contact and uniform pressure to the cylinder walls and to prevent leakage of oil past the piston.
Bronze bushing shall be furnished for the piston rod to support and guide the piston.
The rod shall be coated with hard industrial chromium to minimize wear; thickness shall not be less than 0.1 mm and no more than 0.2 mm.
Oil pipe connections shall be provided with isolating valves for the maintenance activities.

Suitable devices shall be foreseen to slow down the closing velocity of the servomotors in the last part of the closing stroke to limit the impact on the lower sill.

22.11.5.3. PRESSURE OIL SUPPLY SYSTEM

The pressure oil supply system shall include all pumps, oil tank, piping, flexible connections, shut-off, throttle and control valves, gauges, instruments and appurtenances for the complete operation of the gates.
A high quality, anti-wear hydraulic oil shall be used in the system. The oil shall be adequate for start-up at temperature as low as 0°C and have a viscosity grade at 40°C not greater than 32 Cst.

Oil Pumps: Two self-priming oil pumps shall be provided for each gate, one for normal operation and the other as an automatic stand-by. Each of them shall have a capacity to open the gate at the nominal speed.
Each pump shall be equipped with a fully automatic starting device to ensure the no-load pump starting and to load the pump only when rated speed has been reached.
Provisions shall be made to allow the complete disconnection of either pump from the system for maintenance purpose without compromising the system operation.
Each pump shall be equipped with check valve, outlet valve, safety valve and all other accessories necessary for fully reliable operation.
The feeding and discharge lines for the servomotors shall start from a common manifold and each shall be provided with an electro valve so that the servomotor of the gate can be controlled by means of push-buttons.
Adequate flow regulating devices shall be provided on the servomotors in order to guarantee that the gate closing speed will not be excessive in case of any pipe failure.

Oil Sump Tank: the oil sump tank shall be one for each gate. The oil sump tanks shall be made of welded steel plates, duly stiffened with steel sections if necessary.
Its capacity shall be at least 70% greater than the maximum net variation in volume under worst operating conditions, and not less than the 11% of the complete oil circuit volume and able to contain the oil of one cylinder out of two. The most strict of the above requirements shall be applied.
All oil drainage, leakage and/or exhaust pipes, shall be conveyed to the oil sump tank.
The oil tank shall be equipped with manhole, level indicator, filtered air vent, connection for filling and draining, magnetic filters and with plugs for the connection with a portable oil purifier included in the Supply.
The Supply shall include the oil for washing and first filling.
The hydraulic power unit shall be equipped with oil filtration machine.

22.11.5.4. CONTROLS

The Contractor shall provide local control panels in accordance with the General Technical Specification. Intelligent Electronic Devices (IED) such as PLC may also be provided to control the equipment operation and record the relevant data.

The control panels shall house all switches, push-buttons, lamps, indicators, alarms and all others necessary equipment for the local control and operation of the gates. The panels shall also house the terminal boards for the remote control signals. Each RTU (Remote Terminal Unit) installed at the Power Houses for signaling activities shall include a minimum provision of 20% spare I/O modules relative to the initial operational configuration. These modules shall be pre-installed in the rack, powered, and fully configured within the control system.

Manual operation of the solenoid valves for the gates closing shall also be provided.
The gates shall be provided with limit switches signaling the full open and full closed position and with an easily visible measuring stick, to show on a scale, the gate position.

22.11.6. SPILLWAY STOPLOGS LIFTING BEAMS

The Supply shall include a suitable lifting beam for the spillway stoplogs elements, of self-latching and unlatching type as approved by the Contractor, designed to engage and disengage with the stoplogs element depending upon the preset position of the latching mechanism counterweight.
The latching mechanism shall be provided with pressed-in self-lubricated bronze bushing. The use of tag lines for the operation on the latching device will not be permit-ted.
Each end of the beam shall be provided with guide wheels traveling along the stoplogs lateral guides.
These guides wheels shall be of cast or forged steel, have self-lubricated, solid graphite insert type, (Lubrite, Deva or similar) bronze bearings, easy to replace. The pin of the wheel shall be of stainless steel, shall be ground and of ample dimensions to resist unforeseen and abnormal loads bearing on the wheels. It shall be possible to regulate at Site the clearance between the wheels and the guides.

22.11.7. ELECTRICAL EQUIPMENT

The gates shall be complete with all electrical equipment necessary for its operation.
All the electrical equipment shall be mounted on control boards (one or more boards depending on the location of the equipment to be fed), whose door shall be provided with lock and key.
Gate alarms shall be fed at 220 V DC.
All external connections to the pumping unit shall be by standard conduits. Wiring to the motor and valves shall be enclosed in oil resistant liquid tight metal conduits.
Limit switches shall be of the heavy-duty type suited for outdoor installation. All limit switches shall be mounted above operating level.
Limit switches will have at least one make and one break contact. All the limit switches shall operate at 220V DC ±20%, unless otherwise specified.
They shall withstand at least 1,000 switching cycles per hour, under rated current conditions.
Their breaking capacity shall be 2A and making capacity shall be 10A, the current carrying capacity shall be 4A. The contacts shall be made of solid silver or of special alloy.

22.11.8. MAINTENANCE

The design of the gates and stoplogs shall permit easy replacement of the seals.

The Contractor shall provide all the accessories needed for the disassembling as well as the maintenance devices to enable the gate maintenance. The Contractor shall also provide any anchoring bolts and plates to fix the parts into concrete.

22.11.9. FITTINGS AND ACCESSORIES

a) Oil Pressure Gauges

Each oil pump shall be provided with a pressure gauge with an adjustable electric contact signalling abnormal pressure during gate opening.

In correspondence to any pressure gauge, a pressure tap shall be provided to allow the pressure check by means of an external manometer.

b) Chequered Plates

The Contractor shall supply galvanized chequered plates to cover the cables and piping ducts and the relevant galvanized supporting angles to be embedded in the concrete.

22.11.10. STOPLOGS STORAGE

A suitable storage area, accessible by the hoisting facility, shall be foreseen for the Spillway Stoplogs.

The Supply shall include a complete storage system with all steel components and parts to be embedded in concrete.

22.11.11. TOLERANCES

The contacting sealing surfaces of the side and top seals, when assembled on the finished gate, shall not depart more than 1 mm from a plane surface that is parallel to the sliding surfaces of the gate. The planes of the guide plates shall be true within ± 1 mm.

The gates tolerance shall be ± 5 mm in width and ± 8 mm in height.

The water leakage of the gate seals shall not exceed the following values:

Stoplogs	1.2 l/min for each meter of seal.
Radial gates	1.5 l/min for each meter of seal

22.11.12. TESTS

22.11.12.1. FACTORY TESTS

<u>Tests on Materials</u>

All materials shall be submitted to mechanical tests according to the applicable Standards.

The following parts shall be 100% checked by ultrasonic test:

- servomotors cylinder and rod
- connection flanges (if present);

Material test certificates relevant to all the main components of the structure (e.g. skin plates, main girders, tracks, hydraulic cylinders, rods, flanges, etc.) and of other minor components as required by the Contractor shall be provided.

All commercial sub-assemblies such as electric motors, gear boxes, pumps, valves, etc. shall be of approved manufactures and the relevant factory test certificates shall be provided.

Dimensional Controls and Hydraulic Tests

The gates, the servomotors and the hydraulic pumping sets with cabinet and such other equipment shall be shop assembled for inspection and tests.

All assembled equipment shall be checked or tested for dimensional and alignment accuracy, tolerance, operation, fit and travel, and to control that the requirements of the Specifications have been met. Any error or omission discovered shall be corrected.

Gate seals shall be tested for fit but not workshop-assembled.

The Contractor shall furnish two samples of the rubber seals, each not less than one meter long and cut the molded seals at random form and shall test them to demonstrate that they meet the requirements under load.

The hydraulic servomotors shall be tested at a pressure of 150% of maximum operating pressure with oil for thirty minutes. All servomotors shall also be operated under maximum operating load over their full travel.

No leakages shall be allowed through the stem and piston packing.

Operation of the limit switches shall be verified during these tests.

The hydraulic pumping units shall be included in the test. The systems shall be filled with hydraulic oil, thoroughly vented, and tested to full design relief pressure. All fittings, joints, piping and accessories shall remain tight under test.

After shop-assembly, the gates and hydraulic servomotors with adequate matchmarks (if required) shall be disassembled into major units. Control panels shall be shipped completely assembled, except for those fragile components that will require separate packing.

Tests on Electrical Equipment

Motors and panels completely assembled shall be tested according to IEC Standards. For electric motors the torque values as well as the speed and the starting current values shall be measured.

The controls of the oil pumping set completely wired shall be checked in order to ascertain their correct functioning.

A complete list of all tests to be performed shall be anyway detailed in the Quality Control Plan.

Tests on Welding

At least 20% of the major welds shall be examined with ultrasonic or radiographic examination according to the procedure indicated in the General Technical Specifications.

All welds on the skin plates and cylinders shall be checked by magnetic particles or dye penetrants.

Welds on cylinders shall be 100% tested, butt-welds by means radiographic examination, the other types by means of ultrasonic examination.

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22.11.12.2. SITE TESTS

After being installed and before any mechanical test runs are made, all parts shall be properly lubricated, inspected and operated to check clearances and accuracy of alignment and smoothness of operation.
Moreover, the tests to be performed shall be the following:

- pressure test on assembled oil piping at 150% of the rated pressure;
- operation of all the Supply in dry conditions;
- verification of closing and opening speeds with water;
- measurement of the gate leakage.

22.11.13. MANDATORY SPARE PARTS

The Contractor shall supply the spare parts listed here below which are to be considered as a minimum requirement:

- one (1) complete set of gate seals for one radial gate;
- one (1) complete set of stoplogs seals for one stoplog element;
- four (4) wheel assemblies complete in all respect for stoplog;
- four (4) guide rollers assemblies complete in all respect for stoplog;
- two (2) relays of each type used;
- two (2) contactors of each size and type used;
- one (1) seal and gaskets for each type used;
- one (1) bearing of each type used;
- two (2) complete sets of fuses for one radial gate;
- two (2) limit switches of each type used;
- one (1) complete set of lamps for one radial gate;
- ten (10) percent of all nuts and bolts used;
- one (1) position transducer of each type used;
- one (1) pressure switch, level switch, level indicator, temperature switch, pressure gauge, temperature gauge, etc. as needed by the pressure oil control system;
- minor items to ensure the operation for five years from the Installation.

22.12. AUXILIARY SPILLWAY EQUIPMENT

The bidder shall provide for all the equipment as per following description suitable for the operating duties as described and as per the requirement of civil and hydro mechanical design.

22.12.1. OBJECT AND LIMITS OF THE SUPPLY

The Supply shall include the following equipment:

- one (1) set of auxiliary spillway stoplog including lifting beam;

- one (1) set of embedded parts for auxiliary spillway stoplogs;
- one (1) auxiliary spillway gate;
- one (1) set of embedded parts for service gate;
- one (1) hydraulic power unit to operate the gate;
- one (1) local control panels to control the gate;
- one (1) set of mandatory spare parts;
- one (1) set of environmental flow pipes.

22.12.2. DESIGN DATA

Auxiliary spillway stoplog design data:

Type of gate:	stoplog with wheels operated by spillway gantry crane
Number of opening	1
Number of stoplog	1
Dimension of each sluice (w x h) clear opening	5 x 5.8 m
Number of elements of each sluice	2
Sill elevation	844.5 m a.s.l.
Design water level	850.0 m.a.s.l.

Auxiliary spillway service gate design data:

Type of gate:	wheel gate operated by oil pressure servomotor
Number of openings	1
Number of gates	1
Dimension of gate (w x h) clear opening	5 x 5.8 m
Elevation of gate sill	844.5 m a.s.l.
Design water level	850.0 m.a.s.l.
Operation speed	0.3 m/min

22.12.3. DESIGN CRITERIA

22.12.3.1. AUXILIARY SPILLWAY GATE

Fixed wheel type gate with structural steel construction of upstream skin plate and upstream seals shall be provided in each gate. The gate shall be designed against water head corresponding to water level 850.0 m a.s.l.
The gate shall be provided with horizontal girders, vertical stiffeners, side guide roller assemblies, bumpers, wheel assemblies etc. including bottom seal, side seal and lintel sealing elements.
The gate is to be fabricated in suitable number of units to be assembled into single gate at site. Each unit comprises of 4 wheels, 2 on each side. Wheels shall be provided with spherical roller bearings, which shall be protected from

water by suitable sealing arrangements having rotary sealing rings and/ or oil seals/ rings. Wheel pins shall be provided with suitable eccentricity (minimum 5mm) between centers of pins and holes in end girder plates to facilitate adjustment in wheel alignment to have proper contact with the roller path. Each unit shall have three horizontal girders. Suitable drain holes shall be provided on all horizontal girder webs and horizontal stiffeners except top most horizontal girder. Each gate unit shall be joined together at site using splice plate and friction grip (HTFG) Bolts on skin plate, end girders and full depth stiffener plates. End girders and full depth stiffener plates of gate shall have flexible joints between them.

Each gate shall be provided with guide rollers (minimum two guide rollers for each side) to check the side and lateral movement of the gate and to restrain the same within specified limits

The guide rollers should be adjustable (by providing shims). They shall travel on the embedded guides. The guide rollers shall be provided with self lubricating bushes on fixed pins.

The gate shall be calculated according to DIN 19704 standard considering also the seismic effect in accordance with IS: 1893. The design shall be checked for additional forces due to horizontal and vertical earthquake acceleration of 0.141g and 0.094g respectively with increased stresses.

22.12.3.2. AUXILIARY SPILLWAY STOPLOGS

Stoplogs will serve for maintenance purposes only.

The stoplogs shall be made of multiple elements. Each element shall be designed to be lowered and raised by suitable lifting beam of a self-latching and unlatching type by a suitable gantry crane.

Stoplogs will serve for maintenance purposes only and will always be operated under balanced pressure; to this end a by-pass valve will be provided to allow the filling of the vane in the upper element.

The gate shall be provided with horizontal girders, vertical stiffeners, side guide roller assemblies, bumpers, wheel assemblies etc. including bottom seal, side seal and lintel sealing elements.

Each unit comprises of 4 wheels, 2 on each side. Wheels shall be provided with spherical roller bearings, which shall be protected from water by suitable sealing arrangements having rotary sealing rings and/ or oil seals/ rings. Wheel pins shall be provided with suitable eccentricity (minimum 5mm) between centers of pins and holes in end girder plates to facilitate adjustment in wheel alignment to have proper contact with the roller path. Each unit shall have three horizontal girders. Suitable drain holes shall be provided on all horizontal girder webs and horizontal stiffeners except top most horizontal girder.

An adequate number of guide rollers, arranged symmetrically on both sides of the gate unit, shall be provided to check and restrain the side and lateral movement of the gate within specified limits. The guide rollers should be adjustable (by providing shims). They shall travel on the embedded guides. The guide rollers shall be provided with self lubricating bushes on fixed pins.

The stoplogs (mobile and fixed parts) shall be calculated according to DIN 19704 standard considering also the seismic effect in accordance with IS: 1893. The design shall be checked for additional forces due to horizontal and vertical earthquake acceleration of 0.141g and 0.094g respectively with increased stresses.

22.12.3.3. ENVIRONMENTAL FLOW RELEASE SYSTEM

Environmental considerations require that a minimum environmental flow shall be continuously released downstream of the Dorjilung Dam under all normal operating conditions.

As defined by the Environmental and Social Impact Assessment (ESIA) included in the DPR, the minimum environmental flow to be guaranteed downstream of the dam shall be equal to 6.0 m3/s.

The Environmental Flow Release System shall be permanently incorporated into the dam structure and shall ensure safe, reliable and continuous release of the environmental flow throughout the operating range of the reservoir.

The environmental flow release system is located within the Auxiliary Spillway Bay and consists of three embedded environmental flow pipes (450 mm diameter, with inlet and outlet at elevations 838.0 m asl and 825 m asl, respectively). Appropriate measures shall be implemented to prevent inlet clogging by installing a suitably designed trash rack that promotes the upward movement of debris. The inlet submergence shall be selected to minimize the entrainment of floating debris into the intake.

22.12.4. STRUCTURAL DETAILS

22.12.4.1. GATES

The gate body shall consist of a frame of steel structural shapes of sturdy construction supporting a skin plate placed upstream.
If for transportation the gate shall be divided into parts, such parts shall be assembled on site by welding.
A proper number of gauged bolts shall be anyway provided to ensure the correct geometrical assembly of the parts.
The skin plate shall have a minimum thickness of 10 mm. A 2 mm allowance for corrosion shall be considered in the calculation.
The lower part of the gate shall be shaped in such a way as to avoid turbulence and pressure pulsations.
The downpull effect, if any, shall not be considered in the calculation of the weight required for the gravity closure.
The connection with the stem shall be adequately strengthened.

22.12.4.2. SEALS

Seals shall be made of rubber with stainless steel clamping and adjusting bar and stainless steel or hot dip galvanized bolts.
The metal on the embedded parts shall be Stainless steel AISI 304 or AISI 316.
Appropriate welding procedures shall be adopted for welding of two different materials (stainless steel with carbon steel).

The rubber seals shall be molded rubber shapes clamped to the gate by means of steel sections and stainless steel or hot dip galvanized bolts, nuts and washers. These sections shall be adjustable and easily replaceable. Extruded seals will not be permitted.

The seals shall be made of synthetic rubber made of EPDM /SBR (Styrene Butadiene Rubber) meeting the following requirements:

- Polymer Type: SBR
- Hardness Shore A 50 - 70
- Tensile strength [MPa] >21
- Elongation at break % >450
- Ozone resistance at 20 °C 25pphm 120 hr 20 % elong. no crack

For design purposes, the coefficient of friction shall be assumed in accordance to DIN 19704.

Where it is not possible to provide seals in one length, the separate component length shall be tight-butted in the workshop.

The facing ends shall be cut at right angles and dressed slightly longer than required to assure a tight joint.

After their inspection, for gates which need to be disassembled for shipment, the seals shall be match-marked with the gate before removal for packing and shipment to the Site; the seals shall be removed and packed separately.

Holes for seal bolts in the gate leaf and seal clamp bars shall be drilled in the workshop.

Adjustment of the seal shall be carried out with bolts on the downstream side of the gate.

22.12.4.3. GUIDES AND SEALING SURFACES

The gates shall be provided with lateral guides to limit the sideways displacement and to prevent vibrations during operation.

The fixed parts shall start at the sill level and shall reach the elevation of the operating level.

The guides and sealing surfaces shall be smooth, true to form and free from twists, warps and kinks. The surfaces to be in contact with rubber seals shall be lined with stainless steel sheets or sections to be welded to the steel structure.

The guides shall be supplied complete with stiffening bars; anchor plates and other accessories including the plates to be embedded in the first stage concrete.

Stud bolts to be welded to the above plates during erection shall be provided with double nuts and washers for a precise alignment of the guides.

The Contractor shall provide the steel beams to be embedded in the concrete of the sill.

22.12.5. OPERATING SYSTEM

The service gate shall be operated by a hydraulic system with oil operated servomotors, as described hereafter.

22.12.5.1. GENERAL

The service gate shall be operated by an hydraulic cylinder.
For maintenance purposes and for emergency, it shall be possible to have full oil pressure also in the upper servomotor chamber.
The hydraulic system for the gates shall be designed to maintain the servomotor filled when the gate is held in the open position.

22.12.5.2. HYDRAULIC SERVOMOTOR

The servomotor shall consist of a hydraulic cylinder and piston rod. The servomotor cylinder and covers shall be made of cast steel or welded steel plate stress-relieved prior to final machining.
The cylinder shall be accurately bored and shall be provided with fittings for connecting oil piping, and with suitable seals or packing boxes to prevent leakage of oil along the piston rod.
The servomotor piston shall be made of cast steel or steel plate and shall be fitted with not less than two piston rings suitably shaped to give closed contact and uniform pressure to the cylinder walls and to prevent leakage of oil past the piston.
Bronze bushing shall be furnished for the piston rod to support and guide the piston.
The rod shall be coated with hard industrial chromium to minimize wear; thickness shall not be less than 0.1 mm and no more than 0.2 mm.
Oil pipe connections shall be provided with isolating valves for the maintenance activities.
Suitable devices shall be foreseen to slow down the closing velocity of the servomotors in the last part of the closing stroke to limit the impact on the lower sill.

22.12.5.3. PRESSURE OIL SUPPLY SYSTEM

The pressure oil supply system shall include all pumps, oil tank, piping, flexible connections, shut-off, throttle and control valves, gauges, instruments and appurtenances for the complete operation of the gates.
A high quality, anti-wear hydraulic oil shall be used in the system. The oil shall be adequate for start-up at temperature as low as 0°C and have a viscosity grade at 40°C not greater than 32 Cst.

Oil Pumps: Two self-priming oil pumps shall be provided for each gate, one for normal operation and the other as an automatic stand-by. Each of them shall have a capacity to open the gate at the nominal speed.
Each pump shall be equipped with a fully automatic starting device to ensure the no-load pump starting and to load the pump only when rated speed has been reached.
Provisions shall be made to allow the complete disconnection of either pump from the system for maintenance purpose without compromising the system operation.
Each pump shall be equipped with check valve, outlet valve, safety valve and all other accessories necessary for fully reliable operation.

The feeding and discharge lines for the servomotors shall start from a common manifold and each shall be provided with an electro valve so that the servomotor of the gate can be controlled by means of push-buttons.
Adequate flow regulating devices shall be provided on the servomotors in order to guarantee that the gate closing speed will not be excessive in case of any pipe failure.

Oil Sump Tank: the oil sump tank shall be one for each gate. The oil sump tanks shall be made of welded steel plates, duly stiffened with steel sections if necessary.
Its capacity shall be at least 70% greater than the maximum net variation in volume under worst operating conditions, and not less than the 11% of the complete oil circuit volume and able to contain the oil of one cylinder out of two. The most strict of the above requirements shall be applied.
All oil drainage, leakage and/or exhaust pipes, shall be conveyed to the oil sump tank.
The oil tank shall be equipped with manhole, level indicator, filtered air vent, connection for filling and draining, magnetic filters and with plugs for the connection with a portable oil purifier included in the Supply.
The Supply shall include the oil for washing and first filling.

22.12.5.4. CONTROLS

The Contractor shall provide local control panels in accordance with the General Technical Specification. Intelligent Electronic Devices (IED) such as PLC may also be provided to control the equipment operation and record the relevant data.
The control panels shall house all switches, push-buttons, lamps, indicators, alarms and all others necessary equipment for the local control and operation of the gates. The panels shall also house the terminal boards for the remote control signals.
Manual operation of the solenoid valves for the gates closing shall also be provided.
The gates shall be provided with limit switches signalling the full open and full closed position and with an easily visible measuring stick, to show on a scale, the gate position.

22.12.6. SPILLWAY STOPLOGS LIFTING BEAMS

The Supply shall include a suitable lifting beam for the auxiliary spillway stoplogs elements, of self-latching and unlatching type as approved by the Contractor, designed to engage and disengage with the stoplogs element depending upon the preset position of the latching mechanism counterweight.
The latching mechanism shall be provided with pressed-in self-lubricated bronze bushing. The use of tag lines for the operation on the latching device will not be permit-ted.
Each end of the beam shall be provided with guide wheels traveling along the stoplogs lateral guides.
These guides wheels shall be of cast or forged steel, have self-lubricated, solid graphite insert type, (Lubrite, Deva or similar) bronze bearings, easy to replace. The pin of the wheel shall be of stainless steel, shall be ground and of ample dimensions to resist unforeseen and abnormal loads bearing on the wheels. It shall be possible to regulate at Site the clearance between the wheels and the guides.

22.12.7. ELECTRICAL EQUIPMENT

The auxiliary spillway service gate shall be complete with all electrical equipment necessary for its operation. The electrical requirements for the auxiliary spillway stoplog shall be in line with those specified for the spillway stoplog gate, as applicable, and shall comply with the applicable codes, standards and statutory regulations.

22.12.8. MAINTENANCE

The design of the gates shall permit easy replacement of the seals.
The Contractor shall provide all the accessories needed for the disassembling as well as the maintenance devices to enable the gate maintenance. The Contractor shall also provide any anchoring bolts and plates to fix the parts into concrete.

22.12.9. FITTINGS AND ACCESSORIES

a) Oil Pressure Gauges

Each oil pump shall be provided with a pressure gauge with an adjustable electric contact signaling abnormal pressure during gate opening.
In correspondence to any pressure gauge, a pressure tap shall be provided to allow the pressure check by means of an external manometer.
Gauge shall be Glycerine filled for the better accuracy.

b) Chequered Plates

The Contractor shall supply galvanized chequered plates to cover the cables and piping ducts and the relevant galvanized supporting angles to be embedded in the concrete.

22.12.10. STOPLOGS STORAGE

A suitable storage area, accessible by the hoisting facility, shall be foreseen for the Auxiliary Spillway Stoplog.
The Supply shall include a complete storage system with all steel components and parts to be embedded in concrete.

22.12.11. TOLERANCES

The contacting sealing surfaces of the side and top seals, when assembled on the finished gate, shall not depart more than 1 mm from a plane surface that is parallel to the sliding surfaces of the gate. The planes of the guide plates shall be true within ± 1 mm.
The gates tolerance shall be ± 5 mm in width and ± 8 mm in height.
The water leakage of the gate seals shall not exceed the following values:

Stoplogs	1.2 l/min for each meter of seal.
Gates	1.2 l/min for each meter of seal.

22.12.12. TESTS

22.12.12.1. FACTORY TESTS

Tests on Materials

All materials shall be submitted to mechanical tests according to the applicable Standards.

Material test certificates relevant to all the main components of the structure (e.g. skin plates, main girders, tracks, hydraulic cylinders, rods, flanges, etc.) and of other minor components as required by the Contractor shall be provided.

All commercial sub-assemblies such as electric motors, gear boxes, pumps, valves, etc. shall be of approved manufactures and the relevant factory test certificates shall be provided.

Dimensional Controls and Hydraulic Tests

The gates, the servomotors and the hydraulic pumping sets with cabinet and such other equipment shall be shop assembled for inspection and tests.

All assembled equipment shall be checked or tested for dimensional and alignment accuracy, tolerance, operation, fit and travel, and to control that the requirements of the Specifications have been met. Any error or omission discovered shall be corrected.

Gate seals shall be tested for fit but not workshop-assembled.

The Contractor shall furnish two samples of the rubber seals, each not less than one meter long and cut the molded seals at random form and shall test them to demonstrate that they meet the requirements under load.

The hydraulic servomotors shall be tested at a pressure of 150% of maximum operating pressure with oil for thirty minutes. All servomotors shall also be operated under maximum operating load over their full travel.

No leakages shall be allowed through the stem and piston packing.

Operation of the limit switches shall be verified during these tests.

The hydraulic pumping units shall be included in the test. The systems shall be filled with hydraulic oil, thoroughly vented, and tested to full design relief pressure. All fittings, joints, piping and accessories shall remain tight under test.

After shop-assembly, the gates and hydraulic servomotors with adequate matchmarks (if required) shall be disassembled into major units. Control panels shall be shipped completely assembled, except for those fragile components that will require separate packing.

Tests on Electrical Equipment

Motors and panels completely assembled shall be tested according to IEC Standards. For electric motors the torque values as well as the speed and the starting current values shall be measured.

The controls of the oil pumping set completely wired shall be checked in order to ascertain their correct functioning.

A complete list of all tests to be performed shall be anyway detailed in the Quality Control Plan.

The applicable IEC standards will be applied for each type of electrical equipment. In general, all equipment shall comply with the latest editions of the relevant IEC standards.
Where specific tests are required, the corresponding IEC standard and relevant clauses will be clearly referenced by the contractor to ensure unambiguous definition of requirements and full compliance during design, manufacturing, and testing.

Tests on Welding

At least 20% of the major welds shall be examined with ultrasonic or radiographic examination according to the procedure indicated in the General Technical Specifications.
All welds on the skin plates and cylinders shall be checked by magnetic particles or dye penetrants.
Welds on cylinders shall be 100% tested, butt-welds by means radiographic examination, the other types by means of ultrasonic examination.

22.12.12.2. SITE TESTS

After being installed and before any mechanical test runs are made, all parts shall be properly lubricated, inspected and operated to check clearances and accuracy of alignment and smoothness of operation.
Moreover, the tests to be performed shall be the following:

- pressure test on assembled oil piping at 150% of the rated pressure;
- operation of all the Supply in dry conditions;
- verification of closing and opening speeds with water;
- measurement of the gate leakage.

22.12.13. MANDATORY SPARE PARTS

The Contractor shall supply the spare parts listed here below which are to be considered as a minimum requirement:

- one (1) complete set of gate seals for one radial gate;
- one (1) complete set of stoplogs seals for one stoplog element;
- four (4) guide rollers assemblies complete in all respect for service gate;
- four (4) wheel assemblies complete in all respect for maintenance gate;
- four (4) wheel assemblies complete in all respect for service gate;
- four (4) guide rollers assemblies complete in all respect for maintenance gate;
- one (1) relays of each type used;
- one (1) contactors of each size and type used;
- one (1) seal and gaskets for each type used;
- one (1) bearing of each type used;
- two (2) limit switches of each type used;
- ten (10) percent of all nuts and bolts used;
- one (1) position transducer of each type used;

- one (1) pressure switch, level switch, level indicator, temperature switch, pressure gauge, temperature gauge, etc. as needed by the pressure oil control system.

22.13. INTAKE GATES

The bidder shall provide for all the equipment as per following description suitable for the operating duties as described and as per the requirement of civil and hydro mechanical design.

22.13.1. OBJECT AND LIMITS OF THE SUPPLY

The Supply shall include the following equipment:

- two (2) service gate;
- two (2) set of embedded parts for service gates;
- two (2) maintenance gates;
- two (2) set of embedded parts for maintenance gates;
- two (2) hydraulic power units to operate the service gates;
- two (2) local control panels to control the gates;
- one (1) set of mandatory spare parts.

22.13.2. DESIGN DATA

Intake maintenance gate design data:

Type of gate:	sliding gate operated by rope drum hoist
Dimension of gate (w x h) clear opening	6.8 x 8.3 m
Number of gates	2
Elevation of gate sill	821.0 m a.s.l.
Design water level	850.0 m.a.s.l.
Pressure balancing	by-pass valve

Intake service gate design data:

Type of gate:	wheel gate operated by hydraulic cylinder
Dimension of gate (w x h) clear opening	6.8 x 8.3 m
Number of gates	2
Elevation of gate sill	821.0 m a.s.l.
Design water level	850.0 m.a.s.l.
Operation speed	0.3 m/min

22.13.3. DESIGN CRITERIA

22.13.3.1. INTAKE SERVICE GATE

Fixed wheel type gate with structural steel construction of upstream skin plate and upstream seals shall be provided in each gate. The gate shall be designed against water head corresponding to water level 850.0 m a.s.l.
The gate shall be provided with horizontal girders, vertical stiffeners, side guide roller assemblies, bumpers, wheel assemblies etc. including bottom seal, side seal and lintel sealing elements.
The gate is to be fabricated in suitable number of elements to be assembled into single gate at site. Each element comprises of 4 wheels, 2 on each side. Wheels shall be provided with spherical roller bearings, which shall be protected from water by suitable sealing arrangements having rotary sealing rings and/ or oil seals/ rings. Wheel pins shall be provided with suitable eccentricity (minimum 5mm) between centers of pins and holes in end girder plates to facilitate adjustment in wheel alignment to have proper contact with the roller path. Each unit shall have three horizontal girders. Suitable drain holes shall be provided on all horizontal girder webs and horizontal stiffeners except top most horizontal girder.
Each gate unit shall be joined together at site using splice plate and friction grip (HTFG) Bolts on skin plate, end girders and full depth stiffener plates. End girders and full depth stiffener plates of gate shall have flexible joints between them.
Two number guide rollers of each gate unit, one on each side of the gate unit shall be provided to check the side and lateral movement of the gate and to restrain the same within specified limits. The guide rollers should be adjustable (by providing shims). They shall travel on the embedded guides. The guide rollers shall be provided with self lubricating bushes on fixed pins.
The gate shall be calculated according to DIN 19704 standard considering also the seismic effect in accordance with IS: 1893. The design shall be checked for additional forces due to horizontal and vertical earthquake acceleration of 0.141g and 0.094g respectively with increased stresses.
The gates shall close by their own weight, damped by their hydraulic cylinders and required to be operated (raised or lowered) at a speed of 1.0 m/ min ±5%.

22.13.3.2. INTAKE MAINTENANCE GATE

The gates will serve for maintenance purposes only and will always be operated under balanced pressure on upstream and downstream sides; to this end a by-pass system will be provided to allow the filling of the intake. The by-pass system includes a valve integral with the gate leaf remotely controlled from the local panel of the gate. At the beginning of the gate opening procedure the by-pass valve is opened allowing the water to pass through. When the pressure on both sides of the gate is balanced, a pressure switch, included in the supply, shall give the consent for opening the gate. The maintenance gates are normally kept in open position.
The gate (mobile and fixed parts) shall be calculated according to DIN 19704 standard considering also the seismic effect in accordance with IS: 1893. The design shall be checked for additional forces due to horizontal and vertical earthquake acceleration of 0.141g and 0.094g respectively with increased stresses.

22.13.4. STRUCTURAL DETAILS

22.13.4.1. GATES

The gate body shall consist of a frame of steel structural shapes of sturdy construction supporting a skin plate placed upstream.

If for transportation the gate shall be divided into parts, such parts shall be assembled on site by welding.

A proper number of gauged bolts shall be anyway provided to ensure the correct geometrical assembly of the parts.

The skin plate shall have a minimum thickness of 10 mm. A 2 mm allowance for corrosion shall be considered in the calculation.

The lower part of the gate shall be shaped in such a way as to avoid turbulence and pressure pulsations.

The downpull effect, if any, shall not be considered in the calculation of the weight required for the gravity closure.

The connection with the stem shall be adequately strengthened.

22.13.4.2. SEALS

Seals shall be made of rubber with stainless steel clamping and adjusting bar and stainless steel or hot dip galvanized bolts.

The metal on the embedded parts shall be Stainless steel AISI 304 or AISI 316.

Appropriate welding procedures shall be adopted for welding of two different materials (stainless steel with carbon steel).

The rubber seals shall be molded rubber shapes clamped to the gate by means of steel sections and stainless steel or hot dip galvanized bolts, nuts and washers. These sections shall be adjustable and easily replaceable. Extruded seals will not be permitted.

The seals shall be made of synthetic rubber made of SBR (Styrene Butadiene Rubber) meeting the following requirements:

- Polymer Type: SBR
- Hardness Shore A 50 - 70
- Tensile strength [MPa] >21
- Elongation at break % >450
- Ozone resistance at 20 °C 25pphm 120 hr 20 % elong. no crack

For design purposes, the coefficient of friction shall be assumed in accordance to DIN 19704.

Where it is not possible to provide seals in one length, the separate component length shall be tight-butted in the workshop.

The facing ends shall be cut at right angles and dressed slightly longer than required to assure a tight joint.

After their inspection, for gates which need to be disassembled for shipment, the seals shall be match-marked with the gate before removal for packing and shipment to the Site; the seals shall be removed and packed separately.

Holes for seal bolts in the gate leaf and seal clamp bars shall be drilled in the workshop.

Adjustment of the seal shall be carried out with bolts on the downstream side of the gate.

22.13.4.3. GUIDES AND SEALING SURFACES

The gates and the stoplogs shall be provided with lateral guides to limit the sideways displacement and to prevent vibrations during operation.

The fixed parts shall start at the sill level and shall reach the elevation of the operating level.

The guides and sealing surfaces shall be smooth, true to form and free from twists, warps and kinks. The surfaces to be in contact with rubber seals shall be lined with stainless steel sheets or sections to be welded to the steel structure.

The guides shall be supplied complete with stiffening bars; anchor plates and other accessories including the plates to be embedded in the first stage concrete.

Stud bolts to be welded to the above plates during erection shall be provided with double nuts and washers for a precise alignment of the guides.

The Contractor shall provide the steel beams to be embedded in the concrete of the sill.

22.13.5. OPERATING SYSTEM

The wheel gates shall be operated by a hydraulic system with oil operated servomotors, as described hereafter.

The maintenance stoplogs shall be operated by a wire rope hoist described in a dedicated chapter.

22.13.5.1. GENERAL

The service gate shall be operated by an hydraulic cylinder.

For maintenance purposes and for emergency, it shall be possible to have full oil pressure also in the upper servomotor chamber.

The hydraulic system for the gates shall be designed to maintain the servomotor filled when the gate is held in the open position.

22.13.5.2. HYDRAULIC SERVOMOTOR

The servomotor shall consist of a hydraulic cylinder and piston rod. The servomotor cylinder and covers shall be made of cast steel or welded steel plate stress-relieved prior to final machining.

The cylinder shall be accurately bored and shall be provided with fittings for connecting oil piping, and with suitable seals or packing boxes to prevent leakage of oil along the piston rod.

The servomotor piston shall be made of cast steel or steel plate and shall be fitted with not less than two piston rings suitably shaped to give closed contact and uniform pressure to the cylinder walls and to prevent leakage of oil past the piston.

Bronze bushing shall be furnished for the piston rod to support and guide the piston.

The rod shall be coated with hard industrial chromium to minimize wear; thickness shall not be less than 0.1 mm and no more than 0.2 mm.

Oil pipe connections shall be provided with isolating valves for the maintenance activities.
The cylinder shall be provided with lifting lugs to facilitate assembly
Adjustable flow control devices shall be provided in the system to positively limit the rate of closure of the gate to the maximum rate for which it has been adjusted. The flow control device shall be mounted on the cylinder to minimize the risk should a fault develop in the piping system.
This device shall be foreseen also to slow down the closing velocity of the servomotors in the last part of the closing stroke to limit the impact on the lower sill.

22.13.5.3. PRESSURE OIL SUPPLY SYSTEM

The pressure oil supply system shall include all pumps, oil tank, piping, flexible connections, shut-off, throttle and control valves, gauges, instruments and appurtenances for the complete operation of the gates.
A high quality, anti-wear hydraulic oil shall be used in the system. The oil shall be adequate for start-up at temperature as low as 0°C and have a viscosity grade at 40°C not greater than 32 Cst.

Oil Pumps: Two self-priming oil pumps shall be provided for each gate, one for normal operation and the other as an automatic stand-by. Each of them shall have a capacity to open the gate at the nominal speed.
Each pump shall be equipped with a fully automatic starting device to ensure the no-load pump starting and to load the pump only when rated speed has been reached.
Provisions shall be made to allow the complete disconnection of either pump from the system for maintenance purpose without compromising the system operation.
Each pump shall be equipped with check valve, outlet valve, safety valve and all other accessories necessary for fully reliable operation.
The feeding and discharge lines for the servomotors shall start from a common manifold and each shall be provided with an electro valve so that the servomotor of the gate can be controlled by means of push-buttons.
Adequate flow regulating devices shall be provided on the servomotors in order to guarantee that the gate closing speed will not be excessive in case of any pipe failure.

Oil Sump Tank: the oil sump tank shall be one for each gate. The oil sump tanks shall be made of welded steel plates, duly stiffened with steel sections if necessary.
Its capacity shall be at least 70% greater than the maximum net variation in volume under worst operating conditions, and not less than the 11% of the complete oil circuit volume and able to contain the oil of one cylinder out of two. The most strict of the above requirements shall be applied.
All oil drainage, leakage and/or exhaust pipes, shall be conveyed to the oil sump tank.
The oil tank shall be equipped with manhole, level indicator, filtered air vent, connection for filling and draining, magnetic filters and with plugs for the connection with a portable oil purifier included in the Supply.
The Supply shall include the oil for washing and first filling.

22.13.5.4. CONTROLS

The Contractor shall provide local control panels in accordance with the General Technical Specification. Intelligent Electronic Devices (IED) such as PLC may also be provided to control the equipment operation and record the relevant data.

The control panels shall house all switches, push-buttons, lamps, indicators, alarms and all others necessary equipment for the local control and operation of the gates. The panels shall also house the terminal boards for the remote control signals.

Manual operation of the solenoid valves for the gates closing shall also be provided.

The gates shall be provided with limit switches signaling the full open and full closed position and with an easily visible measuring stick, to show on a scale, the gate position.

22.13.6. ELECTRICAL EQUIPMENT

The gates shall be complete with all electrical equipment necessary for its operation.

All the electrical equipment shall be mounted on control boards (one or more boards depending on the location of the equipment to be fed), whose door shall be provided with lock and key.

Gate alarms shall be fed at 220 V DC.

All external connections to the pumping unit shall be by standard conduits. Wiring to the motor and valves shall be enclosed in oil resistant liquid tight metal conduits.

Limit switches shall be of the heavy-duty type suited for outdoor installation. All limit switches shall be mounted above operating level.

Limit switches will have at least one make and one break contact. All the limit switches shall operate at 220V DC ±20%, unless otherwise specified.

They shall withstand at least 1,000 switching cycles per hour, under rated current conditions.

Their breaking capacity shall be 2A and making capacity shall be 10A, the current carrying capacity shall be 4A. The contacts shall be made of solid silver or of special alloy.

22.13.7. MAINTENANCE

The design of the gates shall permit easy replacement of the seals.

The Contractor shall provide all the accessories needed for the disassembling as well as the maintenance devices to enable the gate maintenance. The Contractor shall also provide any anchoring bolts and plates to fix the parts into concrete.

22.13.8. FITTINGS AND ACCESSORIES

a) Oil Pressure Gauges

Each oil pump shall be provided with a pressure gauge with an adjustable electric contact signaling abnormal pressure during gate opening.

In correspondence to any pressure gauge, a pressure tap shall be provided to allow the pressure check by means of an external manometer.

b) Chequered Plates

The Contractor shall supply galvanized chequered plates to cover the cables and piping ducts and the relevant galvanized supporting angles to be embedded in the concrete.

22.13.9. TOLERANCES

The contacting sealing surfaces of the side and top seals, when assembled on the finished gate, shall not depart more than 1 mm from a plane surface that is parallel to the sliding surfaces of the gate. The planes of the guide plates shall be true within ± 1 mm.

The gates tolerance shall be ± 5 mm in width and ± 8 mm in height.

The water leakage of the gate seals shall not exceed the following values:

Gates 1.2 l/min for each meter of seal.

22.13.10. TESTS

22.13.10.1. FACTORY TESTS

Tests on Materials

All materials shall be submitted to mechanical tests according to the applicable Standards.

Material test certificates relevant to all the main components of the structure (e.g. skin plates, main girders, tracks, hydraulic cylinders, rods, flanges, etc.) and of other minor components as required by the Contractor shall be provided.

All commercial sub-assemblies such as electric motors, gear boxes, pumps, valves, etc. shall be of approved manufactures and the relevant factory test certificates shall be provided.

Dimensional Controls and Hydraulic Tests

The gates, the servomotors and the hydraulic pumping sets with cabinet and such other equipment shall be shop assembled for inspection and tests.

All assembled equipment shall be checked or tested for dimensional and alignment accuracy, tolerance, operation, fit and travel, and to control that the requirements of the Specifications have been met. Any error or omission discovered shall be corrected.

Gate seals shall be tested for fit but not workshop-assembled.

The Contractor shall furnish two samples of the rubber seals, each not less than one meter long and cut the molded seals at random form and shall test them to demonstrate that they meet the requirements under load.

The hydraulic servomotors shall be tested at a pressure of 150% of maximum operating pressure with oil for thirty minutes. All servomotors shall also be operated under maximum operating load over their full travel.

No leakages shall be allowed through the stem and piston packing.

Operation of the limit switches shall be verified during these tests.

The hydraulic pumping units shall be included in the test. The systems shall be filled with hydraulic oil, thoroughly vented, and tested to full design relief pressure. All fittings, joints, piping and accessories shall remain tight under test.

After shop-assembly, the gates and hydraulic servomotors with adequate matchmarks (if required) shall be disassembled into major units. Control panels shall be shipped completely assembled, except for those fragile components that will require separate packing.

Tests on Electrical Equipment

Motors and panels completely assembled shall be tested according to IEC Standards. For electric motors the torque values as well as the speed and the starting current values shall be measured.

The controls of the oil pumping set completely wired shall be checked in order to ascertain their correct functioning.

A complete list of all tests to be performed shall be anyway detailed in the Quality Control Plan.

Tests on Welding

At least 20% of the major welds shall be examined with ultrasonic or radiographic examination according to the procedure indicated in the General Technical Specifications.

All welds on the skin plates and cylinders shall be checked by magnetic particles or dye penetrants.

Welds on cylinders shall be 100% tested, butt-welds by means radiographic examination, the other types by means of ultrasonic examination.

22.13.10.2. SITE TESTS

After being installed and before any mechanical test runs are made, all parts shall be properly lubricated, inspected and operated to check clearances and accuracy of alignment and smoothness of operation.

Moreover, the tests to be performed shall be the following:

- pressure test on assembled oil piping at 150% of the rated pressure;
- operation of all the Supply in dry conditions;
- verification of closing and opening speeds with water;
- measurement of the gate leakage.

22.13.11. MANDATORY SPARE PARTS

The Contractor shall supply the spare parts listed here below which are to be considered as a minimum requirement:

- one (1) complete set of seals for sliding gate;
- one (1) complete set of seals for wheel gate;
- four (4) wheel assemblies complete in all respect;
- four (4) guide rollers assemblies complete in all respect for service gate;
- four (4) guide rollers assemblies complete in all respect for maintenance gate;
- one (1) relays of each type used;

- one (1) contactors of each size and type used;
- one (1) seal and gaskets for each type used;
- one (1) bearing of each type used;
- two (2) limit switches of each type used;
- ten (10) percent of all nuts and bolts used;
  - one (1) position transducer of each type used;
  - one (1) pressure switch, level switch, level indicator, temperature switch, pressure gauge, temperature gauge, etc. as needed by the pressure oil control system;
  - minor items to ensure the operation for five years from the Installation.

22.14. INTAKE TRASHRACK AND TRCM

The bidder shall provide for all the equipment as per following description suitable for the operating duties as described and as per the requirement of civil and hydro mechanical design.

22.14.1. OBJECT AND LIMITS OF THE SUPPLY

The Supply shall include the following equipment:

- eight (8) sets of trashrack;
- eight (8) guides for trashrack;
- one (1) trashrack cleaning machine (TRCM) complete with, control cabin, hydraulic grabbing arm, auxiliary hoist for installation, rails and debris collecting equipment;
- spare parts.

22.14.2. DESIGN DATA

Trashrack design data:

Type of trashrack:	removable steel trashrack
Sill elevation	818 m a.s.l.
Design water level	850.0 m.a.s.l.
Number of bays	8
Number of panels	256
Number of panels for each bays	32
Panel dimensions (w x h)	3 x 2.2 m
Materials	IS 226, S235 (or equivalent)
Angle respect to the vertical	10°
Clear bar spacing	75 mm (*)

Maximum deflection	1/800
Unbalanced design head	6.0 mwc
Maximum water velocity	0.8 m/s
Corrosion allowance	1.0 mm

(*) to be confirmed by the Contractor during L1 design

TRCM design data:

Type of TRCM:	movable wire rope TRCM with, auxiliary hoist and hydraulic jib crane with wood gripper
Elevation of rails	853 m a.s.l.
Number of TRCM	1
Operating range	~ 35m
Rails length	~ 56m
Rake width	3 m
Lifting and lowering speed of the rake	approx. 10 m/min
Machine travel speed	8 m/min
Rotation angle	max 270°
Rake capacity	1000 kg
Rake operation	by hydraulic servomotors

22.14.3. DESIGN CRITERIA

22.14.3.1. TRASHRACK

All trashracks panels and metal works of the same design shall be interchangeable.
The trashracks shall be exempt from vibrations that may cause resonance during all operating conditions and shall be sufficiently sturdy to limit as much as possible any deformation.
Each panel shall be completely fabricated and shipped ready for erection. The trash rack assembly shall be designed to ensure minimum head losses at the given design parameters.
Moreover, under uniformly distributed load, the maximum admissible deflection of each panel shall not exceed 1/800 of the maximum distance between supports.
Unless otherwise specified, the following normal loading conditions of the trash rack shall be considered:

- Temporary loads during handling, transport, assembly and erection, for which no permanent deformations and detrimental stresses shall occur.
- Uniform load (differential water head) to be applied to the entire developed area of trash rack panels is limited to 6 m wc.

The design of the panels shall also take into account the impact of a submerged log weighing 10kN moving with a velocity of 1m/s hitting a circular section of 0.5m diameter.
Consistent with transportation and erection needs, the assembly shall be carried out, as much as possible, in the manufacturer's workshop so as to minimize site works. No main site welded connections are allowed.
Special attention shall be paid to the problems of flow – induced vibration and fatigue in the design of the trash racks. The average flow velocities shall be calculated for flow conditions across the effective trash rack area. The design of the trash rack shall assure safety against rack bar resonance and developing vibrations of harmful magnitudes. The natural frequency of the rack bars in water shall be of at least 2 times higher than the vortex shedding frequency for unobstructed trash racks.
The trash rack panels and embedded parts shall be calculated according to the DIN 19704 considering also the seismic effect in accordance with IS: 1893. The design shall be checked for additional forces due to horizontal and vertical earthquake acceleration of 0.141g and 0.094g respectively with increased stresses.

22.14.3.2. TRCM

The rack cleaning machine shall be able to move along the intake and the rake shall move from the operating elevation to the lower part of the trashracks. Limit switches and bumpers shall be provided at the two extremities of the traverse movement.
Cleaning cycle shall be operated by a push button placed on the control panel inside the operator's cab. The operator shall be able to limit the vertical run of the rake to a desired height.
The cleaning cycle shall be either initiated manually, by an operator, or automatically after a signal of excessive head losses. A selector switch inside the operator's cab will select which one of the cleaning modes is active.
For each cleaning cycle, the rack cleaning machine shall remove debris from the entire trashracks, performing the number of passes necessary to sweep the entire sluices surfaces and then discharge the trash after each pass.
The rack cleaning machine shall be design taking into account in addition to the loads due to normal operation, the wind and seismic effects according to the General Technical Specifications and the shock against fixed bumpers.
Consistent with transportation and erection needs, the assembly shall be carried out, as much as possible, in the manufacturer's workshop, so as to minimize site works. No main site welded connections are allowed.

22.14.4. STRUCTURAL DETAILS

22.14.4.1. TRASHRACK

Frames

The frames shall be made of steel sections. The frames of the intake trashracks shall be welded by means of stiffeners and bars to the first stage concrete reinforcing rods. The design shall be such as to provide means of sufficient adjustment in any direction.
The frames shall be supplied complete with stiffeners, bars, anchor plates and other accessories, also in order to avoid undue vibration in the structure.

Trashracks Panels

The minimum thickness of the trash rack bars shall be 8 mm. A 1 mm allowance for corrosion shall be considered in the calculation.

Each panel shall be completely fabricated and shipped ready for erection.

Each panel shall be provided with dowels and holes in which the dowels will fit in order to maintain a proper alignment of the rack bars.

The cross-section of the supporting beams (if any) shall be hydraulically shaped in order to obtain minimum head losses and to avoid vortex shedding.

The assembled trashracks panel shall be square and free from warpage. The overall dimensions shall not vary by more than 2 mm from the rated.

The rack bars of each panel shall be straight and parallel to each other and the spacing between them shall not differ by more than 1 mm at any point from the rated value.

The static calculation of the panels shall take into account, in addition to the uniformly distributed hydraulic load, the load transmitted by the trashrack rake in the most unfavorable position.

22.14.4.2. TRCM

The cleaning machine shall be of the type called with integral rubbish hopper and shall consist of a wheeled platform truck, traveling on rails and equipped with hydraulic servomotors or electric operated hoists driving the rake dolly. The dolly shall run vertically from the footbridge level to the trashrack sill. Embedded in concrete lateral guides shall be provided to allow the smooth travel of the dolly, if necessary.

A steel container with a capacity sufficient to store all the debris collected during a full cleaning cycle shall be embedded inside the machine frame. The container shall have an hydraulic operated clam type opening on the bottom, which allow the discharge of the rubbish into a large concrete lined pit located at left side of the Intake.

The truck of the rack cleaning machine shall be driven by electric motors.

In all working conditions the motion shall be uniform without jolts or vibrations.

The truck of the intake rack cleaning machine structure shall house the control cab and all the necessary equipment for the racking device.

The TRCM shall be equipped with an auxiliary hoist of 5ton for operation of the trashrack panels.

In addition the TRCM shall be equipped with hydraulic jib crane with wood gripper and rotator of adequate capacity.

<u>Hoist</u>

The rack cleaning machine shall be provided with two main hoists, mounted on the same truck framework to be used for the lifting and lowering of the rake and for opening and closing of the comb. The perfect synchronization of movements in all conditions shall be ensured by suitable devices.

The general arrangement of the hoist and hook sheaves shall be such as to limit maximum rope flexion, in order to reduce side wear on the sheaves and rope. The revving on the hoist drums shall be such as to allow the hooks to travel vertically without twisting or tilting.

Raking device

The raking device shall consist of a rake dolly and its opening and closing mechanisms.

The dolly shall be made of a sturdy structure of welded steel sheet and structural shape and shall have a capacity of at least 1.5 m3, and a lifting capacity of at least 1,000 kg.

The dolly shall be operated by the hoisting ropes in two points symmetrically disposed.

Operating sequence and mechanism

The rake cycle is started manually or automatically in case of head losses increase or periodically to keep the trashrack clean.

The maneuver sequences shall be the following:

- lowering of open rake;
- rake stopping at the end of the lowering travel or at a predetermined elevation;
- rake closing;
- lifting.

When the rake has been lifted up to the end of the lifting travel, it shall deposit the trash into the hopper.

After cleaning a trashrack and unloading the trash into the hopper, the operator or the automatism shall shift the rack cleaning machine and restart the cycle until all the trashrack panels have been cleaned. The final step of the cycle is the discharge of the rubbish into the concrete pit.

The rake movement shall be protected by suitable safety devices against:

a) closing lack of the rake due to bulky solid debris;
b) loosening of moving ropes during the rake lowering;
c) excessive rope tension during the lifting phase;

The operating sequence of the trashrack-rake shall be checked by the following contacts:

- traveling limit switch;
- lowering limit switch;
- lifting limit switch;
- rake closing limit switch;
- hopper discharged.

Rails

The rails, heavy web type, shall be supplied for the full length of the intake trashrack, designed and completed with base plate and accessories for fastening and jointing.

The Supply shall include all the accessories embedded in the concrete.

22.14.5. ELECTRICAL EQUIPMENT

22.14.5.1. GENERAL

The rack cleaning machine shall be supplied complete with all electrical equipment weather-proof type necessary for its operation.
All live elements shall be totally insulated or protected in order to prevent any accidental contact.
As the rack cleaning machine is installed outdoor, all the electrical equipment shall be designed for outdoor operation.

22.14.5.2. MOTORS AND RESISTORS

All motors shall be totally enclosed, self-cooled, polyphase induction type, designed for rack cleaning machine and hoist service. All motors shall be wound rotor type.
All motors shall be designed for intermittent service, with an intermittence ratio of 40% referred to 120 maneuvers per hour. Motors shall be equipped with anti-friction bearings and enclosed terminal boxes.
All motors shall be mounted on machined bases, shimmed to correct alignment and secured in a manner as to avoid shear in holding bolts.

22.14.5.3. GROUNDING

All metal parts of the rack cleaning machine and accessories shall be electrically interconnected so that all the equipment can be grounded when installed. Bolted connections with parts in metal to metal contact and moving components with contact surfaces of metal, with no intervening insulating material between the contact surfaces including rails, wheels and bearings may be considered satisfactorily interconnected.

22.14.5.4. SAFETY DEVICES

The Supply shall include automatic load limiting devices which shall prevent lifting of loads greater than the maximum ones.
The limiting shall be adjustable between 80% and 110% of the rated load. The limiting actuation shall not prevent the operator from lowering the load which he attempted to raise.

22.14.5.5. DIFFERENTIAL PRESSURE MEASUREMENT

The system shall check the differential pressure across the trashracks for the automatic operation of the rack cleaning machine.
Two pressure or level sensors, including each one its own pressure transducer, shall feed a differential balance foreseen in the measurement device.
The device shall include one settable alarm threshold.

22.14.6. MAINTENANCE

The design of the TR and TRCM shall permit easy access for maintenance operations.
The Contractor shall provide all the accessories needed for the disassembling as well as the maintenance devices to enable the maintenance.

22.14.7. TESTS

22.14.7.1. FACTORY TESTS

Tests on Materials

All materials shall be submitted to mechanical tests according to the applicable Standards.

Material test certificates relevant to all the main components of the structure and of other minor components as required by the Contractor shall be provided.

All commercial sub-assemblies such as electric motors, gear boxes, pumps, valves, etc. shall be of approved manufactures and the relevant factory test certificates shall be provided.

Dimensional Controls and Hydraulic Tests

The trashrack, the servomotors and the hydraulic pumping sets with cabinet and such other equipment shall be shop assembled for inspection and tests.

All assembled equipment shall be checked or tested for dimensional and alignment accuracy, tolerance, operation, fit and travel, and to control that the requirements of the Specifications have been met. Any error or omission discovered shall be corrected.

The hydraulic servomotors shall be tested at a pressure of 150% of maximum operating pressure with oil for thirty minutes. All servomotors shall also be operated under maximum operating load over their full travel.

No leakages shall be allowed through the stem and piston packing.

Operation of the limit switches shall be verified during these tests.

The hydraulic pumping units shall be included in the test. The systems shall be filled with hydraulic oil, thoroughly vented, and tested to full design relief pressure. All fittings, joints, piping and accessories shall remain tight under test.

Tests on Welding

At least 20% of the major welds shall be examined with ultrasonic or radiographic examination according to the procedure indicated in the General Technical Specifications.

All welds on the bars and cylinders shall be checked by magnetic particles or dye penetrants.

Welds on cylinders shall be 100% tested, butt-welds by means radiographic examination, the other types by means of ultrasonic examination.

Tests on Brakes

On the brakes, tests shall be carried out to prove that the breaking capacity and operation is in accordance with the required capacity.

Tests on Electrical Equipment

Motors and panels completely assembled shall be tested according to IEC Standards. For electric motors the torque values as well as the speed and the starting current values shall be measured.

The controls of the oil pumping set completely wired shall be checked in order to ascertain their correct functioning.

A complete list of all tests to be performed shall be anyway detailed in the Quality Control Plan.

Pre-Erection and Operating Tests

The rack cleaning machine will be completely pre-assembled in the workshop and placed on provisional rails.

Complete operating no-load tests, including lifting and checking of all accessories correct functioning shall be carried out.

22.14.7.2. SITE TESTS

Final checking at site after erection and painting shall carried out.

Field no-load Tests

Before any mechanical test runs are made, all parts shall be properly lubricated, and a thorough inspection made on all mechanical and structural connections.

The tests shall include but not necessarily be limited to the those described hereinafter:

- the rack cleaning machine after being installed and completely wired shall be inspected and operated on the runway to check clearances and accuracy of alignment and tracking on the runway rails;
- all motions of the completely assembled rack cleaning machine shall be thoroughly and completely observed for freedom of operation and from internal mechanical interference, proper alignment of all running parts and freedom from vibrations;
- electrical continuity of all circuits and servicing of all points requiring lubrication shall be inspected.

Field Load Tests

Before starting the load tests, the rack cleaning machine shall be operated under light loads for at least four hours actual operating time, in order to run-in the gearing and to ensure lubrication. After his run-in period, the rack cleaning machine shall be inspected to determine that all parts have remained in correct alignment and no indications of excessive wear can be detected. Adjustments shall be made, if necessary.

The following load tests shall be performed:

- with rated load, all the traveling and hoisting speeds and all minimum incremental movements shall be measured and the correct functioning of all the driving, control and safety devices shall be rechecked.

Following the completion of tests, the racking cleaning machine shall be checked for alignment, damage or indication of excessive wear and the rake load limiter device shall be adjusted for 110 percent of the rated load.

22.14.8. MANDATORY SPARE PARTS

The Contractor shall supply the spare parts listed here below which are to be considered as a minimum requirement:

- one (1) elementary piece of trashrack;
- ten (10) percent of bolts and nuts of each type used;
- one (1) complete set of bearings (including bearings for motors);

- one (1) complete set of brake shoes;
- one (1) complete set of grease seals;
- one (1) set of fittings, seals, packings;
- one (1) limit switch of each type;
- three (3) push-buttons for each type used;
- two (2) complete sets of motor brushes;
- one (1) contactor of each size and type;
- one (1) resistor of each size and type;
- two (2) complete sets of fuses;
- one (1) relay of each size and type;
- one (1) printed circuit of each size and type, if any;
- one (1) complete set of lamps.

22.15. CRANES

The bidder shall provide for all the equipment as per following description suitable for the operating duties as described and as per the requirement of civil and hydro mechanical design.

22.15.1. OBJECT AND LIMITS OF THE SUPPLY

The supply shall include the following equipment:

- one (1) spillway gantry travelling crane;
- two (2) intake fixed wire rope electric hoist;
- one (1) set of mandatory spare parts.

22.15.2. DESIGN DATA

Spillway gantry crane design data:

Number of main hoist:	1
Hoist capacity	approx. 50 t (*)
Elevation of rails	853.0 m a.s.l.
Minimum hook lift	app. 40 m
Length of rails	130 m
Feed	through cables
Control	by control cabin

(*) indicative only, to be confirmed by the Contractor

Intake fixed wire rope hoist design data:

Number of hoists:	2
Hoist capacity	approx. 75t (*)
Gantry crane basement elevation	853.0 m a.s.l.
Minimum hook lift	app. 40 m
Feed	through cables
Control	by control panel

(*) indicative only, to be confirmed by the Contractor

22.15.3. DESIGN CRITERIA

22.15.3.1. SPILLWAY GANTRY CRANE

The spillway gantry crane will be used for erection, operation and maintenance of the spillway and auxiliary spillway stoplogs.

The design shall be according to IS 3177.

Consistent with transportation and erection needs, the assembly shall be carried out, as much as possible, in the manufacture's workshop, so as to minimize site works. No main site welded connections are allowed.

The cranes shall be suitable for outdoor operation.

The crane shall be provided with one main hoist, mounted on the top of the gantry.

The hoisting equipment shall be designed in accordance with IS: 6938.

The hoist capacity shall be calculated considering the worst combination of all friction forces, hydrodynamic loads, dead weights, etc., during both raising and lowering cycles, with a 20% reserve over the worst-case forces. Positive closure of the gate under designed weight shall be ensured, with seating force exceeding 25% of opposing forces.

The motor's breakdown torque shall be not less than 225% of full load torque.

Rotary-type double-acting limit switches shall automatically stop the drive motor at either end of travel. Protective devices shall automatically brake the hoist in case of power failure, and upon power resumption, operation can restart using open or close push buttons. Provision shall be made for lubricating all bearings and bushes, accessible from the hoist working platform.

The general arrangement of the hoist and hook sheaves shall limit maximum rope flexion to reduce side wear on ropes and sheaves. Reeving on the hoist drums shall ensure hooks travel vertically without twisting or tilting.

<u>Rails</u>

The rails, heavy web type, specifically intended for crane service, shall be supplied for the full length of the crane travel, designed and completed with base plate and accessories for fastening and jointing.

The Supply shall include all the accessories embedded in the concrete and stoppers for both ends.

<u>Push-Button Box</u>

A pendant push-button box shall be provided. The box shall be provided with a disconnecting switch, key-operated, and a "stop" button acting on the main contactor coil.

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Each movement shall have an individual command; each motion shall be controlled by an independent spring return button, "dead man" type.
The push-button box shall be hanging from the crane through a cable, and the cable length shall be such that the crane can be easily operated.

Feeding System

At the end of the crane runway provision shall be taken to allow the connection with the power supply to feed the crane. The crane shall be fed through a main feed line disconnecting switch installed at one end of the crane runway equipped on the three phases, with thermal relays of adequate adjusting range and with high interrupting capacity fuses, current limiting type.
An undervoltage relay shall also be provided on the feeding line. It shall not be possible to energize the main contactor coil if the undervoltage relay has operated.
Cables from the main feeding line disconnecting switch and relevant accessories shall be included in the Supply.
They shall be mainly constituted by four copper strand conductors, synthetic rubber insulated cables, which shall be wound on a fully automatic, electric motor driven drum.
The cables shall be of extra flexible type, 4 kV insulation class, suitable for carrying continuously not less than 125% of the full load current (motors plus lights). The cables shall be supplied complete with the terminal block to be installed in the point indicated in the Drawings or to be approved by the Contractor.
The cables length shall be sufficient for the complete travel of the crane.

22.15.3.2. INTAKE WIRE ROPE FIXED HOIST

The hoisting equipment shall be designed in accordance with IS: 6938.
The hoist capacity shall be calculated considering the worst combination of all friction forces, hydrodynamic loads, dead weights, etc., during both raising and lowering cycles, with a 20% reserve over the worst-case forces. Positive closure of the gate under designed weight shall be ensured, with seating force exceeding 25% of opposing forces. The motor's breakdown torque shall be not less than 225% of full load torque.
Rotary-type double-acting limit switches shall automatically stop the drive motor at either end of gate travel. Protective devices shall automatically brake the hoist in case of power failure, and upon power resumption, operation can restart using open or close push buttons. Provision shall be made for lubricating all bearings and bushes, accessible from the hoist working platform.
The general arrangement of the hoist and hook sheaves shall limit maximum rope flexion to reduce side wear on ropes and sheaves. Reeving on the hoist drums shall ensure hooks travel vertically without twisting or tilting. Additional provisions shall include ladders, walkways, lighting, chequered plates or gratings, guard railings, and other necessary safety arrangements on the hoist platform.

Supporting structures

Two number common hoist supporting structure, accommodating two numbers rope drum hoists shall be provided. The hoist machinery for gates shall be mounted on a structural steel hoist platform over structural steel columns. Individual steel ladder shall be provided to approach the hoists. The hoist bridge shall be fabricated of structural steel members adequately braced and stiffened. This shall be securely attached to the structural steel column. The mounting of hoist platform with the structural steel column should have one end fixed and one end free to take care of any thermal expansion/contraction of the platform.

Hoist bridge and its supporting structure shall be designed for the worst combination of the forces encountered during any of the operations on the gates. Besides dead weight of machinery, guard railing, load due to hoisting of gate, a crowd load of (500 kg per sq. meter) wind load, seismic load etc. shall also be considered for the design of Hoist Bridge and trestles. Hoist bridge and trestles shall be designed in accordance with the provision of IS: 800.

All structural parts and hoisting equipment shall also have sufficient strength to resist the forces produced by the actual breakdown torque of the motors and stresses so developed shall not exceed 80% of yield point stress of the materials.

22.15.4. ELECTRICAL EQUIPMENT

The crane and the hoists shall be supplied complete with all electrical equipment necessary for its operation.

All live elements shall be totally insulated or protected in order to prevent any accidental contact.

All the electrical equipment shall be designed for outdoor operation.

Motors and Resistors

All motors shall be totally enclosed, self-cooled, polyphase induction type, designed for crane and hoist service. All motors shall be wound rotor type.

All motors shall be designed for intermittent service, with an intermittence ratio of 40% referred to 120 maneuvers per hour. Motors shall be equipped with anti-friction bearings and enclosed terminal boxes.

All motors shall be mounted on machined bases, shimmed to correct alignment and secured in a manner as to avoid shear in holding bolts. Motors of same characteristics shall be interchangeable and shall be mounted in such a manner that they can be removed while the load is being held by the hoist brake.

Limit Switches

The hoist shall be provided with a geared or screwed type limit switch which shall open the power circuit of the corresponding motor before the hook block exceeds either upper or lower limit of travel.

In addition, a block operated limit switch shall be provided on the hoist to prevent the hook being raised above the highest safe position. This switch shall switch-off the circuit and the reset shall be manual. A limit switch for the by-pass position shall also be provided as well as limit switches on the crane travel.

Grounding

All metal parts of the cranes and accessories shall be electrically interconnected so that all the equipment can be grounded when installed. Bolted connections with parts in metal to metal contact and moving components with

contact surfaces of metal, with no intervening insulating material between the contact surfaces including rails, wheels and bearings may be considered satisfactorily interconnected.

Safety Devices

The Supply shall include automatic load limiter devices which shall prevent lifting of loads greater than the present maximum ones.

The limiter shall be adjustable between 80 percent and 110 percent of the rated load. The limiter actuation shall not prevent the operator from lowering the load which he attempted to raise.

22.15.5. MAINTENANCE

The Contractor shall provide all the accessories needed for the disassembling as well as the maintenance devices to enable the maintenance. The Contractor shall also provide any anchoring bolts and plates to fix the parts into concrete.

22.15.6. TESTS

22.15.6.1. FACTORY TESTS

Tests on Materials

The following test certificates shall be provided by the material suppliers

- hardness and tensile stress tests according to the Standards, on samples of hooks and steel sections of the main girders of the crane (one sample of each delivery);
- 0° C resilience test on samples of hooks and steel sections of the main girders of the crane (one sample of each delivery);
- ropes shall be tested for yield point and ultimate breaking strength;
- magnetic particles (magnaflux) inspections on all major steel and cast iron castings and all major steel forgings (including hooks);
- ultrasonic tests on hook materials.

Tests on Electrical Equipment

Tests as detailed in the IEC Standards will be carried out on electrical apparatus and motors, control panel and cabinets.

For the hoist motors, the values of the starting and rated torque will be measured; manufacturer's test certificates will be acceptable.

A complete list of all tests to be performed shall be anyway detailed in the Quality Control Plan.

Tests on Brakes:

Tests shall be carried out on the brakes to prove that the braking capacity and operation is in accordance with the required capacity.

Tests on Welding:

At least 10 percent of all welds shall be examined with ultrasonic or radiographic examination according to the procedure indicated in the General Technical Specification, and as instructed by the Contractor.

All welds shall be checked with magnetic particles or dye penetrant.

Pre-Erection and Operating Tests:

The crane will be completely pre-assembled in the workshop. The crane shall be assembled on provisional rails placed on the ground and the hoist, with all its equipment, placed on the crane.

Complete operating no-load tests, including lifting and checking for correct functioning of all accessories shall be carried out.

22.15.6.2. SITE TESTS

Site no-load Tests

Before any mechanical test runs are made, all parts shall be properly lubricated, and a thorough inspection made on all mechanical and structural connections.

The tests shall include but not necessarily be limited to the those described hereinafter:

- the crane, after being installed and completely wired, shall be inspected and operated on the runway to check clearances and accuracy of alignment and tracking on the runway rails;
- the hoist shall be reeved, observing proper care in handling wire ropes, to prevent damage thereto. Once reeved, the hoist shall be operated several times through its full travel, without load on the hook block to check operation on the machinery and controls and adjustments of limit switches;
- all motions of the completely assembled crane shall be thoroughly and completely observed for freedom of operation and from internal mechanical interference, proper alignment of all running parts and freedom from vibrations;
- electrical continuity of all circuits and servicing of all points requiring lubrication shall be inspected.

Site Load Tests

After the lubricant levels have been checked, the following load tests shall be performed:

- hook static tests with capacity 140% of rated load and dynamic tests with load 110% of the rated capacity;
- after unloading, the residual (inelastic) deformations to be measured on all the main girders shall be nil;
- with rated load, all the traveling and hoisting speeds and all minimum incremental movements shall be measured and the correct functioning of all the driving, control and safety devices shall be rechecked.

Following the completion of tests, the crane shall be checked for alignment, damage or indication of excessive wear and the hook load limiter device shall be adjusted for 110% of the rated load.

22.15.7. MANDATORY SPARE PARTS

The Contractor shall supply the spare parts listed here below which are to be considered as a minimum requirement:

- one (1) complete set of hoisting ropes;
- one (1) bearing (including bearings for motors) of each type used;

- one (1) brake shoe of each type used;
- one (1) grease seal of each type used;
- one (1) set of fittings, seals, packings (one piece of each type used);
- one (1) limit switch, of each type;
- three (3) push-buttons for each type used;
- two (2) motor brushes of each type used;
- one (1) contactor of each size and type;
- one (1) resistor of each size and type;
- two (2) complete sets of fuses;
- one (1) relay of each size and type;
- one (1) printed circuit of each size and type, if any;
- one (1) complete set of lamps;
- minor items to ensure the operation for five years from the Installation

22.16. DATA SHEETS

Technical Data sheets represent technical questionnaire to be furnished in filled up form with the tender. The data under sub head “Guaranteed data” will form an integral part of the contract and will be reviewed for evaluation and is a confirmation of the bidder having agreed to abide by this data during execution. The data under sub head “Technical data“ will not form an integral part of the contract but will be only informative in nature and may be used by owner to see that it meets in general the requirements of specification. This data will not in any way prejudice or over rule the requirements of the specifications and shall be purely tentative to be finalized during detailed design.

The Tenderer is, therefore, requested to read these Data Sheets with care and to complete them most conscientiously and with every necessary detail.

22.17. MEASUREMENTS AND PAYMENTS

The payment for the hydromechanical works under Items A22, listed in the Bill of Quantity, shall be made on the basis specified in the Bill of Quantities, i.e. per set installed or per number installed, as applicable to each item.

The unit rates and prices entered in the Bill of Quantities shall be deemed to include:

- fabrication design (shop drawings), procurement, fabrication/manufacturing, inspection, shop assembly, shop testing, painting and supply including all necessary spares
- transportation from the fabrication shop to site including insurance
- site assembly, erection/installation, field painting, testing and commissioning of the complete equipment, all in accordance with the Specifications and Drawings.

No separate payment shall be made for any component, activity or service not specifically measured and listed in the Bill of Quantity, and the quoted rates shall be considered full compensation for completing the works in all respects as specified.

The steel liner at Spillway glacis, Piers and Breat Walls for Spillway shall be measured and paid for on the basis of the weight, in kg, of steel installed, at the corresponding Unit Price entered in the Bill of Quantities. Separate payment items shall also apply for transportation and assembly activities, as specified in the Bill of Quantities.

Measurement and payment for the Environmental Flow Release System as described in these specifications shall be based on the lump sum price quoted by the Contractor and shall be paid after successful commissioning of the system as a whole, including all accessories and ancillary equipment required for a complete and operational Environmental Flow Release System.

III. TECHNICAL DATA SHEET

22.18. GUARANTEED DATA

The Bidder shall fill all the following list of Guaranteed Data. The following Guaranteed Data shall conform to the functional performances and technical characteristics requested in the Technical Specifications and, when accepted by the Employer, shall prevail over the Technical Specifications.

22.18.1. GATES

Please consider as reference the bottom sill level of each gate equal to +0 m a.s.l.

22.18.1.1. INTAKE

22.18.1.2. SERVICE FIXED WHEEL GATE

Maximum leakage with max operating level	l/min	_____
Rated / Maximum oil pressure	KPa	_____
Rated Capacity of electric motors for oil pumps	kVA	_____
Minimum opening speed	m/min	_____
Normal opening speed	m/min	_____

22.18.1.3. MAINTENANCE SLIDING GATE

Maximum leakage with max operating level	l/min	_____

22.18.1.4. SPILLWAY

22.18.1.5. RADIAL GATE

Maximum leakage with max operating level	l/min	_____
Rated / Maximum oil pressure	KPa	_____
Rated Capacity of electric motors for oil pumps	kVA	_____
Minimum opening speed	m/min	_____
Normal opening speed	m/min	_____

22.18.1.6. AUXILIARY SPILLWAY

22.18.1.7. SERVICE FIXED WHEEL GATE

Maximum leakage with max operating level	l/min	_____
Rated / Maximum oil pressure	KPa	_____
Rated Capacity of electric motors for oil pumps	kVA	_____
Minimum opening speed	m/min	_____
Normal opening speed	m/min	_____

22.18.2. STOPLOGS

22.18.2.1. SPILLWAY

Maximum leakage with max operating level	l/min	_____

22.18.2.2. AUXILIARY SPILLWAY

Maximum leakage with max operating level	l/min	_____

22.18.3. TRASHRACK AND TRCM

22.18.3.1. INTAKE TRASHRACK

Max head losses with maximum flow	Pa	_____
Max distance between two consecutive bars	mm	_____
Min bars section	mm^2	_____

22.18.3.2. INTAKE TRCM

Rake lifting and lowering speed(s)	m/min	_____
Machine traverse speed	m/s	_____
Rated capacity of rake hoists electric motors	kVA	_____
Rated capacity of traverse motion electric motor(s)	kVA	_____
Net dolly lifting capacity	Kg	_____
Net dolly capacity	m^3	_____

22.18.4. CRANES

22.18.4.1. SPILLWAY GANTRY TRAVELLING CRANE

Rated hoisting capacity	kN	_____
Hook lifting speed	m/min	_____
Minimum hook lift	m	_____
Rated capacity of hook electric motor	kVA	_____
Rated capacity of traverse electric motor	kVA	_____
Max height of hook from operating floor	m	_____
Main girder maximum vertical deflection at rated load	mm	_____

22.18.4.2. INTAKE FIXED WIRE ROPE HOIST

Rated hoisting capacity	kN	_____
Hook lifting speed	m/min	_____
Minimum hook lift	m	_____
Rated capacity of hook electric motor	kVA	_____
Max height of hook from operating floor	m	_____

22.18.5. SPARE PARTS AND SPARE TOOLS FOR ALL EM EQUIPMENT ACCORDING TO TECHNICAL SPECIFICATION AND PRICE SCHEDULES

Include a detail list of all supplied spare parts and special tools. Use additional sheets if necessary. Use separate schedule for each equipment.

Item	Description	Qty

Item	Description	Qty

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Item	Description	Qty

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22.19. TECHNICAL DATA

The Bidder shall fill all the following list of Technical Data. The following Technical Data is intended to give reference information and shall not prevail over the Technical Specifications.

22.19.1. GATES

22.19.1.1. INTAKE

22.19.1.2. SERVICE FIXED WHEEL GATE

Manufacturer		_____
Manufacturing works location		_____
Port of loading		_____
Main part to be manufactured by others		_____
		_____
		_____
		_____
Manufacturers of the parts listed above		_____
		_____
		_____
		_____
Standards adopted		_____
Material of the skin plate		_____
Material of the seals		_____
Net weight of frames	kN	_____
Net weight of one fixed part of the gate	kN	_____
Net weight of the gate body	kN	_____
Net weight of the complete supply item	kN	_____
Shipping size of the biggest part (L x W x H)	m	_____
Shipping weight of the heaviest part	kN	_____

22.19.1.3. MAINTENANCE SLIDING GATE

Manufacturer		_____
Manufacturing works location		_____
Port of loading		_____
Main part to be manufactured by others		_____
		_____
		_____
		_____
Manufacturers of the parts listed above		_____

		_____
		_____
		_____
Standards adopted		_____
Material of the skin plate		_____
Material of the seals		_____
Net weight of frames	kN	_____
Net weight of one fixed part of the gate	kN	_____
Net weight of the gate body	kN	_____
Net weight of the complete supply item	kN	_____
Shipping size of the biggest part (L x W x H)	m	_____
Shipping weight of the heaviest part	kN	_____

22.19.1.4. SPILLWAY

22.19.1.5. RADIAL GATE

Manufacturer		_____
Manufacturing works location		_____
Port of loading		_____
Main part to be manufactured by others		_____
		_____
		_____
		_____
Manufacturers of the parts listed above		_____
		_____
		_____
		_____
Standards adopted		_____
Material of the skin plate		_____
Material of the seals		_____
Net weight of frames	kN	_____
Net weight of one fixed part of the gate	kN	_____
Net weight of the gate body	kN	_____
Net weight of the complete supply item	kN	_____
Shipping size of the biggest part (L x W x H)	m	_____
Shipping weight of the heaviest part	kN	_____

22.19.1.6. AUXILIARY SPILLWAY

22.19.1.7. SERVICE FIXED WHEEL GATE

Manufacturer		_____
Manufacturing works location		_____
Port of loading		_____
Main part to be manufactured by others		_____
		_____
		_____
		_____
Manufacturers of the parts listed above		_____
		_____
		_____
		_____
Standards adopted		_____
Material of the skin plate		_____
Material of the seals		_____
Net weight of frames	kN	_____
Net weight of one fixed part of the gate	kN	_____
Net weight of the gate body	kN	_____
Net weight of the complete supply item	kN	_____
Shipping size of the biggest part (L x W x H)	m	_____
Shipping weight of the heaviest part	kN	_____

22.19.2. STOPLOGS

22.19.2.1. SPILLWAY

Maximum leakage with max operating level	l/min	_____
Number of sets		_____
Manufacturer		_____
Manufacturing works location		_____
Port of loading		_____
Standards adopted		_____
Material of the skin plate		_____
Material of the seals		_____
Type of seal at bottom		_____
Type of seals at sides		_____
Type of seals at top		_____
Net weight of the fixed parts of one sluice	kN	_____
Net weight of one stoplog element	kN	_____
Net weight of the complete supply item	kN	_____
Shipping size of the biggest part (length x width x height)	m	_____x_____x_____
Shipping weight of the heaviest part	kN	_____

22.19.2.2. AUXILIARY SPILLWAY

Maximum leakage with max operating level	l/min	_____
Number of sets		_____
Manufacturer		_____
Manufacturing works location		_____
Port of loading		_____
Standards adopted		_____
Material of the skin plate		_____

Material of the seals		_____
Type of seal at bottom		_____
Type of seals at sides		_____
Type of seals at top		_____
Net weight of the fixed parts of one sluice	kN	_____
Net weight of one stoplog element	kN	_____
Net weight of the complete supply item	kN	_____
Shipping size of the biggest part (length x width x height)	m	_____x_____x_____
Shipping weight of the heaviest part	kN	_____

22.19.3. TRASHRACK AND TRCM

22.19.3.1. INTAKE TRASHRACK

Number of sets		_____
Manufacturer		_____
Manufacturing works location		_____
Port of loading		_____
Standards adopted		_____
Material of the trashrack panels		_____
Material of frames		_____
Net weight of one panel	kN	_____
Net weight of one stoplog element	kN	_____
Net weight of the complete supply item	kN	_____
Shipping size of the biggest part (length x width x height)	m	_____x_____x_____
Shipping weight of the heaviest part	kN	_____

22.19.3.2. INTAKE TRCM

Manufacturer		_____
Manufacturing works location		_____
Port of loading		_____
Manufacturer		_____
Manufacturing works location		_____
Port of loading		_____
Main part to be manufactured by others		_____
		_____
		_____
		_____
Manufacturers of the parts listed above		_____
		_____
		_____
		_____
Standard adopted		_____
Number of parts in which the machine structure is divided for transportation		_____
Net weight of the complete supply item	kN	_____
Shipping size of the biggest part (length x width x height)	m	_____x_____x_____
Shipping weight of the heaviest part	kN	_____

22.19.4. CRANES

22.19.4.1. SPILLWAY GANTRY TRAVELLING CRANE

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Manufacturer		_____
Manufacturing works location		_____
Port of loading		_____
Main part to be manufactured by others		_____
		_____
		_____
		_____
Manufacturers of the parts listed above		_____
		_____
		_____
		_____
Standards adopted		_____
Number of parts for transportation		_____
Net weight of crane	kN	_____
Net weight of complete supply item	kN	_____
Shipping size of biggest part (L x W x H)	m	_____x_____x_____
Shipping weight of the heaviest part	kN	_____

22.19.4.2. INTAKE FIXED WIRE ROPE HOIST

Manufacturer		_____
Manufacturing works location		_____
Port of loading		_____
Main part to be manufactured by others		_____
		_____
		_____
		_____
Manufacturers of the parts listed above		_____
		_____
		_____
		_____
Standards adopted		_____
Number of parts for transportation		_____
Net weight of hoist	kN	_____
Net weight of steel structure	kN	_____

Net weight of complete supply item	kN	_____
Shipping size of biggest part (L x W x H)	m	_____
Shipping weight of the heaviest part	kN	_____

22.19.5. ILLUSTRATION SUBMITTED WITH TENDER

22.19.5.1. GATES

22.19.5.2. WHEEL AND SLIDING GATES

- Brief description of gates;
- general arrangement layout of the gates showing principal dimensions, fully closed and opened positions and embedded parts;
- Erection drawings;
- Other illustrations: catalogue, pamphlet, etc.

22.19.5.3. RADIAL GATES

- Brief description of the radial gates
- general arrangement layout of gate and hydraulic servomotor(s) showing principal dimensions, fully closed and opened positions and embedded parts;
- view and cross sections drawings of typical gate section, guide wheels and seals etc. ;
- general and sectional drawing of hydraulic cylinder(s);
- schematic drawings of hydraulic power unit, hydraulic circuit and piping arrangement.

22.19.5.4. STOPLOGS

- Brief description of set assembly;
- general arrangement showing principal dimensions, fully closed and opened positions and embedded parts;
- Erection drawings;
- Other illustrations: catalogue, pamphlet, etc.

22.19.5.5. TRASHRACK AND TRCM

- Brief description of trashracks;
- General arrangement layout of the trashracks showing principal dimensions;
- Erection drawings;
- List the enclosed illustrative documentation.
- Brief description of trashrack cleaning machine;
- General arrangement layout of the trashrack cleaning machine;
- Other illustrations: catalogue, pamphlet, etc.

22.19.5.6. CRANES

- Brief description of crane;
- General arrangement layout of crane, showing principal dimensions (width, height and lengths) and functionalities;
- Erection drawings of crane;

- Brief description of hoist
- General arrangement layout of hoist and steel structure, showing principal dimensions (width, height and lengths) and functionalities;
- Erection drawings of hoist with hoist steel structure;
- Other illustrations: catalogue, pamphlet, etc.

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23.1. SCOPE OF WORK

(1) This Section covers all labour, materials, equipment and services required for the construction of temporary site roads, balance access roads, if any, up gradation of roads including parking areas, and such other areas in the vicinity of structures as shown on the Drawings or as directed by the Engineer.

(2) The Contractor shall be responsible for maintenance and repair of access roads, temporary site roads and component roads.

(3) Maintenance will include good riding condition, maintenance of side drains, culverts, protection walls and clearance of slides as and when it occurs.

(4) The repair and maintenance of Access roads shall include but not be limited to the following items:

a) Cleaning and sweeping,
b) Repair and maintenance of side drains culverts and other drainage system,
c) Clearance of slips/slides, boulders, stones and slush,
d) Filling of pot holes,
e) Regular (minimum thrice a day) sprinkling of water ,
f) Maintenance of road up to reasonable good riding condition,
g) Any other work required for up keeping the road or as directed by Engineer shall deem to be included in the scope of work.

(5) The Contractor shall establish adequate traffic and dust control measures and safety regulations on all site roads. Paved/ Unpaved roads shall be frequently sprayed with water during dry weather to prevent the formation of dust clouds. Site roads shall be well drained and graded to ensure a firm, non-sliding surface during the rains and in winter. If the contractor does not heed to the instructions in this regard, the Engineer shall be at liberty to get the work done at the cost of contractor.

23.2. TECHNICAL SPECIFICATION

23.2.1. GENERAL

(1) The Contractor shall select, design, construct and maintain all necessary temporary roads, parking areas and other access facilities within the site required for the construction of Permanent and Temporary Works, including all borrow and quarry areas.

(2) The roads shall be wide enough to allow heavyweight traffic in both directions. To prevent excessive erosion, no steeper longitudinal slope than 10% shall be used, except when specifically approved by the Engineer.

(3) Except where rock is encountered, the back slopes of cut banks shall be stable and compatible with existing topography, and shall be flattened and rounded as far as practicable into natural ground surface.

(4) The Contractor shall install suitable devices and drainage structures in sufficient numbers to prevent accumulation of excessive water and erosion of the road surface, drainage ditches, and excavated area.

(5) The Engineer as well as other contractors and subcontractors working on the Project shall be permitted access, free of charge, to all site roads throughout the duration of the Contract.

(6) Upon completion of the Works, these roads shall be handed over to the Employer. Those site roads which the Employer does not choose to keep shall be made impassable to vehicular traffic and the surfaces shall be scarified and left in a condition which will facilitate natural vegetation.

(7) The maintenance and repair of roads shall conform to the following Indian Standards (latest revision) / Bhutan Standard or, where not covered by these Standards, to equivalent International Standards:

Specifications for Road and Bridge works	Ministry of Road Transport and Highways Published by Indian Roads Congress, New Delhi.
Specification for Rural Roads	Ministry of Rural Development Published by Indian Road Congress, New Delhi.
Specifications for Building and Road Works	Ministry of Works & Human Settlement, Depart of Engineering Services, RGoB, Bhutan
IRC:23	Tentative specification for two coat bituminous surface dressing.
IRC:SP:48	Hill Road Manual
IRC:SP:20	Rural Road Manual
IRC:SP:42	Guidelines on Road drainage
IRC:58	Primary Design Guideline
IS:456, IS:10262, IS:383, IS:8112	Concrete Material & Construction Codes
IS:383	Specification for coarse and fine aggregates from natural sources for concrete
IS:516	Testing Codes
IS:2720(Part2)	Determination of water content
IS: 2720(Part8)	Determination of water content dry density relation using heavycompaction.
IS:16014	Mechanically woven, double-twisted, hexagonal wire mesh gabions, revet mattresses and rock fall netting (galvanized steel wire or galvanized steel wire with PVC coating) Specification

(8) In case of conflict between the above standards and the specifications given herein, the specifications shall take precedence.

(9) In case IS codes/specifications are not available for any item, the decision of Engineer based on acceptable sound Engineering practices and local usage shall be final and binding on the Contractor

23.2.2. CROSSING ARRANGEMENTS LIKE BRIDGES/CULVERTS ON TEMPORARY ROADS

Crossing arrangements like bridges/culverts under this head shall comprise the following:

(i) Bridges/culverts to shoal areas, dumping areas, borrow areas

(ii) Bridges/culverts to Contractor's facilities, labour camps, offices, residences, stores, workshops, batching & mixing plants, quality control laboratory etc., required by the Contractor for successful completion of the works.

(iii) Any other additional bridges/culverts on the site as the Contractor may consider necessary for work sites.

The Contractor shall construct the above bridges/culverts and maintain the same as directed by the Engineer at his own cost and all cost towards the same shall be deemed to have been included in the quoted rates/prices entered in the Bill of Quantities.

23.3. MAINTENANCE AND REPAIR WORK

(1) The maintenance of access roads within the Project area to be carried out by the Contractor shall include, but not be limited to, the following work:

a) Immediate repair of all irregularities produced by traffic, water such as pot holes or other damage to the roadway surface,

b) Repair of any road-related structures damaged by traffic or weather,

c) Periodical shaping and grading of the roadway wherever necessary to allow good surface drainage and to maintain it in optimal condition for traffic at all times,

d) Keeping the drainage structures and culverts etc. free of debris or any other material that may reduce their flow capacity,

e) Provide the necessary traffic signs and signals, and

f) Effective dust control by regular sweeping & cleaning and water sprinkling etc.

g) Re-routing of the roads coming under excavation for Permanent works and land development for Plants & Machinery installation or as directed by the Engineer-in-charge.

(2) If there is damage to the protection works (retaining walls, gabions) and these are required to be rebuilt, the same shall be rebuilt at the orders of Engineer.

(3) Clearing of landslides on access roads within the project area will be carried out by the Contractor. The works shall include, but not limited to, the following:

a) Clearing of slides onto the roadway and lateral slopes, during and after rain/snow fall.
b) Disposal of materials removed by the above-mentioned operation to approved dumping/spoil areas.

23.4. MEASUREMENT AND PAYMENT

(1) Measurement for payment for the repair and maintenance of access road will be Km-months which will be calculated as the number of months for which the road is under use multiplied by the length of road in Kilometers.

(2) Payment will be made at the Unit Prices per Km-month entered in the Bill of Quantities, which shall include all costs of labour, equipment, and materials required for repair and maintenance as given in clause in this specification.

(3) No payment will be made for the construction/maintenance of all temporary roads to Quarry and borrow areas and other roads within the contractor's construction facility areas and the cost thereof shall be deemed to be included in the other items of the Works.

23.5. EXCLUSIONS

No extra payment will be made for the following:

(1) Extra work caused by the Contractor's negligence in setting-out the structures and slopes.

(2) Rectification, removal and replacement of the materials which during the placement or afterwards have been contaminated with foreign matter, mixed with unsuitable materials, or lost due to erosion.

(3) Extra work or material required to repair damages to the temporary or final surfaces caused by the erosion or travel of the construction equipment.

(4) Stockpiling, re-handling, reloading, and transport of materials which cannot be directly placed in the final locations after being excavated.

(5) Damage and repair to the concrete structures caused by Contractor's operations.

(6) Additional passes of the compacting equipment ordered by the Engineer if he determines that a higher degree of compaction than specified is required.

(7) Construction and maintenance of temporary site roads, Roads to quarry/borrow /dumping areas etc.

(8) Re-routing of the roads coming under excavation for Permanent works and land development for Plants & Machinery installation.

END OF SECTION B.23

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24.1. SCOPE OF WORK

24.1.1. GENERAL

This section of the specifications covers the provision by the Contractor of all labour, plants and material and performance of all works necessary for the design, manufacture, shop-testing, transport and delivery, erection, testing, commissioning and handing over to the Owner of items of electrical and mechanical equipment which are to be installed by the Contractor at the dam site. Included is the drainage water pumping system complete with piping, valves, fittings, auto starting and stopping features and other accessories and the temporary ecological flow valve system. This equipment, certain of which will be complementary to that being supplied by other contractor, is listed below.

24.1.2. TEMPORARY AND PERMANENT EXTERNAL AND INTERNAL LIGHTING

1) Temporary External lighting equipment and fittings will be provided for the following areas during the execution of the works:
   a) The Approach roads to project area, road to dam top, downstream face of the dam.
   b) Dam crest
   c) Dam control building yard

2) Permanent Internal lighting equipment and fittings will be provided for the following buildings and surrounding areas during the execution of the works:
   a) Dam control building, DG room and Dam galleries etc.
   b) The contractor shall duly coordinate with other contractors.

24.1.3. OTHER ITEMS OF ELECTRICAL AND MECHANICAL EQUIPMENT

1) Grounding equipment for the spillway gates.
2) Drainage water pumping equipment for the dam and spillway galleries.
3) Elevators in RCC Dam.
4) Power supply to OPU unit/ control panels/ illumination fittings/ panels/ drainage and dewatering system etc.

24.2. LIGHTING EQUIPMENT

24.2.1. BASIC DIMENSIONING AND RATINGS

1) All apparatus and materials supplied and all works carried out under this contract shall comply in all respect with the requirements of the regulations and acts in force in Bhutan.

2) Service voltages shall be as indicated in the following table:

Normal lighting system	Three-phase, five wire, 415/240 V, 50 Hz

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A.C. socket outlets	Single-phase, three pin, 240 V, 50 Hz
Power socket outlets	Three-phase, five pin, 415/240 V, 50 Hz

3) Minimum specified illumination levels in general and office areas shall be as follows:

Storage rooms	300 Lux
General (other areas)	150 Lux
Staircases	100 Lux
Traffic routes for people in building	20-50 Lux
Galleries	100 Lux
Offices	400 Lux
Control room	500 Lux
Approach roads & other areas	20-50 Lux.
Access tunnels and gate chamber	100 Lux.

24.2.2. PERFORMANCE CRITERIA AND GUARANTEE

1) The illumination system along with all accessories shall be capable of performing all intended duties and it is the responsibility of the contractor to supply the equipment as per guaranteed technical particulars.

2) All apparatus and material supplied shall comply with the relevant Electricity Act / Rules in force in Bhutan.

24.2.3. DESIGN AND CONSTRUCTION

24.2.4. ILLUMINATION SCHEME AND OTHER FITTINGS

1) Illumination for the dam area, control building area, spillway and approach Roads.
2) Illumination in the dam control building.
3) Illumination for galleries and adits, if applicable.
4) Emergency lighting shall be provided in the control room.
5) Convenient power outlets shall be provided at different places in control room, and shall consist of triple pole neutral and protective earth.

The tenderer shall examine carefully the requirements to be met by the lighting system. The system shall comply with all the requirements of surface and concealed wiring standards. The LED fittings may be proposed for the illumination purposes in all areas. This may also include the spare illumination fittings.

24.2.5. DISTRIBUTION BOARD

1) The boards shall be of wall mounted type and shall be located 1.5 m above the floor. They shall be made of sheet steel not less than 3 mm thick.

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2) Boards shall be waterproof and shall be provided with glands or adapters to receive a screwed conduit

24.2.6. SWITCHBOARDS

The boards with the required number of piano type switches and socket sets shall be made of metal on all sides, except on the front, bakelite sheet of 3 mm thickness shall be fixed with brass screws.

24.2.7. CABLES

1) The cables shall be at least 600 V / 1000 V, grade copper single core conductor, unarmoured PVC insulated.
2) The insulating material of cable shall not deteriorate with age or due to the voltage stresses etc. Each cable coil shall be accompanied by the manufacturer's test giving the results of the insulation test.
3) The wiring shall be done in looping back system. No joints shall be made at intermediate points in the given of the cables.

24.2.8. COLOUR SYSTEM FOR WIRING AND ELECTRICAL FITTINGS

A.C. Three phase (Phase 1- red, Phase-2-yellow, Phase-3-Blue), neutral-black and Earth- green-yellow.
D.C. Two wire system, positive red, negative black.

24.2.9. WIRING

1) It is proposed to carry out surface wiring for illumination circuits as well as for power outlets. In some areas concealed wiring shall be done based on the site requirements.
2) The cables shall be connected to terminals only by lugs.

24.2.10. LIGHTING ACCESSORIES

1) Each socket outlet for lighting and power shall be controlled by a switch which shall be on the live side on the line. The socket outlets shall be pin type, 3rd pin being connected to the earth.
2) All lighting outlets (5 amps & 15 amps) shall be located at the switch board located 1.5 m above the floor.
3) The power socket outlets should be either 16 A and/or 32 A.

24.2.11. CONDUITS

1) The conduits shall be manufactured in accordance with the latest standards and shall be supplied in random length of 4 m to 6 m.

24.2.12. CONDUITS JOINTS

1) Conduit joints shall be made by means of screwed couplers and screwed accessories.

24.2.13. BENDS

1) All necessary bends in the system shall be done by bending of conduits or by inserting suitable solid or inspection type normal boards, elbows or similar fittings whichever is more suitable.

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24.2.14. FIXING OF CONDUITS

1) Conduits pipe shall be screwed to suitable plugs with anchor fasteners.

24.2.15. ERECTION & EARTHING OF CONDUITS

1) The entire system of conduits, after erection, shall be tested for mechanical and electrical continuity throughout and permanently connected to earth by means of earthing clamp.

24.2.16. INSPECTION BOX

1) Suitable inspection boxes shall be provided to permit inspection and to facilitate removal of wires if necessary.

24.2.17. CABLES AND TRENCHES

1) Cables in trenches shall be laid such that the cables laid in it do not touch each other. If necessary cables may be fixed with clamps on the walls of the trenches.

24.2.18. EARTHING

1) The continuous earth shall be run for all the 3 pin sockets.

2) The neutral will be earthed at distribution transformer, the three phase four wires distribution system shall be connected to the station earthing system at two or more places.

24.2.19. QUALITY CONTROL AND ASSURANCE

1) The contractor has to supply the equipment for the illumination system of best quality. The contractor has to maintain quality control during manufacturing of equipment as per the approved Owner's quality assurance plans.

24.2.20. CALCULATION REQUIREMENTS

1) The contractor is required to submit the calculations for the following to the owner for approval during detailed Engineering:

a) Calculations for the illumination levels of the different areas with respect to installation plan.
b) Cable and conduit sizing.
c) Type of luminaries.

24.2.21. SHOP TEST

1) The equipment for the illumination system shall be type and routine tested as per relevant IEC standards & Bhutanese/Indian Standards. The contractor is required to submit all type test certificates and routine test reports to the owner.

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24.2.22. INSTALLATION AND COMMISSIONING

1) The contractor shall furnish all labour, supervision, tools, supplies, bracing, spiders, shims and supports and all other provisions or materials necessary to assemble, erect, install, test and commission the equipment in a thorough workman like manner following the best modern practices. The equipment and all its components shall be placed with great care and accuracy and shall be aligned correctly to provide an installation consistent with the close tolerances used in the erection of modern equipment. The proper elevations and centre lines to which equipment is to be set shall be established by the contractor. The works to be carried out under this contract shall comply with the relevant requirements given in Electricity Act / Rules in force in Bhutan.

24.2.23. FIELD TESTS

1) After installation, the illumination system shall be field tested for operational tests and mega ohm value of insulation as per relevant IEC & Bhutanese/Indian Standards. The contractor shall prepare and hand over to the owner details of all test results in a report on a mutually agreed format.

24.2.24. SPARE PARTS

The contractor shall furnish the following spare parts:

1) Five (5) Multiple plug power sockets suitable for 32/16 / 15/5 A.
2) Two (2) High pressure sodium vapour high bay lighting fittings complete with all accessories
3) Ten (10) Fluorescent fittings complete with all accessories of each type used.
4) Ten (10) DC lamp fittings complete with accessories of each type used.
5) 5%, but at least two pieces of all switches, contactors, terminal blocks, screws
6) 5%, but at least 50 meters of all conduits, cables, wires.

24.3. ELEVATOR

24.3.1. SPECIAL DESIGN AND LAYOUT CONDITIONS

1) The spillway elevator shall serve all the floors and galleries in the spillway Control terminal of elevator shall be placed at the top floor of control room. The design, supply, installation, testing & commissioning shall be conforming to the relevant IS codes.

24.3.2. BASIC DIMENSIONING AND RATINGS

1) The capacity of the elevator shall be at least for 8 passengers and also suitable for tools and tackles. The elevator/lift shall be designed with respect to the best modern practice. The lift shall have modern aesthetically pleasing appearance.

24.3.3. PERFORMANCE CRITERIA AND GUARANTEE

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1) The equipment covered under this contract shall be capable of performing all intended duties and the equipment shall be as per guaranteed technical particulars.

24.3.4. DESIGN AND CONSTRUCTION

1) The elevator/lift shall be designed and constructed with respect to the best modern practice. The construction of lift shall be such that all motions shall take place smoothly and positively with no slippages and jerks and vibration. The contractor is required to submit size of well and dimensions for construction of well.

2) The lift shall be provided with all safety devices, alarms etc. The lifts shall be suitable for 415 V,3 phase,50 Hz AC supply. Counter weight wire ropes, sliding doors, embedded parts, guides, controls, indicators, facials, alarms lighting etc. shall be provided. The insulation of motor shall be class F.

24.3.5. QUALITY CONTROL AND ASSURANCE

1) The contractor has to supply the equipment of best quality. The contractor has to maintain control and quality assurance during the manufacturing, installing, testing and commissioning of equipment as per the approved Owner's quality assurance plan.

24.3.6. CALCULATION

1) The contractor is required to submit detailed dimension of well required for lift. The contractor is also required to submit calculation for selecting the rope and motor size and speed of lift for approval to the owner.

24.3.7. WORK SHOP TESTS

1) The motor, rope of lift and control panel of lifts shall be routine tested as per relevant IEC/IS at the supplier's works. The Supplier is required to submit type test certificates for motor and rope and routine test certificates of equipment.

24.3.8. INSTALLATION AND COMMISSIONING

1) The contractor shall furnish all labour, supervision, tools, supplies, bracing, spiders, shims and supports and all other provisions or materials necessary to assemble, erect, install, test and commission the equipment in a thorough workman like manner following the best modern practices. The equipment and all its components shall be placed with great care and accuracy and shall be aligned correctly to provide an installation consistent with the close tolerances used in the erection of modern equipment. The proper elevations and centre lines to which equipment is to be set shall be established by the contractor.

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2) The contractor is required to provide all dimensions of well for proper construction. If any chipping work is required the same shall be carried out by the contractor before erecting the lift. All assembly and commissioning of the equipment shall be done by skilled workers in a workmanlike manner.

24.3.9. FIELD TESTS

1) The elevators shall be site tested to demonstrate operation capability as per the intended requirements.

24.3.10. SPARE PARTS

1) One complete motor of each type and size shall be supplied as spare parts.

24.4. GROUNDING SYSTEM

24.4.1. GENERAL

1) Embedded earthing system shall be provided for the spillway, diversion cum spillway tunnel gates intake structures, intake gates, The earth electrode system as well as other earthing networks shall be designed and constructed for the operating voltages, the short circuit capacities and the corresponding short circuit and earth fault currents.

24.4.2. SPECIAL DESIGN AND LAYOUT CONDITIONS

1) The Contractor shall design and construct the grounding system for protection of persons and material to allow a safe service and maintenance work on the installations.

2) The earthing system shall be constructed to comply with the requirements of the applicable standards and connected equipment. The grounding system shall be designed to avoid dangerous touch or step voltage.

3) More specifically and independent of the regulation and standards, the earthing system shall provide:
   a) Adequate protection of personnel against dangerous voltages, currents and arcs.
   b) The fault currents shall flow through the earthing system.
   c) Limiting the induced capacity transformed voltages on low voltage, weak current and electronic cables, circuits, panels and other equipment.

24.4.3. BASIC DIMENSIONING AND RATINGS

1) The earthing conductors shall be dimensioned for carrying earth fault current in any section of the plant for at least one second without any harm to the conductors. The equivalent resistance of the whole earth electrode and main earth collector shall be $\leq 1\ \Omega$. Earth conductor in ground shall be welded one to each other.

24.4.4. PERFORMANCE CRITERIA AND GUARANTEE

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1) The complete grounding system covered under this contract shall be capable of performing all intended duties and the equipment shall be as per guaranteed technical particulars and final grounding mat resistance.

24.4.5. DESIGN AND CONSTRUCTION

24.4.6. EMBEDDED EARTHING SYSTEM

a) The embedded earthing system for the spillway and power intake shall consist of a interconnected earthing grid formed by MS electrode, rods and copper conductors of suitable size. The copper conductors shall have contact with the reinforcement bars of the concrete structure.
b) Since the dam area is in near vicinity to the power house area and power supply to dam area is proposed to be taken from power house, so connection of grounding system of dam area with the power house grounding network having four parallel paths may be kept.
c) Prior and during the concreting stage the sub-contractors if any shall provide all material and all information in sufficient details to enable the Civil Contractor to install the earthing conductors, connect them to the reinforcement bars and to form the adequate grid and to install the necessary connection pieces required for the connection of the above ground earthing system to the embedded earthing system.
d) The number and location of these interconnecting points shall be determined by the contractor.
e) All connections of the embedded earthing conductors shall be thermo-welded.
f) The conductors buried in the soil or laid in cable trenches or similar, shall be tinned copper cables

24.4.7. ABOVE GROUND / ABOVE FLOOR MAIN EARTHING SYSTEM

1) The earthing system shall consist of individual loops with connections to the different equipment to be earthed and with connections to the embedded earthing grid. At certain locations earthing measuring points shall be installed.

2) The connection straps from the embedded net to the main protective earthing buses shall be provided with disconnect terminal lugs for measuring, always visible for inspection.

24.4.8. CONDUCTORS AND CONNECTIONS

1) The Contractor shall supply the all embedded conductor system and the connection rods, and design suitable connection facilities for connection of individual conductors to the system.

24.4.9. QUALITY CONTROL AND ASSURANCE

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1) The supplier has to supply all the equipment of best quality. The supplier has to maintain control and quality assurance during the manufacturing, installing, testing and commissioning of grounding system as per the approved Owner's quality assurance plan.

24.4.10. CALCULATIONS

1) The Contractor shall submit design calculations of the whole grounding system, including the embedded grounding system for approval of the Engineer. Additionally to the applicable rules and standards, "Guide for Safety in AC Substation Grounding" ANSI/IEEE Std 80-1986

24.4.11. WORK SHOP TESTS

1) The material used grounding system shall be routine tested for dimension checking, corrosion protection and material strength as per relevant standards at the work's of supplier in presence of owner. The Supplier is required to submit routine test reports of materials.

24.4.12. INSTALLATION AND COMMISSIONING

1) The laying, erection and commissioning of all grounding system shall be carried out by contractor. The concreting shall be done by other contractors. The contractor is required to remain present at concreting for supervision of work. The contractor is required to submit Drawings for grounding system. All erection and commissioning of the grounding system shall be done by skilled workers in a workmanlike manner.

24.4.13. FIELD TESTS

1) The grounding system shall be site tested to demonstrate operation capability as per the intended requirements.
2) The following tests shall be performed:
3) Visual inspection of exposed system
4) Electrical continuity test
5) Measurement of earthing resistance, as far as reasonable of individual loops.

24.5. DRAINAGE WATER PUMPING SYSTEM

A gravity drainage and dewatering system of appropriate capacity and reliability is to be provided for the Dam to discharge leakages and water from drainages system of the dam foundation.
The water will be collected in the Dam drainage galleries and evacuated by gravity directly downstream the dam wherever this is possible.
However, water collected in the drainage galleries below the tailwater level (i.e. 784 m a.s.l.) shall be removed by pumps installed in two separate pits (indicatively at elevation 713m a.s.l.) located in the dam body. In each of these pits, three (3) operational pumps and one (1) in stand-by to the others and one bilge pump shall be provided.

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The total pumps overall capacity shall be not less than 2 m^3/s. In addition, the capacity of each Bilge pump shall be not less than 100 liters/sec.
The outlets of the pumps are connected to a common discharge pipe, located above maximum tailwater flood level.
Shut-off valves and check valves shall be provided to allow disconnection and switching of each pump without emptying pipes.

24.5.1. SPECIFIC REQUIREMENTS OF COMPONENTS

24.5.2. SUBMERSIBLE PUMP SETS

The pumps shall be vertical, single-stage, centrifugal submersible type, suitable for continuous operation fully submerged under the specified service conditions. The pump and motor shall form a close-coupled integral unit, designed for installation in wet wells or pumping stations. The unit shall be suitable for installation on guide rails with automatic coupling to the discharge connection, allowing removal and reinstallation without entering the wet well. The pump casing shall be of cast iron or cast steel, of robust construction, designed to minimize clogging and ensure smooth hydraulic performance. The impeller shall be of stainless steel or high-grade cast iron, dynamically balanced, and designed for high efficiency and resistance to wear and corrosion. Replaceable wear rings shall be provided where applicable.
The pump shall be equipped with double mechanical seals arranged in tandem or back-to-back configuration, operating in an oil-filled seal chamber. The seals shall be suitable for operation in submerged conditions and resistant to the pumped liquid. The motor shall be a submersible, squirrel-cage induction motor, suitable for continuous duty, designed for operation fully submerged. The motor enclosure shall be rated IP68. The motor shall be provided with thermal protection (embedded temperature sensors in windings) and moisture detection sensor in the stator chamber and/or seal chamber.

24.5.3. PIPING SYSTEM

The pipes for the entire drainage water systems are included in the supply.
The pipe shall be installed in a manner to be easily drained. Water and air traps in the pipe system shall be avoided. In case of necessity, the Contractor shall provide adequate valves for the de-aeration or drainage. For field pipe connection steel flanges shall be supplied for welding on the pipes after length adjustment. For small pipe connections, coupling unions shall be accepted. Pipes passing shaft ceilings or walls shall be provided with fixation collars and supports for embedment into the concrete.
Pipes shall be externally protected where required to prevent condensation.

24.5.4. HAND-OPERATED MAINTENANCE VALVES

All maintenance valves with a diameter > 100 mm shall be butterfly type.

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Valve body and valve disc shall be made of welded steel plates or cast steel. The valve sealing shall be made of stainless steel in the valve body with a suitable replaceable rubber sealing on the valve disc. The body shall have two bearings for the valve disc trunnions, bushed with suitable non corrosive bearing material, provided with lubrication facilities.

The bearing shall be tightly sealed and sealing shall be replaceable under inside water pressure.

The operating mechanism shall be of rigid construction, preferably of the worm gear type or spindle with sliding block type provided with hand wheel. All valves shall have a position indication with marks for the completely open and closed position. Provision shall be made for mechanical locking in the open and closed position.

In general, the filling of the downstream side of the valve shall be made by simply opening the valve disc slightly, the operating mechanism being designed to open the valve under unequalized pressure. However, separate by-pass integrated in the valve body and provided with a separate bypass isolating valve shall also be accepted.

24.5.5. OTHER HAND-OPERATED OR MOTOR-OPERATED VALVES

All valves with diameter 100 mm and smaller shall be of the sluice type with rising spindle.

Valve body and gate shall be made of cast steel and the sealing parts shall be exchangeable.

The opening of the valve shall be possible in case of full unequalized pressure. The motor of the motor-operated valves shall suit the requirements as indicated under the General Specifications.

24.5.6. NON-RETURN VALVES

They shall be provided with flanges and equipped with counter-weight and removable seal rings of corrosion resistant material. The valves of a diameter > 200 mm shall be of the short type and equipped with an adjustable oil brake. The valve body and casing shall be of steel, cast steel or modular cast iron.

24.5.7. INDIVIDUAL TERMINAL PANEL

Provided with the necessary equipment for automatic and manual control and signaling, including motor starters. The design of the panel and cabling shall be in accordance with the General Specifications.

24.5.8. EQUIPMENT FOR CONTROL, PROTECTION AND SUPERVISION

Each pump set shall be provided with a pressure gauge at discharge side. The alarm signals shall be wired to the terminal panel for indication on the control boards.

The Contractor shall provide and install all the sensory and operating devices necessary to fulfil the functional requirement of the specification for control system.

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A control and indication panel shall be installed for drainage systems in the control building. Following controls & indications shall be provided:

a) Manual/Automatic/on-off switch for manual/automatic operation of drainage pumps.
b) Remote/ local selector switch
c) Drainage pump selector switch
d) Start/stop push buttons
e) Emergency stop push button switch
f) Lamp test push buttons.
g) Drainage pump running/stop/trip
h) High bearing temp and trip for drainage pump
i) Drainage water no flow
j) Drainage water level " Max"/ "Min"
k) Pumps inlet choked
l) Other required indications and control and current/voltage measurement

The motor for each pumping unit shall be provided with at least the following device:

a) Over load protection
b) Under voltage protection
c) Single phasing protection

The design of the control and supervision equipment shall be in accordance with the Technical Specifications.

24.5.9. INSTALLATION REQUIREMENT

24.5.10. GENERAL REQUIREMENT

The scope of erection activities shall comprise all preassembly, assembly and erection at site of all components supplied by the Contractor, site painting, wiring, and cabling within the limits of supply. Prior to commissioning, verification of complete and correct erection of the various components, including electrical installation, shall be performed and the requirements fulfilled. In particular, the following checks shall be carried out:
Pressure test of the complete water piping system as indicated in this Chapter. Pump for pressure test and all necessary blind flanges, taps, valves, pressure gauges, etc., shall be provided by the Contractor.
Final check of correct locking of all nuts.
Insulation test of the electrical equipment.

24.5.11. INSPECTION AND TEST

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24.5.12. MATERIAL TEST

The Contractor shall prepare a list of all components of the supply to be tested and the corresponding tests to be performed. The Employer, however, reserves the right to request further tests, if he deems it necessary.

24.5.13. COMMISSIONING TESTS AT SITE

After installation of the equipment, the following tests have to be performed, necessary testing facilities being provided by the Contractor:

Pressure test on each complete mounted circuit at 15 kg/cm^2. The systems shall maintain the test pressure for 24 hours without showing any sign of pressure loss (constant temperature provided).

Preliminary tests, such as testing of correct electric wiring and cabling of the control and power circuits, measuring of insulation level on the electrical equipment with megger, and testing and setting of the protective equipment.

Any additional tests required by the Employer to ensure the completeness and the safety of the equipment when operated.

Operation and performance tests, after successful termination of the previous tests, considering the different possible modes of operation.

24.5.14. SPARE PARTS

1) two (2) submersible pumps with motor of each type
2) Two sets of pump shaft seal of each type
3) Two sets of all rings and seals
4) One flow meter
5) One set of pressure gauge of each type used
6) One set of indicating instrument of each type used
7) One set of indicating lamps along with assembly of all types used
8) One valve of each type used
9) One set of relays of each type
10) Any other spares as recommended by the Manufacturer

24.6. MEASUREMENT AND PAYMENT

24.6.1. LIGHTING SYSTEMS

1) The payment for lighting/illumination system shall be made Lump Sum quoted for all areas covering:
   a) The approach road to project area, road to dam top, downstream face of the dam.
   b) dam crest

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c) Dam control building yard

d) Dam control house, DG room, dam galleries etc.

24.6.2. ELEVATOR

1) Payment for spillway elevator shall be made on lump sum quoted by the contractor and shall be paid after successful commissioning of the elevator.

24.6.3. GROUNDING SYSTEM

1) Payment for grounding system for spillway gates shall be made on lump sum quoted by the contractor and shall be paid after successful commissioning of grounding system.

24.6.4. DRAINAGE WATER PUMPING SYSTEM

1) The payment for complete drainage water pumping system for Concrete Dam galleries as described in these specifications shall be based on the lump sum price quoted by the contractor and shall be paid after successful commissioning of the system as a whole.

END OF SECTION B.24

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