GOVERNMENT OF KHYBER PAKHTUNKHWA
IRRIGATION DEPARTMENT

CONSTRUCTION OF JABBA DAM
DISTRICT KHYBER

BIDDING DOCUMENTS
VOLUME-II

SPECIFICATIONS

November 2023

Director General Jabba Dam Project

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   MRS-2019, COMMUNICATION AND WORKS DEPARTMENT, KPK.

SPECIAL PROVISIONS
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SPECIAL PROVISIONS (SPECIFICATION)

The items mentioned hereinbelow in these special provisions are to be provided / arranged by the Contractor within one (1) month after award of Contract without any additional cost to the Procuring entity.

No payment shall be made to the Contractor for the provision of these items, and the cost thereto shall be deemed to have been included in the quoted rates and prices of other items of works.

SP-1 GENERAL

Govt. of Khyber Pakhtunkhwa is taking every step possible to improve living conditions and resources of the area. It is top priority of the Government to take measures to minimize hardships, generally faced by the inhabitants in meeting their daily life demands.

Working on these lines, the Government of Khyber Pakhtunkhwa initiated JABBA Dam Project for the development of Drinking water in order to improve the socio-economic condition of the areas.

In many regions throughout the developing world, sources of water traditionally available in abundance for domestic use are fast depleting. Keen competition from Irrigation and drinking water needs made the depletion faster. In the coming years, the challenge is to promote and facilitate the management of water resources to achieve an equitable balance between competing demands.

Drinking water shortages are acutely felt which should be overcome immediately. In Peshawar, tube wells are installed which are the only source of drinking water. Extensive water withdrawals from the Peshawar and adjoining areas for drinking and irrigation supplies has lowered the water table in the last few decades by as much as 30 to 40 ft. The existing availability of water in not considered adequate to meet the expected future water supply needs. After the Construction of the Jabba dam the populace of Hayat Abad and Jamrud region could be served by surface runoff. This will lead to preservation of ground aquifers till the life of the Jabba dam project. These aquifers will be an asset for next generations.

SP-2 DESCRIPTION OF THE PROJECT AREA

The proposed project area is located in the Khyber district at a distance of 30 kilometers to the South-West of Peshawar; the provincial capital of Khyber Pakhtunkhwa. The area is accessible through blacktopped road from Peshawar. The site can be visited by travelling a distance of about 10 km through Shah Kas Plain from Peshawar-Jamrud Road.

District Khyber (previously Khyber Agency) lies between latitude 33°44′ to 34°20′ North and longitude 70°26′ to 71°30′ East. It is bordered on the north by District Mohmand (previously Mohmand Agency), on the east by Peshawar District, on the south by District Orakzai (previously Orakzai Agency) and Frontier Regions (FR) Tribal areas (now settled areas) adjoining Kohat District, on the west by Kurram (previously Kurram Agency), and on the northwest by Afghanistan. Total area of District Khyber is 2,576 square kilometers. The population of District Khyber as per 1998 census is 546,730 persons.

Both the streams (Chora and Khyber) of the locality get its drainage from its catchment having extent up to Afghan border towards west. The mountain ranges in the lower part are completely barren with low rainfall while the upper part has occasional modest rainfall causing floods in both the streams. The rocks are dominantly metamorphic which disintegrate to form pebbles and gravels with fine grains carried away by surface runoff.

There is an extensive dry piedmont plain in the foothills of Khyber Mountains extending up to the boundary of Hayatabad town. The plain is dominantly composed of loosely cemented gravel to grading up to cobbles and fine-grained silt and clay. Wind and rain have removed the fines from the surface and good part of it gives the looks of a stony waste.

SP-3 SITE OF THE WORK

The site of work is the area for construction of dam project and the related structures including, within the rights-of-way, lines, boundaries and limits shown on the drawings and such additional areas adjacent thereto as may be designated by the Engineer / Engineer representative from time to time for the construction to be performed under the Contract, and all such areas and additional areas shall be comprised in the site of the Conditions of Contract.

Within the areas, which may from time to time be defined as the Site, the Contractor shall carry out and perform construction of the Works and will be permitted to construct roads, camps, buildings, and temporary works subject to the approval of the Engineer/Engineer representative. If the Contractor wishes to use any land other than as aforesaid for construction of camps or for any other purpose, the Contractor shall make all necessary arrangements with the owner thereof and shall bear all rentals or other costs connected therewith. The Contractor shall furnish to the Engineer / Engineer representative for approval plans for additional land 60 days prior to the use of such land.

Subject to any restrictions mentioned in the Contract, the Procuring entity will give to the Contractor possession of as much of the area designated and defined as the Site and shown on the drawings as may be required to implement the Works, after the Procuring entity’s order to commence the work is given.

SP-4 SECURITY

The Contractor shall always be deemed to have acquainted himself with the provisions of Official Secret Act 1923 (as adopted in Pakistan) and other security provisions prevailing in the area in which he is working and shall abide by and confirm to these. He will further ensure and be personally responsible for ensuring that his employees (supervising staff etc.) are acquainted with and abide by the rules, regulation, and orders. Breach of the said provisions on the part of the Contractor or his employees, in addition to any other liability under law may also result in the immediate cancellation of the Contract by the Procuring entity and completion of reminder of the Work at the Contractor's risk and cost by any other agency which the Procuring entity consider suitable to the needs of the case.

SP-5 ACCESS TO THE SITE AND HAUL ROADS

The Contractor shall make his own investigation of the condition of available public or private roads and of clearances, restrictions, bridge load limits and other limitations that affect or may affect transportation and ingress or egress at the job sites. The unavailability of transportation facilities or limitations thereon shall not become a basis for claim for damages or extension of time for completion of the Works. It shall be the Contractor's responsibility to construct and maintain, at his own expense and risk, any access roads, haul roads, bridges, or drainage structures required for construction operations. The Contractor shall obtain any required permits for travel on or work within the right-of-way of all public roads.

Existing secondary or tertiary roads are available for the Contractor's use subject to restrictions imposed by the local authorities. The Contractor shall meet all conditions imposed upon the use of these existing roads by those having jurisdiction there over, including (without limitation of the generality of the foregoing) seasonal or other limitations or restrictions, the payment of excess size and weight fee and repair of road damage caused by the Contractor.

The hauling of sand, gravel, earth or rock material, or other hauling's within the project, over the existing public highways, roads, or bridges shall be in compliance with the applicable local regulations and shall be such as to minimize interference with or congestion of local traffic. Where haul routes cross public highways or roads, the Contractor shall provide traffic barricades, flagmen, and other necessary precautions for the safety of the public as provided in the Conditions of Contract Part-I. Where haul routes utilize existing unmetalled canal access roads, the Contractor shall maintain such roads in good condition by regular grading.

When temporary haulage and construction roads are no longer required, the Contractor shall plough to break up hardened surfaces, remove all imported material and shall reinstate and replace the surface and topsoil of the areas disturbed by such roads and rehabilitate to a natural condition, which may include replanting grass and / or trees, unless otherwise directed by the Engineer representative.

a) ACCESS THROUGH CANAL ROADS & TEMPORARY CROSSINGS

If the Contractor finds it necessary or elects to use existing canal roads, the Contractor shall make all necessary arrangements and obtain all permits from the concerned section of provincial Irrigation Department for travel over and use of such canal roads. The Contractor shall observe all rules regulations of the Irrigation Department regarding the use of said canal roads. The cost of maintaining all necessary safety measures and temporary structures and making any necessary repairs, replacements or similar operations and all or any other costs required by reasons of his use of such canal roads shall be borne by the Contractor and the Contractor shall save harmless and indemnify the Procuring entity in respect of all claims, demands, proceedings, damages, costs, charges and expenses whatsoever arising out of or in relation to any such operation or interference.

The Contractor shall provide and maintain temporary crossings on canals and channels to allow continuous use by vehicular or pedestrian traffic, as indicated on the drawings and as otherwise established by the Engineer/Engineer representative. All costs incidental to furnishing of these temporary crossings shall be deemed to have been included in the tender prices of the related construction items of the Bill of Quantities and no separate payment, for any reason whatsoever, will be made to the Contractor on this account.

b) **RAILWAY TRAFFIC**

Where construction work or operations of the Contractor are performed within the limits of the right-of-way of the Pakistan Railways, the Contractor shall cooperate with the railway administration in order to expedite the work and to avoid interference with the operation of the railway. Before performing any work on his siding's yards or on other transportation facilities adjacent to existing railways, the Contractor shall enter into an agreement with and shall meet all requirements of the railway administration within the area of the Contractor's operation for the protection of railway lines against damage, interference with traffic or service thereon by the operations of the Contractor under this Contract. The Contractor shall not store or place any materials or equipment on the right-of-way of the existing railway in such a manner as to interfere with the operations of trains or the maintenance of the rail bed and track. In advance of any operation which may unavoidably interfere with the operation of the railway, the Contractor shall notify the superintendent of the corresponding Railway division in order that proper flagging or other protection may be provided. The cost of providing and maintaining all necessary safety measures, watchman guards, signals and temporary structures or making any necessary repairs, replacements or similar operations or furnishing indemnity or other required by this article shall be borne by the Contractor and the Contractor shall save harmless and indemnify the Procuring entity in respect of all claims, demands, proceedings, damages costs, charges and expenses whatsoever arising out of or in relation to any such operations or interference.

c) **IRRIGATION FLOW**

The Contractor shall conduct his operations so as to offer the least possible obstruction for maintaining flow in irrigation canals, channels and water courses. The Contractor shall observe all rules and regulations of appropriate authorities regarding the interruption and maintenance of flow in irrigation canals, channels and water sources and the Contractor shall save harmless and indemnify the Procuring entity in respect of all claims, demands, proceedings, damages, costs and expenses whatsoever arising out of or in relation to any such construction, operations or interference with irrigation flows. The Contractor shall maintain alternate channels wherever temporary relocation of irrigation channels is required or where his operations disrupt the irrigation flow, without any compensation from the Procuring entity.

SP-6 UTILITY LINES

The Contractor shall conduct his operations, make necessary arrangements, take suitable precautions and perform all required work vital to the protection of and avoidance of interference with power transmission, telegraph, telephone and natural gas lines, oil lines, water and sewerage mains and other utilities (including buried lines) within the areas of his operations in connection with this Contract and the cost thereof shall be borne by the Contractor and the Contractor shall save harmless and indemnify the Procuring entity in respect of all claims, demands, proceedings, costs, charges and expenses whatsoever arising out of or in relation to any such interference.

SP-7 MAKING GOOD DAMAGE TO SERVICES, EARTHWORK, etc.

The Contractor shall make good, at his own cost, all damages to telephone, telegraph and electric cables or wires, sewers, water or other pipes except where the Authority, Procuring entity or Private Party owing or responsible for the same elects to make good the damage.

All injury to the surface of the land, to the beds of water courses, protecting banks, riverbeds, etc. where disturbed by the works (other than where specifically ordered by the Procuring entity), shall be repaired by the Contractor or the Authorities concerned, at the Contractor’s expense. All such making good shall be to the approval of the Procuring entity.

SP-8 ELECTRIC SUPPLY

The Contractor shall make arrangement for the electric power supply and distribution of the same at the Site of Works for the completion of the Works at his own expense.

SP-9 HEALTH AND SAFETY MEASURES

a) **SAFETY PRECAUTIONS**

The Contractor shall adequately provide for the safety, health and welfare of persons and for the prevention of damage to works, material, equipment for the purpose of or in connection with the Contract.

b) **WORK ZONE SAFETY**

The Contractor shall ensure implementation of Work Zone Safety Plan (placement, signage size, dimensions and lettering) according to the standards and drawings provided by the Engineer/Engineer representative and also provided herein the bidding documents. No separate payment shall be made in this regard.

c) **FIRST AID FACILITIES**

The Contractor shall provide and maintain adequate First Aid Facilities including but not limited to deployment of fully qualified technician's or paramedic's and an ambulance round the clock at the site and shall comply with all instructions as issued from time to time by the Engineer / Engineer representative. No separate payment shall be made in this regard.

d) **SANITATION**

The Contractor shall maintain the Site and all working areas in hygienic conditions and in all matters of health and sanitation shall comply with the requirements as approved by the Engineer / Engineer representative.

The Contractor shall provide, maintain and clean throughout the period of construction of the Works, suitable and sufficient latrines for use by his employees.

SP-10 RATE AND PRICES INCLUSIVE

The rates and prices quoted by the Contractor in the priced Bill of Quantities shall include all freight, customs, import duties, taxes, pilotage, landing charges, wharfage, octroi, excise duties, royalties and all other costs, charges imposed whatsoever in respect of any or other things provided by him for the Works.

The prices in the Bill of Quantities shall include also all additional costs and provisions required for the correct execution of works in compliance with the time schedule and the specifications.

By way of illustration but not enumeration, the Unit Prices shall include besides the costs for supply of material and equipment, cost of their transport, Contractor's profit etc., the cost for provision of the following: -

a) Furnishing and maintenance of Contractor's Equipment, fuel for equipment, temporary works, tests, samples and labor necessary for execution of the works, equipment for transport, machines, test laboratories, site office(s) and sheds including all expenses for the furnishing and maintenance of the workshops and storage areas used by the Contractor.
b) Required power, water and other services.
c) Establishment, furnishing and maintenance of the Procuring entity and the Engineer / Engineer representative site offices.
d) Establishment, furnishing, equipment's and maintenance of the Engineer / Engineer representative material testing laboratory.
e) Providing sufficient technicians & helpers for Engineer / Engineer representative Survey, Quality Assurance and Laboratory testing operations.
f) Illumination and safety at site.
g) Health and safety measures at and off the site.
h) All additional costs due to any kind of difficult working, conditions and interruptions which may possibly be caused by adverse physical conditions.
i) Staff allowances, ambulances, expenses for medical treatment, traveling expenses, holiday wages and salaries and all other costs for all Contractor

employees, the required means of communications such as telephone and the like, the required means for protection against accidents.

j) All expenses for royalties, licenses, liabilities insurances, rent, hire and the like in connection with the Works.

k) Other special work arrangements and provisions not mentioned here but necessary for the proper and complete execution of the Works such as provision & maintenance of Diversions/Detour etc.

l) All Government and/or Municipal taxes, customs duties, excise duties, stamp duties or any other dues, taxes or charges.

m) Cost of all insurances to be kept in force during the period of construction and the period of maintenance / defects liability period of the works under the Contract.

n) Mobilization, demobilization and clearance of site.

o) Contractor's camp for staff and labor including the services.

p) Performance Security and Bank Guarantees as and when required under the Contract.

q) Traffic Diversion / management, work zone safety measures etc. and any other measures required for safe and smooth movement of traffic / road commuters/ workers / pedestrians etc.

The cost of the above shall be deemed to be included in the rates and prices tendered for the works and no separate payment shall be made on these accounts.

SP-11 PROVISION OF PLANT & EQUIPMENT

In respect of any Contractor's Equipment in general, except as provided for in these Documents, which the Contractor shall be required to have available at Site for execution of Works in accordance with the Drawings, Specifications or as directed by the Procuring entity and Engineer / Engineer representative, he shall make his own arrangements for foreign exchange, import formalities, customs, transport to the Site of Works and all other formalities whatsoever at his own cost and responsibility.

The Contractor shall be deemed to have taken into consideration all Government or Local Bodies regulations, for the time being in force, regarding the re-export of any plant and equipment which he may have to import in connection with the works. Any amendments to the existing rules and/or further regulations imposed in this respect by the Government of Pakistan shall be strictly followed by the Contractor.

SP-12 CONTRACT DRAWINGS

a) **Tender Drawings**

The Drawings as listed on the Index of Drawings sheet at the front of the Volume of Drawings, and hereinafter referred to as Tender Drawings, show the scope of the works to be performed by the Contractor. The Tender Drawings shall not be used as a basis for construction but may be used as a basis for placing preliminary orders for materials, subject to corrections based on the future issue of Drawings as provided under sub-clause (b) hereof - Construction Drawings.

b) **Construction Drawings**

After award of Contract, the Tender Drawings will be replaced by drawings issued for construction (Construction Drawings) including supplementary specifications as may be necessary. Such Construction Drawings and Specifications shall be construed to be included in the expressions **Supplementary Drawings and Instructions under Sub-clause 7.1, Conditions of Contract, Part-I**.

The Construction Drawings will include Tender Drawings re-issued, Tender Drawings as may be modified, Approved Drawings, and additional Drawings as required to develop work in greater detail, and modifications as necessary to further detail the construction requirements. The work shall be executed in conformity with the Construction Drawings.

c) **Checking Drawings**

The Contractor shall check all Construction Drawings carefully as soon as practicable after receipt thereof, and shall promptly bring to the notice of the Engineer/Engineer representative, if any errors are discovered.

Where Drawings provided by the Engineer/Engineer representative show typical details for the positions, dimensions or levels of foundations, supports, holes or openings through walls or floors for items of equipment or plant to be provided by the Contractor as part of the Works, the Contractor shall satisfy himself before construction that such positions, levels or dimensions are correct for the actual items being supplied by him. In the event that such Drawings require to be changed to suit the items being supplied, the Contractor shall prepare drawings of such changes and submit them for approval.

SP-13 RIGHT TO CHANGE

When additional information regarding the geological formations or other conditions becomes available as a result of excavation, testing, model studies, or exploratory work, the Engineer / Engineer representative may find it desirable to change dimensions or design of one or more of the features of the Works to conform to the newly disclosed conditions. Towards this end the Engineer/Engineer representative reserves the right to make such reasonable changes, and the Contractor's Plant shall be laid out and his operations shall be conducted so as to accommodate any such reasonable changes in the Works with no increase in cost to the Procuring entity.

SP-14 SUBMISSION AND APPROVALS

Where Drawings are required by the Specifications or the Drawings for planning and performance of the work under the Contract or for materials or equipment to be fabricated, manufactured, and furnished by the Contractor or his Subcontractors, the Contractor shall provide such planning or assembly and detailed shop drawings as required and have them approved before proceeding with the work. All such drawings shall be adequately and properly checked before submittal to the

Engineer/Engineer representative for approval and shall be so designated. All unchecked drawings received by the Engineer/Engineer representative for approval will be returned, “Not approved”.

Four copies of such drawings shall be submitted to the Engineer/Engineer representative in the form of prints from the original checked drawings. One print each of these drawings will be returned to the Contractor by the Engineer/Engineer representative, marked “Approved”, “Approved except as amendments noted”, or “Not approved, resubmission required as noted”.

The notes “Approved” or “Approved subject to amendments noted” will authorize the Contractor to proceed with the fabrication/manufacture/construction of the equipment/structure/item covered by such Approved Drawings, subject to the corrections, if any, noted thereon. When prints of drawings have been marked “Not approved, resubmission required as noted”, the Contractor shall make the necessary revisions on the drawings and shall, within 28 days, submit prints for approval in the same manner as before. Any fabrication or manufacturing or construction during or before approval of the drawings will be at the Contractor's risk.

The Engineer/Engineer representative shall have the right to require the Contractor to make any changes in the design, which may be necessary, in the opinion of the Engineer/Engineer representative, to make the materials or equipment or items conform to the requirements and intent of these specifications without additional cost to the Procuring entity. Approval of the Contractor's drawings shall not be held to relieve the Contractor of any part of his obligations to meet all of the requirements of these specifications or of the responsibility for the correctness of his drawings. At the time of delivery of the equipment or materials, the Contractor, if requested to do so, shall furnish to the Engineer/Engineer representative two complete sets of the final approved drawings that relate to that equipment or materials.

SP-15 COOPERATION WITH OTHER CONTRACTORS

Nothing contained herein and nothing marked on the drawings shall be interpreted as giving the Contractor or other contractors of the Procuring entity exclusive occupancy of the work area provided by the Procuring entity. When the work area of one contract is a necessary or convenient means of access for the execution of another contract, such privilege of access or other reasonable privilege shall be granted by the Contractor or by other contractors of the Procuring entity to the required extent, in the manner and at the times necessary. Any difference or conflict, which may arise between the Contractor and other contractors of the Procuring entity, will be adjusted and determined by the Engineer/Engineer representative. No joint occupancy or use of right-of-way shall be made the basis of any claim for delay or damages to or against the Procuring entity.

SP-16 PROGRESS REPORT

The Contractor shall submit to the Engineer/Engineer representative fortnightly progress reports in two copies detailing the progress in the execution of work during the reporting period. The submission of the progress reports shall be condition precedent to the payment of Contractors Bills by the Procuring entity. One week in advance the Contractor shall submit for the Engineer's/Engineer's representative approval, particulars of the work he proposes to execute within the following two weeks.

SP-17 ATTENDANCE OF MEETINGS

The Contractor shall attend and shall cause his Sub-Contractors to attend any or all meetings when called by the Procuring entity or the Engineer/Engineer representative to discuss progress of the Works and other matters related to the Works and the Contract, without any compensation from the Procuring entity.

The Contractor shall bear all expenses of the Procuring entity and his representatives and the Engineer, and his representatives for any meetings requested by the Contractor for instructions and approvals away from the site within or outside Pakistan.

SP-18 CONSTRUCTION PROGRAMME

The Contractor shall submit to the Engineer/Engineer representative, for approval, his construction program, or schedules in accordance with **Sub-clause 14.1 of the Conditions of Contract**. The schedules shall contain adjustments, if any, to the proposed construction schedule submitted with the Tender. The operations under each section of the schedules submitted by the Contractor shall be broken down in greater detail than that shown on the schedule submitted with the Tender.

The Contractor shall also prepare a network diagram and identify critical activities, using a standard networking programme and submit the same for the Engineer / Engineer representative review. The Contractors progress shall be monitored using the events and milestones identified on the diagram. This network diagram shall be regularly updated periodically as the work proceeds.

SP-19 QUALITY CONTROL AND QUALITY ASSURANCE

The Contractor shall be responsible for providing all Quality Control and Quality Assurance measures to ensure compliance of the Works with the drawings or as stated in the Contract Documents.

The Engineer's representative may independently perform activities such as surveying, quantity measurement, materials testing, as are necessary to verify the quality, accuracy, and quantity of the completed Works.

The materials produced and the workmanship provided in fulfilling the requirements of the specifications shall be in accordance with the Contractor's Quality Assurance Program, duly approved by the Engineer representative.

Construction shall not be undertaken without the Engineer's representative approval, and no payments will be made to the Contractor for quantities of construction works which are not accepted by the Engineer representative.

SP-20 CONTRACTOR'S QUALITY ASSURANCE PROGRAMME

a) GENERAL

The Contractor's Quality Assurance Plan shall include a detailed description of the organization, procedures, and facilities proposed to ensure that the construction is carried out in accordance with the Contract Specifications and Drawings. This plan shall also be applicable to work performed by any sub-contractor.

The Contractor shall submit his Quality Assurance Plan to the Engineer representative for review and approval prior to the commencement of work. The Contractor's Quality Assurance Plan shall be periodically reviewed as the work proceeds.

The Quality Assurance Plan shall include, but not be limited to, detailed procedures, instructions, or statements covering the following items:

b) ORGANIZATION

The Quality Assurance Plan shall describe the Contractor's organization and delineate the responsibility and authority of the various personnel and groups involved. The Quality Assurance Department's internal structure and relationship with other departments shall be defined. An organizational chart shall be prepared showing lines of authority and communication.

c) PERSONNEL

The Contractor shall supply properly trained and qualified personnel to procure samples for testing, to conduct tests and analyze samples of soils, concrete, and other construction materials. The Contractor shall provide for the duration of the Contract, competent, suitably qualified Engineers / Material Engineer's & Geologists etc., whose sole duties shall consist of material location, testing and control in accordance with the Specifications.

The Contractor shall supply properly trained and qualified personnel to prepare shop drawings as required. Drawings, when prepared by the Contractor, will include all information and data required for preparation of As Built Drawings. The Contractor shall provide properly trained and qualified surveyors and survey crews and all necessary survey equipment as may be required to perform all construction survey activities, measurement of quantities, and for any surveys required for preparation of As-Built Drawings.

The above personnel will be subject to approval by the Engineer representative.

The Contractor shall also provide labor, equipment, and materials to the Engineer representative for examining, measuring, and testing any works.

d) DOCUMENT CONTROL

The Quality Assurance Plan shall assure that the Specification requirements are correctly translated into and included in the Contractor's procedures, documents, and drawings. The Plan shall further assure that the latest approved documents, including changes, are available to and used by the required manufacturing, inspection, and test personnel.

e) **SOURCE APPROVAL**

The Contractor shall obtain source approval of all materials prior to their use in the Works. Source approval submittals shall include the name and address of all manufactures and suppliers, recent test results showing complete compliance with the Specifications and specified standards, the date of manufacture, storage conditions, and shelf life if appropriate. In addition, the Contractor shall provide representative samples of the material of a sufficient size that the Engineer representative may perform all specified tests. Once a source approval has been granted by the Engineer representative, all deliveries of the material to the site must in turn be submitted for approval accompanied by all relevant test reports to show full compliance of the material with the Specifications.

Where the required tests cannot be performed at the Site Quality Control Laboratory, then the Contractor shall arrange for independent testings, at a laboratory approved by the Engineer representative, to be performed to show that the material complies with the Specified standards. Cost of such testings will not be reimbursed.

f) **PROCESSED MATERIAL CONTROL**

The Quality Assurance Plan shall provide assurance that procured and subsequently processed material complies with the Specifications. Material identification shall be provided and maintained. Control shall be provided for the documentation and disposal of non-conforming material, and their subsequent rework or repair and re-inspection. The program shall also provide for the prior notification to the Engineer representative of proposed rework or repair or non-conformance for his evaluation and approval.

g) **SPECIAL PROCESSES**

Special Processes such as sandblasting, shotcreting, curing, installation of elastomeric sealant, welding, etc., shall be performed in accordance with documented process procedures and by qualified personnel. The procedure shall describe the process sequence and methods, process perquisites, equipment, qualification of personnel and equipment, and acceptance criteria. The procedures shall describe the preparation and retention of documents used to record the results of Special Processes.

h) **INSPECTION**

The Quality Assurance Plan shall provide for the inspection of activities and completed items of work by the Contractor to assure compliance with the Specifications prior to its submittal to the Engineer representative. Examination or measurements shall be performed at each applicable work operation. The Contractors inspection shall be performed by qualified individuals other than those who performed the activities being examined.

i) **CALIBRATION**

Procedures shall be established to assure that test and measuring devices used to test, or accept materials or components are calibrated at specified intervals to maintain the proper accuracy. Devices used shall be of a proper range, type, and sensitivity to reliably measure the parameters being evaluated.

The Contractor must ensure the precision and accuracy of the measuring and monitoring resources / equipment's / devices through proper calibration. The calibration of measuring and monitoring resources / equipment's / devices must be performed through Pakistan National Accreditation Council (PNAC) approved calibration laboratories. The Contractor shall submit the calibration certificates along with measuring and monitoring resources / equipment's / devices for approval of the Engineer representative.

j) **DOCUMENTATION**

The Quality Assurance Plan shall include a system to ensure that the documentation necessary to attest the completion of any phase of the work, use of correct materials, completion of required inspections and tests, and acceptability of results is generated, reviewed, maintained and submitted to the Engineer representative at the required time. The system shall ensure that such documentation is reviewed by the Contractor for legibility, completeness, validity of data, traceability of document to activity or equipment and acceptability of results.

k) **SUBMITTAL OF CONTRACTOR'S DOCUMENTS**

The Contractor shall submit a draft of the Quality Assurance Plan for review by the Engineer representative within 28 days of the commencement date. The final version shall be submitted within 28 days of receipt of the Engineer representative's comments.

The Contractors Quality Assurance Plan shall be periodically reviewed and revised as the work proceeds.

SP-21 CONTRACTOR'S QUALITY CONTROL TEST PROGRAMME

a) **GENERAL**

The Contractor shall submit his Quality Control Test Program as part of his Quality Assurance Plan to the Engineer representative for review and approval prior to the commencement of work. The Contractor Materials Testing Program shall be suitably documented to assure that the required materials and component testing is properly performed. The test program shall address pertinent test prerequisites, such as test instrumentation selection and calibration, acceptance criteria, documentation of test results, and evaluation of test results by qualified personnel. The Quality Control Test

Program shall include, but not be limited to, location of facilities, type, number, and capacity of equipment, plant layout drawings, staff, vehicles, and procedures.

The Contractor shall ensure that the proper number and types of samples are obtained, location of structures, lift of structures, date of pouring of concrete, identify the tests and analyses required, and ensure that the tests and analyses conducted are in accordance with accepted procedures and standards. The Engineer representative shall be invited to be present during the test or inspection. The Engineer representative will supervise, as necessary, tests performed by the Contractor both in the field and in the project laboratory. The Engineer representative may himself perform such independent tests and scrutinizes as are necessary to verify the results of all the tests conducted by the Contractor.

b) **QUALITY CONTROL TESTING FACILITIES**

As a part of the construction material's quality control program, the contractor shall provide, erect, furnish, run and maintain the **"Project Laboratory"** at the specified and approved location at his own cost. The laboratory shall be in full working order, suitably equipped and staffed to carry out the sampling and testing to the extent and frequency necessary to ascertain that the work complies with the specifications.

The laboratory shall include sufficient office space and furniture for the Engineer's representative supervisory personnel. The office of the Engineer's Material Specialist shall be fully air-conditioned having intercom connectivity with the Engineer's office.

The project laboratory shall be operated by the Contractor's qualified and experienced technical personnel under the supervision of the Engineer's Material Specialist and his representatives to carry out joint testing.

The Contractor's Technical Supervisor(s) shall be well conversant with the project specific quality control testings and shall be assisted by number of helper technicians, depending upon the volume of work and as required by the Engineer's Material Specialist.

The technicians and helpers once assigned to the laboratory shall not be removed from the laboratory unless approved/directed by the Engineer's Material Specialist.

The Engineer's Material Specialist may permit the use of the project laboratory for the Contractor's own testing work on the Project, provided it does not interfere with the testing program of Engineer representatives and provided that test results of all tests carried out in the laboratory are made available to the Engineer's representative.

The Contractor shall also provide service utilities such as electric power, gas, water and sanitation to the laboratory building and maintain these services for the duration of the Contract and/or as directed by the Engineer representative.

An independent testing facility shall also be erected at concrete batching plant capable of performing all routine aggregate tests and sampling of constituents, concrete and shotcrete etc.

c) **QUALITY CONTROL TESTS TO BE PERFORMED BY THE CONTRACTOR**

All samples and tests shall be taken by the Contractor at such locations and in such a manner as approved by the Engineer representative. The required minimum testing frequency to be adopted for the Quality Control Program for all construction materials shall be as specified in the relevant section of specifications, including plant calibration checks. The sampling frequency may vary at the discretion of the Engineer representative.

The Contractor shall inform the Engineer representative well in advance but at least 24 hours before he proposes to carry out any field test or at least 4 hours before any laboratory test so that the Engineer representative may supervise the test or the taking of the sample.

If in the opinion of the Engineer representative field density test results are anomalous, 2 additional tests shall be made by the Contractor under the supervision of the Engineer representative in the same layer, and the average of the 2 additional tests shall be adopted as the true representative value. Results of field density tests shall be made to one decimal place.

Tests required to be performed for purposes of **Sub-clause 36 of Conditions of Contract** shall include, without limitation as to the other tests required for purposes of the said **sub-clause 36** or required specific sections of the Specifications, the following:

d) **SOIL TESTS**

- Auger Sampling (ASTM D 1452) Liquid Limit (LL) (ASTM D 4318) Plastic Limit (PL) (ASTM D 4318).
- Visual Classification, Dilatancy (ASTM D 2488) Toughness, Dry Strength (Earth Manual E 3) Sieve Analysis (ASTM C 136).
- Hydrometer Test (ASTM D 422).
- Moisture Density Relationship -Standard Effort(ASTM D 698) Moisture Density Relationship-Modified Effort (ASTM D 1557).
- Relative Density of Granular Soil (ASTM D 4253 and D 4254) Shrinkage Limit (ASTM D 427).
- Permeability of compacted samples (ASTM D 3385) Proctor Needle Penetration (ASTM D 1558) Moisture Content (ASTM C 566).
- In-place Soil Density (ASTM D 1556) Soluble Salts (Earth Manual E 8).
- Specific Gravity of Soil (ASTM D 854) Direct Shear of Soil (ASTM D 3080)

e) **CONCRETE AND ITS CONSTITUENTS**

- Sampling of Aggregates, (ASTM D 75) Sampling of fresh concrete (ASTM C 172) Sampling of cement (ASTM C 183) Screen analysis of Sand (ASTM C 136).
- Screen analysis of Coarse Aggregate (ASTM C 136) Specific Gravity and Absorption of Sand (ASTM C 136).
- Specific Gravity and Absorption of Coarse Aggregate (ASTM C 127) Slump of concrete (ASTM C 143).
- Unit Weight and Volume of Fresh Concrete (ASTM C 138) Unit Weight of Aggregate (ASTM C 29).
- Air Content of Fresh Concrete (ASTM C 231).
- Total moisture content of aggregate (ASTM C 566) Preparation of laboratory Concrete (ASTM C 1992).
- Casting Cylinders in Cast Iron or Disposable Molds (ASTM C 31) Capping Concrete Cylinders (ASTM C 39).
- Abrasion Resistance of Coarse Aggregate (ASTM C 131) Soundness of Fine and Coarse Aggregate (ASTM C 88) Obtaining and Drilling of Cores (ASTM C 42)

f) **REINFORCEMENT STEEL**

- Physical properties of Steel (ASTM A 615)
- Chemical properties of Steel

g) **CONTRACTOR'S QUALITY CONTROL TEST RESULTS**

All laboratory & field test results conducted as part of the Contractor's quality control procedure shall be submitted to the Engineer representative for review. The test results must show full compliance with the Specifications, in order for the Works to be approved. The materials and test reports submitted to the Engineer representative shall include, but shall not be limited to, the followings:

Soil reports showing location, material source, material type, density, moisture content, density-moisture content relationship.

Concrete reports showing source of all constituents, class of concrete, testing of source material, date of manufacture, testing of material after processing, including determination of moisture content of aggregates, quantities, pour records and testing of manufactured concrete. Certification of all admixtures, cement supplies, and storage records.

Aggregate reports for filters, gabions, showing source of material, test results showing compliance with the Specifications and placing location.

Ancillary reports for materials such as steel, concrete admixtures, water-stops, joint sealants, elastomeric bearing pads, prestressing strand, jointing compounds, paints, etc., showing name of source date of manufacture, shelf life, storage conditions, place of storage, test results showing compliance with the Specifications, and placing records.

The numbering system to be used for recording tests and test results shall be subject to the Engineer representative's approval.

The following Laboratory Equipment shall be at least provided and maintained by the Contractor as per approval of the Engineer's Representative.

Equipment Description	Soil test Model No.	Unit	Quantity
a) General Equipment			
Laboratory Oven, Capacity, 240 Lit.	L-158	Each	1
Laboratory Oven, Capacity, 115 Lit.	L-6	Each	2
Memmert or equivalent			
Hot Plate (max. Temp. 350°C)	L-236	Each	1
Burner (Gas) Two Flames	-	Each	3
Bunsen Burner with Tripod	-	Each	2
Sensitivity of 1 gm balance	L-500	Each	2
Sensitivity of 0.1 gm balance	L-410	Each	2
Electric Balance of 0.01 gm	L-817	Each	2
Platform Balance (115 Kg)	L-855M	Each	1
Wall Clock	-	Each	2
Stopwatch	Lt-475	Each	2
Vernier Calipers	-	Each	2
Electronic Thermometer General 0-200° C	-	Each	4
Max. & Min. Thermometer	-	Each	2
Sampling Tools Complete	-	Each	1
Tongs	G-120	Each	2
Desiccator	G-61	Each	2
Beaker (Pyrex) 250 ml	G-5	Each	3
Beaker (Pyrex) 500 ml	G-8	Each	4
Beaker (Pyrex) 1000 ml	G-9	Each	6
Funnel 250 ml	-	Each	
Funnel 500 ml	-	Each	
Volumetric Flask Stoppered, 100ml	G-40	Each	2
Volumetric Flask Stoppered, 250ml	G-26	Each	2
Volumetric Flask Stoppered, 500ml	G-27	Each	2
Volumetric Bottle Flask, 250 ml	G-41	Each	2
Volumetric Bottle Flask, 500 ml	G-42	Each	2
Wash Bottle, 100 ml	G-10	Each	2
Wash Bottle, 250 ml	G-10	Each	4
Wash Bottle, 500 ml	G-10	Each	4
Graduated Cylinder, 100 ml	G-18	Each	2
Graduated Cylinder, 250 ml	G-19	Each	4
Graduated Cylinder, 1000 ml	G-21	Each	8
Reagent Bottle Stoppered, 2 lit.-		Each	2
Aluminum Cans with Cover, 2" Dia.	LT-30	Each	As Reqd.
Aluminum Cans with Cover, 4" Dia.	LT-30	Each	As Reqd.
Scoop	CN-502	Each	4
Brush (Fine)	-	Each	4
Wire Brush (Coarse)	CL-375	Each	4
Wire Brush (Fine)	CL-216	Each	4
Bucket, 12 lit.	-	Each	3
Trolley	-	Each	2
Shovel (Large)	DR-26	Each	2
Pickax	-	Each	4
Sample Splitter (Coarse)	CL-287	Each	2
Sample Splitter (Fine)	CL-280	Each	2
Sieve Shaker for 8" Dia.	CL-300A	Each	1
Sieve (Motorized)			
Sieve Shaker for 12"/18" Dia			

Sieve (Motorized)	CL-343	Each	1
Tin Pan/Tray 12"x12"x2"	Local Made	Each	10
Tin Pan/Tray 16"x12"x3"	Local Made	Each	2
Tin Pan/Tray 20"x16"x3"	Local Made	Each	8
Tin Pan/Tray 20"x16"x4"	Local Made	Each	6
Mortar Porcelain 200 mm	CL-281	Each	1
Rubber covered pestle	CL-282	Each	1
b) Sieve Analysis for Coarse & Fine Aggregates			
Sieve Set 12"/18" Dia			
3 inch (75 mm)	CAW-18300	Each	2
2-1/2 inch (63 mm)	CAW-18250	Each	2
2 inch {50 mm)	CAW-18200	Each	2
1-1/2 inch (38 mm)	CAW-18150	Each	2
1 inch (25 mm)	CAW-18100	Each	4
3/4 inch (19 mm)	CAW-18075	Each	4
1/2 inch (12.5 mm)	CAW-18050	Each	4
3/8 inch (9.5 mm)	CAW-18037	Each	4
No. 4 (4.75 mm)	CAW-184	Each	4
Sieve Set 8" Dia.		Each	
3/4 inch	CBC-1875	Each	3
1/2 inch	CBC-8050	Each	3
3/8 inch	CBC-8037	Each	3
No. 4 (4.75 mm)	CB-84	Each	6
No. 8 (2.36 mm)	CB-88	Each	6
No. 10 (2.00 mm)	CB-810	Each	4
No. 16 (1.18 mm)	CBC-816	Each	3
No. 30 (0.60 mm)	CB-830	Each	3
No. 40 (0.425 mm)	CB-830	Each	4
No. 50 (0.300 mm)	CB-850	Each	6
No. 80 (0.180 mm)	CB-880	Each	3
No. 100 (0.150 mm)	CB-8100	Each	3
No. 200 (0.075 mm)	CB-8200	Each	4
Wet Washing No. 200	CL-385	Each	3
Pan	CB-8500	Each	3
Cover	CB-8506	Each	3
c) Atterberg Limits			
liquid Limit Test Set (with all accessories)	CL-209	Each	1
Plastic Limit Test Set (with all accessories)	CL-257	Each	1
Shrinkage Limit Test Set (with all accessories)	CL-256	Each	1
d) Sand Equivalent Test			
Sand Equivalent Test Set	CL-230	Set	1
Stock Solution	-	-	As Reqd.
e) Unit Weight & Specific Gravity Tests for Coarse and Fine Aggregate			
Density Basket (Brass}	G-340	Each	2
Sand Absorption Cone & Tamper	G-325	Each	2
Pycnometer 25 ml	G-341	Each	1
Pycnometer 50 ml	G-342	Each	1
Pycnometer 100 ml	G-343	Each	1
f) Abrasion Test for Coarse Aggregate			
Los Angeles Abrasion Machine with Abrasion Charges Set	M-502	Each	1

g) Soundness Test for Coarse & Fine Aggregate			
Distilled Water	-	1	As Reqd.
Sodium Sulphate Solution	-	Kg	As Reqd.
h) Modified Compaction Test			
Straight edge	CN-838	Each	2
Scoop	CN-505	Each	4
Scoop	CN-502A	Each	4
Mixing Spoons	CN-995	Each	4
Sample Ejector	P-103	Each	2
Modified Compaction			
Hammers 10 lbs.	CN-416	Each	2
Modified Compaction Mold 6" Dia	CN-403	Each	2
Modified Compaction Mold 4" Dia	CN-406	Each	2
Preparation Knife	P-89	Each	2
Rubber Mallet	-	Each	4
Mixing Trays 24"x24"x3"	-	-	As Reqd.
i) CBR Laboratory Test			
Soaking Tank 60"x120"x24"	-	Each	1
Additional CBR Mold 6" Dia. (with collars, plate, screws etc.)	N-450	Each	
Filter Screens	CN-556	Packet	As Reqd.
Swell Plates	CN-400	Each	12
Surcharge Weights (Circular)		CN-557	Each
Surcharge Weights (Slotted)	CN-558	Each	12
Tripod Attachment	CN-401	Each	12
Dial Indicator	LC-8	Each	12
Spacer, Disc	CN-393	Each	2
CBR Loading Press (Electronic)	CN-472	Each	1
Proving Ring 2,000 lbs.	PR-60	Each	1
Proving Ring 6,000 lbs.	-	Each	1
Proving Ring 10,000 lbs.	-	Each	1
j) Field Density Test			
Nuclear Gauge (Troxller or equivalent)	-	Each	2
Sand Cone Bottle	CN-992	Each	
Density Plate	CN-994	Each	
Plastic Jug for Sand	-	Each	8
Replacement Jug	CN-993	Each	
Spoon	CN-995	Each	
Plastic Bags	-	Each	
Chisel 12"	CN-998	Each	4
Hammer 2.5 lbs	-	Each	4
Field Balance (Electronic)	L-7708	Each	4
Speedy Moisture Tester	MG-320	Each	4
Sieve No. 30 (0.60 mm)	CB-830	Each	4
Sieve No. 16 (1.18 mm)	CBC-816	Each	4
k) Asphalt Cement Test			
Saybolt Viscometer	AP-122	Set	1
Bitumen Penetrometer	AP-243	Set	1
l) Asphalt Concrete Mix Test			
Marshall Stability Compressive Machine 6" & 4" dia	AP-170A	Each	1
Marshall Specimen Mold Assembly 6" & 4" dia	AP-166	Each	2
Base Plate for Compressive Mold 6" & 4" dia	AP-166	Each	12

Marshall Compaction Hammer	AP-165	Each	4
Marshall Specimen Mold Holder 6" & 4" dia	AP-167	Each	2
Marshal Breaking Head	AP-169	Each	2
Marshall Ring Dynamometer	-	Each	2
Marshall Flow meter	AP-171	Each	4
Mechanical Mixing Apparatus	C-110	Each	2
Water Bath (Thermostatic) Controlled to 60°C	AP-160	Each	1
Glass Plates 15x15x0.5 cm	-	Each	As Reqd.
Bitumen Extractor Apparatus, Complete (Imported)	AP-170	Each	2
Filter Disc	AP-177	Each	As Reqd.
Mixing Dowel (Steel)	AP-190-191	Each	1
Asphalt Oven (115 Lit.) Imp	AP-290	Each	3
Micrometer (for measuring Galvanizing thickness in microns on guardrail etc.,	-	Each	1
Extruder for Stability Mold 6" & 4" dia.	AP-168	Each	
Stability Mold 6" & 4" dia.	AP-169	Each	36
Collar for stability mold and Base plate 6" & 4" dia.	-	Each	4
Compaction Pedestal	AP-172	Each	2
Pavement Core Drill machine with 6" & 4" dia. core	DR-1304	Each	1
Additional Core cutting cylinders for machine 6" &4' dia.	-	Each	As Reqd.
Carbon Tetra Chloride	AP-178	Drum	As Reqd.
Vacuum Extractor	AP-520	Each	1
Extractor Repair Kits	AP-174	Each	1
Thermometer Metallic 350° C	-	Each	6
Digital Dial Thermometer	-	Each	6
Muffle Furnace	-	Each	1
Hubbard-Carmick Specific Gravity Bottle	-	Each	1
Stop Watch for Marshall Test	-	Each	1
Complete equipment for determination of unit weight and stability test etc. of asphaltic base course having maximum size of aggregate 1.5" using 6" mould as per ASTM Designation D5581-96 including mechanical compactor	-	Set	1
m) Concrete & Cement Test			
Electrically-operated Compressive Strength Machine Heavy Duty (250,000 lb.)	CT-755	Each	2
Lab. Concrete Mixer	CT-30	Each	2
Vibrator	CT-106	Each	1
Concrete Tray	CT-58	Each	
Gloves (Asbestos) local	-	Pair	12
Gloves (Rubber) local	-	Pair	12
Spatula Large 8" size	-	Each	6 Nos
Filter Paper 6" & 4" dia. (Imported)	-	Each	1000
Scoop (Large, Medium & Small)	-	Sets	2
Sample Splitter 2' size local	-	Each	1
Mixing Tray (24"x24"x3")	-	Each	6 Nos
Steel (Large)	-	Each	2 Nos
Cylinder Mold Heavy Duty 6" dia.	CT-35	Each	36
Cylinder Capping Apparatus Set	CT-56-4	Each	2+1(4”)
Concrete Capping Compound	CT-55	Each	As Reqd.
Slump Test Apparatus	CT-69	Each	6
n) Soil Investigation and Sampling			
Post-hold Auger, 4 in	DR-34	Each	1

WEATHER RECORDING EQUIPMENT

The contractor shall furnish and maintain in good working conditions throughout the duration of the contract instruments and their necessary appurtenances for recording the daily weather data. Location and model shall be approved by the Engineer's representative.

a) One (1) rain gauge

b) One (1) thermometer

c) One (1) recording barometer

d) One (1) Maximum - minimum thermometer

All Laboratory Equipment, Weather Recording Equipment & Furniture shall be maintained throughout the Contract period and repaired/replaced by the Contractor at his own cost in case of damage or loss. As and when required by the Engineer's Representative, the Contractor shall perform any specified test, at no additional cost to the Procuring entity.

SP-22 QUALITY ASSURANCE BY THE ENGINEER REPRESENTATIVE

a) **GENERAL**

The Engineer representative may himself perform such independent tests and analyses as are necessary to verify the results of all tests and analyses conducted by the Contractor.

The Contractor shall submit for approval of the Engineer representative, a complete list showing the details about **"Project Laboratory"** building, furnishing, permanent & emergency power supply, water supply, sanitation services, safety & security and material testing equipment's. All services supply and equipment shall be new.

The Laboratory equipment & furniture's shall be the property of the Contractor at the end of the Contract.

b) **STANDARDS**

The Contractor shall furnish to the Engineer representative two complete sets of original, USBR Manuals, relevant ASTM Standards, and all other standards mentioned in Contract documents, of the latest available edition, as approved by the Engineer representative.

c) **SURVEY EQUIPMENT FOR ENGINEER REPRESENTATIVE**

The Contractor shall supply and maintain during the course of the Contract one (1) set of latest model survey equipment (Total Station) with all its accessories including software, dedicated computer for downloading the survey data and printer for at least A3 size paper printing. The Survey equipment shall be for exclusive use of the Engineer representative assistants. The Contractor shall submit, for approval of the Engineer representative prior to purchase, a list of all survey equipment including details of make and model.

The Survey equipment shall be the property of the Contractor at the end of the Contract.

SP-23 CONTRACTOR'S CAMP, SITE OFFICE, STORES, WAREHOUSE, MATERIAL YARDS

The Contractor shall make his own arrangements regarding main project camp, site offices, stores warehouses and material yards etc.,

The Contractor shall provide such camps as are required for the proper and efficient progress of the work to house his own employees. The Contractor shall be responsible for and provide all services to living quarters and shall pay all charges in connection therewith and shall comply with all sanitary laws and regulations presently in force in the area.

The location of all facilities shall be subject to the approval of the Engineer representative, who shall have full access to them at all reasonable times. Site buildings shall be maintained in good condition and appearance for the duration of the Contract. Fuel shall be stored according to the requirement of the applicable codes in properly constructed tanks certified as such. Fuel installation shall be secured against unauthorized persons.

The Contractor shall be responsible for and provide all necessary fencing and security to these areas. On completion of the Contract, all buildings and such other works shall be disposed of by the Contractor at his discretion. The Contractor shall be deemed to have taken into account in his Tender the residual/salvage value of all such buildings and materials.

The Contractor's camps shall comply with the provisions of the Pakistan Labor Camp Rules, 1960, issued by the Pakistan Health, Welfare and Local Government Department and the requirements therein set forth.

The Contractor shall make his own arrangement for the shipment, import, internal transportation, storage and use of explosives in accordance with the laws and regulations of Pakistan and international best practice.

The Contractor shall provide a written procedure for the import, transport, storage, use and general safety of any explosives

The import, transport, storage, use and general safety of all explosive and the construction and location of stores for them, shall be subject to the Engineer representative written agreement. Where blasting is permitted, it must be carried out strictly in accordance with arrangement previously agreed in written by the Engineer representative.

Explosive, blasting, and fuse shall be stored in places and in a manner that will ensure safety against accidents and protection against damage and theft.

The Contractor shall be responsible to negotiate with locals for lease of land for the Contractors camps, offices, stores etc. If the Contractor requires additional land for his own purposes, all costs for lease of the land required for such purposes shall be paid by the Contractor.

The Contractor project office shall include an independent conference room for at least 20 persons, fully furnished and equipped with multimedia facility within the Contractor's main camp and approved by the Engineer representative.

No separate measurement and/or payment shall be made for the Contractor's camps, offices, stores etc. and all the costs thereof shall be deemed to have been included in the Contract unit rates of the BOQ items.

SP-24 TELECOMMUNICATIONS

The Contractor shall provide and maintain suitable voice communications around the Site's. The Main Camp offices, Sub-camp offices, the Field First Aid Stations, the Work sites, other major installations/plants and site facilities shall be served by a telephone network and a radio communications network. The Contractor shall make his own arrangements with the authorities for fixed and mobile communication systems.

The Contractor shall be solely responsible for the payment to the relevant authorities of any deposits, connection fees and all other charges in accordance with regulations in connection with telecommunications.

SP-25 SECURITY FACILITIES AND SERVICES

a) **SECURITY FACILITIES**

The Contractor shall establish a security or systems, sufficient to prevent unauthorized entry (by persons or animals) and/or removal of any material and/or plant and/or article, as follows:

(i) Around all his various materials storage and plants / machinery parking areas.

(ii) Around his accommodation camps.

(iii) Around the power generating facilities, including the meters.

(iv) Around the Site offices of the Procuring entity and Engineer/ Engineer representative.

(v) Around the working areas.

b) **SECURITY SERVICES**

The contractor shall operate the security system or systems on a 24-hour, 7-day basis during the entire contract period. He shall cooperate with the local administration and comply with the Engineer representative requirement on all matters relating to security of the works.

The contractor shall institute emergency evacuation procedure at the work sites and site establishment area. This procedure shall be teste at least four times per year on a random basis.

The services provided by the contractor shall ensure the following:

(i) No authorized person or person enter the site.

(ii) No authorized plant and /or material and /or article are removed from the site.

(iii) No authorized firearms are brought on to the site.

(iv) No alcohol or illegal drugs are brought to the site.

(v) No consumption of alcoholic beverages or illegal drugs takes place within the site.

SP-26 FACILITY AND SERVICES FOR THE PROCURING ENTITY AND ENGINEER/ ENGINEER REPRESENTATIVE AND HIS ASSISTANTS

a) **GENERAL**

The contractor shall provide, maintain and repair a separate site office facility within the main contractor's camp premises for the sole use of the Procuring entity and the Engineer representative for the duration of the Contract. If, at any time the Engineer representative orders replacement / improvement of any facility / services, then the Contractor shall replace / improve that facility and services at no cost to the Procuring entity, to the satisfaction of the Engineer representative.

The Procuring entity and the Engineer representative compound shall contain the Procuring entity office, the Engineer representative office and car parking facilities, vehicles maneuvering space and footpaths as required. The Procuring entity and the Engineer representative compound shall be surrounded by a security fence with vehicle and pedestrian gateways and a permanently manned guard hut at the vehicle gate. Bushes and trees shall not be cut except where necessary and then only after approval of the Engineer representative has been obtained.

The site office buildings and associated facilities shall be regularly cleaned, disinfected and maintained throughout the duration of their use. When directed by the Engineer representative, the Contractor shall dismantle and remove from the site all such buildings and associated facilities provide under this Clause and which are no longer required by the Procuring entity and Engineer representative.

b) **OFFICE COMMUNICATION AND COMPUTER EQUIPMENT**

(i) **TELEPHONE AND FACSIMILE**

The contractor shall provide normal PABX telephone services to the Procuring entity and the Engineer / Engineer representative offices as specified hereafter. All service shall be tone dialing. PABX's shall be fully electronic stored program controlled. Reed relays, mini-switches, cross points switching and cross bar technologies are not acceptable.

(ii) **RADIO-TELEPHONE**

The contractor shall provide and maintain in constant fully operable condition a radio-telephone communication system for the exclusive use of the Procuring entity and the Engineer / Engineer representative persons authorized by them. This system shall consist of hand-held and vehicles installed transceivers and shall be capable of providing satisfactory communication between the Procuring entity, Engineer representative and the Contractor's personnel within the extent of the Construction Sites and offices, irrespective of the topographical nature of the area. The system shall use a dedicated radio frequency which cannot be received by any communication system operated by the third party(s) within or outside the construction sites.

c) **PROVIDES SECURITY GUARDS & MANPOWER FOR PROCURING ENTITY & ENGINEER/ENGINEER REPRESENTATIVE OFFICE's**

The Contractor shall provide security guards for the offices of Procuring entity and Engineer / Engineer representative to ensure proper security. The security guards shall perform the duties in three shifts. The guards provided should be from security agency have necessary approval of the Interior Ministry and Home Department of KPK Government.

All the payments to the security agency shall be borne by Contractor.

RECOMMENDED FREQUENCY OF SAMPLING AND TESTING FOR CLAY-CORE ROCKFILL DAM AND ALLIED STRUCTURES

SCHEDULE FOR SAMPLING AND TESTING OF DAM EMBANKMENT CLAY-CORE MATERIALS (ITEM NO: 3.0 - EARTHWORK)

Material	Test	Designation	Sampling and Testing Frequency		Specification Reference
			Variable soil	Uniform soil	
Clay-Core Materials	Classification / Gradation	ASTM D2487	20 to 50 tests per 2,000 Cu.m	10 tests (min) per 5,000 Cu.m	As per Item 3.3 and 3.9
	Atterberg Limits	ASTM D4318	20 to 50 tests per 4,000 Cu.m	10 tests (min) per 20,000 Cu.m	As per Item 3.3 and 3.9
	Moisture Content & Density (Lab) by Standard Proctor Test	ASTM D698	Each layer or 500 to 1,000 Cu.m whichever gives greater number of tests	Each layer or 1,000 to 2,000 Cu.m whichever gives greater number of tests	As per Item 3.3.3 and 3.9.7 etc.
	Field Density.	ASTM D-1556 or ASTM D2167 or ASTM D6938	1/150 Cu.m	1/300 Cu.m	As per Item 3.3.3 and 3.9.7 etc.
	Deleterious Contents		As per visual inspection	As per visual inspection	
	Permeability in-situ	ASTM D2434 ASTM D5084 ASTM D5856 ASTM D5126 USBR 7300-89 USBR 7305-89	20 to 50 tests per 40,000 Cu.m	10 tests (min) per 100,000 Cu.m	As per Item 3.3.4
	Dispersivity	**BS 1377-2: 2022** **Part 5:** Compressibility, permeability and durability tests; **BS1377 part 5/4:** Determination of Swelling & collapse characteristics of Soils	20 to 50 tests per 4,000 to 10,000 Cu.m	10 tests (min) per 10,000 to 20,000 Cu.m	As per Item 3.3.4

Note: The testing frequency's shown are the minimum acceptable rate. More frequent testing may be required as directed by the Engineer/Engineer representative.

SCHEDULE FOR SAMPLING AND TESTING OF DAM EMBANKMENT FINE FILTER, COARSE FILTER AND TRANSITION MATERIALS (ITEM NO: 3.0 - EARTHWORK)

<table>
<tr><th rowspan="2">Material</th><th rowspan="2">Test</th><th rowspan="2">Designation</th><th colspan="2">Sampling and Testing Frequency</th><th rowspan="2">Specification Reference</th></tr>
<tr><th>Variable soil</th><th>Uniform soil</th></tr>
<tr><td rowspan="14">Fine Filter, Coarse Filter and Transition Materials</td><td>Classification / Gradation</td><td>ASTM C136/C136M
ASTM D2487</td><td>20 to 100 tests per 200 Cu.m</td><td>20 tests (min) per 1,000 Cu.m</td><td>As per Item 3.3 and 3.9</td></tr>
<tr><td>Unit Wt.</td><td>ASTM C29</td><td rowspan="10">20 to 100 tests per 2,000 Cu.m</td><td rowspan="10">20 tests (min) per 10,000 Cu.m</td><td rowspan="9">As per Item 3.3 and 3.9</td></tr>
<tr><td>Sp. Gravity & Absorption</td><td>ASTM C127
ASTM C128</td></tr>
<tr><td>Soundness (Sodium Sulphate)</td><td>ASTM C88/C88M</td></tr>
<tr><td>Unconfined compressive Strength</td><td>ASTM D2166/D2166M</td></tr>
<tr><td>Deleterious Contents</td><td>ASTM C142/C142M</td></tr>
<tr><td>Organic Impurities</td><td>ASTM C40/C40M</td></tr>
<tr><td>Particle shape and surface texture</td><td>ASTM D3398</td></tr>
<tr><td>Flakiness index; misshapen particles</td><td>ASTM D4791</td></tr>
<tr><td>Permeability in-situ</td><td>ASTM D2434
ASTM D5084
ASTM D5856
ASTM D5126
USBR 7300-89
USBR 7305-89</td><td>As per Item 3.3.4</td></tr>
<tr><td>Relative Density</td><td>ASTM D4253
(Methods 1A and 1B or 2A and 2B),
and
ASTM D4254
(Method A)</td><td>Each layer
or
200 to 600 Cu.m
whichever gives greater number of tests</td><td>Each layer
or
600 to 1,200 Cu.m
whichever gives greater number of tests</td><td>As per Item 3.3.3 and 3.9.7 etc.</td></tr>
<tr><td>Field Density</td><td>ASTM D4914/D4914M
or
ASTM D5030/D5030M</td><td>1/100 Cu.m</td><td>1/200 Cu.m</td><td>As per Item 3.3.3 and 3.9.7 etc.</td></tr>
<tr><td>Petrographic</td><td>ASTM C 295
ASTM C 289
BS 812: Part 104: 1994
EN 932-4</td><td>3/Source plus 1/2,500 Cu.m</td><td>3/Source plus 1/5,000 Cu.m</td><td>As per Item 3.3 and 3.9</td></tr>
</table>

Note: The testing frequency's shown are the minimum acceptable rate. More frequent testing may be required as directed by the Engineer/Engineer representative.

SCHEDULE FOR SAMPLING AND TESTING OF DAM EMBANKMENT ROCKFILL MATERIALS (ITEM NO: 3.0 - EARTHWORK)

Material	Test	Designation	Sampling and Testing Frequency		Specification Reference
			Variable soil	Uniform soil	
Rockfill materials	Classification / Gradation	ASTM C136/C136M ASTM D2487	10 tests (min) per 100,000 Cu.m	5 tests (min) per 500,000 Cu.m	As per Item 3.3 and 3.9
	Moisture Content & Density (Lab) by Modified Proctor Test **or** Relative Density	ASTM D1557 **or** ASTM D4253 (Methods **1A and 1B or 2A and 2B**), and ASTM D4254 (Method **A)**	10 tests (min) per 100,000 Cu.m	5 tests (min) per 200,000 Cu.m	As per Item 3.3.3 and 3.9.7 etc.
	Field Density	**Direct Testing:** USBR 7220 or 7221 ring density tests, **or** ASTM D4914/D4914M **or** ASTM D5030/D5030M **Indirect Testing:** Fill Settlement measurements (plotting Settlement Vs Roller Passing data)	10 tests (min) per 100,000 Cu.m	5 tests (min) per 200,000 Cu.m	As per Item 3.3.3 and 3.9.7 etc.
	Permeability in-situ	ASTM D2434 ASTM D5084 ASTM D5856 ASTM D5126 USBR 7300-89 USBR 7305-89	10 tests (min) per 100,000 Cu.m	5 tests (min) per 500,000 Cu.m	As per Item 3.3 and 3.9
	Petrographic	ASTM C 295 ASTM C 289 BS 812: Part 104: 1994 EN 932-4	3/Source plus 1/50,000 Cu.m	3/Source plus 1/100,000 Cu.m	As per Item 3.3 and 3.9

Note:

- *The testing frequency's shown are the minimum acceptable rate. More frequent testing may be required as directed by the Engineer/Engineer representative.*
- *Dumping of rock on the embankment surface and subsequent pushing / rolling into place by bulldozer's, generate excessive fines that moved up into the upper part of the lift. An excessive quantity of fines will clog and hamper free draining of rockfill during draw-down of reservoir and can cause excessive post-construction settlements when the reservoir is filled.*
- *The designer shall specify an acceptable amount of fines generation during rock-fill embankment construction and guidance to QA / QC staff, based on the results of rock materials quality testing, obtained from project excavation sites.*

SCHEDULE FOR SAMPLING AND TESTING OF GRANULAR SUBBASE
(ITEM NO: 16.3.1 GRANULAR SUB-BASE)

Material	Test	Designation	Sampling and Testing Frequency	Reference
Aggregate	Gradation	AASHTO T-27	3/Source plus 1/1000 Cu.m	As per Item No. 16.3.1
	Plasticity Index.	AASHTO T-89 and T-90	3/Source plus as required based on visual observation.	- do -
	CBR	AASHTO T-193	3/Source plus as required based on variation in gradation or 1/1000 Cu.m	- do -
	Abrasion	AASHTO T-96	3/Source plus 1/500 Cu.m	- do -
	Moisture Density.	AASHTO T-180	1/1000 Cu.m	- do -
	Field Density	AASHTO T-191, T-238 and T-239	4/layer/400 meter laid 3 Minimum/layer if less than 400 meter laid.	As per Item No. 16.3.1.3.4.
	Sand Equivalent	AASHTO T-176	3/source plus as required based on visual observation.	As per Item No. 16.3.1.2

SCHEDULE FOR SAMPLING AND TESTING OF AGGREGATE BASE COURSE (ITEM NO: 16.3.2 AGGREGATE BASE COURSE)

Material	Test	Designation	Sampling and Testing Frequency	Reference
Aggregate	Gradation	AASHTO T-27	3/Source plus 1/1000 meter	As per Item No. 16.3.2.2
	Plasticity Index.	AASHTO T-89 and T-90	3/Source plus as required based on visual observation.	-do-
	CBR	AASHTO T-193	3/Source/stock pile plus as required based on variation in gradation.	-do-
	Abrasion	AASHTO T-96	3/Source plus 1/5,000 Cu.m	-do-
	Sodium Sulphate Soundness	AASHTO T-104	3/Source plus 1/5,000 Cu.m	-do-
	Fractured faces.	Visual	3/Source plus as required based on visual observation.	-do-
	Moisture Density.	AASHTO T-180	1/1000 Cu.m	As per Item 16.3.2.3.3
	Field Density.	AASHTO T-191 or T-238 and T-239.	4/layer/400 meter laid 3 minimum/layer if less than 400 meter laid.	As per item 16.3.2.3.3
	Sand Equivalent	AASHTO T-176	3/source plus as required based on visual observation.	As per Item 16.3.2.2

SCHEDULE FOR SAMPLING AND TESTING OF ASPHALTIC BASE COURSE PLANT MIX (ITEM NO: 16.4.8)

Material	Test	Designation	Sampling and Testing Frequency.	Reference
Coarse Aggregate	Gradation	AASHTO T-27	1/1000 Cu.m	
	Abrasion	AASHTO T-96	3/Source/stock pile plus 1/5000 Cu.m	As per Item 16.4.8.2;para-1
	Sodium Sulphate Soundness	AASHTO T-104	3/Source plus 1/5000 Cu.m	-do-
	Stripping	AASHTO T-182	3/Source plus 2/5000 Cu.m	--
	Fractured faces	Visual	3/Source plus as required based on visual observation.	As per Item 16.4.8.2;para-1
	Flat and Elongated Particle.	Visual		As per Item 16.4.8.2;para-1
	Specific Gravity. and Absorption	AASHTO T-85	4/Source for each size in Hot bins of Asphalt Plant	For use in preparation of JMF.
Fine Aggregate	Sand Equivalent or Plasticity Index.	AASHTO T-176 AASHTO T-89 and T-90.	3/Source plus as required based on visual observation. 2/1000 CM	As per Item 16.4.8.2;para-1
	Specific Gravity.	AASHTO T-84	4/Source.	For use in preparation of JMF.
	Friable Particles	AASHTO T-112	2/5000 Cu.m	--
Asphalt Cement.	Specific Gravity.	AASHTO T-228	2/Shipment.	For use in preparation of JMF.
	Penetration.	AASHTO T-49	3/Week of plant operation. Samples taken from heating tank at staggered intervals.	As per Item 16.4.8.2;para-2
Mixture	Extraction Gradation Bulk Sp. Gr.	AASHTO T-164 T-30 AASHTO T-166 Method B	2/day's production.	As per Item 16.4.8.2;para-3
	Maximum Sp. Gr.	AASHTO T-209		
	Air Voids	AASHTO T-269		

SCHEDULE FOR SAMPLING AND TESTING OF ASPHALTIC BASE COURSE PLANT MIX (ITEM NO: 16.3.3.2.3)

Material	Test	Designation	Sampling and Testing Frequency.	Reference
Mixture Compacted in place.	Thickness	AASHTO T-230	1/layer @ 100 meter interval per lane.	As per item 16.4.8.4;para-3
	Compaction	AASHTO T-230 ASTM D2950	1/layer @ 100 meter interval per lane.	As per item 16.4.8.4;para-1

Notes:

Test locations will be selected at random.

SCHEDULE FOR SAMPLING AND TESTING OF WEARING COURSE PLANT MIX (ITEM NO. 16.4.10)

Material	Test	Designation	Sampling and Testing Frequency	Reference
Coarse Aggregate	Gradation	AASHTO T-27	1/1000 Cu.m	
	Abrasion.	AASHTO T-96	3/Source plus 1/5000 Cu.m	As per Item 16.4.10.2.1
	Sodium Sulphate Soundness	AASHTO T-104	3/Source plus 1/5000 Cu.m	As per Item 16.4.10.2.1
	Stripping	AASHTO T-182	3/Source plus 1/5000 Cu.m	
	Fractured faces	Visual	3/Source plus as required base on visual observation.	As per Item 16.4.10.2.1
	Flat and Elongated Particle.	Visual	- do -	As per Item 16.4.10.2.1
	Specific Gravity and Absorption.	AASHTO T-85	4/Source for each size in Hot bins of Asphalt Plant.	For use in preparation of JMF.
Fine Aggregate	Sand Equivalent or Plasticity Index.	AASHTO T-176 AASHTO T-89 & T-90.	3/Source plus as required base on visual observation. 1/1000 Cu.m	As per Item 16.4.10.2.
	Specific Gravity.	AASHTO T-84	2/Source	For use in preparation of JMF.
	Friable Particles	AASHTO T-112	1/5000 Cu.m	–
Asphalt Cement.	Specific Gravity.	AASHTO T-228	2/shipment.	For use in preparation of JMF.
	Penetration.	AASHTO T-49	3/week of plant operation. Samples taken from heating tank at staggered intervals.	As per clause 16.4.10.2.2
Premix Asphalt	Extraction Gradation	AASHTO T-164 AASHTO T-30	2/day's production.	As per Clause 16.4.10.2.3
	Flow	AASHTO T-245		
	Stability	AASHTO T-245		
	Bulk Sp. Gravity	AASHTO T-166		
	Loss Stability	AASHTO T-245		

SCHEDULE FOR SAMPLING AND TESTING OF WEARING COURSE PLANT MIX (ITEM NO. 16.4.10)

Material	Test	Designation	Sampling and Testing Frequency	Reference
Mixture compacted in place.	Thickness	AASHTO T-230	1/layer @ 100 meter interval per lane.	As per item 16.4.10.3.2
	Compaction	AASHTO T-230 ASTM D2950	1/layer @ 100 meter interval per lane.	As per Item 16.4.10.3.2

Notes:

Test locations will be selected at random.

SCHEDULE FOR SAMPLING AND TESTING OF CONCRETE, SHOTCRETE AND TUNNEL LINING
(ITEM NO: 6.1.4.3; CHAPTER 6.0 CEMENT CONCRETE)

Material	Test	Designation	Sampling and Testing Frequency	Acceptance Limit.
Coarse Aggregate	Gradation	AASHTO T-27 (ASTM C-136)	2/Stockpile plus 1/1000 Cu.m	As per Item 6.1.4.3; sub-para (3)
	Unit Wt.	AASHTO T-19 (ASTM C-29)	1/Source plus 1/1000 Cu.m	For use in preparation of mix design.
	Sp. Gravity	AASHTO T-85 (ASTM C-127)	2/Source plus 1/1000 Cu.m	- do -
	Absorption	AASHTO T-85	1/Source plus 1/500 Cu.m	- do -
	Abrasion	AASHTO T-96 (ASTM C-131)	1/Source plus 1/5000 Cu.m	As per Item 6.1.4.3; sub-para (3)
	Soundness	AASHTO T-104 (ASTM C-88)	1/Source plus 1/5000 Cu.m	- do -
	Deleterious Substance	AASHTO T-112 (ASTM C-142)	1/Source plus 1/5000 Cu.m	- do –
	Particle shape and surface texture	ASTM D-3398	1/Source plus 1/1000 Cu.m	- do –
	Petrographic	ASTM C 295; ASTM C 227; ASTM C 289	1/Source plus 1/5000 Cu.m	–

SCHEDULE FOR SAMPLING AND TESTING OF CONCRETE, SHOTCRETE AND TUNNEL LINING
(ITEM NO: 6.1.4.3; CHAPTER 6.0 CEMENT CONCRETE)

Material	Test	Designation	Sampling and Testing Frequency	Acceptance Limit.
Fine Aggregate	Gradation	AASHTO M-6 (ASTM C-33)	2/Source plus 1/1000 Cu.m	As per Item 6.1.4.3 ; sub-para (2)
	Unit Wt.	AASHTO T-19 (ASTM C-29)	4/Source plus 1/800 Cu.m	For use in preparation of mix design.
	Specific Gravity	AASHTO T-84 (ASTM C-128)	4/Source plus 1/1000 Cu.m	- do -
	Absorption	AASHTO T-84	1/Source plus 1/1000 Cu.m	- do -
	Organic Impurities	AASHTO T-21 (ASTM C-40)	1/Source plus 1/1000 Cu.m	As per Item 6.1.4.3 ; sub-para (2)
	Soundness	AASHTO T-104 (ASTM C-88)	1/Source plus 1/5000 Cu.m	- do -
	Fineness	AASHTO M-6 (ASTM C-136)	1/Source plus 1/1000 Cu.m	- do -
	Deleterious Substance	AASHTO M-6 (ASTM C-33)	1/Source plus 1/5000 Cu.m	- do -
	Petrographic	ASTM C 295; ASTM C 227; ASTM C 289	1/Source plus 1/5000 Cu.m	–

SCHEDULE FOR SAMPLING AND TESTING OF CONCRETE, SHOTCRETE AND TUNNEL LINING
(ITEM NO: 6.1.4.3; CHAPTER 6.0 CEMENT CONCRETE)

Material	Test	Designation	Sampling and Testing Frequency.	Acceptance Limit.
Concrete	Density (unit weight) ,Yield and Air Content Test for Cement Content	AASHTO T-121 (ASTM C-138)	1/Lot or 1000 Bags	As per Item 6.1.3.1
Cement	Setting Time	AASHTO T-131 (ASTM C-191)	1/Lot or 1000 Bags	As per Item 6.1.4.1
	Mortar Strength	AASHTO T-132 (ASTM C-190)	1/Lot or 1000 Bags	As per Item 6.1.4.1
Water	Chemical Tests	ASTM C-1602; ACI 318M-08	1/Source	As per Item 6.1.4.2
Concrete mix	**Compression (Cube or Cylinder)**	AASHTO T-22 (ASTM C-39)	6/Shift or 50 Cu.m (2 sets of 3 each)	As per Item 6.1.3.1; Table -1
	Slump	AASHTO T-119M/ T 119 (ASTM C-143)	2/shift or 50 Cu.m	- do -
	Core	ASTM C-42 ASTM C-1542	As directed by the Engineer	As per Item 6.3.6.2

SCHEDULE FOR ADDITIONAL SAMPLING AND TESTING OF SHOTCRETE ONLY
(ITEM NO: 6.24; CHAPTER 6.0 CEMENT CONCRETE)

Material	Test	Designation	Sampling and Testing Frequency.	Acceptance Limit.
Shotcrete mix	**Production of test panels:** Spraying of production test panels (with the works)	-	One panel per day of shotcreting or, as required by the Engineer.	As per Item 6.24.4.7
	Thickness and visual inspection: • **From production test panels** – Frequency of coring • **From the Works** – Frequency of drilling holes	ASTM C-42 ASTM C-1542	Each production test panel Random core for each **50 m^2** or part thereof	As per Item 6.24.4.7.2
	Determination of 28 Day Compressive Strength • **From concrete supply** – Frequency of moulding specimens and testing	AASHTO T-22 (ASTM C-39)	As specified herein above for concrete	As per Item 6.1.3.1; Table -1
	• **From test panels –** Frequency of drilling test specimens	ASTM C-42 ASTM C-1542	One set of 3 cores per Test panel	As per Item 6.24.4.7.2
	Determination of • **Permeability;** • **Toughness;** • **Flexural strength;** • **Bond strength** From the works and the production shotcrete	BS EN 12390-8 ASTM C1550 ASTM C1609 ASTM C1583	One set of 8 cores for each **1500 m^2** or, as required by the Engineer	As per Item 6.24.4.7.2

TABLE FOR ALLOWABLE TOLERANCES
(EMBANKMENT, PAVEMENT COURSES AND CONCRETE)

Description	Thickness (mm)	Level (mm)	5M Straight-edge (mm)	Cross-fall (%)	Longitudinal Grade in 30 M (%)
Embankment(Clay core, filters and transition materials)	± 20	+ 0 - 40	30	± 0.5	± 0.1
Subbase (Granular or Stabilized)	+ 10 - 20	+ 0 - 25	20	± 0.3	± 0.1
Base Course (Granular or Stabilized)	+ 5 - 10	+ 5 - 10	6	± 0.2	± 0.1
Asphaltic Base Course.	+ 3 - 10	+ 3 - 10	6	± 0.2	± 0.1
Asphaltic Wearing Course.	± 3	± 3	5	± 0.2	± 0.1
Concrete for structures	± 5	± 10	5	- -	- -

Note:

Accumulative tolerance shall not be more than that as specified against the final layer.

ALLOWABLE TOLERANCE FROM THEORETICAL WEIGHTS (REINFORCEMENT) AS PER AASHTO M-31

Diameter of Bars	Lot under *	Individual Bar under
All	3.5 %	6%

* The term “Lot” means all bars of the same nominal weight per linear meter contained in an individual shipping release or shipping order.

Note: Reinforcing bars are evaluated on the basis of nominal weights. In no case shall the overweight of any bar or lot of bars be cause of rejection.

TABLE FOR ALLOWABLE TOLERANCE
(REINFORCED CONCRETE PIPES OF CLASS - II AND IV)
AS PER AASHTO M-170

Description	Internal diameter variation (%)	Wall Thickness	Permissible Variation in the Position of Reinforcement
Pipes of internal diameter of 300 mm to 610 mm	± 1.5	- 5 mm or - 5 percent Whichever is less	± 10 percent of wall thickness or ± 12 mm. whichever is less
Pipes of internal diameter of 690 mm to 2750 mm	± 1.0	- 5 mm or - 5 percent Whichever is less	± 10 percent of wall thickness or ± 12 mm. whichever is less

Notes:

1. Pipe having localized variations in wall thickness exceeding those specified above shall be accepted, if the three-edge bearing strength and minimum steel cover requirements are met.

2. Pipes having variations in the position of the reinforcement exceeding those specified above shall be accepted if the three-edge bearing strength requirements on a representative sample are met.

PARTICULAR SPECIFICATIONS

CHAPTER - 01

GENERAL

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GENERAL

PS-1 INTRODUCTION

PS-1.1 PREAMBLE

These particular specifications have been produced for Irrigation department, Govt. of Khyber Pakhtunkhwa to cover the “Construction of Jabba Dam District Khyber” specific requirements and construction activities to be supervised by this organization and to be read in conjunction with the drawings and “Technical Specification for Workmanship, MRS – 2019” Govt. of Khyber Pakhtunkhwa.

This specification section of Volume-II provides a general description of the scope of work. The Contractor shall refer to the appropriate detailed drawing and specification section for specifics.

PS-1.2 SCOPE OF THE PROJECT

The main components of the project consist of construction of:

- Dam Embankment
- Coffer Dam
- Diversion Tunnel
- Intake tower
- Spillway
- Access Road
- Bridges
- Delivery Pipe

PS-1.3 DOCUMENTS MUTUALLY EXPLANATORY

The Technical documents, including Particular specifications, Supplementary specifications, General specifications and Contract drawings are taken to be correct, but complete accuracy is not guaranteed. Any error or ambiguity as noted by the Contractor must be reported to the Procuring Entity and the Engineer / Engineer representative before starting the work affected. In the event of any dispute arising as to the true intended meaning of these technical documents, the Engineer / Engineer representative shall interpret the same and his interpretation shall be accepted as final and binding upon all parties concerned.

PS-1.4 STANDARDS

These Specifications describe the requirements and procedures for execution of work items to achieve required workmanship and quality. The materials to be used shall conform to specifications and testing procedures as per the American Society for Testing and Materials (ASTM), American Association of State Highway and Transportation Officials (AASHTO), British Standard (B.S.) or USBR Earth Manual, Second Edition or other standards (including Codes of Practice) as indicated in their latest editions. Samples of materials for laboratory tests and their subsequent approval shall be utilized according to these references.

Where a specific ASTM, AASHTO, British or other standard is referred to in the Specification, another standard can be acceptable, provided that it ensures a quality of material and workmanship equal to or better than the standard referred to. If the Contractor intends to use such alternative standard, he shall notify the Engineer/Engineer Representative thereof, submitting with his notice two copies (in English) of the proposed standard, and shall not order any material or perform any work unless and until he has obtained the Engineer's / Engineer’s Representative specific approval of such alternative standard.

PS-1.5 MANPOWER

Contractor shall also provide skilled manpower in adequate number, who can perform execution with quality and workmanship control in accordance with the requirements of the work item.

PS-1.6 EQUIPMENT

Number and kind of Equipment required for different items of work shall be planned by the contractor keeping in view the workmanship required by a particular item and the quantity of finished item required to be carried out in eight hours shift. The Engineer/Engineer Representative shall approve such planning or any changes shall be proposed for guidance of the Contractor. However, this procedure shall not relieve the Contractor of his contractual obligations pertaining to performance and maintenance of project.

PS-1.7 ALTERNATIVE EQUIPMENT

While some of these specifications may provide that equipment of a particular size and type is to be used to perform portions of the work, it is to be understood that the deployment and use of new or improved equipment is to be encouraged.

The Contractor may request, in writing, permission from the Engineer/Engineer Representative to use equipment of a different size or type in place of the equipment specified or recommended in these chapters.

The Engineer/Engineer Representative, before considering or granting such request, may require the Contractor to furnish, at his expense, evidence to satisfy the Engineer/Engineer Representative that the equipment proposed for use by the Contractor is capable of producing work equal to or better in quality than, that which can be produced by the equipment specified.

If such permission is granted by the Engineer/Engineer Representative, it shall be understood that such permission is granted for the purpose of testing the quality of work actually produced by such equipment and is subject to continuous attainment of results which, in the opinion of the Engineer/Engineer Representative, are equal to, or better than, that which can be obtained with the equipment specified. The Engineer/Engineer Representative shall have the right to withdraw such permission at any time when he determines that the alternative equipment is not producing work of equal quality in all respects, to that which can be produced by the equipment specified. Upon withdrawal of such permission by the Engineer/Engineer Representative, the Contractor will be required to use the equipment originally specified and shall, in accordance with the directions of the Engineer/Engineer Representative, remove and dispose of or otherwise remedy, at his expense, any defective or unsatisfactory work produced with the alternative equipment. Neither the Procuring Entity nor the Contractor shall have any claim against the other for either the withholding or the granting of permission to use alternative equipment, or for the withdrawal of such permission.

Nothing in this clause shall relieve the Contractor of his responsibility for furnishing materials or producing finished work of the quality specified in these specifications.

PS-1.8 STORAGE OF MATERIALS

Articles or materials to be incorporated in the work shall be stored in such a manner as to ensure the preservation of their quality and fitness for the work, and to facilitate inspection.

PS-1.9 DEFECTIVE MATERIALS

All materials which the Engineer/Engineer Representative has determined as not conforming to the requirements of the drawings and specifications will be rejected whether in place or not. They shall be removed immediately from the site of the work, unless otherwise permitted by the Engineer/Engineer Representative. No rejected material, the defects of which have been subsequently corrected, shall be used in the Work(s), unless approval in writing has been given by the Engineer/Engineer Representative. Upon failure of the Contractor to comply promptly with any order of the Engineer/Engineer Representative made under the provisions in this clause, the Engineer/Engineer Representative shall have authority to cause the removal of rejected material and to deduct the cost thereof from any payments due or to become due to the Contractor.

PS-1.10 QUARRY MATERIALS

Quarry material is rock, sand, gravel, clay, or other mineral material, other than local borrow or selected material, obtained on the project. Quarry material does not include materials such as cement, lime, marble powder etc. obtained from established commercial sources.

Quarry Materials shall be furnished by the Contractor from any source the Engineer / Engineer representative may select and approved after proper laboratory testings, except that when mandatory local sources of certain materials are designated in the Special Provisions, the Contractor shall furnish material from such designated mandatory sources.

The furnishing of quarry materials from any source is subject to the provisions of "Examination of drawings, Specifications, and item of Work".

Unless approved in writing by the Engineer/Engineer Representative, material sources shall not be excavated at locations where the resulting scars will present an unsightly appearance from any highway. No payment will be made for material obtained in violation of this provision.

The Contractor shall, at his expense, make any arrangements necessary for hauling over local public and private roads from any source.

Full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in conforming to the provisions in this clause, for furnishing and producing materials from any source shall be considered as included in the price paid for the contract item of work involving such material and no additional compensation will be allowed there for.

PS-1.11 TRADE NAMES AND ALTERNATIVES

For convenience in designation on the drawings or in the specifications, certain articles or materials to be incorporated in the work may be designated under a trade name or the name of a manufacturer and the catalogue information. The use of an alternative article or material that is of equal quality and of the required characteristics for the purpose intended will be permitted, subject to the following requirements:

The responsibility of proof as to quality and suitability of alternatives shall be upon the Contractor and he shall furnish all information necessary as required by the Engineer/Engineer Representative. The Engineer/Engineer Representative shall be the sole judge as to the quality and suitability of alternative articles or materials and his decision shall be final.

Whenever the specifications permit the substitution of a similar or equivalent material or article, no tests or action relating to the approval of such substitute material will be made until the request for the substitution is made in writing by the Contractor accompanied by complete data as to the equality of the material or article proposed. Such request shall be made well in time to permit approval without delaying the work.

Where the term "or similar" is used it shall be construed as "or equivalent".

Any further information that the Engineer/Engineer Representative may require shall be produced by the Contractor when called for.

PS-1.12 FREQUENCY OF TESTS & TEST DESIGNATION

Frequency of tests for the items of construction has been given in subsequent chapters. Test designation and procedure will be used as given in the latest version of relative publication.

PS-1.13 TESTING

Unless otherwise specified, all tests shall be performed in accordance with the methods used by ASTM/BS and shall be made by the contractor under the supervision of the Engineer/Engineer Representative or his designated representative.

Whenever these specifications provide an option between two or more tests, the Engineer/Engineer Representative will determine the test to be used.

Whenever a reference is made in the specifications to a specification manual, or a test designation either of the American Society For Testing and Materials, British standard specification, or any other recognized national organization, and the number or other identification representing the year of adoption or latest revision is omitted, it shall mean the specification, manual or test designation in effect on the day 30 days prior to the date for submission of bids. Whenever said specification manual or test designation provides for test reports (such as certified mill test reports) from the manufacturer, copies of such reports, identified as to the lot of material, shall be furnished to the Engineer/Engineer Representative. When material that cannot be identified with specific test reports is proposed for use, the Engineer/Engineer Representative may, at his discretion, select random samples from the lot for testing. Test specimens ‘from the random samples, including those required for retest, shall be prepared in accordance with the referenced specification and furnished by the Contractor at his expense. The number of such samples and test specimens shall be entirely at the discretion of the Engineer/Engineer Representative.

When desired by the Engineer/Engineer Representative, the Contractor shall furnish, without charge, samples of all materials entering into the work and no material shall be used prior to approval by the Engineer/Engineer Representative. Samples of material from local sources shall be taken by or in the presence of the Engineer/Engineer Representative, otherwise the samples will not be considered for testing.

PS-1.14 SURVEYING AND SETTING OUT

Prior to the commencement of the Works, the Engineer/Engineer Representative shall provide a number of benchmarks located on or near to the Site. Before starting any work, the Contractor shall check the horizontal and vertical control points in the presence of the Engineer/Engineer Representative and shall notify the Engineer/Engineer Representative of any error or misalignment which may be discovered during such checking. After the benchmarks / control points have been thus checked and any errors corrected, the Contractor shall certify his acceptance of the benchmarks to the Engineer / Engineer Representative in writing. Benchmarks shall, where possible be preserved, or else be relocated. Where benchmarks could be destroyed, they shall be accurately tied in to permanent concrete reference points before work is commenced.

Based on the benchmarks mentioned above, the Contractor shall set out the work using the data shown on the drawings or as per the Engineer's / Engineer’s Representative instructions. The Contractor shall then reference these points with permanent beacons of a type approved by the Engineer/Engineer Representative. Each point shall have not less than three reference beacons, which shall be placed where they will not be disturbed by the Works and the method of referencing shall be agreed with the Engineer/Engineer Representative. The Contractor shall supply the Engineer/Engineer Representative with records in an acceptable form including such drawings, sketches, measurements and references as may be necessary for the location or relocation of relevant points and shall keep such records up to date by formal notice to the Engineer/Engineer Representative. The reference beacons shall be used as benchmarks and their levels shall be agreed with the Engineer/Engineer Representative. The levels of all benchmarks shall be checked by the Contractor at monthly intervals and he should immediately notify the Engineer/Engineer Representative whether or not there are any discrepancies.

The contractor shall set construction stakes establishing lines, slopes, and continuous profile-grade in the Dam embankment work, and center line and bench marks for spillway work, intake work, protective and accessory structures and appurtenances and will furnish the Engineer/Engineer Representative with the original copy of the field notes together with all necessary information relating to lines, slopes and grades. These stakes and marks shall constitute the field control by and in accordance with which the contractor shall establish other necessary controls and perform the work.

If, in the opinion of the Engineer/Engineer Representative, modification of the line or grade is advisable, before or after stakeout, the Engineer/Engineer Representative will issue detailed instructions to the Contractor for such modification and the Contractor will revise the stakeout for further approval. No change in bid unit price will be made for such modifications.

The contractor shall be responsible for the preservation of all stakes and marks, and if any of the construction stakes or marks has been destroyed or disturbed, the Contractor will replace them at his own expense.

The Contractor shall be responsible for the accuracy of all lines, slopes, grades, and other survey work.

PS-1.15 UTILITY LINES

The Contractor shall conduct his operations, make necessary arrangements, take suitable precautions and perform all required works incidental to the protection of and avoidance of interference with power transmission, telegraph, telephone and natural gas lines, oil lines water and sewerage mains and other utilities within the areas of his operations in connection with his contract and the Contractor shall save harmless and indemnify the Procuring Entity in respect of all claims, demands, proceedings, costs, charges and expenses whatsoever arising out of or in relation to any such interference.

PS-1.16 SAFETY PRECAUTIONS.

The Contractor shall adequately provide for the safety, health and welfare of persons and for the prevention of damage to works, materials and equipment for the purpose of or in connection with the Contract.

PS-1.17 INSPECTION

The Engineer/Engineer Representative shall, at all times, have safe access to the work during its construction, and shall be furnished with every reasonable facility for ascertaining that the materials and the workmanship are in accordance with the requirements and intentions of these specifications, the special provisions, and the plans/drawings. All works done and all materials furnished shall be subject to inspection by Engineer/Engineer Representative.

The inspection of the work or materials shall not relieve the Contractor of any of his obligations to fulfill his contract as prescribed. Work and materials not meeting such requirements shall be made good and unsuitable work or materials may be rejected, notwithstanding that such work or materials have been previously inspected by the Engineer/Engineer Representative or that payment therefor has been included in a progress estimate.

PS-1.18 REMOVAL OF REJECTED AND UNAUTHORIZED WORK

All works, which have been rejected, shall be remedied, or removed and replaced by the Contractor in an acceptable manner and no compensation will be allowed to him for such removal, replacement, or remedial work.

Any work done beyond the lines and grades shown on the plans or established by the Engineer/Engineer Representative, or any extra work done without written authority will be considered as unauthorized work and will not be paid for. Upon order of the Engineer/Engineer Representative, unauthorized work shall be remedied, removed, or replaced at the Contractor's expenses.

Upon failure of the Contractor to comply promptly with any order of the Engineer/Engineer Representative made under this Item, the Procuring Entity may cause rejected or unauthorized work to be remedied, removed, or replaced and to deduct the costs from any payment due or to become due to the Contractor.

PS-1.19 ALTERNATIVE METHODS OF CONSTRUCTION

Whenever the plans or specifications provide that more than one specified methods of construction or more than one specified type of construction equipment may be used to perform portions of the work and leave the selection of the method of construction or the type of equipment to be used up to the Contractor, it is understood that the Procuring Entity does not guarantee that every such method of construction or type of equipment can be used successfully throughout all or any part of any project. It shall be the Contractor's responsibility to select and use the alternative or alternatives, which will satisfactorily perform the work under the conditions encountered.

In the event some of the alternatives are not feasible or it is necessary to use more than one of the alternatives on any project, full compensation for any additional cost involved shall be considered as included in the contract price paid for the item of work involved and no additional compensation will be allowed thereof.

PS-1.20 CONFORMITY WITH CONTRACT DOCUMENTS AND ALLOWABLE DEVIATIONS.

Work and materials shall conform to the lines, grades, slopes, dimensions and material requirements, including tolerances, shown on the plans or indicated in these specifications. Although measurement, sampling and testing may be considered evidence as to such conformity, the Engineer/Engineer Representative shall be the sole judge as to whether the work or materials deviate from the plans and specifications, and his decision relating to any allowable deviations there from shall be final.

PS-1.21 TRIAL SECTION

Contractor shall submit complete methodology of trial section for approval of the Engineer/Engineer Representative. Trial sections shall be prepared for each type of dam embankment component. In spite of the approval of

Engineer/Engineer Representative for trial section, contractor shall be responsible for the quality of work. Contractor will provide minimum of following information’s in the methodology.

a) Equipment to be used.
b) Layer thickness adopted.
c) Per day production.
d) Results of tests.

PS-1.22 FINAL CLEANING AND RIGHT-OF-WAY RELEASES

On completion of construction, the Contractor shall remove all temporary structures, rubbish, and waste materials resulting from his operations.

On completion of work in rights-of-way, the Contractor shall obtain, from concerned public authority affected, a written signed release verifying that the cleanup has been performed and completed to his satisfaction and that he has no further claim upon the Contractor or the Procuring Entity as a result of such work. All such releases shall be turned over to the Engineer/Engineer Representative prior to the issuance of the Certificate of Completion. No additional payment will be made for this work. The cost of this work is deemed to be included in the price tendered for the mobilization and demobilization required.

PS-1.23 CONSTRUCTION SUBMITTALS

This section will include general requirements and procedures related to the Contractor's responsibilities for preparing and transmitting submittals to the Engineer/Engineer Representative to demonstrate that the performance of the work will be in accordance with the Contract requirements. Submittals include schedules, test results, topographic surveys, Contractor's drawings, samples, methods of construction, and record drawings. Other requirements for submittals are specified under applicable sections of the standard specifications and special provisions.

Providing for and complying with requirements, set forth in this section will not be measured for payment. No additional payment will be made for this work. The cost of this work is deemed to be included in the price tendered for the execution of the items of works for which submittals are required.

1. **SUBMITTAL REQUIREMENTS**

Submittals shall be scheduled and coordinated with the Engineer/Engineer Representative and Contractor's construction schedule. A complete submittal schedule and list of required submittals shall be submitted with the first submittal, but not later than 15 days after receipt of the Notice to Proceed. The schedule for submission of submittals shall be arranged so that related equipment items are submitted concurrently. The Engineer/Engineer Representative may require changes to the submittal schedule to permit concurrent review of related equipment.

2. CONSTRUCTION SCHEDULE

Within 15 days after the date set forth in the Notice to Proceed with the start of construction activities, the Contractor shall prepare and submit for review to the Engineer/Engineer Representative an "expanded" construction schedule showing the order in which he proposes to carry out the work and the dates upon which he proposes to start and complete each major work item. The schedule shall show each major work item provided in the Contract, and shall include the dates for submittals, Sample testing approval of materials and Contractor's drawings, and the procurement of materials and equipment. The construction schedule shall be in chart form showing expected completion percentages and arranged to record actual completion percentages at stated intervals.

The schedule shall outline in detail the proposed equipment, manpower and production rates necessary to achieve the schedule. The Contractor shall update the schedule every 2 weeks with any and all changes in equipment, manpower, etc. annotated. The Engineer/Engineer Representative may require and the Contractor shall furnish such additional information and data as required to justify the basis of the schedule. The accepted construction schedule shall be kept up-to-date as work progresses, including work added by change order, and shall be submitted to the Engineer/Engineer Representative every 2 weeks and with the request for payment. If the Contractor fails to submit the updated schedule within the time prescribed, the Engineer/Engineer Representative may withhold approval of progress payment estimates until such time as the Contractor submits the updated schedule.

The construction schedule shall determine the order in which the work is to proceed. However, the Engineer/Engineer Representative may request and authorize minor changes to this schedule whenever such changes are of advantage to or necessary for the operations of the Procuring Entity.

3. CONTRACTOR'S DRAWINGS

Tender Drawings are the drawings prepared by the Procuring Entity for the purpose of the tender and furnished to the bidders together with the bid documents. The tender drawings show all relevant features of the Works in sufficient detail to enable the bidders to assess correctly the nature and scope of the work requested from him and to price the Bills of Quantities forming part of the bid documents. The whole of the works shall agree in all particulars with the levels, dimensions and details contained in the drawings.

The Contractor shall carefully check the drawings supplied to him and shall bring any errors or discrepancies discovered therein to the attention of the Engineer/Engineer Representative, who will issue the necessary instructions for corrections.

Where dimensions and levels are shown on the drawings or mentioned in the documents forming part of or issued under the contract, these shall be verified by the Contractor on the Site and he will be held responsible for pointing out promptly any errors or discrepancies in such dimensions or levels. The Engineer/Engineer Representative will issue the necessary instructions for corrections.

Failure to discover and/or to notify the Engineer / Engineer Representative of any errors or discrepancies in the drawing shall not relieve the Contractor of the responsibility for unsatisfactory work or faulty construction resulting there from, the obligations of rectifying and making good such work or construction at his own expense and to the complete satisfaction of the Engineer/Engineer Representative.

a) **SHOP DRAWINGS**

The Contractor shall in close consultation with the Engineer/Engineer Representative prepare all the shop drawings deemed necessary for the execution of the works and shall submit the same for approval to the Engineer/Engineer Representative well in advance before the start of the work, to allow 14 days for Engineer's / Engineer's Representative checking and approval. Drawings shall be accompanied by calculations or other information to completely explain the structure, or system described and its intended use.

The Engineer/Engineer Representative shall check and approve or return the same to the Contractor for correction/modification. All works are to be executed in accordance with shop drawings, approved before the commencement of the works. Shop drawings should truly reflect the provisions of typical drawings. Any deviation from the provision of contract drawings shall not be allowed unless written approval is issued by the Engineer / Engineer Representative.

The approval procedure shall be agreed upon with the Engineer / Engineer Representative. The review and approval of Contractor's drawings by the Engineer / Engineer Representative shall not relieve the Contractor from his responsibility with regard to the fulfillment of the terms of the Contract. All risks of error and omissions shall be assumed by the Contractor, and the Engineer / Engineer Representative will have no responsibility.

b) **MANUFACTURER'S INSTALLATION RECOMMENDATIONS**

Manufacturer's installation recommendations and instructions shall provide written detailed step-by-step preparation and installation of the materials and products including recommended quality control testing, seaming and joining, and repair specifications.

c) **METHOD OF CONSTRUCTION**

When so specified or directed by the Engineer/Engineer Representative, the Contractor shall submit proposed methods of construction for specific portions of the work(s). This submittal shall include a detailed written description of all phases of the construction operation to fully explain to the Engineer/Engineer Representative the proposed method of construction. If required by the specifications, submit installation drawings to supplement the description. Review and approval by the Engineer/Engineer Representative will be in accordance with approval process described hereinbelow and shall not relieve the Contractor from his responsibility with regard to fulfillment of the terms of the contract. All risks associated with the proposed method of construction shall be borne by the Contractor.

4. **APPROVAL PROCESS**

Each submittal shall be in accordance with the Contractor's drawings submission schedule. 14 days will be required for checking and appropriate action by the Engineer/Engineer Representative. Contractor's drawings will be returned stamped with one of the following classifications:

- **APPROVED -** No corrections, no remarks.

- **APPROVED AS NOTED -** A few minor corrections. All items of work may be executed as proposed without further resubmission. Resubmit a corrected copy to the Engineer/Engineer Representative.
- **REVISE AND RESUBMIT -** Minor corrections. Work Items not noted to be revised and corrected might be executed. Resubmit drawings as per original submissions with corrections noted. Allow 14 days for checking and appropriate action by the Engineer/Engineer Representative.
- **NOT APPROVED -** Requires corrections or is otherwise not in accordance with the contract documents. No work items shall be executed. Allow 14 days for checking and appropriate action by the Engineer/Engineer Representative.

5. **MATERIAL SAMPLES**

The Contractor shall be required to collect and test material samples to certify that they meet the requirements of these specifications. The cost of sample testing shall be borne by the Contractor. These certified test results shall be submitted by the Contractor to the Engineer/Engineer Representative for approval of the material. The Engineer/Engineer Representative may conduct separate testing of material samples to confirm test results.

Materials for which samples have been approved by the Engineer/Engineer Representative shall be used only in those areas and locations for which the approval was granted. Materials for which samples have been rejected shall not be delivered to the site, or if delivered, shall be removed promptly.

a) **APPROVAL PROCESS**

At least 10 days will be required by the Engineer/Engineer Representative for checking and appropriate action. Failure of a sample to pass such tests will be sufficient cause for refusal of that material and its source. Rejected samples will be returned upon request, and any or all re-submittals required shall consist of new samples and an additional 10 days for checking and approval. All sample testing will be performed by the Contractor at the Contractor's own expense. Upon approval, one sample so noted will be returned and the remainder will be retained by the Engineer/Engineer Representative until completion of the work(s). When requested, all approved samples will be returned for installation provided their identity is maintained in an approved manner until final acceptance of the project. Samples of various

materials or equipment delivered to the site may be taken by the Engineer/Engineer Representative for testing.
Samples failing to meet the requirements of this Contract will automatically void previous approvals and re-submittal or retesting of the samples will be required.

6. **AS-BUILT DRAWINGS**

During construction, the Contractor shall keep an accurate record of all deviations of work as actually installed from that shown or indicated on the Contract drawings or revised during construction.

Upon completion of the Works and prior to obtaining the Substantial Completion Certificate, the Contractor shall deliver all “As Built” drawings to the Engineer/Engineer Representative in one transparent and four blue print copies, showing the Works as constructed, together with all other information that may either be required or be useful for the operation and maintenance of the Works in the future.

PS-1.24 MEASUREMENT AND PAYMENT

a) **MEASUREMENT**

The quantities of various pay items which constitute the completed and accepted structures shall be measured for payment according to the plans and specifications for the several pay items appearing in the Bill of Quantities and in term of the prescribed units provided for the several pay items. Only accepted work shall be included for payment and the measured quantity shall be based on the dimension of component as shown on the plans or as directed in writing by the Engineer/Engineer Representative.

b) **PAYMENT**

The quantities measured as provided above shall be paid for at the unit prices bid for the several pay items appearing in the Bill of Quantities which payment and prices shall be full compensation for furnishing, preparing, fabricating, transporting, placing, erecting, QA & QC submittals and testing of all materials for the complete structure; for all labor, equipment, tool and all other items necessary for the completion of work. Such payment shall constitute full payment for completed structure and no allowance will be made for cofferdam construction, formworks, falseworks and other incidental expenses.

PS-1.25 SCOPE

These particular specifications are integral part of the contract documents, which shall be read in conjunction with the following contract documents, as are mutually explanatory to one another and with the order of precedence as given in the Conditions of Contract.

a) Contract Agreement.
b) Letter of acceptance.
c) Instruction to bidders.
d) Addenda to the Contract (if any)
e) Supplementary Conditions of Contract.
f) Conditions of Contract Part - II.
g) Conditions of Contract Part - I.
h) Special Provisions /Particular Specifications/Supplementary Specifications.
i) Drawings.
j) General Specifications.
k) The bid and Appendices "A to L".

CHAPTER NO. 02

HANDLING AND CARE OF WATER

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ITEM PS-2: HANDLING AND CARE OF WATER

PS 2.1 DESCRIPTION

The work shall consist of planning, designing, testing, construction, maintenance and removal of the all-temporary diversion, drainage and protective works for the handling and care of all water entering the open and tunnel works areas including seepage of ground water, surface runoff and leakage and river/ nullah flows which are necessary for surface drainage and the prevention of the ingress of water into the various parts of the Works.

PS 2.2 CONSTRUCTION REQUIREMENTS

The Contractor shall design, supply, construct, operate and maintain diversion works which shall comprise, but are not necessarily limited to dewatering (sumps, pumps, piping etc.) during the implementation of the tunnelling works, and cofferdams, levee banks, dykes, temporary stop-logs, channels, flumes, conduits, drains, pumps in the open area works, as may be required for dewatering the construction areas. The diversion and protective works shall be located in such a way that there is no encroachment on any area required for the works.

Water removed from the work areas shall be disposed of in such a manner as will not harm the environment, the stability of existing and constructed slopes, the works and the public property and health.

On completion of the works, all temporary diversion and protective works, except where specified otherwise in these specifications or directed by the Engineer/Engineer representative, shall be removed and disposed of or shall be levelled in a manner to give a tidy appearance, and so as not to interfere in any way with the operation or usefulness of the works.

PS 2.3 CONTRACTOR DUTIES AND RESPONSIBILITIES

In accordance with these specifications and as shown on the drawings, or as directed by the Engineer/Engineer representative, the Contractor shall deal with all surface water and groundwater from any source, as may be required, so that all the construction works so specified can be performed in areas free from water and so that the works are protected from damage.

In the design of these facilities, the Contractor shall take into account the likely seasonal fluctuations of the river and nullah water flows, which will continue in open areas during construction of the works.

The Contractor shall be solely and fully responsible for the handling and care of water including stream / nullah flows and underground construction inflows throughout the period of construction and for any damage to persons and property, as provided in the Conditions of Contract.

The Contractor shall be responsible for any damage or detriment to the permanent works or delay to the works, which may result from any overtopping, breach, breakdown, collapse of tunnel's primary support system or other failure of his measures for the handling and care of water, and shall make good such damage to the satisfaction of the Engineer/Engineer representative, at no additional cost to the Procuring entity.

The Contractor shall perform all the surface and underground drainage and dewatering activities in accordance with the National Environment Quality Standards (NEQS) of Pakistan revised in 1999 or with more rigorous standards as directed by the Engineer/Engineer representative.

The Contractor, in the event of failure of the care of water, diversion/ protective works and/or dewatering installations constructed by him, shall indemnify the Procuring entity against claims by other contractors employed by the Procuring entity working on the Site or by landholders or other persons, arising out of any such failure.

PS 2.4 STREAM'S DIVERSION

PS 2.4.1 ENGINEER/ENGINEER REPRESENTATIVE DIVERSION SCHEME

The Engineer/Engineer representative diversion scheme as shown in relevant drawings is general plan for management of both the **Khyber and Chora Khwar's** (stream) flows during construction of the Main Dam, Spillway and Diversion Tunnel. It is intended to enable the various elements of the Permanent Works to be constructed in a logical sequence, whilst providing a sufficient margin of safety against inundation of any part of the permanent works under construction.

The Engineer/Engineer representative diversion scheme comprised of completion of a permanent diversion tunnel and two cofferdams (upstream and downstream), that will keep the Main Dam construction area dry. The Engineer/Engineer representative diversion plan has been designed considering the steep valley type site topography and availability of sound rocks for tunnelling. The upstream cofferdam has been designed to integrate later with the Main dam body, while the tunnel will be used for installation of **1.0 m Ø MS pipe** for water supply up-to WTP. The Engineer/Engineer representative scheme envisages construction of diversion tunnel and portals in the 1st stage of diversion works. In 2nd stage, upstream and downstream cofferdams will be constructed plugging the main channel (**Khwar**) and diverting the flow into already constructed diversion tunnel.

The Engineer/Engineer representative diversion scheme is related primarily to the overall control of river flows and water levels in the vicinity of the Main dam construction site, so includes information on such matters as waterway sizes and cofferdam crest elevations.

Inclusion of all or part of the Engineer/Engineer representative diversion scheme in the Contractor's diversion scheme shall not remove or diminish the Contractor's responsibility for the suitability and adequacy of his measures for the diversion of stream flows and care of water throughout the construction period.

PS 2.4.2 CONTRACTOR’S DIVERSION SCHEME

The Contractor shall plan, design, construct, operate, maintain and remove, when required, all parts of his scheme for controlling and diverting the **Khyber and Chora Khwar’s** (stream) flows, and for taking care of surface and ground water throughout the construction period.

The Contractor's diversion scheme shall be suitable and sufficient for the intended purpose and shall provide protection against the 1:10 year return period flood.

Any stream / nullah diversion and training works included in the Contractor's diversion scheme shall be designed by the Contractor. The Contractor shall carry out sufficient surveys as may be needed to establish the required extent of the stream / nullah diversion and training works and demonstrate to the satisfaction of the Engineer/Engineer representative that diversion and training works will perform as intended.

The Contractor shall include with the cofferdams such effective and continuous barriers to the passage of water as will control seepage to an amount, which can be dealt with practicably by the proposed drainage and dewatering measures.

PS 2.5 SUBMITTALS AND APPROVALS

The Contractor shall plan, design, construct, operate, maintain and remove, when required, all parts of his temporary works for dewatering, controlling and diverting surface and ground water throughout the construction period. The Contractor shall plan and execute the works taking fully into account the requirements of the sequence and timing of certain works activities as specified on the drawings or construction programme or as approved by the Engineer/Engineer representative. The Contractor shall make timely submissions for the Engineer/Engineer representative approval of his proposals for the following principal activities as specified in subsequent clauses:

a) Dewatering various areas of the Site in order to construct the works in the dry;

b) Drainage of seepage, run-off, leakage or other ingress of water into the works areas.

c) For each proposal, the Engineer/Engineer representative may require the Contractor to submit further information or amended proposals until, in the Engineer/Engineer representative opinion, the proposals are satisfactory. The Engineer/Engineer representative will then approve the Contractor's proposals as required.

d) Not later than seventy (70) days after the Commencement Date, the Contactor shall submit to the Engineer/Engineer representative the detailed design of all diversion, protection and dewatering systems and necessary flow measurements. The design shall be consistent with the outline description submitted with his bid, and shall include the following:

   (i) Descriptions and drawings of the various stages of the dewatering

   (ii) Design assumptions and calculations and construction methods of all the features of the dewatering system,

   (iii) Descriptions of the methods, including the layout and capacity, of the diversion arrangement, cofferdam, diversion channel, protection and drainage and dewatering systems and measurement devices proposed for the diversion and care of water ingress into the works areas including construction of diversion tunnel, all cofferdams and other diversion/temporary works

   (iv) Cross sections of cofferdams or dike and diversion waterways,

   (v) Any other arrangement or installations, the Contractor may propose for temporary protection of the works and for dewatering of the working area both in surface and underground.

   (vi) Description of any aspects of the Contractor's proposal, which may differ from that submitted with his Tender, giving the reasons for such differences.

   (vii) Not later than twenty-eight (28) days after approval of the Contractor's proposal, the Contractor shall submit for the approval of the Engineer/Engineer representative full detailed designs of all the features including equipment such as pumps and pipework forming the proposal, together with full technical specifications and all necessary construction details as required.

PS 2.6 MATERIALS

The materials used for all care of water and water handling features shall conform to the requirements of the appropriate sections of these specifications and be subject to the approval of the Engineer/Engineer representative.

Fill materials of cofferdam's shall be obtained from required excavations, quarries, borrow pits or stockpiles, as proposed by the Contractor and approved by the Engineer/Engineer representative and shall comply with the requirements of the appropriate sections of these specifications and/or as provided in the drawings.

PS 2.7 DEALING WITH SURFACE WATER DRAINAGE

PS 2.7.1 GENERAL

The work to be performed by the Contractor in connection with dewatering shall include, but not necessarily be limited to, the following:

a) The supply, installation, operation, maintenance and subsequent removal of all pumps, pumping stations, pipework and other equipment, including sufficient standby equipment, for the dewatering of the works areas, maintaining those areas free of water as required.

b) The construction, maintenance and subsequent removal of any temporary sumps, lagoons, chambers, flumes, cofferdams, protective bunds, dykes or similar works. All temporary sumps and lagoons shall be placed at least 15 m beyond the limits of any permanent works.

c) The construction, maintenance and subsequent removal of such temporary drains or ditches as are required to efficiently carry all water to sumps or other collection or disposal locations.

d) The supply, installation, maintenance, operation and subsequent removal of dewatering wells and/or well points.

e) After having served their purpose, all temporary protective works shall be removed or levelled so as not to interfere in any way with the operation of the project works, and to give a tidy appearance to the satisfaction of the Engineer/Engineer representative.

f) Unless otherwise directed by the Engineer/Engineer representative, dewatering by gravity drainage will be preferred to dewatering by pumping wherever feasible.

   Subject to the Engineer/Engineer representative approval, which shall not be unreasonably withheld, the Contractor may deploy any drainage gallery or other appropriate part of the permanent works as part of his drainage and dewatering arrangements.

PS 2.7.2 SPOIL AREAS

The Contractor shall do whatever is necessary to prevent water from flowing over spoil areas and adequate measures shall be taken to prevent erosion of the material by surface runoff and watercourses.

Pipes and conduits through spoil dumps shall be solid and continuous and will require specifically formed inlets and outlets headwalls in impermeable and non-erodible material. Pipes or conduits shall have dimensions sufficient for discharge requirements. Pipe or conduit outlets shall be suitably constructed to prevent erosion.

Unless otherwise directed by the Engineer/Engineer representative, a surface drainage system shall be installed to replace the pipes and conduits system on the completed spoil dump.

PS 2.7.3 CARE OF WATER

Excavations and platforms shall at all times be maintained in a well-drained condition and free of ponded water from whatever source including precipitation run-off, groundwater percolation, water back-up, or water for construction operations.

Water removed from any excavations shall be treated if necessary and disposed of in such a manner as will not endanger public health, the environment, the stability of existing slopes, or the Works.

Drains, ditches, sumps and other facilities shall be lined as required or directed to prevent erosion of the underlying soil or rock.

All waters arising from the works from whatever cause shall be treated as may be necessary prior to re-entering the stream or any tributary thereof.

PS 2.7.4 GROUNDWATER PRESSURE RELIEF

The Contractor shall evaluate all groundwater information and take whatever measures are necessary to ensure the stability of all structures and ground surfaces during construction. The measures needed may depend on the precise sequence of such matters as excavations, construction and the installation of permanent drainage wells and blankets.

The Contractor's dewatering arrangements may require the drilling of drainage wells from the ground surface, together with the installation of piezometers to monitor groundwater levels and the performance of the dewatering arrangements.

If, in the opinion of the Engineer/Engineer representative, the foundation is damaged due to any inadequacy or failure of the Contractor's system for groundwater pressure relief, then the Contractor shall take all corrective measures necessary, as directed by the Engineer/Engineer representative, at no additional cost to the Procuring entity.

PS 2.7.5 DEALING WITH WATER IN UNDERGROUND WORKS

PS 2.7.5.1 GENERAL

The Contractor shall perform all works necessary to collect service and infiltrating groundwater, drain / convey it to main conduits, and lead it out from underground works such as tunnels or shafts. 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 including power supply,

c) Relocation of dewatering facilities required during progress of the works,

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

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

Exploration holes shall be drilled as needed to provide information on the inflow of water into the tunnels or shafts 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 shall be carried out, as directed by the Engineer/Engineer representative.

The Contractor's duties and responsibilities in dealing with underground water ingress and installation of requisite dewatering system shall confirm to relevant section “De-watering of Underground Construction Sites” of Chapter No. 04 of these specifications.

The approval by the Engineer/Engineer representative of the underground dewatering systems shall not relieve the Contractor of his responsibilities for the design and operation of the dewatering systems and he shall be liable for any damage or delays caused by its failure.

In the event of any dispute arising as to the true intended meaning of these specifications and /or drawings, the Engineer/Engineer representative shall interpret the same and his interpretation shall be accepted as final and binding upon all parties concerned.

PS 2.7.5.2 MATERIALS AND EXECUTION

The Contractor shall construct, in the permanent tunnel, the drainage trenches/pipes in the inverts or elsewhere as directed, immediately following the main excavation. The lining of the trenches in the tunnels shall be carried out as soon as practicable after their excavation and as required and directed by the Engineer/Engineer representative.

After the excavated profile has been checked and cleared, the groundwater, which runs or drips into the excavated space, shall be diverted into the drainage trenches 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 inflows shall be sealed off with a quick-setting sealing compound.

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 tunnels invert results from water being allowed to flow over or stand upon the sensitive or swelling material, the Engineer/Engineer representative may order the removal of the affected material and its replacement with concrete. The Engineer/Engineer representative may order installation of additional rock supports in connection with such remedial work at no cost to the Procuring entity.

Prior to commencement of the placing of the tunnel concrete lining, concrete or PVC pipes shall be placed in the trenches and embedded in concrete to allow for a continuous drainage. Openings shall be left in the lining to serve as cleaning and control pits at intervals not exceeding 100 m, or as directed by the Engineer/Engineer representative.

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 occur to the concrete. The length of the affected sections over which water has to be diverted shall be as per instructions of the Engineer/Engineer representative.

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

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/Engineer representative.

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/Engineer representative in writing. The Contractor shall notify the Engineer/Engineer representative in writing before any such openings are permanently closed. Pump and piping recesses or chambers shall be covered with concrete wall after undertaking permanent rock support measures for the recesses or chambers as approved by the Engineer/Engineer representative.

PS 2.7.5.3 MEASUREMENT OF FLOW RATES

The Contractor shall furnish, install, maintain and relocate when required, the various measuring devices such as measuring weirs, venturis, calibrated measuring buckets, water meters in pipelines, etc. These measuring devices shall be checked and approved by the Engineer/Engineer representative before they are used for measurement of the total rate of water flow in the gravity and pumping system.

Daily average flow rate shall be based on at least three (3) measurements per day during pump operating times. The pump operation durations in continuous twenty-four (24) hours at the measurement day shall also be recorded to calculate the daily average groundwater seepage flow. Measurement frequency can be reduced to once a month if the water flow rate is stable and approved by the Engineer/Engineer representative. The measurement of water flow rates shall be performed jointly by the Engineer/Engineer representative and the Contractor. The results shall be regularly documented and shared with the Engineer/Engineer representative. The volume of service water shall also be recorded each time the measurement is taken. The measured daily flow shall be determined as the average of the out-flowing discharges at the outlet from the trenches / pump line(s).

PS 2.7.5.4 REMOVAL OF TEMPORARY WORKS

Temporary Works for the handling and care of water shall be removed promptly after they have served their intended purpose. The Engineer/Engineer representative may, however, permit the removal of certain temporary works to be delayed, if the Engineer/Engineer representative is satisfied that this will cause no detriment to the permanent works or to the safe conveyance of water through and/or past the site of the permanent works, and that the Contractor has made adequate provision for their subsequent timely removal.

Removal of all temporary works for the diversion and care of water shall be carried out in a workmanlike manner and to the approval of the Engineer/Engineer representative, leaving a clean appearance to the remaining surfaces, and so as not to interfere with the proper completion or future functioning of the project. Waste material shall be properly disposed of, to the approval of the Engineer/Engineer representative.

The site of any diversion channel shall be backfilled and reinstated to such levels and in such a manner as the Engineer/Engineer representative may direct, having regard to the subsequent construction of permanent works on or near the site of the diversion channel and the safe conveyance of water through and/or past the works.

Any surfaces which are affected by erosion or deposition due to the flow of water shall be reinstated in such a manner and at such a time as the Engineer/Engineer representative may direct, having regard to the construction, safety, stability and proper functioning and appearance of the permanent works.

PS 2.8 MEASUREMENT AND PAYMENT

No measurement or payment shall be made for diversion, drainage, dewatering or care of water, except as specified herein and included in the Bill of Quantities.

The lump sum price included in the priced Bill of Quantities shall be deemed to cover all costs of diverting the flows, conveying flows through and/or past the site of the permanent works, keeping each part of the works protected against inundation, well drained and properly dewatered during construction, including performing all pumping and drainage operations, furnishing of all power and energy necessary to comply with these specifications; and of constructing, maintaining, operating and removing all temporary works in connection therewith. Any costs resulting from accidental inundation of any open and underground working areas, whether due to breakdown, failure or overtopping of the temporary works, shall be to the account of the Contractor.

The lump sum price shall be deemed to include all measures for the handling and care of water required for the proper completion of the permanent works, whether or not they are specifically mentioned in the Contract.

The lump sum price shall also to take account of any effects of the measures adopted for the handling and care of water on any surfaces in the open and underground works, including such effects as erosion and deposition due to the flow of water. The lump sum price shall be deemed to include all costs resulting from the reinstatement of such surfaces.

Progress payments for handling and care of water shall be made according to such schedule as the Engineer/Engineer representative approves as reasonable, having regard to the construction schedule of each feature of the works.

CHAPTER NO. 03

DRILLING AND GROUTING FOR DAM and HYDRAULIC STRUCTURES

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ITEM PS–3: DRILLING AND GROUTING FOR DAM AND HYDRAULIC STRUCTURES

PS 3.1 DESCRIPTION

The work shall consist of drilling grout holes, exploratory holes, and check holes; pressure testing, pressure washing, and injecting suspension grout under pressure through rock or concrete in dam foundation area, dam abutment areas, foundations of spillway and intake tower & other locations as shown on the drawings and/or as directed by the Engineer/Engineer representative.

The work shall include supplying, transporting, mixing and injecting grout materials, supply and installation of grouting pipes, headers, risers, and grout outlets, and all other works as specified in these specifications.

The work to be done under these specifications shall include, but not limited to:

a) The necessary plant, labour, equipment and materials for drilling and grouting, all in accordance with these specifications, as shown on the drawings or as directed by the Engineer/Engineer representative;

b) Drilling with and without core recovery in the dam and hydraulic structure excavations for exploration, ground investigations, geological / core logging and dewatering purposes, as indicated in the "Geological and Geotechnical Design Report of the Dam" and /or as directed by the Engineer/Engineer representative.

c) Pre-drilling works, which shall include rock testing, grouting, drainage, and rock stabilization prior to or after excavation, as the Engineer/Engineer representative may direct.

d) Washing and pressure testing in drill holes as and where directed by the Engineer/Engineer representative.

e) Installation of testing equipment for the measurement of stress and strain in the rock or other rock characteristics in drilled holes or elsewhere in the works, as directed by the Engineer/Engineer representative.

Grouting operations shall include:

a) Consolidation grouting in the foundations at pressures up to 5 MPa and in zones of sheared and disturbed material if required and/or as directed by the Engineer/Engineer representative;

b) Curtain grouting, at pressures up to 10 MPa, in the Dam foundation and in foundations of hydraulic structures and other locations as shown on the drawings or as directed by the Engineer/Engineer representative;

c) Curtain grouting in the Coffer Dams cut-offs as shown on the drawings and/or directed by the Engineer/Engineer representative;

d) Final grouting of temporary drainage holes if required and/or as directed by the Engineer/Engineer representative

The Contractor shall be responsible for designing, execution and completion of drilling, water pressure testing and grouting program, to seal the bedrock fractures and reduce the rock foundation’s hydraulic conductivity to a **residual Lugeon value of 3 or less**. This target residual permeability of the rock mass grouting program shouldn’t be confused with the Apparent Lugeon value, which will have to be calculated during the grouting of any single stage and will actually represent the grout refusal criterion.

The actual number of drill holes, diameter, inclination, depth, location, as well as the composition and consistency of the grout mixes, grouting pressures, pumping rates and sequence in which the holes are to be drilled and grouted shall be adapted to the geological conditions and as determined by trial drilling & grouting demonstration and / or as approved by the Engineer/Engineer representative.

All equipment and materials shall be new and approved by the Engineer/Engineer representative before starting the drilling and grouting work.

The Drilling and grouting works are a critical dam component and the contractor shouldn't use inefficient and poor-quality equipment and a labor intensive "brute force" approach for the job. The Contractor shall employ qualified, specialist sub-contractors equipped with modernized setups and experienced personnel for execution of the works.

PS 3.2 APPLICABLE STANDARDS AND CODES

Unless otherwise specifically indicated in these specifications, all equipment design, fabrication, material selection, manufacturing, welding, testing, inspection, assembly, and other operations related to the drilling , water pressure testing and grouting work shall conform and comply to the specifications of the latest edition or issue of all relevant applicable standards and codes from the United States Bureau of Reclamation (USBR), ASTM, API, British-European and other International Standards.

Design, materials and workmanship incorporated into the services and not specifically covered by these specifications and applicable codes shall be of the highest quality and shall conform to standard engineering practice and without limitations, shall be in accordance with the latest versions of the international organization's standards and norms.

The most recent version of the following standards shall be followed during the works:

a) International Society for Rock Mechanics (ISRM);

b) Bureau of Reclamations Earth Manual, Part – 1, Third Edition, Chapter 2 (BOR, 1998);

c) Bureau of Reclamations Design Standards No. 13: Embankment Dams, Chapter 15: Foundation Grouting (Sep 2014);

d) U.S. Army Corps of Engineers (USACE) Manual, EM 1110-2-3506 (Mar 2017);

e) Engineering Regulation (ER) 1110-1-1807 - USACE 2006;

f) Australian Drilling Manual (ADI, 1992); and

g) National Drill Association Drilling Manual (NDI, 1990)

PS 3.3 SUBMITTALS AND APPROVALS

1. At least 56 days prior to the start of drilling and grouting operations, the Contractor shall submit the following for approval to the Engineer/Engineer representative. No work shall commence prior to the Engineer representative's approval of the various submittals:

   a) the proposed equipment and installation methods for executing and monitoring drilling, water pressure testing and grouting operations.

   b) the technical references of the Contractor and of his personnel to be employed on drilling and grouting works.

   c) Grout material sources, manufacturer's test certificates and the proposed mix design.

   d) Methods and equipment for calibration of the proportioning of the grout constituents.

   e) Methods and equipment for calibration of the grout quantity pumped and pumping rate.

   f) Statement of the proposed sequence of operations.

   g) Copies of proposed drilling and grouting record forms.

2. At least twenty-one (21) days prior to the scheduled date of commencement, the method of execution for drilling, water pressure testing and grouting shall be demonstrated by preliminary in-situ tests, under the supervision of the Engineer/Engineer representative.

3. At least fourteen (14) days prior to the scheduled date of commencement, the Contractor shall submit for approval of the Engineer/Engineer representative, the "Quality Assurance Manual" detailing the measures to be adopted to ensure the specified quality, control and tests etc., including's;

   a. General plan and description of proposed monitoring operations.

   b. Description and specifications of monitoring equipment and instruments.

   c. Proposed methods to obtain and record monitoring data.

   d. Copies of proposed monitoring data forms

4. Within one week after the end of each section of work as defined hereinabove, the Contractor shall submit the QA / QC test reports to the Engineer/Engineer representative.

5. Drilling records, hole logs and photographs of drilled cores duly labelled and placed in albums as described hereinbelow, shall be submitted to the Engineer/Engineer representative for exploratory test holes or check holes and cored holes within forty-eight (48) hours of the completion of such holes.

6. Water pressure test records as described hereinbelow shall be submitted to the Engineer/Engineer representative within twenty-four (24) hours of completing such tests.

7. Field progress records for all grouting work shall be submitted to the Engineer/Engineer representative at the end of each shift, giving the data as

described in these specifications.

8. Records of grout tests described in these specifications shall be submitted to the Engineer/Engineer representative within twenty-four (24) hours of testing.

PS 3.4 DRILLING – GENERAL REQUIREMENTS

PS 3.4.1 TRIAL SECTION DRILLING AND GROUTING PROGRAMME

Full-Scale trial section's drilling and grouting shall be demonstrated, prior to production of grouting to fully establish suitable drilling and grouting protocols, including accurate prediction of quantities, performance and the required depths etc of grouting. Extensive water-pressure-tests shall be done in verification holes to confirm both the geometry and the residual permeability of the grouted zone.

The test program should include testing to determine the actual limiting pressures for dilation, uplift, and/or hydrofracturing, which then can be used to establish safe injection pressures for production work.

The minimum length of the test section shall be 60 m or as directed by the Engineer/Engineer representative otherwise.

The Contractor shall be responsible for setting out the positions of exploratory/grouting holes and shall take surface levels at each position from a suitable bench mark. The Engineer/Engineer representative may, at his discretion, provide the Contractor at the time of instruction, with a plan showing proposed exploratory hole/excavation locations and anticipated depths, but both may be subject to variation as the work proceeds.

PS 3.4.2 REQUIREMENTS FOR IN-SITU DRILLING

1. The Contractor shall perform drilling for curtain and consolidation grouting operations in the following locations:
   a) Upstream and Downstream Coffer Dam – cut-offs
   b) Dam – foundation area
   c) Spillway & Intake Tower – foundation area
   d) Other locations as shown on the drawings or as directed by the Engineer/Engineer representative.
2. Excavation of the foundation of hydraulic structures may reveal conditions which will require the construction of concrete-grout caps. The location and extent of these grout caps shall be as determined by the Engineer/Engineer representative.
3. The exact location, direction, order and method of drilling and grouting, and the depth of each hole or stage of each hole shall be as shown on the drawings or as directed by the Engineer/Engineer representative and will be subject to modification during the progress of the drilling, testing and grouting.
4. During the course of the work, the Engineer/Engineer representative may direct the Contractor to drill vertical or inclined holes with core recovery to determine the nature of the rock before grouting (primary test holes) and the effectiveness

of the grouting operations (check holes). Water pressure testing shall be carried out in each of these holes in stages as the drilling progresses over their entire length.

5. In addition to the systematic grouting of primary, secondary or tertiary holes, it may be necessary to drill & grout additional holes for treatment of peculiar geological features, such as faults, folds, fissures, seams, shear zones and other discontinuities. The drilling of secondary holes in any zone of foundation must not be taken up until the primary holes are completed.

6. When drilling for fissure grouting operations, or for karstic treatment under existing structures, air flush or air-water "mists" shall not be permitted. In the former case, it will obscure fissures with cuttings blocking access for grout, while in the second case it will have a very deleterious mechanical effect on clay infillings and can travel long and potentially dangerous distances in the foundation and in the embankment. Only water-powered, down-the-hole hammers shall be adopted.

PS 3.4.3 EQUIPMENT

1. The Contractor shall supply equipment of sufficient type and capacity to execute the drilling and grouting works according to the requirements of these specifications. The equipment shall be supplied in sufficient numbers, have the proper dimensions and be in good working condition. The equipment and the layout thereof shall meet all applicable requirements of provincial and federal regulations and codes, both safety and otherwise.

2. All drilling equipment, as approved by the Engineer/Engineer representative, shall be suitable for operation in open-air as well as in underground locations and in any direction.

3. Rotary or percussion wet drilling equipment will be required, and only electric, or air-driven tools will be accepted for works to be executed, underground and in galleries. Diesel or gasoline driven machines or equipment may be used only for open-air operation.

4. When coring is not required, Down the Hole (DTH) or roto-speed percussion wet drilling equipment can be used provided that the hole is smooth enough to allow the water tightness of the packer used for water test. All DTH equipment shall be of the Reverse Circulation (RC) type or preferably Water DTH hammers (WH).

5. All drilling equipment shall use continuous water circulation to flush out drill cuttings. Use of dry drilling machines or dry drilling followed by water flushing will not be permitted.

6. Drilling equipment and methods shall be such as to minimize oversizing or caving-in of drill holes.

7. The Contractor shall have available at the project site the required numbers of drilling equipment. The diameter of drill holes for grouting, exploration, drainage and rock bolting may vary from 46 to 76 mm, with the finally selected diameter shall be as determined by the Engineer/Engineer representative in each case.

8. The Contractor shall provide a properly planned water distribution system of sufficient discharge capacity for all drilling and grouting operations. The system should extend across the site and have tees and associated valves strategically located. It should also be located such that it does not interfere with equipment maneuverability.

9. The Contractor shall provide sufficient water pump capacity and compressed air storage to ensure a continuous supply of water and air to all drilling and grouting operations at all times. The equipment shall be capable of maintaining a pressure in the water and air pressure supply lines.

10. Drilling equipment for grouting, rock bolting, drainage and exploration shall be able to drill at any angle, upward or downward and to perform:

    a) exploratory hole (upto 100 mm core barrel) upto a length of 150 m;

    b) holes (46-76 mm) for curtain grouting upto a length of 100 m; and

    c) holes for the installation of rock bolts, dowels.

11. Equipment for water pressure testing:

    a) Special emphasis shall be given to the control devices for pressure and volume of water pressure tests.

    b) Pressures and flow rates during pressure testing shall be monitored with electronic systems.

    c) The pressure applied shall be measured at the borehole head and transmitted to appropriate automatic recording instruments.

    d) Synchronized operation of pressure and discharge recorders must be ensured. For regular checking of pressure at the pumps, these shall be fitted with additional pressure gauge having an accuracy of 0.1MPa (1bar).

    e) All pressure gauges used shall permit accurate reading to within 0.1MPa (1bar) of the true value; gauge divisions and the top of the scale shall be adjusted to suit the applied pressure. Pressure and discharge recorders shall be of a type approved by the Engineer/Engineer representative and shall be checked against calibrated gauges at intervals as directed by the Engineer/Engineer representative.

    f) The Contractor shall provide one complete set of pressure testing equipment per drilling and grouting location (with spares) to allow simultaneous testing at the various drilling and/or grouting locations.

    g) The pumps shall have a minimum capacity of 300 litres per minute at a pressure of 60 bar at the top of the hole. The pumping system shall be capable of maintaining any desired pressure without fluctuation and the pressure and discharge shall be continuously adjustable.

    h) Water pressure shall be measured by means of a pressure gauge with an accuracy of 0.5 bar and a range of 65 bar. The water meter shall be able to measure the discharge volume with an accuracy of 1 litre. Water meters, as well as all pipes, hoses and couplings, shall be designed to resist a pressure of 100 bar;

    i) Water meters and pressure gauges shall be calibrated and certified by an independent laboratory prior to installation at the project 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/Engineer representative for further checking purposes. Pressure gauges shall be installed close to the collar of the drill hole.

j) Packers shall consist of mechanically expanded rings or pneumatically expanded sleeves of rubber or other suitable material, which can be set tightly in a drill hole at any depth required. Packers shall be capable of withstanding pressures of upto 50 MPa without leakage. The Contractor shall keep at the project site an adequate supply of packers, of various sizes to suit the various hole diameters.

PS 3.4.4 LOCATION AND METHODS

1. The location, direction and length of holes and their reference numbers will be as shown on the drawings or as determined by the Engineer/Engineer representative, who may at any time increase or decrease the number of holes or instruct drilling to a greater or lesser depth. The order and timing in which holes are to be drilled shall be as directed by the Engineer/Engineer representative.
2. In order to keep the dam foundation watertight and to avoid piping underneath foundations, double line curtain grouting shall be adopted, as shown on the drawings or as directed by the Engineer/Engineer representative.
3. The starting direction of a hole shall not deviate more than 3° from the specified angle, but according to site conditions, certain holes may be needed to be drilled within 2° of the specification, and the location shall be within 150 mm of that specified, except that the location of holes for rock reinforcement installation shall be within 100 mm of that specified.
4. Holes shall be sounded to their alignment at 5 m intervals with a multi-shot or similar approved instrument if sunk deeper than 30 m.
5. Holes having a deviation of more than 3° from their intended alignment shall be stopped, filled with grout and re-drilled nearby at the Contractor’s expense.
6. After the last grouted stage, the hole shall be filled with grout at low pressures.
7. Grout holes shall not be smaller than 51 mm diameter. For grouting with cement, 76.2 mm holes shall be used for dam foundation or as recommended by the Engineer/Engineer representative otherwise.
8. If foundation conditions and rock conditions, as revealed by the excavation, drilling, testing and grouting operations, indicate that grouting at greater depths or closer spacing or in other locations than those shown on the drawings is necessary, the Contractor shall drill holes to such depths and spacing as directed by the Engineer/Engineer representative.
9. Grout, test, exploratory and instrumentation holes may be drilled with rotary type diamond drills. All drilling shall be with continuous water flushing. No dry drilling or dry drilling with subsequent water flushing will be allowed.
10. In the event wagon drills are used, drilling shall be carried out with water under pressure and in sufficient quantity to ensure an efficient and continuous flushing out of rock cuttings with a minimum quantity of outflow shall be 1.0 litre/second for a 76.2 mm diameter hole.

11. The DTH (Down-The-Hole) drilling equipment shall be of the Reverse Circulation (RC) type or preferably Water DTH hammers (WH). All drilling equipment shall use continuous water circulation to flush out drill cuttings.

12. The diameters specified shall be obtained at the maximum depth required. The equipment shall be capable of drilling holes to a maximum length of 150m into rock (Considering the inclined length of curtain grout holes). The drilling equipment shall be capable of drilling at any inclination and be capable of being set to an accuracy of 1 degree of angle.

13. All holes shall be drilled without mud-support and without the use of grease, “rod-dope” or other non-water-soluble material for the lubrication of the drill rods. The Engineer/Engineer representative may permit the use of an additive in the drilling water. A sample of any proposed additive shall be submitted to the Engineer/Engineer representative at least seven days prior to its being used. The concentration of the permitted additive shall not exceed the manufacturer’s recommendation.

14. Drilling through concrete less than seven (7) days old shall not be permitted, except if stand pipes have been previously placed into the concrete.

15. In case of complete loss of water during drilling of hole to be injected, the drilling shall be stopped and the section grouted where the loss is observed.

16. Unless otherwise ordered by the Engineer/Engineer representative, all holes shall, immediately after drilling, be thoroughly washed out with water under pressure from the bottom of the hole. Water flushing shall continue until the waste water runs clear or until otherwise directed by the Engineer/Engineer representative.

17. On completion of drilling and flushing of grout holes the Contractor shall immediately install grout nipples with caps or plug the holes with wooden plugs or steel caps and shall protect them from entry of dirt, muck, grout, surface water or any other material. Any hole which becomes obstructed before being grouted shall be cleared by and at the expense of the Contractor.

PS 3.4.5 DRILLING SEQUENCE

1. Unless otherwise specifically mentioned, the first holes drilled into the foundations shall be widely spaced and shall be drilled and grouted before intermediate holes are drilled and grouted, and in this manner the drilling and grouting of holes shall be completed to such final spacing by the split-spacing method, or as directed by the Engineer/Engineer representative otherwise.

2. After holes in a region have been drilled and grouted, it may be found necessary to drill additional grout holes. No allowance above the tendered rates in the priced Bill of Quantities will be made for drilling of such holes or for the expenditures of moving the equipment from other operations and returning to a previously drilled area.

PS 3.4.6 CASING

1. In all boreholes or drillholes where boring and drilling is being carried out in any stratum which is water bearing, compressible, friable or not sufficiently cohesive to stand firmly without a casing, the boreholes or drillholes shall be cased. The casing shall always be driven slightly in advance of the bottom of the hole.

2. Unless otherwise approved by the Engineer/Engineer representative, casing

shall be removed immediately prior to or simultaneously with the grouting process.

3. For lengths of the hole being so fragile or incompetent to withstand hydrostatic pressure, the casing left in place shall be perforated to ensure effective grouting operation.

4. The Contractor shall be solely responsible for ensuring that casings are of a suitable size and are inserted in such a manner as to render them recoverable and the Contractor shall have no claim for damage, loss or delay caused by difficulty or failure to recover casing. The Contract rates for boring or drilling operations shall be deemed to cover for driving and recovering the casing, loss or damage to the casing etc.,

PS 3.4.7 GROUT SLEEVES

1. For grouting in rock through cutoff wall, the holes shall be cased with PVC pipe of 76 mm minimum diameter terminating about 300 mm above the cutoff wall top. Elsewhere, the holes in overlying soil and weathered rock at the abutment platforms shall be cased with PVC pipes of a diameter to suit the drilling equipment, with a minimum of 50 mm, and sleeve grouted.

2. PVC sleeves shall be unplasticized pipes complying with BS EN 1452 or equivalent ASTM standard.

3. The space between the sleeved pipe and wall of the hole shall be grouted with a suitable bentonite-cement grout (sleeve grout) and any casing that has been inserted during drilling shall be removed as the sleeve grouting proceeds. The sleeve grout shall attain a set strength not less than 0.4 MPa and not more than 0.75 MPa at 7 days.

PS 3.4.8 BORING (IF APPLICABLE)

1. Boring shall be carried out wherever possible by means of an auger or clay cutter and only where this is impracticable owing to the nature of the strata shall it be augmented or replaced by shell, bailer, chisel or other tools. No wash borings in soil shall be carried out without the Engineer/Engineer representative's permission in writing.

2. All boring shall be of such a size and carried out in such a manner as to permit the Contractor to recover 100 mm diameter undisturbed samples in approved sample tubes, if ordered by the Engineer / Engineer representative.

3. In cohesive materials water shall only be added with specific approval by the Engineer/Engineer representative.

4. In boring through permeable materials, the Contractor shall avoid any unnecessary disturbance to the material and shall ensure that: -

   a) the water level in the hole shall be maintained slightly above the water table in the permeable stratum;

   b) the casing shall be left as near to the bottom of the hole as possible; and

   c) close-fitting tools shall be withdrawn slowly to avoid suction pressure.

PS 3.4.9 CORE DRILLING

1. The Contractor shall core drill vertical or inclined holes as may be required to determine the condition of the foundation rock or the effectiveness of the grouting operations where and as directed by the Engineer/Engineer

representative.

2. Drilling shall be carried out at the locations indicated by the Engineer / Engineer representative. If there are local surface features or other operations which would otherwise interfere with the drilling operation, holes may be relocated as agreed with the Engineer / Engineer representative.

3. The nature of the foundation shall be ascertained by coring primary test holes along the grout curtain. Each test hole will be cored and water pressure tested over the entire length. The location and length of the holes shall be as shown on the drawings or as directed by the Engineer/Engineer representative. The results of the test holes shall provide guidance on:

   a) the need to deepen the curtain;

   b) the grout mix and grouting pressures; and

   c) the choice of grouting method.

4. After completing sections of the curtain, vertical or inclined verification holes shall be cored and water pressure tested to check the effectiveness of the grouting work. The location of verification holes shall be, as directed by the Engineer/Engineer representative.

5. All core drilling shall be performed with standard rotary-type, core-drilling equipment using NMLC size, bottom discharge, diamond bits and triple or double tube, swivel inner tube type core barrels. The NMLC holes shall be drilled to varying depths with a maximum depth of 150m into rock (Considering the inclined length of curtain grout holes). The Contractor shall ensure that cores obtained are in as good a condition as possible from all holes. Triple tube core barrels shall be used for coring in highly shattered or weathered strata.

6. All necessary steps shall be taken to ensure maximum core recovery from verification holes. This may require that drilling lifts be terminated and the coring be accomplished in shorter runs than 1.5m as considered necessary, to secure the maximum possible amount of core. Drilling lifts shall not be longer than the length of core barrel.

7. The core shall be removed from the hole immediately, regardless of the length of run drilled, if blocking of the bit or grinding of the core is indicated.

8. All vertical and inclined verification holes shall be pressure grouted in accordance with these specifications and as directed by the Engineer/Engineer representative following the completion of water pressure testing.

PS 3.4.9.1 RECORDS

1. Within 24 hours of completing drilling of a cored hole, the Contractor shall submit in duplicate a complete log of the hole in a form approved by the Engineer/Engineer representative. The log shall include the following data:

   a) location;

   b) coordinates

   c) borehole number;

   d) type and diameter of boring;

   e) ground level;

   f) final drilling depth

g) immediate, intermediate and equilibrium water levels with times and dates, Notes on colour and losses, etc.;

h) description and state of weathering of rock and the levels of its boundaries;

i) percentage core recovery;

j) fracture log;

k) the results and locations of all in-situ testing;

l) a record of the driller's observations on progress of boring, rate of penetration, type of bit and speed of rotation of bit; and

m) water pressure test results.

n) location of sample extraction (water / core material) for tests and change in strata

o) diameter of casing and depth to which taken.

PS 3.4.9.2 LOGGING AND PRESERVATION OF CORES

1. The Contractor shall provide the logging of rock cores based upon the Geological Society Engineering Group Working Party Report "The Logging of Rock Cores for Engineering Purposes", Quarterly Journal Eng. Geology. Vol. 3 1970 London or ISRM Suggested Methods.
2. Preferably, cores should be logged by the same person to avoid discrepancies in description of rock. The presence of Engineer representative and sharing / keeping a record of the drilling shall not relieve the Contractor from the requirement for keeping an accurate log as described hereinbelow unless specifically approved, in writing, by the Engineer / Engineer representative.
3. Cores, whether from exploratory holes made by the Contractor for his own convenience or directed by the Engineer / Engineer representative, shall be handled and stored in fully labelled core-boxes in a satisfactory manner for future reference.
4. The Contractor shall provide strong (wood or sheet metal) 1.05m long core boxes, the details of which shall be submitted by the Contractor for approval of the Engineer / Engineer representative. Each box shall hold cores from 5 m of hole and they shall be provided with fasten-able lids. All boxes shall be uniform in size.
5. The Contractor shall place the core in the box in the correct sequence after extraction from the core barrel. The core at the bottom of each lift shall be marked immediately after it has been placed in the box and a corresponding mark shall be printed on the side of the core box and on the rock core. When core is not recovered, timber blocks of square cross-section shall be placed in the box by the Contractor. These timber blocks shall be cut to the same length as the core loses and placed in the positions for which the core was lost. If these positions cannot be determined, the blocks shall be placed at the top of the lift. A box shall not contain cores from more than one hole. Designating marks, hole numbers and elevations shall be placed on the boxes and along the line of cores. The covers shall be fastened securely to the core boxes, and the boxes shall be delivered to the Engineer / Engineer representative at a point designated in the vicinity of the Works.
6. Where directed by the Engineer / Engineer representative, the cored holes shall be water pressure tested and grouted in accordance with these specifications.

7. Cores shall be colour photographed in the core boxes, one box per photograph, with labels clearly indicating the project name, drillhole number with initial and final depths of the drillhole covered by the core in each box. The photographs duly labelled and placed in albums shall be duly submitted to the Engineer / Engineer representative at the end of each month or such other period as determined by the Engineer / Engineer representative.

8. The Contractor shall keep accurate records of all drilling, sampling operations, water level and temperature measurements as they are carried out. The records shall be made on an approved form and shall comprise: -

    a) Drilling hours spent, length drilled, nature of formation, changes of formation, location of fissures; points of observation made during drilling, in particular where wash water is lost, core loss position, blocking of core barrel, cored material removed, stability of hole, rod vibration, colour and cores abstracted, together with details of all drillhole orientations.

    b) Groundwater levels in drillholes using an electrical water level measuring device accurate to 10 mm. All records should contain depth, date and time of day when the measurement was made.

    c) Rate of penetration in hours per metre when drilling, rotary head speed, feed pressure, pump/flush rate, drill bit type, number and wear.

    d)

PS 3.5 DRILLING HOLES FOR GROUTING

PS 3.5.1 DRILLING THROUGH OVERBURDEN AND EXISTING DAM EMBANKMENTS

The project specific requirements for the grout hole alignment, accuracy, and restrictions on use of specific drilling equipment principally depends on protection requirements of the in-place conditions of the dam embankment or other structure and underlying strata materials that have to be penetrated. Materials typically encountered during drilling for grout holes usually varies from clay cores, random fills, and rock shells in dam embankments to boulders and running sands / gravels in natural deposits. Each of these zones or materials requires consideration of the equipment most suitable for penetration without damaging the material surrounding the hole.

The Contractor's decision about the type of equipment to be used and selection of drilling method shall be based on, the subsurface material that may vary significantly across the project site in both the horizontal and vertical directions; the terrain that the drilling equipment must traverse and set up on steep terrain; the environmental requirements of the drilling process; the need to support the drilled hole; the need to obtain samples and the required accuracy and condition of the final grout hole as provided in these specifications and/or as agreed by the Engineer's / Engineer's representative.

1. Hole size

The hole size for drilling & grouting operation shall be decided by the Engineer / Engineer representative, who can make the decision in the light of geotechnical investigation data, of the most efficient size for the materials to be encountered. The primary factor in selecting the hole size shall be that the hole must be sufficiently large to accommodate all of the subsequent drilling and grouting equipment and tools.

Drilling of holes through existing dam embankments or other earthen hydraulic structures shall be considered critical because of the potential for damage to the embankment materials due to excessive pressure of the flushing medium, which can cause significant scour or erosion of the boring sidewalls or can cause pneumatic or hydraulic fracturing of the embankment. Air, gas, water, mud, or any other drilling fluid shall not be used in the impervious core of the dam, and the core trench or foundation soil under the core. In addition, drilling fluids shall not be used in portions of dams where possibility of contamination of filters or drainage features exists. However, exemptions may be made to this prohibition, subject to the Engineer's / Engineer's representative approval in special circumstances and when all other acceptable alternatives have been exhausted. These prohibitions shall be based on the primary concern of protecting the impervious section of embankments.

Holes that are drilled outside the limits of the clay-core footprint or within coarse shell zones should be treated as non-critical, because of lesser damaging potential to the embankment due to the drilling process.

2. Casing of Holes.

a) General.

Holes drilling through overburden materials or existing dam embankments shall be cased for subsequent rock drilling and grouting in the underlying bedrock. Casing eliminates erosion of the hole during rock drilling, washing, and grouting operations; eliminates the potential for holes to cave in the overburden; and aids in the alignment of subsequent rock drilling. Cased holes also allow the packer to be seated inside the casing for treatment of the soil/bedrock interface zone and the top length of fractured rock. For applications of solution grouting multiple-port sleeve pipe (MPSP) casing, with grouting ports at regular intervals along the casing, shall be used. The ports shall be covered with a rubber gasket that shall expand under pressure and shall allow the grout to flow from the inside of the casing to the sidewall of the hole and into the soil. The gaskets, upon the removal of injection pressure, shall contract to prevent the injected grout from intruding back into the casing.

b) Casing Materials.

The size of the casing shall be determined according to the tooling used for rock drilling and grouting. More accurate holes can be drilled with larger-diameter drill strings, but at the cost of larger casing and more grout backfill. The overburden bore hole can be supported with plastic or light-gauge steel casing for being cost-effective. Depending on the size of the hole drilled through the overburden and the required casing size, the casing shall be either flush joint or coupled pipe.

For soil permeation grouting applications, PVC casing shall be used for multiple-port sleeve pipe (MPSP). In case of low mobility grouting (LMG), or compaction grouting application in soil, the standard practice of leaving the steel drill casing in place and injecting grout directly through the tooling shall be adopted. However, the steel casing may be withdrawn at a controlled rate during placement of LMG, depending on the length of the zone to be treated.

c) **Casing Sealing.**

Casing within the embankment or overburden shall be sealed before drilling and grouting operations in underlying rock. The Contractor's proposed method for proper isolation and sealing of the casing shall be approved by the Engineer / Engineer representative.

For remedial curtains under existing dam embankments, the "standpipe" (*inaccurately referred to as "casing"*) shall be first placed and sealed through the embankment and for some distance into bedrock. The standpipes shall be placed within the previously installed temporary drill casing, which may be withdrawn as, or before, the standpipe is sealed into the formation and embankment via annular grouting. Simple practice of "end of casing grouting" to provide this seal shall not be allowed. The "rock socket" shall not be relied upon to not consume grout, to avoid the chances of incompletely filled annular spaces. This in turn will cause damage to the standpipe during subsequent rock drilling, and/or subsequent escape of water and/or grout up the annulus and into the embankment. In extreme cases, a completely open annulus will provide a direct connection from the developed phreatic surface through the dam embankment to a defect in foundation or pipe, where such a direct connection did not exist previously. The resulting open annulus may lead to developments of sinkholes, thereby necessitating major rehabilitation works in future.

For shallow blanket holes, percussion drilling with air shall be an ideal choice where the cuttings can be easily blown out. Similarly, percussion drilling or rotary drilling with air shall be adopted, where expansive clays in cavity fillings tend to plug the holes, when water is used as flushing medium.

In the events of site-specific constraints over the use of mud, air, water, or other circulating medium to remove cuttings while drilling through the soil overburden and/or as directed by the Engineer / Engineer representative, the Contractor shall adopt sonic drilling method or equivalent, with installation of PVC casing in compliance with Army Corps of Engineers Regulation ER-1110-1-1807.

A Sonic or Resonant Sonic drill with multiple casing system, shall have mechanical oscillators of high frequency, for transmitting resonant vibrations and rotary power through the specially designed drill tooling to the drill bit, to achieve the desired advancement without the use of water or air.

Sonic drilling shall be preferred over rotary sonic for production of accurate holes with respect to deviation through the use of large diameter, stiff casings. Hardest geological formations can be easily drilled by rotary sonic; however, the vibratory action pulverizes the rock at the casing shoe having carbide button bits, thereby leading to insignificant rock core-recovery.

100mm PVC casing (max) shall be installed through the soil overburden and socketed a minimum of 0.6 meter into the underlying bedrock. The annulus between the casing and boring wall shall be grouted using a cement-bentonite grout or as directed by the Engineer / Engineer representative otherwise.

For setting the standpipe, the inner casing shall be removed after drilling a prespecified distance into bedrock and leave the outer steel casing in place. The standpipe shall be inserted to the bottom of the hole inside the outer casing. The standard industry practice shall be adopted by leaving the outer steel casing in the hole during barrier bag inflation and annular space grouting. However, the outer casing shall be pulled back and set at a depth just above the bag during inflation to avoid locking the steel casing in place. Similarly, leaving the casing in during the annular space grouting will reduce the risk of collapse around the PVC standpipe, and will ensure complete encapsulation of the standpipe by grout material. The steel casing shall be withdrawn after grout starts ejecting at the surface.

PS 3.5.2 ROCK DRILLING, WASHING, AND PRESSURE TESTING

The selection of the drilling method for grout holes in rock primarily depends on the characteristics of the rock to be drilled, the hole depth, access to the hole location, and the cost Vs time requirement to drill a properly aligned clean hole.

1. Basic Drilling Requirements

a) Hole Diameter

The diameters of grout holes shall be in the range of 51 –127 mm with the preference of 76.2 mm diameter in rock or as directed by the Engineer / Engineer representative otherwise. Depending on the application, such as drilling through a concrete structure and into rock, a maximum hole size shall be provided to minimize damage to the structure, such as cutting reinforcement.

The selection of the minimum or maximum hole diameter requirements should be site specific and shall be based on the hole depths, the equipment access requirements for the subsequent grouting operations, and the need for any special treatments, such as telescoping casing through unstable strata within the rock.

b) Hole Orientation.

Orientation of curtain grouting shall be kept such to intersect maximum number of joints or beddings. Orientation and number of different joints/beddings running beneath the structure of the dam shall be ascertained from the Geological surface map and core logging of the foundation. The favourable direction, according to USACE EM 1110 – 2 – 3506 recommendations, shall be towards the upstream or based on the dipping of the joints.

The Contractor shall be responsible for accurate layout and proper orientation of the hole locations at the surface. Construction of stable platform for the drilling rig, accurate setup of the rig and continued monitoring of the hole orientation during the drilling process are the sole criterion for proper alignment of the drillhole. The Contractor proposal for adoption of conventional survey equipment for proper drill layout, or electronic levels with accuracies of 0.1 degrees, or orientation equipment with twin digital inclinometers attached to the drill mast etc., shall be demonstrated synchronically with the field trials of proposed drilling systems and shall subject to approval by the Engineer / Engineer representative.

The Contractor shall be responsible for establishment of drill hole locations by survey and tying with the project control points. The hole designation or identification system to be used shall be approved by the Engineer / Engineer representative. At the time of layout, the hole identification codes shall be color painted on a durable surface such as the grout cap or the cleaned foundation rock surface and shall be refreshed during each shift.

c) Hole Alignment and Deviation.

The deviation of the hole bottom from its planned location is affected by the angle of drilling, the depth of the hole, the type and condition of drill used, the diameter and stiffness of the drill tooling, the condition and type of bit, the accuracy of the drill setup, and the geologic conditions.

To exercise good control in the field, the drill setup shall be positioned within a two degree of its planned inclination and azimuth with the use of Brunton compass, bubble levels, and plumb bobs. Digital inclinometers with 0.1-degree of resolution hardly introduce more than 1.0-degree deviation from the planned angle in the initial setup.

Transits should be used to verify alignment of the drill in the plane of the grout curtain or borehole azimuth. Holes shall be drilled as close as possible to the marked location, but in no case should a starting location deviate by more than 150 mm from its planned location.

Under favorable conditions with vertical holes in relatively homogeneous materials, the equivalent total angular deviation for hole depths of 30 – 60 meters should fall in the range of 2–4 degrees. However, complex geologic conditions, introduction of inclinations, and/or the absence of equipment specifically designed to reduce deviations can result in actual deviations significantly in excess of this range.

For a good seepage control, the sum of the basic hole spacing and the potential deviations at any depth should not exceed the distance over which grout can effectively travel under pressure to form a continuous barrier. The allowed borehole deviation, in any case, shall not be more than 3.0-degree at full length.

Borehole imaging systems, such as the Robertson Geologging System, integrate borehole deviation surveys with imaging of the hole sidewalls. The imaging of borehole walls and fractures combined with the measure deviation of the hole allows the strike and dip of the fractures to be accurately calculated. Systems that use magnetic north for orientation should not be used inside metal casings.

d) Spacing of Drillholes

Spacing of drillholes shall be as shown on the drawings and/or as directed by the Engineer / Engineer representative.

USACE EM 1110-2-3506 recommends the closure criteria at each stage in each hole for spacing between drilled holes. For curtain grouting, primary hole spacing shall vary from 3 m to 12 m, while the final spacing for secondary, tertiary and quaternary holes shall be between 0.75 m to 3 m depending whether the closure criteria achieved or not.

In the split spacing method as proposed by USBR, an initial spacing of 25 m between primary holes shall be adopted, with secondary holes drilled halfway between primary and so on; grouting shall continue until refusal achieved at each stage of each grout hole. The subsequent holes shall be drilled and grouted until closure achieved for each stage in the final hole pattern, which may be tertiary or quaternary or even additional pattern of holes.

2. **Hydraulic Applications**.

Grout holes through rock shall be drilled with water as the flushing medium. Drilling with air as the flushing medium will not be permitted if subsequent rock permeation grouting has to be conducted. However, air flush methods can be used for grouting applications like void filling, compaction grouting, and structure foundation stabilization, since the clogging of fractures is not critical.

The readied drill holes shall be caped to avoid running of drill cuttings from adjacent drill holes, thereby requiring additional cleanup efforts.

a) **Washing of Holes While Drilling**.

During drilling, the flow of water shall be maintained to remove the drill cuttings with the upward velocity of flushing water. The flow rate, necessary to produce sufficient upward water velocity to remove different cuttings, shall be established in combination with annular space availability and be properly demonstrated during trial grout hole drilling. Excessive flows shall be avoided in geologic formations prone to erosion.

Upon completion of a portion of a hole, the flow rate of the drilling water shall be slightly increased and allowed to continue to flow while moving the drill tooling up and down at the bottom of the hole until no materials are brought to the surface. The efficacy of the washing shall be checked in the field by measuring the hole depth at completion of the washing with the drill and then rechecking after an hour or so. If there is only a minor difference in measurement, then the washing is effective. If there is a significant difference, then washing at the completion of drilling is not effective, and either materials are settling out of suspension to the bottom of the hole, or caving in the hole is occurring after completion of drilling. The issue of inadequate washing or caving of materials can be resolved by sampling of materials from the bottom of the hole.

For payment purposes, water charges, washing that is performed while drilling and at the completion of drilling shall be treated as incidental to the drilling process.

b) **Hole Washing After Drilling**.

(i) **General.**

During drilling, the flow of water shall be maintained so that the upward velocity removes the drill cuttings and other materials that may be encountered. Holes shall be thoroughly washed before grouting to maximize access of grout to fractures. At the completion of drilling work, the coarser cuttings that tend to settle at the bottom of percussion drilled holes, shall be removed by raising and lowering the drilling tools several times a short distance to allow the drill water to circulate. However, proper cleaning of grout holes can't be accomplished from drill water circulation alone. An independent hole washing setup shall be established for the purpose.

(ii) Equipment.

The equipment for drillholes washing shall include washout bits, pumps, and hoses / pipes for water injection and shall be approved by the Engineer / Engineer representative. Hoses with a minimum diameter of 25 mm shall be used for injecting the water and are preferred over pipe for being lighter in weight with accessibility to greater depth. The insertion and retraction process of the hose is also quicker than pipe, which has to be added or removed in sections. The diameter of the special washout bit attached to the bottom of the hose should be similar to that of the borehole, but small enough to permit rock fragments and cuttings to pass between the bit and the hole sidewall. A 50 mm diameter bit, with closely spaced 3.2 mm diameter holes and limited bottom discharge, shall be provided for a 75 mm drillhole.

Water pumps shall be capable of supplying water at a minimum pressure of 0.75 MPa and flow rates at a minimum of 30 gpm at the top of the drillhole. The water pressure needs to be adjusted according to the rock formation being cleaned to prevent damage to the rock.

Washing shall begin at the top of the hole and progress downward. Washing of any interval of the hole should be accomplished by raising and lowering the washing bit in short increments, and washing should continue until the flow is clean. The process shall be repeated to the bottom of the hole. If the wash water is not returning to the surface, the hole shall be washed for a minimum of 5–10 minutes.

After a hole is completely washed, a plug should be installed in the hole collar to prevent debris from entering the hole. If the hole is in a depression, a standpipe should be grouted into the top of the hole and then plugged.

3. Pressure and Flow Measurement Systems.

Grout holes shall be pressure tested to provide information on the permeability of the formation to be grouted, to identify highly permeable zones, to help identify unstable zones that may require special grouting, and to evaluate the permeability reduction being achieved as grouting progresses.

Pressures and flow rates during pressure testing shall be monitored either with mechanical or electronic systems, as proposed by the Contractor and approved by the Engineer / Engineer representative.

Either of the system shall have a tee just before the instruments. The tee and the associated valves, commonly referred to as a return loop or circulation loop, shall be used to control the pressure applied to the hole by bypassing water back to the pump before the pressure is applied to the formation.

All equipment shall be calibrated. The calibration frequency, for each individual measuring instrument shall be approved by the Engineer / Engineer representative. The calibration shall be routinely checked onsite with an approved economical system, like filling a vessel of a known volume by mechanical meters, to keep a “master header” for periodically checking the calibration of electronic equipment.

The master instrument system shall consist of a calibrated flow meter and pressure transducer pair that shall not be used in the production job and shall be held by the Engineer / Engineer representative for the sole purpose of checking the calibration of production equipment.

PS 3.5.3 DRILLING THROUGH CONCRETE

1. Drilling through concrete shall be rotary drilling.
2. Drilling through concrete less than seven (7) days old shall not be permitted, except if standpipes have been installed prior to pouring of concrete.
3. Where drilling is to be conducted through reinforced concrete or adjacent to piping or other embedded parts, then standard mild steel pipes for guides shall be installed in the forms prior to concreting. The inside diameter of such a "guide sleeve" shall be sized so as to take the largest size bit to be used.

PS 3.5.4 DRILLING FOR CONTACT OR CAVITY GROUTING

1. The Contractor shall drill holes for contact or cavity grouting as shown on the drawings or where as directed by the Engineer / Engineer representative.
2. The hole shall be drilled by rotary (51 mm min. diameter) through the concrete or shotcrete lining or through a pipe sleeve embedded in the concrete, and shall be drilled to a minimum depth of 0.3 m into rock.
3. Drilling of holes for contact or cavity grouting in any structure shall not be started earlier than 28 days after placement of concrete or shotcrete at the particular location, unless otherwise directed by the Engineer / Engineer representative.

PS 3.5.5 DRILLING FOR CURTAIN GROUTING

1. The Contractor shall drill the holes for curtain grouting as shown on the drawings or as directed by the Engineer / Engineer representative otherwise.
2. The location, direction and method of drilling and grouting and depth of each grout hole for curtain grouting shall be as directed by the Engineer / Engineer representative or as shown on the drawings and will be subject to modifications during the progress of the drilling, testing and grouting.
3. The primary grout holes should be laid at 6 m spacing in order to achieve a target permeability of 3 – 5 Lugeon values, subsequently followed by secondary

and tertiary holes at a progressive smaller spacing usually 3 m to 1.5 m respectively.

4. Drilling for curtain grout holes shall not commence until seventy-two (72) hours after completion of cavity grouting within 10 m.
5. Additional holes shall be drilled and grouted, to treat peculiar geological features such as faults, folds, fissures, seams, shear zones and discontinuities etc., as directed by the Engineer / Engineer representative.
6. In the downstage holes, or as instructed by the Engineer / Engineer representative, set grout shall be re-drilled in order to resume next stage grouting. Holes which have been grouted shall not be re-drilled within twenty-four (24) hours of grouting.
7. Holes drilled in soft rock or fractured formations shall be cased with a perforated steel pipe or cemented and re-drilled as required and approved. Where practicable, such casings shall later be removed. Casing shall only be allowed to remain permanently in place where as approved by the Engineer / Engineer representative.

PS 3.5.6 DRILLING FOR STAGED GROUTING

1. When grout holes are longer than about 10 m (30 ft), it should be divided into shorter lengths, called stages, and then grout each of these stages separately.
2. Lengths of planned stages should be multiples of drill rod lengths to make each rod change worthwhile, since drill rods usually come in 10-ft (3 m) lengths. In weak rock formations, deep stages should not be much longer than surface ones.
3. In the Upstage grouting method, also called Packer-Grouting, Stage – Up, Stop – Grouting and Ascending – Stages grouting, the hole shall be first drilled to full depth, followed by washing, seating the packer at the top of bottom-stage and then water pressure testing this stage prior to grouting it. The process shall be repeated by seating the packer at the top of second bottom-stage and so on until top of the hole reached.
4. The time interval between grouting of stages shall be as agreed by the Engineer / Engineer representative. The standard industry practice recommends either a minimum of 6 hours gap b/w the two stages or delaying the lifting of packers until pressure dissipates in the stage just finished or grouted.
5. In the Downstage grouting method, also called Stage – Down and Descending Stages grouting, the top stage shall be first drilled, washed, water tested, grouted and allowed the grout surrounding the hole to take initial set; washed out the hole before the grout has set sufficiently to require redrilling, drill the hole to another limited depth in the second-stage, and so on down–the–hole with a packer may be used or not to separate the stages and grouting; The second-stage and the subsequent ones should not be drilled sooner than twenty-four (24) hours since grouting of the previous stage.
6. Drilling and stage grouting of fresh rock shall be performed by using the upstage method, except where the Engineer / Engineer representative determines that the downstage method is necessary for satisfactory grouting. If the downstage method is used, the stage length shall be 5 m.

7. Treatment of weathered rock zones shall be performed using the downstage method, unless Engineer / Engineer representative determines otherwise. For the downstage method the drilling shall be performed in successive operations, consisting in each case of:

   a) drilling holes to a limited depth and grouting at that depth;

   b) allowing the grout in the grout holes to set for at least 24 hours, unless washing out of the hole is directed by the Engineer / Engineer representative; and

   c) drilling the hole to an additional depth and then grouting at the additional depth and thus successively drilling and grouting the hole in stages until the required depth of hole is completely drilled and grouted.

PS 3.5.7 DRILLING FOR ROCK BOLTS, ANCHORS AND DOWELS

1. The diameter of each hole for rock bolts, anchors and dowels shall be as specified in drawings and /or relevant section of these specifications.
2. The length of drill holes shall be such as to receive the specified rock bolts, anchors or dowels and to provide for its satisfactory anchorage.
3. After drilling, each hole shall be flushed with clean water and blowing out all drill cuttings and debris with compressed air. The holes in rock which tends to swelling 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. The holes shall be capped until just prior to installation of rock bolts, anchors or dowels.
4. If a rock bolt, anchor or dowel is not installed immediately after drilling the hole, and the hole has been left uncapped, the hole shall be washed and cleaned as stipulated hereinabove immediately prior to installing the rock bolt, anchor or dowel.

PS 3.6 WATER PRESSURE TESTING

PS 3.6.1 GENERAL

1. Immediately before water pressure testing of any hole started, the hole shall be thoroughly flushed with clean water to remove any accumulation of drilling sludge and cuttings by flushing through a water pipe which shall be inserted to the bottom of the hole. Flushing shall continue until the return water, as judged by the Engineer / Engineer representative, to be clean.
2. The Contractor shall perform water pressure tests by the Lugeon test method in every stage of every consolidation, curtain, verification and exploratory holes or section of holes, as the drilling proceeds or after completion of a drill hole, and as directed by the Engineer / Engineer representative. The test method shall be as described for packer tests in BS 5930 or ASTM D4630-96 (Reapproved 2002).
3. The general procedure for water pressure testing shall be as follows:

   a) Before the packer is installed, the drillhole shall be thoroughly flushed and the Contractor shall check that the flow through the packer is unobstructed.

b) The water pressure test shall be carried out between a packer and the bottom of the hole or between packers in depth stages to suit the variation of jointing of rock. The in-situ pressure head shall be measured and registered before and after each test.

c) The length of the test section of hole shall be 5 m or as directed by the Engineer / Engineer representative, plugged by single packer for tests carried out in the bottom section of hole and double packer for tests carried out in any part of hole.;

d) The Water used shall be clean and comply with the requirements of ASTM C1602 (2012d).

e) Pressure shall be adjusted for each stage to reach the constant effective pressure, as the water pumped into the section

f) Water level above the packer shall be checked and recorded.

g) Pressure losses due to equipment losses, friction in pipes and their fittings, and static groundwater level etc. shall be determined, to the satisfaction of the Engineer / Engineer representative when the pressure is not taken directly from the packer, to apply required corrections in determining Lugeon values.

h) The rate of flow shall be determined to an accuracy of 10 % for flows exceeding 1 litre/min, using an air vessel to smooth out fluctuations of pressure in case of piston type pump.

i) Progressive cavity type pumps (positive displacement pump) shall preferably be used or as instructed by the Engineer / Engineer representative otherwise.

j) The permeability as measured in the drillholes shall be expressed in Lugeon units, with 1 Lugeon unit being equal to a water take of 1 litre per minute per linear metre of hole at a pressure of 1 MPa.

4. For selected primary holes, exploratory holes, check holes, instrument installation holes and as instructed by the Engineer / Engineer representative, multiple-pressure water pressure tests shall be performed as described below.

a) Water shall be pumped into the hole through a header and pressure shall be applied in stages up to the maximum pressure. The maximum pressure shall be determined by the Engineer / Engineer representative depending on geological conditions, but shall in general not exceed 2 MPa (20 bar) above the in-situ pressure head that the rock would experience in its design life.

b) Where water-pressure tests carried out in grout holes, the maximum pressure shall not exceed the maximum grouting pressure to be used. Unless otherwise directed, the pressure at the various stages of testing shall be as shown in Tables 3.1 and 3.2 in sound rock:

Table 3.1: Pressure at the Various Stages of Testing Up-to 10m Depth from Top of Hole

Stage	Gauge pressure – in situ pressure head (bar)
1	2
2	5
3	10 or as directed
4	5
5	2

Table 3.2: Pressure at the Various Stages of Testing From 10m Depth Downwards.

Stage	Pressure Steps (bar)
1	10
2	20
3	50 or as directed
4	20
5	10

c) Uplift and dilation of the rock shall be monitored by the computer base monitoring system on a real-time basis during water pressure testing.

d) Discharge measurements shall be started only after a stable pressure has been established. For each stage of pressure, water absorption shall be measured two times for periods of 5 minutes each. The time for each stage of pressure test shall therefore be 10 minutes.

e) If during discharge measurements the rate of absorption or pressure changes, the test shall be extended until discharge and pressure remain constant over a period of 5 consecutive minutes.

f) If, due to high absorption, it is not possible to maintain the required pressure, the pump shall be operated at its maximum discharge rate for 10 minutes with the pressure measured at (1) minute intervals. If the results do not give an adequate indication of the required grouting pressure, the tests shall be repeated using shorter stage lengths.

g) If surface leakages occur, the leakages shall be sealed and the hole retested

PS 3.6.2 SUBMITTALS AND APPROVALS

The Contractor shall regularly document daily water pressure testing carried out at site on approved format for the Engineer / Engineer representative review. For each test, information provided shall include at least the followings:

a) identification of the hole,

b) level(s) of the packer(s),

c) level of water (if any) in the borehole before and after the test;

d) level of water (if any) above the packer during the test;

e) level of pressure gauge;

f) head loss between the pressure gauge and the tested section (in pipes, tees, bends, joints, valves);

g) pressure measured at the collar of the hole;

h) the volume of water injected at each pressure stage and the total quantity of water injected;

i) duration of each pressure stage of the test;

j) any observed flow from adjacent holes, joints or other openings;

k) Flowrate and effective pressure (P/Q) diagrams, for interpretation of the hydraulic behaviour of tested section

l) Test results by Lugeon values;

m) Plots of pressure and lugeon values for each test sequence plotted as bar graphs.

n) Description of any unusual occurrences.

PS 3.7 PRESSURE GROUTING

PS 3.7.1 GENERAL REQUIREMENTS

1. The Contractor shall perform pressure grouting operations in the locations as shown on the drawing and/or as directed by the Engineer / Engineer representative, including foundation area of dam, spillway and intake structure's etc.,

2. Grouting works shall be staffed with qualified personnel. All key personnel shall have prior grouting experience and shall be subject to approval by the Engineer / Engineer representative

3. The equipment used for grout processing shall safely withstand the anticipated maximum grouting pressures.

4. The aim of the pressure grouting work shall be, to improve the rock mass specific properties, like strength, stiffness or watertightness, by drilling boreholes of suitable diameter, length and direction into the rock material, placing packers near the bore hole opening (or some other means of providing a pressure tight connection to the borehole), connecting a grout conveying hose or pipe between a pump and the packer and pumping a prepared cement-based or chemical-based grout by pressure into the cracks and joints of the rock surrounding the bore holes.

5. Drilling, water pressure testing and grouting operations shall be performed in accordance with the requirements of these specifications, standard engineering practices and with the procedures developed by the Contractor taking account of experience gained as the work proceeds and submitted to and approved by the Engineer / Engineer representative from time to time.

6. Grouting operations are inter-dependent with other construction operations. Excavation and blasting in the vicinity of the area that has already been grouted may cause leakage of grout and render the grouting operation ineffective or it

may be necessary to complete the grouting operations to enable a start to be made of other operations, such as core trench filling / compaction, concreting or masonry work.

Sometimes it may be necessary to carry out grouting before removal of the overburden to obtain the necessary load of surcharge over the zone required to be grouted. In other cases, removal of the overburden may be necessary to facilitate sealing of the sub-surface rock cracks prior to grouting.

Draining boles should always be drilled only after grouting is completed within the expected distance of grout travel.

It is preferable to complete blasting before taking-up the grouting operations. If blasting after grouting is unavoidable, thorough testing and regrouting shall be conducted after blasting.

7. Curtain and consolidation grouting shall be carried out by the split spacing method.

    a) Within any row of grout holes, drilling, water pressure testing and grouting shall always proceed in a split-spacing sequence, commencing with drilling of primary holes at a relatively wide spacing, to avoid passage of grout from one hole to the next and as directed by the Engineer / Engineer representative.

    b) Drilled primary holes shall be grouted first. Secondary holes shall be drilled midway between the primary holes, water pressure tested and grouted. Zones, where third series of holes (tertiary holes) may be necessary, shall be proceeded likewise as per instructions of the Engineer/Engineer representative.

    c) No holes of subsequent series shall be drilled, until grouting has been completed to full depth in both sides of adjacent holes of the previous series.

8. If the Engineer / Engineer representative considers the excavated surface is not satisfactory for grouting, he may require surface treatment by placement of a grout cap prior to grouting to improve the strength and restraining ability of the rock above a grout curtain.

    The grout cap shall be 0.6 to 1.2 meter deep and to extend 0.6 meter upstream and downstream of the curtain, or as directed by the Engineer/Engineer representative otherwise, to provide vertical confinement during grouting efforts and forces the grout to travel horizontally instead of vertically.

9. Water pressure test shall always be performed prior to starting the grouting operation of each stage, to assist in estimating the magnitude of the grout take.

10. Grouting pressures, pumping rates and sequence of holes grouting shall be determined in the field trial demonstrations and agreed with the Engineer / Engineer representative. Control of pressures during grouting operations shall be exercised, as excessive local pressures could lead to cracking or buckling the concrete or hydro-fracturing of the rock.

    The Engineer / Engineer representative may order the establishment of level reference points, upheaval gauges, etc. for checking against uplift. Any possible movement shall be taken as an indication that the grouting pressure being used is excessive and shall be immediately relieved.

11. Grouting shall be performed in stages of 3 – 5m, using packers to seal the borehole for each stage, as shown on the drawings, and/or as otherwise directed by the Engineer/Engineer representative.

12. Immediately before the start of grouting, the holes shall be thoroughly washed under pressure, until the water runs clear. All intersected rock crevices, seams of faults containing clay or other washable materials shall be completely washed with water under pressure to remove as much of such materials as possible. Thereafter the packer shall be placed just above the section to be grouted, whereupon the hole shall be water pressure tested and grouted, as directed.

13. During grouting of each stage, the Apparent (grout) Lugeon value shall be compared with the water test determined Lugeon value, obtained from water pressure testing of that particular stage and if there is mismatch, then the grout mix constituents and mix proportions shall be promptly reconsidered with the approval of Engineer/Engineer representative.

14. If during the grouting works, grout is found to flow from adjacent grout holes, such holes shall be capped temporarily.

    In case grout flows between adjacent boreholes, the affected boreholes shall be thoroughly cleaned before the grout has set, in order to ensure proper subsequent grouting of such hole.

    If grout is found to flow from any part of structures, such leaks shall be plugged by the Contractor as directed.

15. Grouting of each stage shall conclude by bringing the stage to natural refusal by systematically varying the grout composition and injection parameters. The apparent grout lugeon value shall be brought steadily to zero (reducing grout consumption rate to zero) at maximum pressure or as directed by the Engineer/Engineer representative.

    Pumping shall be continued for at least 10 minutes at refusal. Upon completion, the packer shall remain in place until there is no back pressure. Unless otherwise directed by the Engineer/Engineer representative, grouting of holes shall continue without interruption.

16. The Engineer/Engineer representative has the right to prohibit the start of grouting work or to stop it completely, in case of malfunctioning of the pressure and grout rate control equipment producing unsatisfactory results. The Contractor shall have no right to claim for any additional payment for such stoppages of work.

17. The time elapsed between completion of the mixing of the grout and its injection into the grout holes shall not exceed the maximum duration of use, as fixed by the setting time tests during laboratory mix-design of each mix type.
    Grout that has remained in the mixer or holdover tank with or without agitation, for more than the specified duration shall be discarded.

18. Records of grouting works shall be submitted to the Engineer/Engineer representative, as specified hereinbelow, containing remarks on techniques, surface leaks, refusals, quantities of materials used, injection times and pressure stages of grout and water tests for each hole separately.

19. After grouting is completed, the contractor shall remove the grouting plant and all related parts, equipment, and supplies from the site. The clean-up shall include unused materials and waste.

PS 3.7.2 SUBMITTALS AND APPROVALS

The Contractor shall make the following submittals to the Engineer/Engineer representative in continuance of relevant paras of ***Submittals and Approvals*** of these specifications.

1. Submit a description of materials, grout mix design, type and location of mixing equipment, pumps and operational procedures to accomplish the grouting operation.
2. Submit a grout mix design report, including:
   a) Grout type and designation.
   b) Grout mix constituents and proportions, including materials by weight and volume.
   c) Grout densities and viscosities, including wet density at point of placement.
   d) Initial set time of grout.
   e) Bleeding, shrinkage/expansion.
   f) Compressive strength.

   For cellular grout, also submit the following:

   a) Foam concentrate supplier's certification of the dilution ratio for the foam concentrate.
   b) A description of the proposed cellular grout production procedures.
3. Maintain and submit logs of grouting operations indicating pressure, density, and volume for each grout placement, including at least the following:
   a) type of grouting operation (such as consolidation, curtain, foundation, anchor, slope stabilization or other);
   b) location, depth and orientation of holes and hole identification;
   c) packer position and length of stage;
   d) date and time of drilling;
   e) date and time of grouting;
   f) grout pressure, refusal pressure and gauge reference number (plot of recorder);
   g) rate of injection;
   h) grout take (plot of recorder);
   i) grout mix;
   j) quantities of the various grout ingredients;
   k) water pressure test results for each stage;
   l) apparent Lugeon values for each stage;
   m) observations, e.g., connections to adjacent grout holes;

n) closure analysis and verification.

The records should be submitted at the end of each work shift.

4. Relevant Standards and recommendations of EN 12715, DIN 4093, American Petroleum Institute Test Procedure API RP 13B-1 and the ISRM report (International Society for Rock Mechanics) on rock grouting (ISRM 1996) may be consulted for guidance.

5. Grouting reports in an approved format shall be compiled from these records and submitted daily to the Engineer/Engineer representative for approval. These shall then constitute the basis for payment.

PS 3.7.3 MATERIAL REQUIREMENTS

PS 3.7.3.1 GENERAL

1. Grouts used in hydraulic and underground construction / rehabilitation projects are generally categorized into

   a) suspension-type grouts,

   b) emulsion-type grouts and

   c) solution type grouts.

   The suspension-type grouts include clay, cement and lime, while the emulsion-type grouts include bitumen and the solution-type grouts include a wide variety of chemicals.

2. Within each grout family, there are primary grout subtypes Following are the subtypes of primary grout mixes, which can be used in conformity with the project specific requirements and approval of the Engineer / Engineer representative.

   a) Cement Grout

   (i) Neat cement grout, with multiple admixtures including super-plasticisers and fluidifiers;

   (ii) Cement-sand grout, with admixture;

   (iii) Cement (with silica fume) grout with or without sand;

   (iv) Microfine-cement or Ultrafine-cement grout.

   b) Chemical Grout

   (i) Chemical groups are more correctly termed “colloidal,” “chemical solution,” or “solution” grouts.

   (ii) Chemical grouts are injected into voids as a chemically reactive solutions, in contrast to cementitious grouts, which are suspensions of particles in a fluid medium. Chemical grouts initially behave as a fluid, but reacts after a predetermined time to form a solid, semisolid, or gel.

   (iii) Chemical grouts each are unique in composition. They have the advantages of low viscosity, good injection ability, more resistant against wash out phenomena and expulsion of water.

(iv) Chemical grouts are truly solution grouts with no suspended solids, and having a high degree of penetrability into soils and rock. They can be injected into fine sands or microfractures. However, chemical grouts not only pose a health and environmental hazards but are also more expensive.

(v) The chemical grout family includes sodium silicate, acrylic gels and polyurethane expansive foams.

(vi) Acrylates and acrylamides are highly penetrable in all mediums and form a gel when reacted. These materials are highly effective for water control because of their ability to set almost instantly within variable, but controllable periods of time. However, there are disadvantages, including shrinking and swelling during wetting and drying cycles.

3. Prevailing rock conditions controls the quantities of sand and admixtures used in Cement based grout.
4. Cement, sand, water and admixtures for use in grout shall conform to the requirements of **Chapter 6 – Cement Concrete**, of General & Supplementary Specifications.
5. Cement for grout shall in general be either Ordinary Portland Cement Type – I, or Rapid Hardening Portland Type – III conforming to ASTM C150.
6. Cement used in pressure grouting shall have a minimum specific surface area of 5,400 cm^2 per gram as determined by the Blaine air-permeability method (ASTM C204) or as directed by the Engineer/Engineer representative.
7. No cement particle shall be retained on BS Standard Sieve No. 200 (0.075 mm). If adequate grout penetration cannot be achieved with standard Type I or III cements, then microfine or ultrafine cement shall be used.
8. Cement grouts, also called suspended solids grouts, have particulates that derive their composition from grinding action of portland cement clinker. Portland cement to be used for grouting works shall have particulate sizes on average of 15 microns. Microfine cements shall range from 6 to 10 microns while ultrafine cements shall have average particulate sizes of 3 to 5 microns.
9. Micro-cement for grout shall be milled from pure portland cement clinker and shall have a minimum Blaine specific area of 900 m^2/kg with 95% of all particles < 10 µm and with a maximum particle size of 15 µm.

   - ACI Committee 552, Geotechnical Cement Grouting, defines microfine cement as a material in which $\mathbf{d_{max} < 15\ \mu m}$.
   - According to the European Standard for grouting (SFS-EN 12715), microfine cements are characterized by a specific surface area >800 m^2 / kg and $\mathbf{d_{95} < 20\ \mu m}$.
   - The Norwegian proposal divides two groups of micro-cements:

     $\mathbf{d_{95} < 30\ \mu m}$**,** Microfine Cement, and

     $\mathbf{d_{95} < 15\ \mu m}$**,** Ultrafine Cement
   - In U.K. practice, ultrafine cements are characterized by $\mathbf{d_{max} \leq 6\ \mu m}$

10. Application of admixtures like superplasticizers (for fluidity increase), dispersants, retarders, accelerators (applied in high flowing formations) shall be adopted to counter the wash out effects of the suspensions and clogging of the grouting pipes, especially in high water pressure or flowing water conditions.

11. For improving the fluidity, stability and sulphate resistance of the grout, additives like bentonite (improves stability), slag, silica fume (to increase stability or to lower the pH-value of the grout), sodium silicate, fly ash or pozzolan may be added. Fly ash, if used in grouting, shall contain less than 5% carbon with 20 % of the cement replacement. Alternatively, Portland-Pozzolan cement may be used. Fly ash shall only be used if proved to be compatible with other grouting materials by testing prior to the start of grouting. Pozzolans and Fly Ash shall comply with ASTM C618 (2012e).

12. Where required, bentonite shall be added to the cement at a rate of 2 to 7 % by weight of cement. Bentonite shall be sodium montmorillonite with properties, as specified by the American Petroleum Institute and mentioned hereinbelow.

Table 3.3: Properties of Bentonite

Property Description	Requirement
Wet Screen Analysis Residue on U.S standard sieve No.200	2.5 %, maximum
Moisture	10 %, maximum
Fan Reading	30, minimum at 600 rpm
Yield Point	3 x viscosity maximum
Filtrate	13.5 cc, maximum
Liquid Limit	> 350
Plastic Limit	> 28
Plasticity index	> 400

13. Properties of sodium silicate to be used as accelerator, if required for pressure grouting, shall be as specified in the following Table 3.4

Table 3.4: Properties of Sodium Silicate to be Used as Accelerator

Property Description	Requirement
Specific gravity at 15ºC	more than 40 Be (Baume gravity meter)
SiO_2	28 to 30 % by weight
Na_2O	9 to 10 % by weight
Fe	less than 0.02 % by weight
Matter insoluble in water	less than 0.2 % by weight

14. Water used shall be clean and free from injurious amounts of oil, acid, organic

matter, or other deleterious substances.

15. Where the grouting is being done below the ground water table, the ground water should be analysed for calcium sulphate, magnesium sulphate, sodium sulphate, organic or mineral acids, alkalies and pH value, which may affect the rigidity and thixotropy of the grout.
16. The minimum percentage of water required for complete hydration of cement shall be 30% when expressed by weight (45% by volume) of cement. The quantities of water for use in grouting shall be greater than in concrete, because of the water being the carrier of the products in suspension during injection.
17. Water having a temperature above 30°C shall not be used in grouting operations. The use of water at a temperature not exceeding 30°C has been designed to limit the temperature rise in the grout during the grouting operation. The Contractor, as directed by the Engineer / Engineer representative, shall provide shelters from the effects of hot weather and wind for the stored cement, water and grout lines and the other equipment handling the grout.

    The recommendations for “Hot Weather Concreting”, as envisaged in **Chapter 6 – Cement Concrete** of General & Supplementary Specifications, may be adopted for grouting operation with the approval of Engineer / Engineer representative.

PS 3.7.3.2 SAND

1. Sand shall conform to ASTM C33. Sand shall be either natural sand, composed of clean, hard, durable uncoated particles resulting from the disintegration of siliceous and/or calcareous rocks; or manufactured sand resulting from the crushing of boulders or shingle.
2. Sand shall be clean and free of injurious amounts of organic impurities; deleterious substances.
3. Unless otherwise specified, the gradation shall be within the numerical limits as specified in the following Table 3.5

Table 3.5: Sand Gradation for Grout

Sieve designation (U.S. Standard Square Mesh)	Percent passing by weight
16	100
50	20 – 50
100	10 – 30
200	0 – 5

PS 3.7.3.3 SILICA FUME

Silica fume is a by-product of the production of silicon or alloys containing at least 75% silicon. The silica fume particles are spherical in shape with an average particle size between 0.1 to 0.15 µm. The small particle size makes it act as small ball bearings, keeping the larger cement particles into motion in the mix, enhancing the penetrability of the grout.

Silica fume enhances durability by reducing the permeability of the cured grout. The stability and resistance against pressure filtration characteristics of a grout can be enhanced with the introduction of silica fume. Silica fume is also known to provide water-repellent characteristics to the grout.

PS 3.7.3.4 ADMIXTURES

1. Chemical admixtures (superplasticizers) and fluidifers etc shall be added to grout mixes to produce balanced and stable High Mobility Grouts (HMG) by modifying the flow and set characteristics (rheology) of grouts. Grout parameters, such as the rheological properties (i.e., yield stress and viscosity) and the injectability of cement grout, (i.e., coefficient of permeability to grout) governs the performance of cement-based permeation grouting in porous media.
2. Admixtures must be chemically compatible with the other components of grout formulations and with one another. Only admixtures tested prior to the start of grouting work and approved by the Engineer/Engineer representative shall be used. Manufacturer's certificates or guarantees will not be accepted as relieving the Contractor of his responsibility for the suitability of any admixture.
3. When chemical admixtures or grouts are required or proposed for use in grout, these shall be accompanied by the relevant manufacturer's certificate (including toxicity, health, safety and environmental certification), substantiating commercial use with satisfactory results in similar type of work. The manufacturer’s full technical knowledge and support should be obtained in the use of admixtures such as at what point in the mixing sequence the admixture should be used. The storage, handling and usage shall be strictly adhered to the manufacturer’s instructions.
4. **Anti-Washout Agents**: Viscosity modifiers such as **diutan gum** provide resistance to washout. Additional resistance to washout can be achieved using commercially available anti-washout agents. These admixtures can be employed with cementitious grouts, in the flowing water environment, with the approval of the Engineer/Engineer representative. These products are cellulose based and may have compatibility issues with other admixtures.
5. **Foaming Agents**: Foaming agents are used to lower grout densities. Grouts created using foam are often referred to as “foamed grouts,” “aerated grouts,” or “controlled low strength material”.
6. The dry admixtures are easier to use as they are simply added to the mixer as the final component. The wet foaming mixtures are less expensive, but require a foam generator. The dry mixes are applicable to batch-type mixing and placements, while the wet foaming agents are advantageous when large quantities are anticipated. Foamed grouts should not be used where the grout will be exposed to flowing water environment, as these grouts are typically less durable.
7. The use of toxic chemicals such as acrylamide shall not be permitted for use in the Works.

PS 3.7.4 GROUT MIX DESIGN

PS 3.7.4.1 GENERAL

a) Unless otherwise specified explicitly in these specifications and drawings, only

Cementitious grouts shall be used in the grouting works.

b) All types of cement-base grouts shall be high mobility grouts (HMG), balanced stable grouts with low water/cement ratios using multiple admixtures including super-plasticisers and fluidifiers.

c) Low mobility grouts (LMG) may be used in the case of compaction grouting, where it is necessary and approved by the Engineer and Engineer representative. Under high inflow / high pressure conditions, sodium silicate can be added as a flash setting additive. Sand should be used when required to fill large voids.

d) Grouts shall be designed to achieve the optimum combination of penetrability, durability and strength as required.

PS 3.7.4.2 DEFINITIONS

a) **Bingham Fluids**: Bingham Fluids are non-Newtonian fluids which do not follow **Newton's** law of viscosity and, thus, their viscosity, a ratio of shear stress (grouting pressure) to shear rate (flow rate of the grout) is not constant and is dependent on the shear rate. If enough force is applied to these **fluids**, their viscosity will change.

   Bingham Fluids are basically **visco-plastic fluids** that possesses a yield strength which must be exceeded before the fluid will flow. There are different behavioural characteristics of non-Newtonian fluids including viscoelasticity, time-dependent viscosity, etc. In Cement based Grouts, Cementitious suspensions behave as Bingham fluids.

b) **Newtonian Fluids:** Newtonian fluids obey **Newton's** law of viscosity. The viscosity is independent of the shear rate. **Newtonian fluids** have a constant viscosity that doesn't change, no matter the pressure being applied to the fluid. In other words, the ratio of the shear stress to the shear rate is constant throughout the fluid. Example: Water, air and gasoline.

c) **Visco-plastic fluids**: Grouts for which the viscosity changes with shear rate (flow rate).

d) **Yield Point.** The yield point or cohesion defines the minimum pressure required to start grout flowing and the pressure at which grout stops moving (refusal) within a fracture.

   At any stress greater than the yield point, grout will continue to flow in the fracture. For a constant fracture width, the rate at which grout flows in the fracture is controlled by the pressure in excess of the yield point and the grout viscosity. As grout moves away from an injection hole, the pressure decreases due to head loss within the fracture. As the pressure, experienced (or “felt”) by the grout, farthest from the hole reduces, the flow rate continues to drop.

e) **Shear thickening & thinning:** Grouts where the viscosity increases with increasing flow rate (pumping rate) are identified as exhibiting shear thickening. Shear thinning behaviour refers to a grout for which the viscosity reduces with increasing flow rates.

f) **High Mobility Grouts (HMGs):** behave as a fluid and can be mixed, circulated, and injected with relative ease using normal grout mixing and pumping equipment. HMGs range from pourable to a thick consistency that is just barely able to be mixed and pumped with normal equipment. HMGs are commonly used for permeation grouting of coarse soils and fractured rock.

g) **Low-Mobility Grouts (LMGs):** are of a mortar-like consistency and exhibit both plasticity (stay together when deformed) and have high internal friction due to the high concentration of solids in the mix. With plastic type behaviour lacking enough fluidity, LMGs are not pourable. The best-known application of LMG is for compaction grouting, where the grout is injected into a soil for displacement and/or densification, resulting in a higher modulus and higher strength. The expanding property as a non-permeating bulb of plastic material, make LMG's a best choice for void filling in karst terrain of dam foundations and tunnel works.

h) **Balanced Stable Grout:** The term refers to a grout mixture that is formulated to provide the desired rheological properties that also remain constant during the injection process. Stable grouts do not separate into distinct phases in the absence of agitation and do not undergo significant property changes until they begin to take a set.

With use of Additives, a balanced stable grout can be created (significantly reduced or zero bleed potential) with the desired rheologic properties that remain nearly constant during injection since the pressure filtration coefficient is low.

i) **Unstable Suspension Grouts**. Grouts which in the absence of continuous agitation, separates into two distinct phases (water and a very thick suspension). Unstable grout exhibits more than 5% bleed or sedimentation when placed in a graduated cylinder. At all locations except within the agitator itself, the properties of unstable suspension grouts are in a process of change throughout the grouting process.

j) **Pressure filtration coefficient**: The tendency of the grout to lose water during injection is quantified by the term pressure filtration coefficient ($\mathbf{K_{pf}}$). It measures the stability of the grouting mixture against segregation of the mixture particles. All the grout mixtures having ($\mathbf{K_{pf}}$) less than $\mathbf{0.05\ (min)^{-1/2}}$ shall be considered as stable mixtures.

The test for measuring pressure filtration coefficient of grout shall be conducted in accordance with American Petroleum Institute Test Procedure API RP 13B-1.

Mathematically, the pressure filtration coefficient is defined as the volume of water lost in the pressure filtration test divided by the initial volume of grout in the cylinder of the apparatus, divided by the square root of the of the filtration time in minutes.

A high resistance to pressure filtration or a low-pressure filtration coefficient is desirable to ensure that the grout rheology remains constant during the injection process.

Neat cement grout mixes and unstable mixes have very poor resistance to pressure filtration. During grouting, unstable mixes will be subjected to substantial and almost immediate water loss where flow channels are narrow. The remaining grout forms a filtrate in the pores or fissures close to the injection point and refusal is reached quickly.

A balanced suspension grout has a good resistance (low $\mathbf{K_{pf}}$) to pressure filtration and a low to moderate cohesion. Although, a regular stable cement-based grouts have a low $\mathbf{K_{pf}}$ but the high cohesions limit their grout spread. By introducing high range water-reducers, the cohesion of the grout can be reduced without adding water, thus maintaining high resistance to pressure filtration.

k) **Grout penetration:** The length of how far grout penetrates in the rock through fractures from a bore hole. The penetrability of grout is directly related to its cohesion. In general, the higher the cohesion of a grout the higher is the resistance to pressure filtration.

l) **Grout Filtration**: Plug building at fracture constrictions which reduces the penetrability of the grout.

m) **Amenability:** It is a measure of the suitability for a given suspension grout to permeate fissures and apertures, accessible to water, in the grout-zone.

The **amenability coefficient (Ac)** shall be determined by dividing the Lugeon value of the formation (Lu_G) determined by using grout as the test fluid by the Apparent Lugeon value of the formation determined during water testing (Lu_W).

Amenability = Lu_G / Lu_W

n) **Grout Lugeon value:** Lugeon value, when testing with water corrected by the ratio of the apparent viscosity of water to that of the stable, non-sanded grout. i.e.,

- Apparent Water Lugeon Value **=** Grout Lugeon Value **X** Ratio of Marsh Funnel Viscosities
- Lu_W **=** Lu_G **X** ($V_{\text{Marsh of Grout}}$ **/** $V_{\text{Marsh of Water}}$)
- $V_{\text{Marsh of Grout}}$ **=** Efflux time (sec) for 1 liter of grout, via the Marsh cone
- $V_{\text{Marsh of Water}}$ shall have the standard value b/w 26 to 28 seconds.

The Grout Lugeon Value shall be determined in the first minute or two of grout injection, but after the flow and pressure have stabilized.

o) **Rheology:** It is the science of deformation and flow of fluids. The rheological properties of Cementitious grouts change with time due to hydration of the cement. The rheology of cement grout is of prime importance in transporting, pumping, pouring and spreading of the material.

p) **Thixotropy:** The decrease of viscosity with time by application of shear and the recovery of viscosity when the material is at rest. Quick structural restore, or high thixotropy, of Cementitious grouts helps in controlling of water inflow in karst passages of underground works.

PS 3.7.4.3 DESIRED PROPERTIES OF CEMENT-BASED SUSPENSION GROUT.

The properties of cement-based grouts shall be classified into two categories:

a) **Fluid characteristics:** cohesion and its evolution with time, thixotropy, viscosity, pressure filtration coefficient, bleed, initial and final gelation.

b) **Set characteristics:** initial and final set-time, unconfined compressive strength, durability, resistance against chemical attack, and permeability coefficient.

The properties that shall be desirable in the cement-based suspension grout for curtain grouting works are outlined hereinbelow:

a) Zero bleed, in order for a grout to be considered stable and the fractures or voids that are filled during the injection remain filled.

   Grout with 5% or more bleed will be treated as Unstable suspension grout.

b) High resistance to pressure filtration, so that the water-to-solids ratio remains constant during the injection.

c) Water repellent, so that the grout suspension does not dissociate when injected into water.

d) Resistant to particle agglomeration due to electrostatic and chemical interactions, to deter the development of macro-flocs (increase in grain size) from the hydration process during the period of injection.

e) Cohesion values consistent with the desired penetration distance. A low cohesion is desirable to maximize penetration from a given hole and limit the total drilling length required. In karst or very high permeability formations, a mix or mixes with a high cohesion might be desirable to keep the travel distance within the intended treatment zone.

f) Viscosity compatible with the pumping pressures and low enough that an economical injection rate is achieved.

g) Thixotropic, so that the grout is resistant to washout after placement.

h) Well-graded grain size distribution of the cured grout (a well-graded structure of the cured grout reduces the matrix permeability and thus improves durability).

i) Long-term durability.

The Contractor's grouting engineer shall have a good understanding of the characteristics and the function of each component in the grout to formulate a balanced, stable, suspension grout with the desired rheology and set characteristics.

PS 3.7.4.4 BALANCED STABLE GROUT MIX COMPOSITION, TESTING AND PRODUCTION

1. Type and proportions of materials used in grout mixtures and any adjustments thereto during grouting operations shall be only as approved by the Engineer/Engineer representative. Proportions shall be varied to suit actual conditions encountered at site.

   Grout mixes shall be balanced stable grout mixes. The use of additives in cement-based suspension grouts may improve one or more properties of the grout, but the probability of adversely affecting other properties cannot be ruled out. The Contractor's Material Engineer should have the proficiency in the design and proportioning of grout mixture with the use of admixtures to achieve the required properties.

2. During laboratory trial mix design, the different grout mixes shall be designated on the basis of relevant physical properties such as marsh funnel viscosity,

compressive strength, pressure filtrate, and the specific gravity, while the additive dosages shall be based on % by weight of cement used.

Whenever there is a change in bulk materials (i.e., cement from a new supplier or a new water source) on an ongoing grouting work, the physical properties of the new mixes shall be verified through testings, and the material proportions and additive concentrations shall be modified to provide the desired properties.

3. Due to variability of the grout components, a full-scale mix design program shall be carried out by the Contractor under the supervision of the Engineer/Engineer representative in the project main laboratory before production grouting. The trial mix testing (Job Mix Formula) shall use all the actual components and actual mixing and proportioning equipment intended for use in the production program, including the mix water.

4. Trial mix design & testing program of grout shall be started with a “medium” mix. The typical sequence of mixing when preparing stable grouts with multiple admixtures shall be to add the water to the mixer followed by the pre-hydrated bentonite slurry. (The bentonite slurry contains a significant portion of the mix water)

   After the water and bentonite slurry, the cementitious materials shall be added. This includes the cement and any pozzolanic additives such as fly ash or silica fume. Once the cementitious materials have been added and mixed, the water reducer or superplasticizer shall be added, followed by any viscosity modifiers. Any accelerators or retarders shall be added at the time recommended by the material supplier, but these should be added in the last.

   For very thick mixes, the superplasticizer might be added to the water before the cement. While adding the superplasticizer to the water in advance of the cement does facilitate mixing, a higher dose (up to two times) of superplasticizer will be required if added before the cement.

6. After the establishment of LJMF (Laboratory Job Mix formula), the mix design shall be tested on site under the supervision of the Engineer/Engineer representative, to investigate any changes in properties arising from differences in materials, mixing equipment, or procedures between laboratory testing and production grouting.

   Baseline data for Production Job Mix Formula and Quality Control parameters shall be established jointly by the Engineer/Engineer representative and the Contractor, once the composition of the trial mix grout from the mixing plant tested, pressure injected and adjusted satisfactorily with the prevailing geological formations.

7. During Production grouting, the properties of the grouts shall be measured regularly to ensure that grouts are being batched correctly and that mixes continue to be consistent with the site conditions as required under quality control and quality assurance procedures as stated in these specifications and/or approved by the Engineer/Engineer representative.

8. Any grout not injected within one hour of mixing shall be wasted.

PS 3.7.4.5 MIX DESIGN CRITERIA

Mix design criteria for balanced stable grouts shall be as described hereinbelow or as directed by the Engineer/Engineer representative to suit site specific conditions and grouting requirements.

a) **Setting time for grouting fractured rock**:

(i) Initial set time 10 to 16 hrs

(ii) Final set time 12 to 20 hrs.

Balanced stable grouts have a longer set time (whether initial gel or initial set) than neat cement grouts, because of the formulation of a stable grout with a fully dispersed structure that delays the hydration process.

The set time can be varied, depending on the purpose of the grouting program, by using admixtures such as retarders or accelerators.

b) **Water-to-Cement Ratio (By Weight**):

Depending on the geology and the objective of the grouting, w/c of the starting mix shall be in the range is 3:1 (thinnest) to 0.6:1 (thickest).

The weight of cement shall include all cementitious materials including fly ash or silica fume.

c) **Bleed or Sedimentation** according to ASTM C940 shall be less than 5% after 2 hrs.

d) **Viscosity:** To be adjusted for each specific work, apparent viscosities as measured with a marsh funnel shall be of a low range of 35–40 sec to a maximum of 60–70 sec with a tolerance on the specified viscosity of + or - 5 sec. A minimum 5 sec change in marsh funnel flow time should be provided, and a 10 sec change b/w the thinner mixes.

e) **High resistance to pressure filtration**. Pressure filtration coefficient shall be < or = to 0.05 $(min)^{-1/2}$ required at standard test duration of 30 min.

f) **Uniaxial compressive strength** after 28 days:

(i) Contact and consolidation grouting, cavity grouting, steel linings and embedded items injections: > 9 MPa.

(ii) Others works (curtain grouting): > 5 MPa.

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PS 3.7.4.6 MIX DESIGN PROPORTIONING

1. **Fly Ash.** Fly ash is designated as Class F or Class C based on the sum of the silicon, aluminium, and iron oxides. The benefits and detriments of the fly ash depends on the fly ash source and should be checked if fly ash is to be used where heat of hydration, sulphate resistance, alkali-silica reaction, or expansion are critical to the grout performance.

   Typical dosages by weight of **Portland cement** shall be

   Class F fly ash: **10–30%**

   Class C fly ash: **< 20%**

2. **Silica Fume**: The typical dosage shall be b/w **5 – 10%** by weight of **Portland cement**.

3. **Bentonite**: The typical dosage shall be b/w **2 – 5%** by weight of **Portland cement**.

Bentonite shall be added as a pre-hydrated suspension with a minimum of 12 hrs hydration before use. When pre-hydrated bentonite is used, the amount of water in the pre-hydrated suspension shall be considered in the batch calculations.

4. **Diutan Gum (Viscosity Modifier & Anti-Washout):** The typical dosage shall be b/w **0.1 – 0.2%** by weight of **Portland cement**.
5. **Superplasticizer (Dispersants or water reducers)**: The typical dosage shall be b/w **1.5 – 3%** by weight of **Portland cement.**

PS 3.7.4.7 TESTING GROUT PROPERTIES

1. The Contractor shall prepare and test the trial HMG mixes as directed by the Engineer/Engineer representative, at least 28 days before commencement of grouting work. Materials for use in grout mixes shall be tested for compliance with the applicable requirements, stipulated in these specifications for Grouting Materials.
2. Tests on proposed grout mixes (JMF) shall be performed in the project field laboratory, during pre-production prior to grouting and during production grouting to demonstrate retainability of requisite grout properties. The Engineer/Engineer representative may direct changes to the proposed grout mixes, based on the results of sample testings.
3. The following tests should be carried out during laboratory testing phase, field pre-production phase and production phase or as otherwise directed by the Engineer/Engineer representative:
   - Specific gravity
   - Cohesion (g/mm²)
   - Apparent viscosity (seconds) – Marsh Funnel and / or Flow Cone (*Marsh Funnel versus Flow Cone depends on viscosity of mixes; thicker mixes have infinite Marsh Funnel time, therefore Flow Cone results can be used, if approved by the Engineer / Engineer representative*)
   - Bleed or sedimentation 1-hour, 2-hours, 3-hours.
   - Pressure filtration resistance (min$^{-1/2}$)
   - Washout resistance (as required and directed by the Engineer/Engineer representative)
   - Filler segregation
   - Initial & Final Gel Time (hours: mins)
   - Initial & Final Set Time (hours: mins)
   - Compressive Strength (psi) 3-days, 7-days,14-days and 28 days.

   Production Quality Control Testings shall be conducted at minimum frequencies mentioned herein Table:3.6 and shall be subject to adjustments (increase or decrease) by the Engineer / Engineer representative.

Table 3.6 Quality control tests for High Mobility Stable Grouts

Test	Test Method	Equipment	Frequency

Apparent viscosity	ASTM D6910 or API Method RP 13B-1	Marsh funnel	Three times per mix per day
Specific gravity	API 13B-1	Mud balance	Three times per mix per day
Bleed	ASTM C940 (2010b)	Graduated cylinder	Once per mix per every second day
Pressure filtration coefficient	API 13B-1	API filter press	Once per mix per every second day
Set time	ASTM C191-92 (2008)	Vicat needle	Once per mix per every second day
Cohesion and gel times		Viscometer	Once per mix per every second day
Strength *	ASTM C942 (2010c)	Grout cubes	Once per mix per every second day
Apparent Cohesion	Weaver (1991), p. 152	Steel plate (**100 mm x 100mm x 1mm)** *Lombardi plate cohesimeter*	Once per mix per every second day

*****_The standards specify testing for UCS using cylinders having a 2:1 aspect ratio or 2-in (50mm) cubes. It is impractical, however, to use cylinders for early age and low strength testing as it is difficult to extract the relatively fragile specimens from cylindrical moulds without damaging them._

2-in. cubes are commonly used to test grout compressive strengths in reference to ASTM C942 and C109

4. Sampling and testing will be supervised by the Engineer/Engineer representative according to the approved Quality Assurance Plan (QAP) for grouting activities.
5. During and simultaneously with the actual field production grouting operations, the Contractor shall carry out tests on rheological properties of grout mixes from time to time during each shift to ensure that the grout is being properly formulated, proportioned and mixed, and that the desired properties have been achieved under ambient conditions, and that those properties have not changed during the holding period. Among other required testing data, the temperature of grout and that of the mixing water, the time at which the grout was mixed, the elapsed mixing time, the time and location at which it was sampled and the time at which the test was made shall be recorded. The grout sampling point should be representative of the grout that is being injected into the hole.
6. In the event, change of source of cement become inevitable, the Contractor shall promptly inform Engineer / Engineer representative. Thereafter, if the new cement brand is approved by the Engineer / Engineer representative, then the Contractor shall proceed with the revised grout mix design (Revised JMF), re-test the specified mix properties in the laboratory, production plant and pressure injection into the hole etc., for compliance, under the supervision of the Engineer

/ Engineer representative, prior to proceeding for regular grouting operations.

7. The Contractor shall prepare records of these tests on approved format, which shall be submitted to the Engineer/Engineer representative on a daily basis.

PS 3.7.5 GROUTING EQUIPMENT

PS 3.7.5.1 GENERAL

1. Prior to shipment of grouting equipment to the site, the Contractor shall submit drawings and general descriptions of equipment he proposes to use for the approval of the Engineer / Engineer representative. All equipment shall be maintained in first-class operating condition at all times.
2. The grouting equipment shall be new and of a type, capacity and mechanical condition to suit the work to be carried out, as determined and approved by the Engineer/Engineer representative, and shall consists of, but not be limited to, pumps, mixers, agitators, pressure gauges, flowmeters, pipes, fittings, material measuring devices, and all accessories and tools necessary to maintain a continuous supply of grout of suitable consistency and quantity.
3. Automated recorders for pressure and volume of grout shall be provided for all types of grouting works.
4. The mixing and pumping equipment shall be installed in one or more central stations to enable continuous, undisturbed work, independent of weather conditions and to guarantee a constant mixture as required.
5. For the grouting operations, reliable communication system between the main working stations and the central grout mix and pump stations shall be provided.
6. Stand-by equipment and necessary spare parts for uninterrupted continuation of the work shall be provided. The distance between the grouting site and the pumps shall be limited to allow for continuous operation without risk of the pipes becoming clogged.
7. The Contractor shall arrange the grouting equipment in such a manner as to ensure the continuous and uninterrupted flow of grout to the hole being injected and to permit accurate pressure control. The grouting shall be carried out by a return flow system to guarantee continuous circulation of grout to the hole being injected and return surplus grout which is not accepted by the hole to the holding tank.
8. The pressure applied shall be measured at the borehole head and transmitted to appropriate automatic recording instruments.
9. Synchronized operation of pressure and discharge recorders must be ensured. For regular checking of pressure at the pumps, these shall be fitted with additional pressure gauges having an accuracy of 0.1MPa (1bar).
10. The Contractor shall prevent the fowling of the equipment and lines by ensuring constant circulation of grout and by periodically flushing out the system with water. Flushing shall be performed with the grout intake valve closed, the water supply valve open, and the pump running at full speed.
11. Prior to the commencement of grouting work and during the work as specified or as requested at the end of such work, all pressure gauges, recorders and

discharge meters shall be checked, calibrated and properly documented for record and approval of the Engineer / Engineer representative.

PS 3.7.5.2 GROUT HOPPERS, MIXERS AND AGITATOR TANK

1. Where there is a need for grouting using both ordinary portland cement and micro-cement, the grouting rig should be equipped with two hoppers. This will help in switching over to alternate cement types without a long break in the grouting work. The hoppers should be equipped with tight lids, so as to prevent water from dripping into the cement. A cement bag-breaker should be mounted above the hopper intake, so that the hoppers can be filled without crew members having to be close by.

   Feed screws should be checked regularly and cleaned when necessary. Hoppers must be emptied in the event a prolonged stoppage.
2. If bulk cement or fly ash is used, it shall be stored in weather tight bins or silos equipped and arranged to discharge directly into a weighing hopper, and hence, directly into the grout mixer without spillage and without intermediate handling.
3. The weighing hopper shall be capable to measure the volume of materials in cement grout with a tolerance of less than 2% of the receipt quantity in grout.
4. Water meter shall show the water volume in liters and with a switch to reset volume measure after each mix.
5. Grout mixers shall be the mechanically operated, high speed, high shear “colloidal” double-drum Colcrete or Hany type with vortex action capable of thoroughly wetting and mixing cement and other admixtures to create a homogeneous suspension and operating at 1500 to 2500 RPM. Paddle type mixers shall not be allowed for mixing and production of high-quality HMG.
6. Paddle mixers shall only be used for large backfilling or void-filling projects where incomplete dispersion of the cement particles and interruptions of the grouting are of little consequence and as approved by the Engineer / Engineer representative.
7. Batching of grouting components shall be, as approved by the Engineer / Engineer representative, in the order of water, bentonite slurry (if bentonite is used), cement, admixtures (time of addition in mixing sequence shall be as per manufacturer’s instructions) and sand (if used in the mix).
8. Bentonite shall be premixed with water (hydrated) for at least 24 hours and batched as a slurry in specified proportions (2-5%) of the weight of cement. Sand shall be added to the grout mix when open-karst formations have to be grouted and for grouting anchor bars and rock anchor bolts, roof bolts and high strength anchors.
9. Additive and Admixture dispensers shall be provided at the mixers to measure and add correct amounts of additive or admixture directly into the mixer.
10. Mixers shall be provided with equipment for measuring weight and volume of mix components with an accuracy of 2% and a water meter, calibrated in litres, with a reset switch for zeroing after each delivery.
11. The mixer shall complete the mixing process efficiently within 1-minute time after all components have been added to the mixer and shall be capable of re-

circulating the grout into the mixing tank for complete wetting of the cement.

12. The mixing time should not be excessively long and shall be controlled to avoid flash setting of the grout mix due substantial heat generation by the high shearing force, imparted to the grout materials.

13. The minimum mixer sizes shall be of 0.25 – 0.3 m^3 (225–280 Liter) capacity for handling "two-bag" or "three-bag" mixes for the grouting works and shall be capable of mixing neat cement grout mixes with water-to-cement ratios as low as 0.5:1 by volume or about 0.35:1 by weight.

14. Mixers with too small or large capacities for the grouting operations may result in overworking of mixer operator, interruptions in the grout supply, increased average age of the injected grout, and wastages of greater quantities of grout.

15. Paddle-assisted high-shear mixers of 5.6 m^3 (5600 Liter) per batch capacity shall be used for large volumes of grout, such as backfilling behind pre-cast tunnel segments or voids filling in karst formations.

16. High speed mixers shall be cleaned after each round of grouting. Impeller/paddles should be replaced every other year.

    Inadequate cleaning may result in set cement falling into the fresh cement being mixed and causing operating problems during grouting. Impeller/paddles/knives become worn-out and gradually give poorer mixing results. They should be replaced when they no longer give the same shear force in the mixing process.

17. One water meter with a "reset-to-zero" feature and graduated in tenths of gallons or hundredths of cubic feet shall be used with each mixer.

18. After the initial mixing is completed, the grout shall be discharged through a 1/8-in. - mesh screen to remove pieces of sacks, strings, wire, ties, or other foreign matter that may be dropped into the mixer into a cylindrical tank called agitator, to keep the grout mix in suspension.

    The agitator shall be equipped with a stirring paddle having rotating speed of approximately 100 RPM to guarantee complete circulation of the entire tank content, prevent settlement of the mix and at the same time not generate excessive heat, as the grout may remain in the agitator for an extended period of time. The tank shall also be equipped with baffles to prevent vortex formation. One additional paddle should be provided near the bottom of the tank to sweep the bottom of the tank.

    The agitator tank shall have at least 30 % more capacity than the mixer so that there is sufficient volume for one batch of grout to be pumped while the next batch is being mixed. The agitator discharge shall be by pumping and not by gravity flow.

    After each round of grouting, the agitator tank shall be thorough cleaned to prevent cement build-up.

17. Equipment for proportioning grout mixes based on the number of cement bags or weighing of cement from bulk silo, and dosing of bentonite and water shall have dosing accuracies of 2 % and 5 %, respectively. Manual batching shall in general not be allowed except where explicitly approved by the Engineer/Engineer representative.

PS 3.7.5.3 GROUT PUMPS

1. All grout pumps shall be of progressive cavity or helical rotor type, also called double helical screw-type, for producing continuous, uniform flow of grout into a hole at relatively constant pressure throughout the grouting process.
2. The grouting pumps, as approved by the Engineer / Engineer representative, shall have ample capacity for the maximum pressure to be used. Pumps with continuous, uninterrupted grouting capacity of 100 liter per minute at about 80% of the specified maximum pressure or, operate up-to 10.0MPa (**100kg/cm^2**) working pressure, with only small fluctuations in pressure during pumping would be desirable.
3. Single acting or double acting piston pumps deliver a pulsating pressure that makes the pressure control difficult when constant or low pressures are required and therefore shall not be used for pumping HMG.

   These pumps are better suited for chemical solution grouting, jet grouting's, pumping of sand mixes to fill large voids, caverns, for contact grouting and on drills as booster pumps to increase the water flush pressures.
4. The grouting equipment shall be arranged so as to provide a supply line from the grout pump and a return line from the grout hole to the grout pump.
5. The pump shall be equipped with pressure and capacity control valves, which allow the independent setting of the maximum pressure and the flow. The pump shall automatically stop whenever the pre-set pressure is reached, and shall maintain that pressure without fluctuation.
6. The air supply shall meet the requirement of the pumps and shall not be less than 200 cubic feet per minute per plant.

PS 3.7.5.4 PRESSURE AND FLOW RATE GAUGES

1. The grouting rig shall have equipment for automatic logging of all parameters that are included in the injection reporting. These shall include volume of different recipes injected in each hole, pressure and start & stop time for different mixtures

   Automatic log system shall be installed and calibrated as approved by the Engineer/Engineer representative.

   Such recorders shall be of modern and sturdy design warranting reliable operation and exact recording of measurements. No grouting works shall be permitted without the use of such instruments.

   Records from such accurate automatic recording instruments, as approved by the Engineer/Engineer representative, shall serve the basis for payment of grout material quantities and time.
2. Water flow shall be measured using electronic flow meters and grout gauge pressure shall be measured using either electronic pressure transducers or dial type mechanical gauges. If dial type mechanical gauges are used, the dial size should be greater than 100mm (4 inches). The gauges should cater for a variety of pressures ranges and should have a pressure range exceeding the pressure expected to be used for grouting.

3. Flow meters and pressure gauges shall be calibrated and certified by an independent laboratory, prior to the commencement of each grouting work.
4. After each usage, gauges shall be cleaned and recalibrated at intervals approved by the Engineer/Engineer representative.
5. A master instrument system consisting of a calibrated flow meter and pressure transducer pair shall be provided by the Contractor and to be held by the Engineer / Engineer representative for the sole purpose of periodically checking the calibration of electronic equipment.
6. All electronic pressure transducers shall be accurate to < 0.5 of full scale and mechanical pressure gauges shall be accurate to within 1% of the range. Graduated water discharge meters shall be accurate to ± 5 %.
7. The Contractor shall provide pressure gauges for both low and high-pressure ranges **(0-1.5 MPa and 0-10.0 MPa).**
8. Two pressure gauges for the applicable range shall be provided on each grout line. One gauge shall be installed at the pump and the other at the collar of the hole. Gauges shall be non-clogging or use gauge-savers also called diaphragm-seal or grease to prevent clogging. Spare gauges shall be available at the plant at all times.
9. The Contractor shall arrange to have available on site an adequate number of calibrated water meters and pressure gauges, as approved by the Engineer/Engineer representative, so that water pressure testing and grouting operations are not held up at any time due to lack of calibrated gauges.

PS 3.7.5.5 GROUT HEADERS - CIRCULATION LINES AND EQUIPMENT ARRANGEMENT

1. Grout headers shall include arrangement of valves and pressure gauges used to control the quantity of grout that flows to the hole, control the pressure of the grout applied to the hole, bleed fluid off the hole during grouting and seal the hole after grouting is completed.
2. The header system for electronic monitoring of pressure and flow for HMG injection shall consist of a pressure gauge or pressure transducer, a flow meter, a diaphragm valve on the return line to control the injection pressure, a diaphragm valve and a ball or plug cock valve on the injection line, and a blow-off or bleed line with a ball or plug cock valve.
3. The size of the piping and fittings shall be compatible with the mixers size and anticipated injection rates. All fittings, piping, and valves shall be similar to the diameter of the grout injection pipe or hose.
4. Smaller fittings tend to block more easily, and larger fittings permit a reduction in the grout velocity and subsequent blocking and settling of cement particles.
5. The grouting equipment shall be arranged in circulation loop system so as to pump the grout from the agitator to the header via supply line and to enable the grout, not required at the grout hole, to return to the agitator tank through a recirculation line from the header.
6. The supply and recirculation lines, equipped with quick release couplings, shall be able to sustain an internal pressure exceeding the maximum produced by the pump. The internal diameter of the lines shall be such that no appreciable

sedimentation of grout take place when pumping at the minimum discharge capacity of the pump. No manifolds shall be used.

7. The total length of pipe and hose between the hole being grouted and the pump shall be kept to a minimum.

   Connections between sections of hose shall be quick-connect unions or couplings to minimize the time in disassembling the lines for flushing and length changes.

   Lines should be flushed at least once per shift to minimize the build-up of grout in the line.

8. Direct injection system, involving pumping of grout from the agitator to the hole, with no return line shall not be permitted.

   However, in large void-filling applications, direct injection with larger-diameter hose may be adopted if approved by the Engineer/Engineer representative.

PS 3.7.5.6 POWER SOURCES

1. Power for mixers, agitators, and pumps shall be provided by direct connection to an electric motor, internal combustion engine, or hydraulically or pneumatically operated motors. The type of power used shall be based on the contractor's preference, but have to approved by the Engineer / Engineer representative.
2. In confined spaces, electric and pneumatic systems shall be adopted due to air quality concerns.

PS 3.7.5.7 PIPE MATERIALS

1. All standard galvanized pipes and fittings for grouting, special grout outlets, all nails, tie wire, wooden plugs, mastic material for sealing purposes, temporary supports and other accessories required for installation of the grouting systems, as described hereinabove, shall be furnished by the Contractor. The pipe shall be cut to length, threaded and fabricated where required, and placed by the Contractor.
2. The steel pipes shall comply with the requirements of BS EN 10216 and shall be hot dip galvanized to BS EN ISO 1461.
3. The pipe fittings shall be malleable cast iron in accordance with BS EN 1562, suitable for the pressure to be applied during grouting, or as approved by the Engineer/Engineer representative otherwise.

PS 3.7.5.8 PACKERS

1. The Contractor shall furnish friction, mechanical and inflatable / pneumatic type packers, according to the local rock conditions, expected uniformity of the hole size and whether the packer to be installed in the hole casing or directly in the grout hole.
2. The type of packer's to be used shall subject to approval by the Engineer/Engineer representative, and the Contractor shall have all required types available on site for immediate use.

3. All sort of packers for use in grouting operation shall guarantee proper sealing of the respective borehole section and shall be capable of withstanding the desired pressures without leakages. The sizes of packers shall suit the various hole diameters and spacing of the expandable sleeves shall suit the stage lengths.

PS 3.7.5.9 WATER DISTRIBUTION SYSTEM

1. The Contractor shall establish a well-planned water distribution system for efficient operations of drilling, water pressure testing and grouting works.
2. The system should extend across the site and have tees and associated valves strategically located.
3. It should be so located to avoid interference with equipment manoeuvrability and other site construction activities.
4. As directed by the Engineer / Engineer representative, water heater or boiler shall be provided during cold weather grouting.

   Similarly, water distribution line between the pump and the batching plant shall be insulated for both hot and cold weather operations.

PS 3.7.6 GROUTING OPERATIONS

PS 3.7.6.1 GENERAL

The grouting operations in the dam foundations and appurtenant structures shall be carried out as described in these specifications or as directed by the Engineer/Engineer representative.

The specified maximum safe pressure for each particular hole or stage shall be measured by the gage at the collar of the hole and not at the pump. The pressure gages in use shall be checked frequently against a master gage of known accuracy or against a column of water or mercury in the presence of the Engineer / Engineer representative. For very low pressures (**less than 0.035 MPa**) and sensitive conditions, low pressure gages shall be used and checked regularly before each use.

Injection procedures described hereinbelow are general guidelines and may be altered in the field by the Engineer/Engineer representative to suit the conditions encountered and to meet the design objectives.

PS 3.7.6.2 CONTACT AND CAVITY GROUTING

1. Low pressure contact or cavity grouting shall be carried out to fill all voids between concrete structures and foundation rock after setting of the concrete.
2. Water pressure testing, subject to approval of the Engineer / Engineer representative, shall normally not be required prior to contact or cavity grouting.
3. Vent pipes for the release of air and water during grouting shall be provided at locations, as directed or approved by the Engineer/Engineer representative.
4. Contact and cavity grouting shall be carried out at a relatively low pressure using neat cement or cement and admixture or cement sand grout as approved by the Engineer/Engineer representative and shall be continued until all voids

are filled.

5. Grouting will be regarded as being satisfactory if the pressure can be maintained for at least 10 minutes without further grout take. 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.
6. Contact grouting shall be accomplished at the highest safe pressure as directed but initially not exceeding 69 kPa (10 psi).
7. After completion of grouting, all grout pipe heads shall be plugged with hard mix mortar to make smooth surface.

PS 3.7.6.3 CURTAIN GROUTING

1. Curtain grouting in main dam foundation shall be double-line and angled as shown on the drawings and/or as directed by the Engineer/Engineer representative.
2. Initial details of suitable borehole directions, spacing, inclination and depth of curtain grout holes shall be determined from the trial section demonstrations in the presence of the Engineer/Engineer representative.
3. Pressure grouting in dam foundations shall be completed to achieve a **residual Lugeon value of 3 or less**.
4. The curtain grouting shall be performed after completion of the consolidation grouting.
5. The maximum pressures to be used in grouting shall be determined by the Engineer/Engineer representative depending on geological conditions and trial tests carried out as stated hereinabove, but shall in general not exceed 2 MPa above the in-situ pressure head that the rock would experience in its design life.
6. Curtain grouting shall be carried out using the following criteria, unless otherwise directed by the Engineer/Engineer representative.

   a) Within any row of grout holes, drilling and grouting shall always proceed in a split-spacing method.

   b) Grouting shall be carried out in stages adapted to properties of the rock (jointing, etc.) and the grout to be used, but the stage length shall not exceed 5m and shall be performed using the upstage method except where the Engineer/Engineer representative determines that the downstage method is required.

   c) Packer shall be set in the concrete structure for the first stage (shallowest stage) of the hole.

   d) In downstage grouting, sufficient time shall be allowed for the grout to set before the next stage is commenced.

   e) The water pressure test shall, where directed by the Engineer/Engineer representative, be carried out in stages before grouting. Permeability shall be measured in Lugeon units at the stage in the hole being tested.

f) The grouting of each stage shall commence with a high mobility grout of the type most likely to penetrate the rock according to the jointing, etc. of the rock and of the results of the water pressure test, with the grout pressure being increased towards the maximum grout pressure.

g) Unless otherwise directed by the Engineer/Engineer representative, hydro-fracturing shall be avoided. The maximum grouting pressure shall be 1 to 1.5 MPa for the stage nearest to the collar and increasing in the deeper stages which shall in general not exceed 2 MPa above the in-situ pressure head that the rock would experience in its design life, rock strength and geological conditions or as approved by the Engineer/Engineer representative otherwise.

h) 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 shall be successively connected to the grouting header to subject them to full pressure.

i) The Apparent (grout) Lugeon Value during grouting shall be compared with the water test determined Lugeon value for the particular stage and if there is mismatch then the mix constituents and mix proportions shall be reconsidered or as approved by the Engineer/Engineer representative otherwise.

j) The viscosity of the grout should be changed, or as considered appropriate by the Engineer/Engineer representative, if the initially established viscosity does not result in a satisfactory rate of take at the required pressure.

k) The Engineer/Engineer representative may instruct, as an alternative to changing the grout type, the technique of hydro-jacking to be adopted to increase the spread of the grout. The maximum grout pressure may be increased providing that surface heave is avoided. The hydro-jacking technique shall not be used in holes adjacent to the concrete structure.

l) During grouting, grout leaks shall be caulked; if caulking cannot be achieved and the leaks are excessive, then the grouting shall be stopped and resumed later when the grout already injected into the leaking fissures has hardened or as directed by the Engineer/Engineer representative otherwise.

m) The Engineer/Engineer representative may order the establishment of level reference points, upheaval gauges, etc. to be observed as a check against the uplift. Any possible movement shall be taken as an indication that the grouting pressure being used is excessive and it shall be immediately relieved.

n) Where grouting is practicable, the full grouting pressure shall be maintained constantly during injections. However, as a safeguard against rock or concrete displacement or while grout leaks are being caulked, the

Engineer/Engineer representative may require the reduction of the pumping pressure or the suspension of pumping.

o) After the grouting of the holes or connections are completed, the grout holes should be closed by means of stopcocks or other suitable valve devices, to maintain the grout pressure for a sufficient period to prevent escape of the grout due to back pressure and flow reversal, caused by artesian conditions.

Unless otherwise directed by the Engineer/Engineer representative, a period of one to two hours will be sufficient.

PS 3.7.6.4 REFUSAL CRITERION

The grouting of a hole shall be considered complete (**grout refusal criteria**) when the Apparent lugeon value of zero (**absolute refusal**) or a take of **0.1 gpm or less** in 10 minutes is achieved at the maximum allowable pressure for that stage or as agreed by the Engineer/Engineer representative otherwise.

Pumping shall be continued for at least 10 minutes at refusal. Upon completion, the packer shall remain in place and the pressure shall be held for 15 minutes or until the excess pressure has dissipated. Unless otherwise directed by the Engineer/Engineer representative, grouting of holes shall continue without interruption

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PS 3.7.6.5 CONTROL OF GROUT CONSUMPTION

In the event, when pressure does not build up even after grouting a thick grout, with water cement ratio lesser than 0·6 : 1 by weight or richer, or by grouts with fillers, such as clay, sand and bentonite, further grouting shall be stopped after the predetermined limit of consumption has been reached.

Unless directed by the Engineer / Engineer representative otherwise, additional holes preferably multiple line curtain, shall be drilled in the vicinity of the hole, in which further grouting was stopped due to the achievement of consumption limit, and grout them with more fluid grouts in order to penetrate the finer cracks and joints which may not have been grouted in the initial operation.

In the outer lines thick grouts shall be used to prevent overtravel and to block the more pervious zones, while in the inner or central lines, grouts may be thickened very gradually and comparatively thinner grout may be used at the start.

Similarly, the thickening of grouts may be carried out more gradually in tertiary holes as compared to primary and secondary holes.

PS 3.7.6.6 VERIFICATION HOLES

1. In order to verify the effectiveness of grouting the Contractor shall drill additional holes between one (1) and three (3) days after completing grouting in an area to enable water tests and possible supplementary grouting to be carried out.

Unless otherwise directed by the Engineer/Engineer representative, the required number of verification holes shall be approximately 10 % of the originally grouted holes and shall be spread over the entire grouted area, as shown on the drawings.

2. The Engineer/Engineer representative shall decide the location, angle and depth of the verification holes within the range of the adjacent grout holes.
3. Except as otherwise required by the Engineer/Engineer representative, check holes shall be grouted by the same method as adopted for grouting of original holes.

PS 3.7.6.7 CLOSURE ANALYSIS AND PROGRAM VERIFICATION

At completion of the curtain grouting, the Contractor shall carry out Closure Analysis and Program Verification to ensure successful achievement of the objectives of grouting by analysis of water pressure test data, apparent lugeon value data, grout take data etc. and verification hole data.

The analysis shall include plots of the results on a profile with the different hole series and multiple plots of pressure test data and grout takes by hole series shown and statistical analysis. The same shall be submitted in a format, as approved by Engineer/Engineer representative for review and payment verification purposes.

PS 3.7.6.8 RECORDS

Unless otherwise specified, the contractor shall keep drilling logs and complete records of all grouting operations. The information to be provided on daily basis shall include: -

a) Time logs of grout mixes and admixtures used in each stage or lift for each hole, related pressures and pumping rates, back-pressures;

b) Grouting method, packer grouting or full depth grouting and stage whether first, second or third;

c) Time of grouting started, time of each change in mix, pressure, or pumping rate; and time of hole completion;

d) Total quantity of cement used for each pressure or mix change;

e) Water-cement ratio at the start and each change thereafter;

f) Grout consumption and time required for consumption of each batch;

g) Pressure recorded at 3 min to 15 min intervals and on completion;

h) Rate of injection;

i) Cement washed;

j) Total quantity of cement injected into the hole; and

k) observations on excessive leakage and other non-routine conditions.

The drilling log shall include date, hole location, depth of rock, and depths to various rock features. Rock features shall be described as hard, soft, weathered, cracks, or cavities.

The Contractor shall cooperate in providing all information related to drilling and grouting activities required by the contract. The daily record shall be submitted in a format, as approved by Engineer/Engineer representative.

PS 3.8 MEASUREMENT AND PAYMENT

PS 3.8.1 MEASUREMENT

a) General

For the various items of work executed under the drilling and grouting for Dam and Hydraulic Structures, measurement shall be made as narrated under the respective items. The actual quantities to be paid for shall be measured and determined by the conditions encountered in the course of the work, except where changes have been made by the Engineer/Engineer representative and order has been given in writing.

The Contractor shall not be entitled to additional payment beyond the unit prices indicated in the priced Bill of Quantities by reason of changes in the number and length of drilled holes, grouted or un-grouted holes, by quantity of materials absorbed, by reason of the location of the drilling and grouting works directed by the Engineer/Engineer representative, or by reason of the timing of the drilling and grouting works in relation to excavation, concreting and other site activities.

Additional allowance above the rate in the priced Bill of Quantities for drilling of grout holes shall not be made on account of the requirement for washing out holes before further drilling.

No separate payment shall be made for drilling of exploratory (cored & non-cored) and Instrumentation holes and the cost thereto shall be deemed to include in the unit price for drilling and grouting work.

No separate payment shall be made for PVC grout sleeves and backfilling the PVC sleeves with sleeve grout after completion of grout injection. The cost thereto shall be deemed to include in the unit price for grouting works.

No separate measurement shall be made for the Contractor's Quality Assurance-Quality Control Program, including verification testing, all of which shall be considered part of the grouting work.

Test program, including verification testing, shall be deemed complete when the test elements are installed, and the test grouting report is submitted and the results accepted by the Engineer / Engineer representative.

All items, where use of water is required, are inclusive of water charges and no separate payment shall be made for.

b) Drilling

Drilling of grout holes and exploratory holes shall be measured for payment on the basis of linear meters of holes actually drilled in concrete, rock or soil, including redrilling in grouted holes, as shown or as directed by the Engineer / Engineer representative and accepted.

Measurement for determining the depths shall be made from the surface of the rock, concrete or grout where drilling is actually started to the actual depth drilled, if approved by the Engineer / Engineer representative, into rock, concrete, grout or any combination of these materials.

Exemption to this shall be the redrilled grout. Any re-drilling required because of the Contractor's failure to clean the grout out of the hole before it has set shall be at the expense of the Contractor.

c) Grouting

The measurement for all types of grouting shall be made on the basis of the number of **kilograms of solid cement** or **sacks of cement (50 kg per sack**) used in the grout mix and satisfactorily injected into the grout holes and verification holes, including wastages where such wasting is not due to the Contractor's negligence.

d) Water Pressure Testing

Measurement for payment for water-pressure tests shall be of the number of tests satisfactorily performed, irrespective of size, length, or inclination of hole.

PS 3.8.2 PAYMENT

The accepted quantity measured as provided above shall be paid for at the contract unit price respectively for the pay items shown in the Bill of Quantities which price and payment shall be full compensation for furnishing all materials, labour, equipment, tools and incidentals and any works pertaining to drilling, water pressure testing and grouting which are not paid for separately, necessary to complete the items.

The unit prices for drilling, water pressure testing and grouting works shall include cost of mobilization of all necessary equipment, operation, maintenance during the works and demobilization at the end.

a) Drilling

Payment of drilling & redrilling of all grout holes and drilling of all exploratory holes as determined under measurement shall be made at the contract unit price per linear meters of holes for the pay item shown in the Bill of Quantities. Such price and payment shall be considered full compensation for all materials, labour, equipment, tools, plant and incidentals necessary to complete the item as specified in these Specifications.

No additional allowance shall be made above the Contract price for interrupting the drilling of a hole:

(i) to permit stage grouting.

(ii) to permit washing or cleaning out holes before further drilling or grouting.

No additional allowance shall be made above the Contract price for any moving of equipment that may be necessary due to the requirements for grouting operation.

An increase or decrease in the amount of drilling of any description, shall not be cause for changes in Contract unit price.

The rates for drilling shall be inclusive of the cost of special washing.

The rates for drilling shall be inclusive of cost of casing pipes and all charges for fixing casing pipes, to the extent necessary and taking out the same after final measurement.

b) Grouting

Payment for curtain, contact and cavity grouting's shall be by the weight (kg) of cement consumed in the grout mix. Payment shall be made at the unit rate **per kg of cement** or **per 50 – kg sack of cement** entered in the priced Bill of Quantities, which shall include the entire cost of plant & equipment setup; entire cost of labour; the entire cost of supply, handling, transportation, storage and testing of grouting materials like cement, sand, bentonite, water and admixtures etc., in accordance with these specification; grout mix design (JMF) and trial grout injection demonstrations; washing out of the holes; maintaining the holes free from obstructions; processing, mixing, hooking-up to the hole, pressure injection of holes; hole closures and clearing up; QA / QC testings at locations shown on the drawings or as directed by the Engineer/Engineer representative.

No extra payment will be made for the following:

(i) installation and removal of grout stub pipes;

(ii) 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 the drilling of new holes to replace these;

(iii) preparation and testing of trial grout mixes;

(iv) grouting mixture's which have been prepared more than one hour prior to injecting & thereby rejected or which have been lost due to improper handling or rejected due to improper mixing;

(v) supply and injection of water for flushing of bore holes etc; and removal of surface water encountered at the place of operation;

(vi) plugging and caulking leaks during grouting;

(vii) protection of drainage system during grouting;

(viii) closure of the holes as specified and clean-up;

(ix) preparation and submission of records and reports on grouting operations;

(x) grout pipes embedded for the purpose of drilling grout holes directly into rock or through concrete.

(xi) an increase or decrease in the amount of grouting of any description;

(xii) all transportation of equipment & plant to and from site and any shifting of the same from one place of operation to another;

(xiii) orderly disposal of any debris or spoil resulting from drilling, grouting or testing operations;

(xiv) lighting of the working area, as necessary;

(xv) all equipment for communication between the batching/mixing plant and the location of grouting activities.

c) Water Pressure Testing

Payment shall be made at the unit price per test entered in the priced 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/Engineer representative, and all costs associated with interruptions to the drilling caused by the intermittent nature of the testing work.

CHAPTER NO. 04
EXCAVATION FOR DIVERSION TUNNEL

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ITEM PS-4: EXCAVATION FOR DIVERSION TUNNEL

PS-4.1 DESCRIPTION OF WORK

This work shall consist of excavating and satisfactory disposal of all types of rocks or soils, generated from open excavations for tunnel portals & shaft(s) and underground tunnel excavations, using any excavation method that would fulfill the specified requirements i.e., using conventional technique of full face excavation by NATM (New Austrian Tunneling Method); or top heading and benching; or multi-drifting with suitable drilling methodology like perimeter blasting / line drilling / presplitting etc., and mechanical excavation methods, along with incidental / ancillary works connected with construction of tunnel and other structures not otherwise provided for in these specifications and in conformity to the alignment, grade, level and cross-sections shown on the plans or as directed by the Engineer / Engineer representative.

The Contractor shall provide all material, labour and equipment and carry out all permanent works and temporary works including exploratory and pilot / probe drilling, earthworks in cutting in all kinds of soils / rocks, at approaches to tunnel, construction of temporary inlet / outlet ditches for tunnel dewatering during the construction stage and excavating the alluvial and other depositions inside the tunnel etc., and satisfactory disposal of surplus spoils with all lead and lifts.

It shall also include the furnishing of all necessary explosive materials, equipment, illuminations, ventilations, communication, compliance with all health and safety HSE requirements, construction of cofferdams, dewatering, sheeting and shoring, etc., which may be necessary for execution of the work, and subsequent removal of cofferdams and other temporary works once the work is completed.

The Contractor shall satisfy himself as to the geological & geotechnical nature of the ground, the hydrological and climatic conditions, the quantities and nature of the surface & underground works, materials necessary for the completion of the diversion tunnel & allied works and in general shall himself obtain all necessary information as to risks, contingencies, and other circumstances which may influence or affect his Bid rates.

The Procuring Entity does not guarantee the correctness of any data / information / drawings either verbal and/or written provided herein nor any interpretations, deducing’s or conclusions relative to conditions at Site. The Contractor must form his own opinion of the character of the underground works and of the materials to be excavated etc. He must make his own geological interpretations, and satisfy himself by his own investigations and research regarding all conditions affecting the surface & underground works to be done. No extra payment will be made for variation in rock / soil characteristics encountered during the construction of diversion tunnel, portals and shaft(s).

The Contractor shall assume full and sole responsibility for safe working conditions and all methods of working in underground works, including the design, provision and erection of all workings necessary to safeguard the Works, workmen, and visitors to the worksite.

All procedures necessary to safeguard the works and workmen, except for any emergency measures that may have to be taken by the Contractor to ensure safety, shall be subject to the prior approval of the Engineer / Engineer representative, but such approval shall not relieve the Contractor of any of his responsibilities to complete the works in time.

PS-4.2 SUBMITTALS

PS-4.2.1 METHOD STATEMENT

Not less than 56 days prior to the commencement of the excavation of the surface and underground works, the Contractor shall submit to the Engineer/Engineer representative for approval, his proposed method of excavation for tunnel, portals & shaft(s) and primary support installations, methods of drilling pilot holes, geological mapping, 3D Monitoring targets installations for checking cavity deformations etc., QA/QC testing of construction materials, including:

a) The excavation sequence of various underground works in a general schedule format.
b) A detailed schedule of the working cycle for excavation and support in each rock class shall be presented. It shall be compatible with the overall project base-line schedule.
c) The statement shall show the quantity / No’s, make & model, capacity etc. of drilling, mucking, grouting and transporting equipment’s, blasting pattern and charge per hole, time for completion of drill /blast /muck cycle, sequence of works and number of crews to be deployed in each shift of tunnel excavation.
d) Methods of temporary and permanent support installations including rock bolting, shotcreting, wire – meshing, steel ribs, lattice girders, erection of travelling type formwork (**Gantry**), in situ concrete linings, concrete compaction, construction joints and contact grouting etc. together with the manufacturer's specifications and instructions for installation.
e) Proposals for erection of wood blockings, lagging and lateral bracing in tunnel portals.
f) Description of standards related to the use of explosives as mentioned hereinbelow to be applied to the portals, shaft(s) and underground excavation works.
g) Layouts of spoil areas for dumping or temporary stockpiling of any suitable muck materials for future incorporation in Works; stockpiles drainage arrangements and the final landscaping.
h) The methods of dealing with ground water ingress & egress, ventilation, illumination, & safety measures in underground works.
i) Construction supervision plan.
j) Hazard analysis and risk assessment.
k) Before commencing the rock excavation work, the Contractor shall prepare and present to the Engineer / Engineer representative a Quality Assurance Plan that ensures that the rock excavation work will be performed according to the Contract requirements.
l) Blasting procedures in different types of rock, including blasting pattern and charges for each type of rock classified, for each cross section or subdivided cross section, containing the following information:

- Drilling pattern, hole diameters, spacing, depth and inclination.
- Type, strength, amount in terms of weight and cartridges of explosives to be used in each hole, on each delay and the total for the blast.
- Distribution of the charge in the holes and priming of each hole.

- Type, sequence and number of delays, delay pattern; wiring diagram for blast; size and type of hook-up lines and lead lines; type and capacity of firing sources; type of condenser discharge blasting machine.
- Stemming of holes and matting or covering of blast area.
- Written evidence of the qualifications of the persons who will be directly responsible for supervising the charging and firing of the round.

The approval given by the Engineer/Engineer representative to the Contractor's method statements and equipment deployments etc., shall not relieve the Contractor of his full responsibility for proper and safe execution of tunnel, portals & shaft excavations, or of liability for injuries to persons or fatal accidents, or any obligations under this Contract.

PS-4.2.2 DAILY PROGRESS REPORT

During the execution of underground excavations, the Contractor shall submit to the Engineer / Engineer representative for review & approval, daily progress report encompassing at least the following information's:

a) length of tunnel excavated and theoretical volume of solid materials excavated according to the excavation classes defined in these specifications;

b) amount, location, spacing and type of steel ribs, lagging and spiling (fore-pole) installed;

c) volume and location of shotcrete, with and without fibres, quantity of fibres and wire mesh installed (if any);

d) number, lengths, types and location of rock bolts installed;

e) rock-falls, zones of instability and logs of pilot holes;

f) water inflow at the heading and the rate of discharge of water from the de-watering systems, along with the temperature of the water;

g) personnel employed during the various stages of operation;

h) unusual occurrences including all delays and the reasons for these.

The Contractor shall record the results of all rock mechanics tests performed by him and submit these documents to the Engineer / Engineer representative without delay;

The Engineer/Engineer representative may require any additional information deemed necessary to be included in the submitted documents.

PS-4.2.3 PRECEDENCE AND REFERENCES

a) Other relevant sections of the project technical specifications (Special provisions & particular/ supplementary / general specifications etc.,) should be referred together with **specifications for Excavation of Diversion Tunnel**. In cases of apparent conflict or ambiguity, clauses presented in this chapter shall take precedence over the clauses stated in other chapters & sections of these specifications.

b) The Contractor's submittals as discussed hereinabove, shall follow the following reference standards (or guides):

(i) Norwegian Tunnelling Society – Safety in Drill and Blast Tunnelling.
(ii) BS 6031:2009 Code of practice for earthworks.
(iii) BS 5607:1998 Code of practice for the safe use of explosives in the construction industry.
(iv) BS 6164:2001 Code of practice for safety in tunnelling in the construction industry.
(v) ANSI/ASSP A10.16-2009 (R2016) – Safety Requirements for Tunnels, Shafts and Caissons.
(vi) Occupational Safety and Health Administration (OSHA), USA regulations No. 1926.800 for Underground Construction.
(vii) Technical Manual for Design and Construction of Road Tunnels — Civil Elements FHWA-NHI-10-034 December 2009.
(viii) LRFD Road Tunnel Design & Construction Guide Specifications-2019.
(ix) International Tunnelling Code of Practice (ITCOP).
(x) The Explosives Rules 2010, Ministry of Industries, Govt of Pakistan.

If no codes or standards exist for a given activity, the Contractor shall perform the work according to an internationally recognized practices, as approved by the Engineer/Engineer representative.

PS-4.3 CONSTRUCTION REQUIREMENTS

PS-4.3.1 GENERAL DESCRIPTION

Underground excavations shall comply with the widths, lengths and depths shown on the Drawings. Proper allowance shall be made for ground deformation and construction tolerances.

Excavation for diversion tunnel and shaft(s) shall be carried out in a uniform and controlled manner to create a minimum size of the opening. New Austrian Tunnelling Method (NATM) of controlled drilling and blasting (D&B) techniques for excavation and ground support installation through primary lining (outer lining) shall be so adopted to avoid the overbreak and stabilize the exposed excavation.

The outer lining shall consist of shotcrete, generally reinforced by wire mesh, steel lattice girders, structural steel H beams, fore-poling’s and/or rock bolts (dowels) as shown on the drawings or as instructed by the Engineer / Engineer representative and shall provide the immediate support and stability to the excavation. The inner lining, which is either shotcrete, rock bolts and/or cast-in-place concrete lining, shall provide the long-term support and durability to the tunnel.

The Contractor may choose his own methods for drilling, blasting and transporting the rock. However, the tunnel construction operations shall be carried out in a ‘Time cycle’ consisting of the following activities;

- Surveying and Profile marking.
- Advancing the face by appropriate excavation methods.
- Drilling, Loading, Charging & Firing Operations.

- De-fuming (after blasting) and scaling.
- Mucking including disposal.
- Plotting of excavated profile and geological mapping.
- Support Installation – temporary and/or permanent.

The Contractor shall allow in his driving program for one stoppage per week of 12 hours duration at each heading enabling the Engineer/Engineer representative to carry out check surveys for alignment, level and cross-section.

Before commencing any drilling and blasting the Contractor shall submit for the Engineer's / Engineer's representative approval the drilling, charging and ignition patterns he proposes to use. Such approval shall, however, not exempt the Contractor of the full liability of any blasting operations.

In case the Contractor suffer delay's due to his adopted working techniques, the Engineer/Engineer representative reserves the right to stipulate other working methods and deployment of new alternate equipment, if these can be expected to result in a speedier progress of the work. The Contractor shall not make any extra claims for such modifications to the working method and/or equipment.

Charging of drill holes as well as type of ignition, drilling patterns etc., shall be according to modern methods and recognized good practice. Only experienced supervisors, foremen, qualified blasting license holders and well-trained tunnelling crews shall be employed for the work.

The Contractor shall observe and carry out all excavation work according to rules and regulations regarding the import / local procurement, transport, storage and use of explosives issued by and public authority having jurisdiction in respect of the same.

PS-4.3.2 DEFINITIONS AND GENERAL TERMS

For the sake of clarity, the following terms shall be used in connection with the Works as defined herein:

1. **Excavation by Drilling and Blasting:** Excavation of tunnels, chamber, shafts and appurtenant structures applying drilling and blasting (D&B);
2. **Bench**: The unexcavated ground normally at the lower face of a tunnel undergoing staged excavation, or the second level of a three-level staged excavation (top/heading – bench – invert).
3. **Heading Face:** The advance end of a heading excavation at which the work is progressing;
4. **Bench Face:** The advance end of a bench excavation at which the work is progressing;
5. **Heading Zone:** The section of the D&B tunnels, ascending or descending, extending from the heading face over the previous three round lengths;
6. **Bench Zone:** The section of the D&B tunnels, ascending or descending, extending from the bench face over the previous three round lengths;
7. **Rear Zone:** Refers to the entire tunnel extending retrospectively from the heading or bench zone, as appropriate, to the portal;

8. **Pull:** The advance of the heading or bench face in from one blasting round to the next (equivalent to round length);

9. **Leading edge:** Surface of a tunnel or shaft lining that is closest to the excavation face. The opposite surface is the trailing edge.

10. **Fore poling:** A system of placing poles or boards into the ground ahead of a tunnel face to provide support to the crown so that excavation can safely take place.

11. **Spiles:** Bars inserted from a tunnel face at a outward raking angle, so as to act as a form of collapse prevention when excavating the next section beneath them. Bars may be solid or hollow and then grouted, and can be self-drilling or pushed into the face.

12. **Jumbo:** A piece of equipment that consists of a frame on which drilling rigs are mounted for drilling multiple boreholes concurrently. Typically used in drill and blast tunnels, or for the drilling of ground support.

13. **NATM:** New Austrian Tunnelling Method is a philosophy of excavating tunnels. It uses the strength of the rock mass together with a shotcrete lining to provide a flexible support system. The performance of underground construction works is monitored during construction. The term is often incorrectly used interchangeably with SCL, **Sprayed Concrete Lining** as the methods employ similar techniques, though employ different philosophies – NATM permits ground movement to gain advantages of the natural rock arching effect, whereas SCL erects a stiff lining immediately to minimize ground movements.

14. **Niches:** An area or adit off the main tunnel used for emergency supplies and communications, or a small refuge in which a person can stand to avoid a train or dumping machinery.

15. **Overbreak:** This is an unintentionally excavated larger tunnel diameter than required due to poor rock or soil breaking away into the excavation.

16. **Look-up:** A tunnel ring that has look-up is rising more steeply (or falling less sharply) when compared against the design alignment. The look-up is measured by the difference over the tunnel diameter between the actual plane and theoretical plane when viewed from the side. Negative look-up is referred to as over-hang.

17. **Over-hang**: A tunnel ring that has over-hang is falling more sharply (or rising less steeply) when compared against the design alignment. The over-hang is measured by the difference over the tunnel diameter between the actual plane and theoretical plane when viewed from the side. Negative over-hang is referred to as look-up.

18. **Pattern bolting**: Systematic spacing of rock bolts in a tunnel to provide ground support, often as defined by a rock mass classification system, such as the Q system.

19. **Plane check**: A check performed on a tunnel or shaft lining to determine the degree by which the leading edge differs from a perfect plane and by which the best fit plane differs from a plane perpendicular to the design alignment.

20. **Trigger values:** Also called “hazard warning levels” or “response levels” are common geotechnical terms to show the actual behavior of the structure in comparison of what was predicted from pre-calculations. The systems normally

include the time in which detections have to be made and reviews, decision and modification have to be carried out.

21. **Convergence:** Changes in the distance between fixed points on a cross-section of a tunnel lining as a result of loading on the lining.

22. **Tights or Underbreak:** Projections of rock in a tunnel inside the minimum excavation profile (A-line) that need to be removed prior to placement of lining.

23. **Scaling:** Removal of rock protrusions by immediate hammering in the wake of blasting.

24. **Water Sheet or Panning and Drain Hose:** PVC-sheet, PVC-pan and PVC-hose used to collect and drain off ground water from areas at either the excavated surface behind the shotcrete lining or to collect and drain seepage through the shotcrete lining.

PS-4.3.3 EXCAVATION LINES AND TOLERANCES

Typical cross sections, excavation lines and dimensions of excavations shall be as shown on the Drawings and defined hereinbelow.

1. The **A' - line** is defined as **"Theoretical Excavation Line"**.

Theoretical excavation profile is the line which does not include allowances for the anticipated ground deformations or tolerances related to excavation accuracy.

It is the Contractor's responsibility to determine the **minimum excavation profile** by adding these allowances to the theoretical excavation line in the radial direction.

The Contractor shall provide to the Engineer / Engineer representative documentations, to demonstrate that the excavated profile meets the required construction tolerances. Convex surfaces shall not be accepted. If convex surfaces occur, they shall be trimmed back prior to shotcreting.

2. The **A-Line** also called "**Minimum Excavation Line**" of the tunnel, is a line which is beyond and parallel to the **A'-Line.**

Depending on the quality & competency of the rock, an appropriate enlargement of the **theoretical excavation profile (A'-Line)** shall be made in order to provide enough space for radial deformations. **The Minimum Excavation Line (A-Line)**, is the line taking into consideration the radial deformations above theoretical excavation line.

Within **A-Line**, no ground / rock materials and no unexcavated material of any kind (i.e., timbering, metallic, or other support elements) will be permitted to remain protruding under any circumstances after initial excavation and barring down / scaling.

3. The **B-Line** (**Excavation Pay Line**) of the tunnel is a line which is beyond and parallel to the **A-Line.** The "**excavation pay line**" is the line for measuring payment of underground excavations.

The distances between **A-Line** and **B-Line** shall vary from 0.0 mm to 250 mm for adjusting construction tolerances and excavation undulations.

This additional excavation allowance up-to 250 mm beyond the **A-Line** shall depend on the Contractor's intended excavation and support measures and equipment excavation accuracy.

4. The **C-Line (Boundary Surface – C)** is a line which is beyond and parallel to the **B-Line**. The distance between **B-Line** and **C-Line** may vary from 250 mm to 550 mm, depending upon the tunnel dimensions and strata of the medium through which the tunnel is being excavated.

   Boundary Line - C is the limit of the Contractor’s risk sphere for geological overbreak. The Contractor is required to perform the excavation works in such a way that the final excavation surface is located between the “minimum excavation line or **A-Line**” and the “excavation pay line or **B-Line**”.

5. In his bid, the Contractor shall define up to which distance from the theoretical excavation line **(A’-Line),** any overbreak shall be considered “**technical or avoidable**” and therefore included in the unit rates for underground excavation.

   Any overbreak that remains inside the **boundary line - C** shall be considered in the risk sphere of the Contractor’s and the Contractor shall have no entitlement for either Extension of Time for Completion or additional remuneration due to this overbreak.

6. An allowance for convergence / radial deformations & crown settlements etc. shall be provided such that upon stabilization of excavation **the primary lining shall not encroach B-line**. The allowance shall be provided as agreed by the Engineer/Engineer representative, depending upon actual observations made from deformation data.

7. Convergence / radial deformations and settlement values shall be adjusted to suit actual deformations as experience is gained during excavation. Adjustments shall be approved by the Engineer/Engineer representative and the pay line shall accordingly be modified.

8. The Contractor shall make all reasonable efforts to maintain the excavation profile as per the design / drawing by exercising careful control of drilling and by varying the various elements of smooth blasting.

9. The breakthrough of tunnel shall be achieved with a maximum deviation of tunnel centreline of 50 mm from the design centreline, both in the horizontal and the vertical direction.

   The maximum allowed deviation at breakthrough includes all inaccuracies relating to the surveying grid, to surveying carried out by the Contractor and to setting-out.
   Average deviation of the tunnel centreline from the design centreline, along a 100 m length of any tunnel section, shall not exceed 30 mm.

10. If deviations in the excavated tunnel or shafts exceed the specified tolerance, the Contractor shall be required to adapt his working methods so that the

specified tolerances are achieved. If the maximum allowed deviation of the tunnel or shaft at breakthrough is surpassed, the Contractor will be required to adapt the tunnel or shaft alignment to accommodate the permanent concrete lining and to smooth out the actual deviation, including additional excavation and/or permanent lining concrete at his own cost and as directed by the Engineer/Engineer representative.

11. Before commencing excavation of a round and after completion of this round, the Contractor shall take survey measurements sufficient to define the excavation cross-section dimensions and elevations of the original surfaces and exposed surfaces of rock excavation. This shall be subject to the Engineer/Engineer representative's approval prior to proceeding further.

12. The position of the internal face of any shaft or tunnel shall not deviate from that detailed in the drawings by more than the following permissible deviations.

Structure	Dimension or alignment	Permissible deviation
a) Tunnel	Finished diameter	1%
b) Tunnels without secondary lining	Line Level	50 mm 25 mm
c) Tunnels with secondary lining	Line Level	20 mm 10 mm

PS-4.3.4 OVERBREAK AND GEOLOGICAL OVERBREAK

1. Overbreak is the space created when the ground breaks beyond the "**excavation pay line**" for the various rock classes. Occurring of overbreak may be caused by improper workmanship and careless working technique (**avoidable overbreak**) and/or by reasons which cannot be influenced by the Contractor (**unavoidable overbreak**). Unavoidable overbreak is overbreak caused by unfavorable geological conditions.

2. The Overbreak, whether avoidable or unavoidable shall be decided by the Engineer/Engineer representative and his decision in this regard shall be accepted as final and binding upon all parties concerned. The quantity for the Overbreak in case decided by the Engineer/Engineer representative as unavoidable shall be measured beyond the design **"Boundary Line – C".**

3. In the event of unavoidable geological overbreak occurrence, the Engineer/Engineer representative shall be immediately informed and given the opportunity for inspection, while both the cause and the extent of the overbreak are clearly visible. However, the Contractor shall adopt appropriate safety measures and install adequate rock reinforcement and support as deemed necessary.

4. Where it is decided by the Engineer/Engineer representative that the overbreak has been caused by unforeseeable geological conditions beyond the control of the Contractor and has not arisen because of incorrect methods of work or carelessness, the cavity or void formed by the overbreak shall be measured in-

situ. The materials required to complete the backfill shall be quantified and approved by the Engineer/Engineer representative and certified for payment only if the cavity or void is beyond the design **“Boundary Line – C”** and exceeds a volume of **2.0 Cu.m** in each individual case.

PS-4.3.5 EXTRAORDINARY GEOLOGICAL OCCURRENCE (EGO)

1. Only exceptionally adverse and unexpected geological conditions and/or an unexpected severe influx of water, under circumstances leaving no possibility of further advance by the construction methods reasonably provided for by the Contract, and leading to a serious and protracted interruption (in general more than 7 days) in the advance of the drill and blast excavation, will be considered as an extraordinary geological occurrence (EGO).
2. Any variation in intact rock and rock mass properties, geological units and lithologies along the tunnel and shaft alignments at any section from the data provided in the contract documents, as well as deviations from the estimated quantities allocated in the priced Bill of Quantities to respective excavation classes, as described and defined in the Contract documents shall not be accepted or construed as an extraordinary geological occurrence (EGO).
3. To forewarn of possible adverse geological conditions, the Contractor shall drill vertical cored exploratory holes in the tunnel roof or invert, as directed, at a maximum distance of 20 m behind the face, and horizontal or ascending percussion pilot holes ahead of the face.

   Any interruption to the advance on account of such drilling and subsequent ground treatment (including grouting or pre-bolting of the face) shall not be considered as EGO.

   Drilling and grouting ahead of the face and grouting for the control of water inflow at tunnel face shall not be considered as EGO.
4. No EGO shall be acknowledged if loosening / deterioration of rock mass occurs due to delayed rock support installation, due to equipment malfunctioning or interruption in supply of support elements to the face or for any other lack of support arrangement reasons.
5. No EGO shall be acknowledged or accepted in the rear zones.
6. If an EGO occurs, the Contractor shall without delay propose a method to be used to overcome the situation and undertake, with the approval of the Engineer/Engineer representative, all the necessary steps to expeditiously resume the tunnel excavation.
7. The EGO provisions do not in any way release the Contractor from his responsibility to excavate with caution and to provide rock support and/or other measures as needed to prevent unnecessary worsening of poor geological conditions or of combined stability and water problems.

PS-4.3.6 UNDERGROUND EXCAVATION BY DRILLING AND BLASTING (D&B)

1. Excavation procedures shall be adapted to local ground conditions. In unfavorable ground conditions, the Contractor shall propose special excavation methods and specific procedures acceptable to the Engineer / Engineer representative which he considers can meet the requirements of the particular ground conditions so as to achieve safe excavation conditions with minimum

deterioration or loosening of the ground surrounding the excavation, or to avoid overbreak and limit negative effects on already installed primary lining.

2. The typical support systems for different types of rock shall be as shown on the drawings and are indicative of the range of measures that could be adopted in the generally prevailing rock conditions. Any radical departure from these conditions would need adoption of durable and robust methods which the Contractor shall propose for approval of the Engineer/Engineer representative prior to installation. However, such approval from the Engineer/Engineer representative shall not relieve the Contractor of his obligations under the Contract.

3. Where special support measures such as forepoling may lead to over-excavation, the Contractor shall ensure that the excavation profile is kept to the absolute minimum required to progress the Works.

4. Drilling and blasting shall be done in such a manner to achieve maximum pull (advance) with breakage of rock along the desired lines. In order to limit the over-break and to prevent shattering of the rock surfaces, with no protuberances inside the concrete lining thickness and no deep indentations so as to require large quantities of concrete at the time of placing the permanent lining, controlled blasting methods such as perimeter blasting (soft blasting, smooth contour blasting technique) shall be used on all final rock surfaces.

5. The diameter and the spacing of the blast holes shall be regulated according to the prevailing rock conditions. The Contractor shall develop and continuously improve the blasting techniques as the works move forward to obtain the best possible excavation surface after blasting.

6. 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 at his own cost, in a manner agreed by the Engineer/Engineer representative.

7. Opening up a new round of excavation shall only follow the installation of support elements of the previous round as shown on the drawings and agreed by the Engineer/Engineer representative. The length of a new round shall not exceed the maximum length of unsupported excavation indicated in the corresponding drawings for the respective rock class. The spacing of the steel ribs or lattice girders and the spacing of holes or even the pull of the rounds shall be reduced if ground conditions so dictates.

8. After completion of the excavation of a particular construction stage, the Contractor shall immediately apply a sealing layer of shotcrete / primary support (minimum 50 mm thickness) to minimize or avoid deterioration of the ground due to exposure. Sealing layers for the bench / invert sections may be omitted when tunnelling in competent rock. The requirements for sealing layer shall be as specified in the drawings or as otherwise instructed by the Engineer / Engineer representative.

9. To ensure the safety of the works, tunnel excavation and primary lining application shall be continuous at all times unless otherwise accepted by the

Engineer / Engineer representative. If the state of the work permits, interruptions may be allowed on weekends and public holidays, provided that the works are secured in a safe condition. In this case, the Contractor shall submit for the Engineer’s / Engineer’s representative acceptance, a proposal on how the current state of the works be secured during the shutdown period including implementation and inspection procedures.

10. The interruption shall not be allowed until all the support elements at all necessary locations have been completed including shotcreting of the excavation face. Notwithstanding the above requirements for prolonged stoppages, for any interruptions to the works longer than 72 hours, the Contractor shall identify the change on a daily progress report and shall carry out any additional support measures as recommended and/or requested by the Engineer / Engineer representative.

11. The sequence of excavation (heading and bench, full face or others) for each excavation class will be proposed by the Contractor to suit his equipment and excavation methods, but will be subject to the Engineer / Engineer representative approval. Notwithstanding the Contractor's proposal, the Engineer/Engineer representative may instruct modifications to the excavation method to suit the prevailing ground conditions. The Contractor shall have no right whatsoever to claim additional costs or an extension of the Time for Completion due to such modification of the excavation method.

12. When traversing weakness zones or other areas of heavily jointed or otherwise incompetent rock, pilot tunnelling, dividing of the section, and/or advancing with shorter pull than normal may become necessary. Spiling, immediate application of shotcrete, pressure grouting or other support measures, as described in these specifications, may also be required, but shall subject to the Engineer's / Engineer’s representative approval.

13. A rigid template of the same shape and dimensions as the theoretical cross-section shall pass through. Deviation of the theoretical cross section from the center line, beyond the specified tolerance, will not be approved.

14. Any subsequent scaling, wedging or re-drilling of rock that may be necessary in order to meet the above requirements is the responsibility and at cost of the Contractor.

15. Rock-drilling with air flushing shall not be allowed in underground excavations, unless required by the ground conditions and / or as approved by the Engineer/Engineer representative.

16. The Contractor shall select the type of equipment for underground excavation works and transportation, suitable for the works specified with respect to performance and safety regulations.

17. Underground mechanical plant and equipment shall be powered by electricity, compressed air or diesel engine. Diesel engines must be fitted with filters for the treatment of exhaust fumes. Petrol engines are forbidden.

18. The key items of equipment for excavation and support of the excavation, including, but not limited to, drilling, explosive charging, mucking, shotcrete

production and application, rock bolting, etc. shall be new, or refurbished for use on this Project. Refurbished equipment shall not be older than 4 years.

19. The costs of handling seepage and ground water inflows into the tunnel, less than 300 liter/min per 100-meter length of tunnel, shall be deemed to be included in the unit rates for the underground excavations.

20. The basic target for water tightness of diversion tunnel & shaft, is that the overall remaining seepage shall be no more than 20 liter/min/100-meter length. This level is chosen based on an optimization of the cost of grouting versus the cost of pumping facilities, i.e., pumping capacity, pumping energy.

21. After excavating, the Contractor shall adequately protect the invert surface from damage caused by construction traffic, e.g., by the timely placement of a layer of graded muck or by placement of invert concrete, as appropriate at his own cost.

22. Damage or alteration at any of the work areas, caused by improper blasting or due to any other operation executed by the Contractor, shall be repaired by him at his own expense in a manner acceptable to the Engineer / Engineer representative.

PS-4.3.7 SHAFT EXCAVATION BY RAISE BORING AND DRILL AND BLAST METHOD

1. Shaft excavation may be either by raise boring and downward excavation by drilling and blasting techniques or by any other method, subject to the Engineer/Engineer representative’s approval.
2. The Contractor shall submit details of the methods and equipment for Shaft excavation including raise boring method such as diameters and maximum allowed deviation of pilot drilling and up-reaming, monitoring and control method for alignment, protection of reamed hole, counter measures to correct excessive deviations, downward shaft excavation (drilling, mucking, transporting etc.) and other required works for the Engineer/Engineer representative’s approval.
3. The approval given by the Engineer/Engineer representative to the Contractor's methods and equipment does not relieve the Contractor of his full responsibility for proper and safe execution of shaft excavations. The reamed hole shall be used for the removal of excavation through which the material can be mucked out and disposed.
4. The excavated materials and water from shaft excavation shall be disposed of through the reamed hole and the Tunnel. The Contractor shall establish a safe and efficient mucking and disposal plan, which is to be submitted for the Engineer/Engineer representative’s approval prior to commencement of shaft excavation.
5. The Contractor shall apply drilling and blasting techniques (smooth blasting) for downward excavation of the Shaft and comply with construction methodology provisions specified hereinabove.

PS-4.3.8 SAFETY PRECAUTIONS

PS-4.3.8.1 DRILLING AND BLASTING

1. For drill & blast tunnel excavation, only electric blasting shall be adopted. A separate circuit, independent of power and light circuits shall be used for blasting. No electrically energized circuit shall be installed on the same side of the tunnel with the blasting circuits. All electric lights or other energized circuits shall be disconnected for at least 70 m from the point of explosives loading.
2. For inserting the explosives and charging blast holes, the blastmen shall be equipped with permissible battery lamps & air filter masks. Drill Jumbo's basket shall be used to lift the man-power to charge the holes, which are on the upper portion of the working face.
3. Adequate warning notices shall be given to all persons employed indicating the period, or danger at the time of firing and it shall be the duty of the Contractor to provide adequate shelters or screens for protection of workers exposed to risk of injury from the explosion or from flying material.
4. After the blast takes place in the tunnel, the workmen shall not be allowed to approach the tunnel face till all the toxic gases are expelled-out from the tunnel. A minimum of 15-30 minutes shall be required for de-fuming process.
5. In rocks with rock-burst potential, the scaling, shotcreting and rock bolting equipment shall be operated at a safe distance from newly exposed rock surfaces.
6. Blasting shall be permitted only after proper precautions have been taken for protection of all persons, work and property.
7. Drilling, blasting, excavating and shotcreting operations shall be conducted by methods and with equipment which shall positively control dust, fumes, vapours, gases, fibres, fogs, mists or other atmospheric conditions. Following each round, the broken rock or muck pile shall be wetted down sufficiently to prevent excessive dust during mucking operations.
8. To ensure the safety and the security of the works, tunnel excavation shall be continuous by day and night except as otherwise approved by the Engineer/Engineer representative. Shift change has to be at the work face so that continuous work is assured. If the state of the work permits, intermissions will be allowed at general holiday periods, provided that the works are secured in a safe condition. In addition, the face of any heading shall be sealed with shotcrete (minimum thickness 50mm) except in stable rock conditions or, as otherwise approved by the Engineer/Engineer representative.

PS-4.3.8.2 HANDLING OF EXPLOSIVES

The Contractor shall assume full responsibility for compliance with federal and provincial regulations i.e., the Explosives Act - 1884, the Explosives Rules - 1940 and the Khyber Pakhtunkhwa Explosives Act - 2013, for possession, transportation, storage and use of explosives etc.,

All explosive materials have to be stored at a safe place in a specially designed shelter. The design drawings of the shelter as well as the completed structures must be approved by the Inspector of Explosives in the Ministry of Defense and/or Chief Inspector

Department of Explosives, an attached department with the Federal Ministry of Industries and Production.

The Contractor shall be fully conversant and comply with the relevant sections of all Regulations relating to the storage, issue, transport and use of explosives, which are enforceable by law under Pakistan Explosives Act 2010 and with BS 5607 and its recommendations.

The Contractor shall be responsible for providing all materials such as electric delay detonators, gelatinous explosives, detonation cord, etc. according to the requirements. The primary source of obtaining explosives in Pakistan will be *Bofors Company* residing in Wah Ordinance Factory near Taxila.

The Contractor shall obtain a transit license for the transport of explosives from the local authorities of each District through which he intends to travel.

Before construction commences the Contractor shall submit to the Engineer/Engineer representative his full proposals for the control of explosives in accordance with this clause. He shall submit details of his proposals for explosive storages on the surface, means of transportation of explosives in the tunnel and handling of explosives in the tunnel.

At least 28 days prior to proceeding for drilling and blasting scheme, the Contractor shall submit the following relevant plans, as appropriate to the explosive activities for open & underground excavation works, for approval of the Engineer/Engineer representative.

a) explosives manufacturer operating plan
b) explosives transportation plan;
c) explosives storage plan;
d) explosives use & blasting plan.

PS-4.3.8.3 SECURITY PLAN

1. The Contractor shall, in relation to use of explosives, conduct a risk assessment of the entire operation for explosive transportation, storage and blasting and develop a security plan for approval of the Engineer/Engineer representative.

2. The Contractor's plan shall also state how to deal with incidental sleeping shots, the minimum safety distance between the face blasting site and underground workmen, guarding of the blast site where a blasting operation is of a nature that requires charging up for more than one day.

3. The Contractor shall appoint a competent person as security coordinator to be in charge of security in respect of activities involving explosives.

4. The Contractor shall also employ well-trained and experienced Explosive & Blasting Control Manager(s) for control & management of surface and sub-surface drilling and blasting operations.

5. Explosive & Blasting Control Manager(s) shall have the required certificate of competency to supervise the use of explosives in a surface and underground

works; to store, transport and to deal commercially with the explosives as per prevailing mines and explosive regulations.

6. Explosive & Blasting Control Manager shall ensure that a box, carton or paper bag that once contained explosives is not used again, and that the packaging material is burnt after checking to ensure that the contents have been effectively removed.

PS-4.3.8.4 DRILLING AND LOADING OF BLAST HOLES

The Explosive & Blasting Control Manager shall ensure that

a) drilling of a borehole for blasting is carried out only according to a drilling and blasting scheme, approved by the Engineer/Engineer representative, and given to the respective drill crew and blastmen;

b) the drill and blast scheme shall

- show the position, direction, number, length and diameter of boreholes of the blast;
- provide details on type and quantity of explosives, the delays of detonators and the initiation system;
- provide health and safety instructions specifying the exclusion zone, number and position of blast guards, minimum duration of re-entry period and arrangement of water blast; and
- give the distance of the auxiliary ventilation to the face in headings.

c) drilling and loading of blast holes at a blast site are not undertaken at the same time;

d) drilling is not carried out in the floor, walls, face or back of a development or stop heading, or in a bench or shaft bottom, until the area to be drilled has been washed down and the sockets washed and cleaned and examined for misfires, cracks and loose rocks and other dangers;

e) loose and loosened rock and ground are removed from the face and immediate vicinity of the area to be drilled;

f) a misfired hole is plugged with a wooden plug of a type approved by the control manager and marked with a circle;

g) a blastman shall point out to each driller working under that blastman and, wherever possible, clearly mark with chalk, paint or other material, the exact position and direction of any hole to be drilled and a person shall not in drilling deviate from the position and direction indicated.

h) a blastman shall be the first to enter a working place where blasting is carried out, either at the beginning of the shift or after blasting.

PS-4.3.8.5 CONDITIONS FOR CHARGING OF DRILL HOLES

The Explosive & Blasting Control Manager shall ensure that

a) before a borehole is charged, the blast site is barricaded and no other work is allowed within a safety distance of at least thirty meters;

b) only a blastman charges a drill hole;

c) a non-certificated person works under the continuous control and supervision of a certificated blastman and handles only the container or tube and valve of the injector pipe when a round is being charged;

d) the wooden plug with which a misfired hole or socket of a hole has been plugged is handled or removed only by a blastman; and

e) a person other than a blastman will not open or interfere in any manner with a box containing explosives.

PS-4.3.8.6 CHARGING OF DRILL HOLES

A blastman shall

a) thoroughly clean out drill holes before attempting to charge up the holes;

b) ensure that only ANBA, ANFO or emulsion blasting agent is poured or pumped directly into a bore hole;

c) for the purpose of initiating a charge with capped fuse, and in making up a charge after inserting the detonator with its attached fuse in the primer cartridge, securely fasten it to the cartridge by means of a string or other suitable material so that the fuse and detonator cannot be inadvertently withdrawn;

d) ensure that only tools made of wood, brass, copper or plastic are used in the process of initiating a charge;

e) ensure that explosives which are in cartridges are not forcibly pressed into a hole of insufficient size;

f) ensure that only sand which is loosely filled in, sand and lime mixed and made up in cartridge form, soft clay slightly tamped or water cartridges are used as tamping material; and

A person other than a blastman shall not extract or attempt to extract tamping or explosives from a hole which has once been charged.

Where water and compressed air which are under adequate pressure are not ordinarily available, a blastman may extract tamping only by means of a wooden or copper scraper, to the extent that allows a misfired hole to be re-fired.

PS-4.3.8.7 SAFETY FUSES

a) Explosive & Blasting Control Manager shall ensure that a safety fuse which is less than one meter in length and which has a rate of burning of less than eighty seconds or more than hundred seconds for each hundred meters is not used in the tunnel excavation without the consent of the Engineer/Engineer representative.

b) Explosive & Blasting Control Manager shall ascertain the rate of burning of the fuses; and

c) ensure that the rate of burning of the fuses as ascertained are made known to persons who are required to use the fuses.

PS-4.3.8.8 BLASTING PRECAUTIONS UNDERGROUND

The Explosive & Blasting Control Manager shall ensure that

a) the minimum safety distance between blast and tunnel personnel shall not be less than two hundred meters.

b) before firing, personnel in the blast area withdraw to a safe area which is at such a distance from the blast site that

(i) it will not be affected by fly rock, vibration or air overpressure;
(ii) blasting fumes and dust from the blast site will not reach that safe area.
(iii) areas of the tunnel which are likely to be contaminated by blasting fumes are cleared of personnel before blasting;
(iv) blasting is carried out at the end of the shift, except for blasts where less than five kilograms of explosives are used; and
(v) where blasting operations are close to neighboring workings, a warning is given if the distance is less than two hundred meters and if the distance is less than fifty meters, work places in the neighboring working are evacuated before any blast.

c) in the event, where electric or electronic detonators are used, disconnect the cables from the exploder after firing;
d) a blastman shall not, in relation to a blast for which he is responsible, permit a person to enter the blasted site before thirty minutes have elapsed and until the blastman has examined the site and made it securely safe.

PS-4.3.8.9 EXAMINATION OF BLAST SITE AFTER BLASTING AND MISFIRES TREATMENT

a) A blastman shall, carefully examine the blast site for misfires; and
b) not allow any person to enter the working area, until the fumes caused by the explosion have been sufficiently dissipated.
c) a misfired hole containing ANBA or ANFO explosives shall be thoroughly washed out and the resultant socket plugged; and
d) a misfired hole that cannot be washed out, is re-fired.

PS-4.3.8.10 SCALING AND CLEANING OF EXCAVATED SURFACES

1. Scaling shall be systematically performed in tunnel and shaft excavations, prior to applying any rock reinforcement and support.
2. Loose rock that presents a rockfall hazard must be removed as quickly as possible or stabilized in a safe manner. The method used to remove loose rock and secure it in place must be assessed continuously.
3. After each blasted round and possibly prior to the removal of the bulk of the material loosened by the blast, the Contractor shall scale the newly exposed surface of loose fragments and debris. Methods applied shall not cause further or unnecessary fracturing of the surfaces.
4. Scaling shall be performed on all exposed rock in the tunnel and shaft walls and arch, as an initial rock surface treatment, including any rock loosened within the previous three rounds and always prior to the application of shotcrete.
5. Appropriate scaling methods shall be:
   - **mechanized scaling**, based on profile and geology, and
   - **manual scaling** (scaling using crowbars and scaling rods).

   Mechanized scaling shall always be followed by manual scaling. Extensive flushing of erosive zones with high pressure air-water flushing or the removal of key interlocking blocks must be avoided The Contractor shall ensure that no unauthorized persons present in the vicinity of the scaling work.

6. In competent rock formation, a small to moderate high-frequency hydraulic hammer adapted to the strength of the rock mass shall be used, instead of a larger low-frequency hammer, so that only loose rock is cleared, and new fractures and cracks are not caused by excessive hammering.

7. Manual scaling shall be done by a crew with the necessary experience and insight into the work The number of persons on the working platform, mounted on a mobile base machine or lift machine, shall always be assessed on the basis of space and need.

PS-4.3.8.11 DISPOSAL & TEMPORARY STOCKPILING OF EXCAVATED MATERIALS

1. All excavated materials from the tunnel, shafts and surplus material from excavation at the portals which are not suitable for or in excess of the construction requirements shall be disposed of in permanent stable spoil tips situated in locations, shown on the drawings or as approved by the Engineer/Engineer representative.

2. The Contractor shall be responsible for the management and sorting of all excavated materials to enable the placement and disposal of materials in accordance with the Contract.

3. Following each round, the broken rock or muck pile shall be wetted down sufficiently to prevent excessive dust during mucking operations.

4. Suitable materials from tunnel, shafts and portals excavations shall be utilised in the project to the extent practicable. All materials from open and underground excavation suitable for use as rock-fill, concrete aggregates or for other purposes and meets the specifications requirements shall be cleaned, crushed, pulverized and stockpiled temporarily in the project area, as directed or approved by the Engineer/Engineer representative, if the immediate placement in the final location in permanent works is impractical.

5. The Procuring Entity shall be the Owner of the materials resulting from open and underground excavations and the Contractor cannot sell or use it in works not covered by this Contract without the Procuring Entity's consent and / or Engineer/Engineer representative's prior approval. Other entities or persons authorized by the Procuring Entity to use materials resulting from excavations may utilize only excess material left by the Contractor.

6. The spoil areas shall be constructed, finished to a neat and orderly appearance, and shaped and trimmed to the lines and grades shown on the drawings or as directed by the Engineer/Engineer representative.

7. The Contractor shall provide adequate diversion of existing and intermittent water courses and the proper drainage in the spoil areas in accordance with the drawings and as stipulated in these specifications. The Contractor shall be liable for any damage to temporary or permanent works, or to the property of third parties, caused by insufficient drainage in the spoil or temporary stockpile areas.

8. All costs of loading, transportation, any lead and/or lift, permanent disposal, temporary stockpiling, dressing, cleaning, crushing, pulverizing etc. shall be deemed to include in the unit prices for the open and underground excavations.

PS-4.3.8.12 ROCK MECHANICS TESTING AND MAPPING OF UNDERGROUND WORKS

1. The Contractor shall make available to the Engineer/Engineer representative all geological data in his possession regarding the underground excavation. The Contractor shall strictly follow the nomenclatures of the geological report (units, lithologic types, etc.) in any geological/ geotechnical documents he may produce or be required to submit.
2. When deemed necessary and instructed by the Engineer/Engineer representative, the Contractor shall carry out long exploratory drillings with core recovery as described in relevant chapter “Drilling and Grouting in Tunnels & UG Structures” of these specifications.
3. The Contractor and the Engineer/Engineer representative shall jointly conduct mapping and photographing of freshly exposed ground and agree the geological conditions along the tunnel and shaft, following which the Engineer/Engineer representative may instruct rock mechanics tests. The number and type of tests and the mapping conducted will depend on the rock conditions encountered.
4. The Contractor shall provide assistance and unrestricted access for any profile and cross section surveys to be undertaken by the Engineer/Engineer representative.
5. All sampling of rock or soils shall be performed by the Contractor jointly with the Engineer/Engineer representative. Similar procedures shall also apply to the selection of locations for in-situ testing. No claim whatsoever from the Contractor will be recognised based on sampling or tests which are not witnessed by the Engineer/Engineer representative.
6. The Contractor shall provide adequate lighting, ventilation, and reasonable access to the Engineer/Engineer representative for the mapping of the underground works.

PS-4.3.8.13 WATER PRESSURE TESTING

1. Water pressure testing, as described in relevant chapter “Drilling and Grouting in Tunnels & UG Structures” of these specifications shall be performed by the Contractor's personnel under the direct supervision of the Engineer/Engineer representative.
2. The Contractor shall make provision in his planned excavation activities to enable water pressure and any rock mechanics testing to be carried out concurrently with the underground excavation. The Contractor will neither be granted extension of time for the completion of such testings, nor for the necessary preparatory work.

PS-4.3.8.14 GEOTECHNICAL OBSERVATION AND MEASUREMENT

1. Observation and measurement of geotechnical condition of the excavated face as per rocks competency and condition of already supported tunnel shall be carried out by the Contractor as a daily activity and /or as directed by the

Engineer/Engineer representative and are to be recorded and shared with the Engineer/Engineer representative for review.

2. Instrumentation and monitoring of structural deformations of ground, lining and support elements shall be carried out, during & after tunnel construction and shall include the following measurements.

   a) Convergence of the tunnel wall, crest settlement and spring-line closure.
   b) Deformations at ground surface including settlements and tilts of surface structures.
   c) Deformations in the ground around the tunnel.
   d) The stresses, strains, cracks in the lining and the pore water pressures.

   The instruments shall be embedded in lining, ground, boreholes and must be durable in the long term and not prone to damage during and after installation.

   The Contractor's submittal for "Construction Method Statement" shall include proposals for instrumentation and monitoring system installation, in conformance with the project specific design, hazard sensitiveness and anticipated risk level etc.,

3. The observation of the convergences inside the tunnel / wall's displacements shall be carried out with 3D-optical measuring system, consisting of manually operated total stations, special bi-reflex targets, hardware like PC or notebook, interface for data-transfer from Total stations to PC, output devices and comprehensive software system including: data base management, geodetic calculations, graphical evaluation etc.

   Automatic data logging by 3D-optical measuring system will assist in making prompt judgments about regaining of stability by the tunnel's cavity and adequacy of the supports installed. If deformation rate of tunnel is larger than expected then additional support will be swiftly planned and installed to confine the deformation.

4. Depending on the rock mass competency, the longitudinal distances between two consecutive targets shall vary from 25m (highly competent rock mass) to 5m (soft, squeezing or swelling rock conditions).

5. Radial deformations with whole cross section shall vary from 20mm in case of stable rock conditions to 100mm for rock with squeezing / swelling characteristics.

6. In the events, deformation reaches the warning limit then additional rock bolts, ribs, lattice girders or closing of ring by providing deep invert, as recommended by the Contractor and approved by the Engineer/Engineer representative, shall be provided for improving rock competency.

7. With the progress of tunnel, the measurement frequency behind the face area shall be gradually reduced from days to weekly basis and then to monthly basis and disengaged once the deformation is confirmed to have completely ceased.

PS-4.3.8.15 DE-WATERING OF UNDERGROUND CONSTRUCTION SITES

1. The Contractor shall be responsible for the control of water in underground works and shall keep the Works well drained until the issuance of Defects Liability Certificate for the Contract.

2. The Contractor shall design, furnish, maintain and remove temporary works for protecting the Works under construction against flood flows, and design, furnish, operate, maintain and dismantle the temporary dewatering facilities required to remove water from construction activities and from natural surface flow or groundwater seepage from working areas on the surface as well as in the tunnels and shafts and other underground excavations.

3. The Contractor will be held responsible for all damages caused by his dewatering procedures or the lack of such, and he shall reinstate or repair disturbed ground or structures to their original condition or as otherwise approved by the Engineer/Engineer representative.

4. The Contractor shall install, operate and maintain all temporary pumping plants and drainage facilities and remove all accumulated silt, suspended solids and debris necessary for the proper execution and completion of the underground works. Standing water inside the tunnel will not be allowed.

5. The Contractor shall drill probe holes ahead of the advancing tunnel face and grout suspect areas or pre-install drainage to divert the underground water before excavation to control or decrease the inflow volumes so as to excavate successfully and avoid instability. The Contractor’s proposed methods and strategies for groundwater control shall be presented in the Contractor’s Methods Statements.

6. The Contractor shall carry out free unhampered gravity flow and/or continuous pumping in the events of inflow in the tunnel. Water shall be controlled at the heading, keeping the tunnel invert and any tunnelling machinery clear of water as much as practical at all times.

7. The capacity of pumping plant installed and maintained shall be at least two times the expected volume of water inflow. In addition, pumps shall be provided at each working heading of sufficient capacity to maintain acceptable working conditions for excavation and construction of the lining.

8. **Longitudinal Drainage:** The tunnel shall be drained by trenches in the bottom of the respective heading. In areas of large water inflows, installation of partly perforated or slotted hard-PVC pipes with a diameter of 150 mm to 300 mm depending on the amount of water to be diverted may be necessary.

   In case of descending headings sumps shall be provided at regular intervals from where the water shall be pumped out of the tunnel.

9. **Radial Drains:** For concentrated water inflows, relief holes shall be made into the ground. Perforated hard-PVC pipes, diameter 40 mm, shall be installed into the holes. The space between the pipe and mouth of the borehole shall be sealed with quick-setting mortar. The mouth of the pipe shall be connected to a

hose for diversion to the temporary longitudinal drainage, to sumps or longitudinal trenches in the bottom of the respective headings.

10. In wet areas on the rock surface, water shall be collected by semi-circular pipe portions (preferably from corrugated, soft-PVC pipes) which are fixed to the rock by quick setting mortar or shotcrete and diverted to sumps or longitudinal trenches in the bottom of the respective headings.

    Wet areas in the shotcrete lining shall be drilled open and treated as explained hereinabove. Weep holes drilled through the shotcrete up-to 1-m into the rock shall avoid the buildup of excessive water pressure onto the shotcrete lining.

11. The Contractor shall remove the temporary drainage system, including channels, pipes, after completion of the Works, except where permanently embedded.

12. Unless otherwise specified, all water emanating from the underground excavation shall be treated for effluents in accordance with the prevailing Environmental Quality Standards and to the satisfaction of the Engineer/Engineer representative, to prevent pollution of existing watercourses, before discharging into surface and subsurface water bodies.

13. The tunnel roadway shall be kept trafficable at all times by appropriate water control measures during & after the underground excavation work.

14. The Contractor shall install, operate, maintain and relocate the necessary devices for flow measurements. These measuring devices shall be checked and approved by the Engineer/Engineer representative before they are used.

    Gauging stations shall be installed and measurement of the total discharge shall be made at locations approved by the Engineer/Engineer representative.

    The daily average flow rate shall be based on at least three (3) measurements per day jointly by the Engineer/Engineer representative and the Contractor or as otherwise agreed upon.

PS-4.3.8.16 DIVERSION TUNNEL MAINTENANCE

The Contractor shall be responsible for maintaining the completed underground works throughout the construction and contract period. As part of the maintenance schedule, as approved by the Engineer/Engineer representative, remedial works shall be carried out when repairs are required to the structural or allied systems or when grouting is required to stop water inflow and de-silting of tunnel in routine and following each flood passage.

The Contractor shall, in addition to monitoring the tunnel support system, carry out regular maintenance & repairing of the underground works, including but not limited to tunnel structural system, water ingress & egress management system, light bulb replacement, general cleaning, ventilation system, and cable maintenance etc.,

PS-4.3.8.17 HEALTH, SAFETY & ENVIRONMENT REQUIREMENTS

The safety of underground excavations shall, at all times, be the responsibility of the Contractor, as well as the adoption and fulfilling of all necessary measures to protect the personnel engaged in underground work from cave-ins, harmful gases or vapors, explosions, intoxications, electric discharges, floods and all other accidents of probable occurrence in the construction of tunnel.

The Contractor shall submit a written plan for health, safety and environment (HSE plan) in conformity with ***BS 6164:2011*** *- Code of practice for health and safety in tunnelling in the construction industry*, and *US Safety and Health Regulations for Underground Construction,* ***Standard Number: 1926.800***, for approval of the Engineer/Engineer representative, prior to proceeding for rock excavation in the Tunnel. The HSE plan must be prepared on the basis of a risk analysis and made available to the employees working underground. Moreover, it should be updated regularly as required. The proposed HSE plan for underground excavation should contain:

- measures for relevant risk factors (escape routes, rescue/refuge containers, personal ID tags).
- a description of how coordination will be addressed.
- rules for safe use of methods and equipment.
- a description of contingency plans.
- a general outlay of the working area.
- information about the ventilation system
- a description of measures for preventing explosions.
- requirements pertaining to personal protective equipment and preventive measures against harmful gases.
- contingency plans and measures for preventing and fighting fire.
- identification and assessment of hazards.
- information about safety assessments of workplaces and equipment

The HSE plan shall make it clear that the risks to which the workers are exposed at the workplace have been identified and assessed, and shall detail the measures that are to be implemented to prevent accident and injury. In particular, it shall be evident from the plan that the design, use and maintenance of workplace and equipment have been assessed for safety.

The Contractor shall take all precautions normally adopted for this type of work and those that the Engineer/Engineer representative may deem necessary within the scope of the Work. In particular such measures shall include the following: -

a. Provision of proper site safety and emergency regulations and fire, gas and electric shock precautions.

b. Provision of a first-aid box, stretchers, resuscitation apparatus, approved equipment and rescue facilities at tunnel portal or shaft.

c. Provision of a fully equipped first-aid post manned day and night by a trained nurse and served by a field ambulance and having a day and night duty driver. The first-aid post shall be in electronic communication with portals and shafts in their areas.

d. Safe storage, handling and use of explosives, gases, fuels and other dangerous goods.

e. Provision of safety helmets for all personnel including authorized visitors to the site; provision where necessary of safety, hard hats, water proof clothing, etc. for personnel including the Engineer/Engineer representative's and his Assistants.

f. Provision of lighting and exhaust fans to provide adequate illumination and ventilation of the Works, including spares and standby equipment.

g. Provision of notices, 1.5 m by 1.0 m in size, written in bold letters, to be erected on existing tracks and at points of access likely to be used by the public to warn them of the existence of the Works specially when blasting is being carried out at the portals and in any open area. These notices shall be in addition to any statutory requirements demanded from the Contractor.

h. Copies of approved safety and emergency regulations by the Engineer/Engineer representative, shall be reproduced by the Contractor and distributed to all of his employees and staff and to the Engineer/Engineer's representative and his Assistants. Notices shall be displayed at portals detailing emergency and rescue procedures.

i. Smoking, Fire Hazard (Naked Lights)

j. Smoking shall be prohibited in the tunnel and the Contractor shall ensure that materials for smoking including lighters and matches are not taken underground by any person. If required by the Engineer/Engineer representative the Contractor shall make arrangements to search all persons entering underground excavations.

k. Welding and other processes which involve naked flames, sparking etc. shall not be carried out in the tunnels without the written authority of the Engineer/Engineer representative.

l. Combustible Materials and Flammable Liquids

m. In the confined area of a tunnel, the quantities of combustible material (timber, paper, etc.) and flammable liquids (oils, paraffin, acetylene and other compressed gases) shall be kept to the minimum and consistent with construction and safety requirements. Any materials not required within a reasonable period ahead, generally the working shift, shall be removed to a surface storage area, except for such items as emergency timber lagging.

n. Combustible materials shall not be stored in the vicinity of any tunnel portal.

o. Underground Ventilation

All underground excavation works shall be properly and adequately ventilated by positive artificial means of ventilation system of pipes and booster (jet) fans, to keep the working cavities safe for continuous working of the workers and to the satisfaction of the Engineer / Engineer representative.

A minimum of 200 cubic feet (5.7 m^3) of fresh air per minute shall be supplied for each employee underground.

Once installed, confirmation that the system is adequate and aerodynamically efficient, must be demonstrated and get approved from the Engineer/Engineer representative.

The direction of mechanical air flow shall be reversible.

Following blasting, ventilation systems shall exhaust the explosive gases, smoke and fumes to the outside atmosphere before work is resumed in affected areas.

Minimum requirements of purity of air, dust control & volume of air shall be in accordance with ***BS 6164:2011*** - *Code of practice for health and safety in tunnelling in the construction industry*; *US Safety and Health Regulations for Underground Construction,* ***Standard Number: 1926.800*** and *Norwegian Tunnelling Society* ***Publication No. 24***, or latest.

The Contractor shall assign a competent person who shall perform all air quality and monitoring activities during the underground works.

Personal respiratory protection, clothing and equipment shall be readily available to all workers of underground works, where it may be required and the workers should be trained in the care and use of equipment appropriate to the work being performed.

In the event of the breakdown of the ventilation system, work shall cease and all men shall be withdrawn from the tunnel if the system is not restored to full operation within 20 minutes of breakdown, or such other period as the Engineer/Engineer representative may determine. No relaxation of the requirements for ventilation will be made other than in exceptional circumstances.

The linear velocity of air flow in the tunnel bore, in shafts, and in all other underground work areas shall be at least 9.15 m per minute where blasting or rock drilling is conducted, or where other conditions likely to produce dust, fumes, mists, vapors, or gases in harmful or explosive quantities are present.

No part of any ventilation system shall be dismantled without the authority of the Engineer/Engineer representative. In particular the ventilation system shall not be dismantled in any section of tunnel situated between two openings to atmosphere until it has been determined that the natural ventilation is satisfactory. Natural ventilation in such a section shall be considered satisfactory if the direction of flow remains constant and is not subject to temporary reversal due to changes in external atmospheric conditions.

The atmosphere in all underground work areas shall be tested quantitatively for carbon monoxide, nitrogen dioxide, hydrogen sulfide, and other toxic gases, dusts, vapors, mists, and fumes as often as necessary to ensure that the permissible exposure limits are not exceeded as specified herein below.

The amount of air supplied to each tunnel face or shaft bottom shall be sufficient to render the concentrations of noxious fumes harmless (having regard both to the concentration and time of exposure) and to prevent the accumulation of dangerous dust or toxic gases and in any case shall not be less than 10 m³/min per man plus 3 m³/min for each horsepower of diesel engine plant working in the heading. Toxic gases shall not exceed the levels shown below at any time when workers are in the tunnels or as directed otherwise by the Engineer/Engineer representative.:

Toxic gases	**Limits**
CO	25 ppm
CO_2	5000 ppm
SO_2	2 ppm
NO_2	2 ppm
NO	25 ppm

The Contractor shall also monitor any presence of hydrogen sulphide (H_2S) and flammable gases such as methane (CH_4) and carbon monoxide (CO) in order to prevent an unexpected accident. The Contractor shall measure the concentration of hydrogen sulphide in locations within 150 mm of the invert of the underground excavation during underground excavation. The Contractor shall monitor the concentration of flammable gases within 300 mm of the crown of the underground excavation.

An electronic gas detector approved by the Engineer/Engineer representative shall be maintained by the Contractor at each tunnel face or shaft bottom at all times. It shall be certified and calibrated by an approved testing laboratory and shall provide an alarm when the oxygen content falls below 18% and when the content of methane rises to 20% of the LEL (Lower Explosive Limit) of methane. The total length of the tunnels shall be monitored for methane layers at least once per shift.

The monitoring/measuring records shall be submitted to the Engineer/Engineer representative on a daily basis.

Petrol driven machinery or equipment and all stationery internal combustion engines shall not be used in underground workings. No petrol driven vehicle shall be allowed underground except when an emergency necessitates one, such as need for an ambulance.

No separate payment will be made for the cost for underground ventilation and monitoring of gases. All costs thereof shall be deemed to be included in the various items of excavation in the Bill of Quantities of Diversion Tunnel.

p. Underground Electrical Installations

All electrical supply and distribution equipment shall comply with recommendations of BS 6164 section 7, Clause 25 and the IEC (International Electrotechnical Commission) Standards.

All the Electrical machines & plant use shall have protection against short circuit, open circuit and overload protection of machine and human being.

Lighting system shall be operated at 110 volts where practicable during construction of Tunnel. The lighting circuit shall be separated from other sub-circuits and provided with protection switch gear.

In order that the electric detonators shall not be exploded prematurely, electric wiring shall be removed for a distance of not less than 20 m whenever the charges are being prepared. Lighting fittings should be of the waterproof, dustproof and flameproof type if the conditions warrant it.

House electrical distribution panels, junction boxes in suitable sealed cabinets with grommet entry and outlet glands. Provide sealed electrical cabinets with automatic chemical-spray fire extinguishing units discharging automatically at 68˚C. The panel shall be Earthed.

Provide and maintain suitable Detachable Hand-Held Search light suitable for 1000 meters operating range at each working face for emergencies and inspection of the work. Electrical heaters or radiators having exposed coils or element shall not be permitted underground.

Adequate safety precautions in regard to electrical equipment and wiring installation and maintenance during underground excavation, mucking & dewatering operations shall be taken as specified here in these specifications.

- The Contractor shall ensure that an employee working underground does not engage in the electrical wiring, apparatus, and equipment installation activities unless the employee is a licensed electrician, or the employee is working with, or under the supervision of, a licensed electrician.

- The Contractor shall ensure that all live parts of electrical equipment operating at 110 volts or more are properly guarded against accidental contact.

- The Contractor shall limit access to energized electrical equipment such as, but not limited to switch gear, transformers, and service panels, to qualified employees.

- The Contractor shall ensure that a bare conductor or earth return is not used for any temporary circuit.

- The Contractor shall provide barriers or other means to ensure that the work space for electrical equipment is not used as a passageway during periods when energized parts of electrical equipment are exposed.

- All electrical power circuits that supply to portable or hand-held tools, lights, or equipment shall be protected by approved ground-fault interrupters.

- Each employee working underground shall have an acceptable portable hand lamp or cap lamp in his work area for emergency use, unless natural light or an emergency lighting system provides adequate illumination for escape.

- Only acceptable portable lighting equipment shall be used within 20 m of any underground heading during explosives handling.

- Electric lines crossing work areas, employee foot or vehicular traffic aisles, shall be fastened overhead or protected by a cover capable of withstanding the imposed loads without creating a tripping hazard.

- BS 7430 or latest shall be followed as “code of practice for earthing”.

q. Electrical Cables:

All exposed electrical cables installed within the tunnel shall comply with BS 6387 Cable “Fire Retardant Low Smoke (FRLS) Type CWX or equivalent”.

Supply cables at 3.3 KV or below shall be of 3-core with the armoring used as Earth return, in conditions, where the cables are not subject to continuous movement after installation or where the supply is to a fixed point(s).
For supply to mobile or transportable equipment where operation of the equipment subjects the cable to flexure, cables shall be with outer sheath of flame retardant “Low Smoke Free of Halogen” (LSFH) insulation.

r. Site Illumination

The Contractor shall install, operate, and maintain a lighting system in the underground works during construction. A minimum average illumination level of average 100 Lux shall be provided during drilling, mucking & sealing. When mucking is done by tipping wagons, running or trolley tracks, a minimum average of 50 Lux shall be provided for efficient & safe working.

The Contractor shall provide at least 60 W of electric lighting every 10 m, or its equivalent, in all tunnels, shafts and chambers and shall take all necessary precautions by suitable insulation and protection to prevent the danger of electrocution and accidental detonation of charges

Each working face shall be brightly illuminated by one or more additional high intensity movable lamps. Emergency lighting equipment shall be placed within 100 m of the Tunnel face.

Blue LED lights at specific intervals shall be installed to allows construction drivers to more easily gauge distance from tunnel walls and vehicles in front and to maintain safe driving distances.

Suitable high-intensity movable lamps shall be provided by the Contractor to illuminate any area in the underground works where testing or other inspection is carried out. The Contractor shall install a plug point (socket) at every 50 m along the tunnels to facilitate lighting for the surveying and monitoring work.

Burnt-out Compact Fluorescent Lamp (CFL) or any other energy efficient luminaries used shall be replaced every shift.

All lighting luminaries shall be weather-proof and confirming to the relevant 'IP' (Industrial Proof) standards.

A temporary light shall be equipped with a guard to prevent accidental contact with the bulb, except that a guard is not required when the bulb is fully recessed in the reflector.

A temporary light shall not be suspended by the electric cord unless the cord and light are designed for suspension.

Upon completion of the work, all temporary lighting systems shall be removed including the power supply source.

s. Circuit protection.

Circuit protection shall be provided by fuses or circuit breakers for each feeder and branch circuit and shall be based on the current carrying capacity of the conductors and power load.
A fuse puller shall be used to install or remove a cartridge fuse when 1 or more terminals are energized.
A circuit protection device shall not be placed in a grounded circuit except where the device simultaneously opens both the ground and energized circuit.

t. **Inspection and repair of electrical equipment.**

The Contractor shall ensure that Electrical equipment are inspected periodically. The inspection shall be made at reasonable intervals according to the equipment use and the severity of conditions under which it is used, or as agreed by the Engineer / Engineer representative otherwise.

Worn and frayed cable shall not be used.

Repairs of electrical equipment shall be made by a licensed electrician or an employee supervised by a licensed electrician.

u. **Welding, cutting, and other hot work:**

The Contractor shall ensure that burning and welding works are performed at the surface whenever possible.

Open flames and fires shall be prohibited in all underground construction operations except as permitted for welding, cutting and other hot work operations in compliance with above mentioned Occupational Safety and Health Regulations.

Welders, equipment, and electrodes shall comply with the requirement of AWS D1.1. ARC Welding Transformer shall be provided with proper Earth protection.

No more than the amount of fuel gas and oxygen cylinders necessary to perform welding, cutting, or other hot work during the next 24-hour period shall be permitted underground.

Noncombustible barriers shall be installed below welding, cutting, or other hot work being done underground.

W. Standby Generators

The Contractor shall provide 100% standby diesel-driven generators adequate to power all pumping, ventilating and lighting plant in the tunnel for use in the event of any breakdown in the normal system of supply of power.

The generators or alternative supply shall be capable of simultaneously operating the lighting system and the pumps required to prevent flooding of the underground works besides operating other utilities requiring electrical power so as to allow the work function smoothly. It shall have suitable Automatic Mains Failure (AMF) panel. Standby DG sets shall be tested and run without load weekly for 10 to 15 minutes to ensure that they are in good working order and ready for use in case of emergency.

X. Communications

Telephone or Wireless Communication System, as approved by the Engineer/Engineer representative, shall be provided by the Contractor in all areas of the underground works where work is in progress and they shall be connected to all above ground facilities as well as to the Engineer/Engineer representative's site communication system.

When natural unassisted voice communication is ineffective, a power-assisted means of voice communication shall be used to provide communication between the tunnel work face, the bottom of the shaft, and the surface.

Powered communication systems shall operate on an independent power supply, and shall be installed so that the use of or disruption of any one phone or signal location will not disrupt the operation of the system from any other location.

Communication systems shall be tested upon initial entry of each shift to the underground, and as often as necessary at later times, to ensure that they are in working order.

A sound or visual system of communication using bells or lights shall also be devised and used as a backup system in case of Communication System failure or in an emergency.

Fire Alarm, Extinguishers, Smoke Control

Facilities for raising an alarm, either by manual or automatic means, and responding to a fire to safeguard all areas of tunnel and workers shall be approved by the Engineer/Engineer representative prior to installation.

Portable fire extinguisher types shall be to fire ratings of BS EN 3 Part – 1, either dry-powder, stored pressure type with a pressure gauge and colored red with a blue label, or AFFF (Aqueous Film Forming Foam) electrically tested, complete with CO_2 charge container and colored off-white for ease of identification.

Hose reel (for fire brigade), in maximum sectional lengths of 30m of 19mm internal diameter hose, (assuming that emergency points are located at 50m centers) shall be made available, to extinguish non-electrical fires.

Lifting Equipment

All chains, ropes and slings shall be tested and marked with their safe working load.

Persons transported by hoists or cranes shall only ride in special cages or modified skips which gives protection to the occupants against impact or falling objects.

PS-4.4 MEASUREMENT AND PAYMENT

PS-4.4.1 MEASUREMENT

The estimated quantities for each excavation class given in the priced bill of quantities are to be considered as estimation of the quantity of work only, since the predicted and the actual length of each excavation class may differ due to geological conditions encountered in the course of the works. The Contractor shall not be entitled to any extra payment over and above the unit prices entered in the priced bill of quantities by reason of changes to the actual quantities of the various excavation classes except in the case of an extraordinary geological occurrence (EGO) or in the case of large deviations in the total quantities for rock excavation as per the Conditions of Contract.

1. The definitions of the excavation classes are only relevant for the measurement and payment of the excavation work. The rock supports will be measured and paid separately.

2. The quantity for underground excavation in tunnel, shaft and niches (if any) shall be in cubic meter of in-situ rock, for each rock class, excavated within **B-Line** (Payment line) and accepted with all its additional requirements, irrespective of whether the actual excavation falls within / beyond the said line.

3. The actual length of tunnel and shaft excavated shall be measured as linear metres (m) obtained by the length measured along the design centreline of the tunnel and shaft. At the point of intersection between a tunnel and a shaft, the length of the shaft will be measured to the point where the design centre line of the shaft intersects with the "excavation pay line" of the tunnel. The excavated volume shall be calculated by multiplying the theoretical cross-sectional area defined by the excavation pay-line and the length of excavation.

   Measurement will be done for subdivisions of excavation cross sections as shown on the drawings. In case a temporary invert is required for top heading the measurements for bench excavation will be reduced accordingly.

4. Within the specified distance of 300 mm between **B-Line** (Payment Line) and **C-Line** (Boundary Surface), no separate remuneration for unavoidable overbreak will be made.

5. For the portion of the unavoidable overbreak, (excessive overbreak due to unfavorable geological conditions) that exceeds / beyond **C-Line** (Boundary Surface), and as agreed by the Engineer / Engineer representative, will be

measured in-situ by actual quantities, provided the volume of the overbreak exceeds **2.0 m³** in volume in each case.

6. Over breaks less than **2.0 m³** will not be measured for payment.

7. No separate payment will be made for over-excavation & backfilling work at the invert.

8. The Contractor shall have no right to claim for additional payment, due to increment of excavation & backfilling quantities, for correcting errors of setting-out sustained from his fault.

9. If for any reason, other than accepted geological reasons, excavation is carried out beyond the **C-Line** (**Overbreak – Line**) by Contractor's careless blasting etc., the Contractor shall at his own cost remove the excess material and backfill the void to the satisfaction of Engineer / Engineer representative.

10. Additional costs for tunnel excavation due to water inflow exceeding 300 liter/min per 100-meter length of tunnel for a period of 24 hours, in upward and downward drives shall be compensated for by separate items as shown in the bill of quantities, independent of the encountered rock class. In upward tunnel drives, the measurement of the water inflow shall be carried out 25 m behind the tunnel face. In downward tunnel drives, measurement shall be performed for the water inflow occurring within the last 5 m behind the tunnel face.

11. The costs of temporary water control for quantities up to 300 liter/min per 100-meter length of tunnel for a period of 24 hours, including adequate drainage, diversion and disposal of water during excavation works is the responsibility of the Contractor and will not be measured for payment and shall be included in the unit rates for underground excavation.

12. Water used for drilling, flushing, grouting or other works will not be measured for payment.

13. No separate remuneration shall be paid for the demolition of shotcrete linings at the tunnel face at portal slopes. These costs shall be included in the unit rates for underground excavation.

14. No separate remuneration shall be paid for the removal of temporary support installed at the tunnel face or at the top heading invert. These costs shall be included in the unit rates for underground excavation.

15. No separate remuneration shall be paid for geological mapping during tunnel excavation. These costs shall be included in the unit rates for underground excavation.

16. Where forepoling is required no separate remuneration for the additional excavation will be made, i.e., the additional excavation shall be included in the excavation costs. All costs for drilling the holes for and grouting of the rock bolts, spiling (steel bars forepoling) and canopy tubes (pipe umbrella method) shall be deemed to include in the unit rates for underground excavation.

17. No separate compensation for the provisions for the start of tunnel excavation from the pre-cut is envisaged. The quoted rate for underground excavation shall include all costs required for the construction of the canopy structure (false portal).

18. No separate remuneration shall be paid for pulverizing the surface and underground excavated materials with hydraulic breaker / jackhammers, including loading, unloading, hauling and disposal of all excavated materials to a

temporary disposal site as approved by the Engineer/Engineer representative or to a permanent disposal area or to an embankment site etc., and all pulverization, transportation and disposal costs shall be deemed to include in the unit price for underground excavation.

19. Construction and maintenance of temporary services such as adequate roadways, drainage including all pumping as necessary, all pipes, cables, ventilation, illumination, lightning protection, earthing and fire protection, communication systems etc., are the Contractor’s responsibility and will not be measured for payment.

20. All work involved with and any partial or short interruptions or inconveniences caused by the check surveys, installation of 3D Monitoring Targets, instruments and performance of monitoring, performance of the rock mechanics tests and geological mapping, will not be measured for payment and shall be deemed to include in the unit price for underground excavation.

21. The Contractor shall supply & install geotechnical instruments like extensometer and piezometer including the convergency bolts in the tunnel walls, the settlement markers at portals & crown and taking of readings at intervals, as directed by the Engineer/Engineer representative or as mentioned in the drawings.

    The Contractor shall also provide all auxiliary works and equipment required for geotechnical monitoring, e.g., staff for assistance in installation of the instruments, drilling of boreholes, grouting, mortars and other accessories, lighting, lifting equipment, as well as the installation of the convergency bolts as instructed by the Engineer/Engineer representative, etc.

    All these geotechnical instruments supply, installation, testing, recording, monitoring, maintenance and related auxiliary works will not be reimbursed separately and the costs for these items shall be deemed to include in the unit price for underground excavation.

22. The unit prices for underground excavation shall include mobilization of all necessary equipment, operation and maintenance during the works and demobilization at the end.

23. The unit prices for underground excavation shall include maintenance of tunnel and allied facilities including de-silting of tunnel after each and every flood passage till completion of the project.

PS-4.4.2 PAYMENT

1. The quantities determined as provided above shall be paid for at the contract unit rates respectively for each of the particular pay items shown in the bill of quantities, which price and payment shall be full compensation for all the costs of labor, supervisors, materials, the Contractor’s equipment, material testings including but not limited to

    a) drilling for pilot holes and holes for blasting; developing and improving controlled blasting methods, blasting tests and performance of blasting;

    b) cleaning, washing, protection, and maintaining excavated surfaces in satisfactory conditions, and protection of tunnel invert until the concrete lining is placed;

    c) all enlargements and additional excavations required by the Contractor for his construction methods, auxiliary facilities, removal of temporary rock support (e.g., temporary shotcrete invert, face bolts), necessary changes of excavation equipment;

d) provision of necessary equipment for rock breaking into smaller pieces, loading, unloading, hauling of the excavated materials and disposal of all excavated material from the excavation face to a temporary stockpile or to permanent disposal area, or points of incorporation into the permanent Works;

e) clearing, formation and maintenance of the disposal areas and the stockpile areas, dumping and spreading the material, fill slope trimming and protection/stabilization of the disposal embankment;

f) all cost and hindrances due to seepage water inflow, rock mechanics testing, geotechnical measurements, water pressure testing, geological mapping and hindrances due to installation of support elements, ventilation, lighting and communication system;

g) all OHSE precautionary measures and measurement of dust, silica, and noxious and flammable gases during excavation;

h) all QA / QC sampling / testing / documentation etc. and all other work necessary for the proper completion of the work prescribed in these specifications.

2. The unit excavation prices will be certified for payment when the particular quantity has been excavated and dumped at spoil areas or stockpiled temporarily for future use, all as approved by the Engineer / Engineer representative.

3. Payment shall be made for excavation within the payment line. No payment shall be made for overbreak which in the opinion of the Engineer/Engineer representative is considered as avoidable.

4. Reimbursement for excavation will exclusively be based on the rock class as determined for the top heading. For bench and invert the same unit rates per cubic meter as for the top heading shall apply. Support measures shall not be criterion for excavation reimbursement.

CHAPTER -5

RE-DRILLING AND GROUTING IN TUNNEL AND UNDERGROUND STRUCTURES

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SECTION PS–5 PRE-DRILLING AND GROUTING IN TUNNEL AND UNDERGROUND STRUCTURES

PS 5.1 DESCRIPTION

The work shall consist of drilling through concrete or rock, washing and pressure testing grout holes and supplying, transporting, mixing and injecting grout materials, supply and installation of grouting pipes, headers, risers, and grout outlets, core drilling and water pressure testing of test holes, and all other work as specified in these Specifications.

The work to be done under these specifications shall include all labour, materials and equipment necessary to complete the job to the full extent of the specifications, drawings and /or Engineer/Engineer representative’s satisfaction.

All drilling and grouting equipment and work shall be to the approval of the Engineer/Engineer representative. The quantities, patterns, inclinations, spacing, types and depths of drill holes and the grouting requirements shown on the Drawings are tentative and are subject to alteration or omission as a result of conditions encountered during the progress of the works.

The work shall also include probing ahead of the tunnel face with 20 to 30 m long pre-drillings, for dewatering and ground investigation purposes, as indicated in the "Tunnel Geological and Geotechnical Report" and /or as directed by the Engineer/Engineer representative. The probing shall be repeated and overlapped so that at no time a single probe is less than 10 m ahead of the tunnel face.

The number of probes and their positions and angles shall be governed by the type of ground and available site investigation data. Radial probes may also prove necessary.

PS 5.2 SUBMISSIONS

a) All probing details, including the number of probes, their positions and angles, as governed by the type of ground and available site investigation data, shall be approved or instructed by the Engineer/Engineer representative.

b) At locations where excessive ground water flow is expected to occurs, pre-drilling ahead of the tunnel face in order to reduce the water pressure at the tunnel face may be recommended subject to the approval of the Engineer/Engineer representative.

c) In case unexpected conditions are met during tunnel drivage, such as confined ground water, suspicious colour or smell of the water, floor heave, cavities or gas the conditions ahead of the face shall be observed carefully and documented properly. The Engineer/Engineer representative has to be informed immediately.

d) The potential for groundwater inflows into hard rock tunnel excavations
and the nature of impact upon both the tunnel construction and the surrounding area must be sufficiently investigated and documented before an effective

grouting program can be developed in consultation with the Engineer/Engineer representative.

Data regarding Inflow into underground openings as determined by the permeability/transmissibility of the rock mass, the groundwater pressure (groundwater table) and the size of the underground opening etc. shall be submitted to the Engineer/Engineer representative for his review on daily basis or as directed otherwise.

e) The Contractor shall be responsible for the validity of the information gained by pre-drilling, especially regarding additional costs owing to inadequate and inaccurate information gained by pre-drilling.

PS 5.3 CONSTRUCTION REQUIREMENTS

PS 5.3.1 USE OF SPECIALIST CONTRACTOR FOR DRILLING AND GROUTING

The Contractor shall employ a specialist grouting Engineering firm that will provide State-of the-Art Level 3 real-time Integrated Systems Technology for controlling, monitoring and evaluation of rock grouting. The system shall incorporate the use of Advanced Integrated Analytical (AIA) Systems.

The Contractor shall provide:

a) Qualifications and experience of the firm and individuals who will establish the drilling and grouting and monitoring and evaluation system on the project.

b) Description of equipment and procedures.

The specialist Subcontractor shall be subject to the approval of the Engineer/Engineer representative, The Contractor shall be entirely responsible for the workmanship and proper execution of drilling and grouting work to be carried out by the specialist subcontractor.

PS 5.3.2 CONTROL, MONITORING AND EVALUATION OF GROUTING OPERATIONS

State of the Art Level 3 Real-time Integrated Systems Technology Fully Automated Computer controlled and monitored systems shall be used for all drilling and grouting operations.

The computer-based system should have the following input and output and product capabilities among others or as approved by the Engineer/Engineer representative:

- Input of Project parameters, refusal criteria etc.
- Input of geological structure data including units and orientations
- Definition of grout pattern or hole locations and orientations
- Input of hole parameters including hole identification, station, elevation, inclination, drilling method, groundwater level etc.

- Distribution of grout holes according to any desired criteria as to length, depth, penetration into a geologic unit, spacing and inclination
- Identification and definition of stages
- Generation of profiles displaying ground surface and geologic structure
- Display of proposed holes and time stamping and display of completed holes with grouting information.
- Display of water pressure test data including Lugeon values and colour coding of stages by lugeon values
- Calculation and use of calibration and correction factors including head loss curves for water and multiple grout mixes
- Graphical stage records showing mix changes
- Alarms at reach of refusal
- Automatically generated closure plots with user-defined limits
- Display in real time and printing of permanent records of grouting data for each hole including gauge pressure, effective pressure, flow rate, grout mix, apparent Lugeon value etc.
- CADD display of data and CADD layering of enabling any desired combination of information to be generated and displayed.

To ensure that proper proportions of each ingredient for each planned grout mix is used and continue to accurately measured, all equipment must be calibrated at the outset of the work and periodically every 6 months, or as directed by the Engineer/Engineer representative, thereafter.

The monitoring and interpretation of the data generated by the computer control and monitoring system shall be the responsibility of an experienced grouting Engineer/Engineer representative supported by experienced geologists and other staff.

PS 5.3.3 REFERENCE STANDARDS

The following list of the American Society for Testing and Materials (ASTM) or equivalent should be followed during the execution of works. Drilling methods recommended by internationally recognized institutions, such as International Society for Rock Mechanics (ISRM), Bureau of Reclamations Earth Manual, Part I, Third Edition, Chapter 2 (BOR, 1998), the Australian Drilling Manual (ADI, 1992), and the National Drill Association Drilling Manual (NDI, 1990) shall also be used.

Table 5.1: Reference Standards

ASTM C33	Specification for Concrete Aggregates
ASTM C109	Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2 in. or 50 mm Cube Specimens)
ASTM C136, D6913, D7928	Filler Grain size distribution
ASTM C150	Standard Specification for Portland Cement
	Time of setting

ASTM C566	Sand Moisture content
ASTM C618	Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
ASTM C940-16	Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory
ASTM C1240-15	Standard Specification for Silica Fume Used in Cementitious Mixtures
ASTM C1602	Mixing Water Used in Production of Hydraulic Cement Concrete
ASTM D 2113-08	Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation
ASTM D4220	Standard Practice for Preserving and Transporting Soil Samples
ASTM D4016	Viscosity
ASTM D4380	Density, specific gravity
D6286	Standard Guide for Selection of Drilling and Direct Push Methods for Geotechnical and Environmental Subsurface Site Characterization.

PS 5.3.4 CONTRACTOR's DUTIES AND RESPONSIBILITIES

a) The work shall be executed strictly in accordance with the drawings and the specification contained herein.

b) The Contractor shall have available at the Project area the necessary plant, labour, equipment and materials for drilling and grouting, all in accordance with these specifications, as shown on the drawings or as directed by the Engineer/Engineer representative.

c) Drilling with and without core recovery will be required in the Tunnel excavations for exploration, rock testing, grouting, drainage, and rock stabilization prior to or after excavation, where the Engineer/Engineer representative may direct.

d) The Contractor shall drill exploratory holes ahead of the face or elsewhere, as directed or approved by the Engineer/Engineer representative. Coring of an exploratory hole, partly or totally, may be requested. Grouting ahead of the face may also be called for.

e) The Contractor shall conduct water pressure testing in drill holes as and where directed by the Engineer/Engineer representative.

f) Testing equipment for the measurement of stress and strain in the rock or other rock characteristics may be installed by the Engineer/Engineer representative in drill holes or elsewhere in the tunnel works. The Contractor shall assist the Engineer/Engineer representative in such work.

Upon the requirement for the prevailing geological conditions in underground excavation, the Contractor shall establish a general procedure for rock mass grouting and submit for approval to the Engineer/Engineer representative. The approach hereby should consider all necessary aspects of a successful grouting works, which may include:

a) Cavity grouting, at pressures up to 3 MPa, to fill voids between concrete lining and concrete in the tunnel plug, or between concrete placements in tunnel plugs after the concrete has cooled;

b) Curtain grouting, at pressures up to 10 MPa, of the rock surrounding the concrete at the tunnel plug, which shall commence after completion of cavity grouting;

c) Consolidation grouting in the heading zone, at pressures up to 10 MPa, in zones of sheared and disturbed material or of high water inflow;

d) Contact grouting in tunnel lining, at pressure up to 1 MPa; Contact grouting is done to fill the cavities/voids between concrete and rock mass on account of shrinkage of concrete and uneven overbreak's.

e) Compaction grouting of large in-filled voids in rock.

f) Final grouting of temporary drainage holes.

g) The actual number of drill holes, diameter, inclination, depth, location, as well as the composition and consistency of the grout mixes, grouting pressures, pumping rates and sequence in which the holes are to be drilled and grouted shall be adapted to the conditions, as determined by the Engineer/Engineer representative.

h) All equipment and materials to be used shall be approved by the Engineer/Engineer representative before starting the drilling and grouting work.

i) Geological logging will be performed by the Contractor and supervised by the Engineer/Engineer representative. The Contractor shall prepare cores for core logging, in particular with handling of core boxes and cleaning of cores.

PS 5.3.4.1 SUBMITTALS AND APPROVALS

1. At least twenty eight (28) days prior to the scheduled date of commencement, the Contractor shall submit to the Engineer/Engineer representative for his approval a detailed method statement and program for drilling, water testing, and grouting operations, showing proposed methods of access, the sequence of works, the proposed equipment, provisional program for grout mix design for each specific work and results of the trial mixes for grout, the maximum grouting pressure, the rate at which the grout is injected, the pressure application (continuously or by stages), the composition of the grouts for each specific work, manufacturer's test certificates for all materials to be used for grouting and Quality Assurance Manual detailing the measures proposed to ensure the specified quality, including control and tests.

2. The method of execution for grouting shall be defined by preliminary in situ tests, which shall be carried out under the continuous supervision of the Engineer/Engineer representative.

3. Exploratory drilling records, logs, photographs etc. as described herein these Specification including instrument installation shall be submitted to the Engineer/Engineer representative within forty eight (48) hours of the completion of such holes.

4. Water pressure test records as described herein shall be submitted to the Engineer/Engineer representative within twenty four (24) hours of completing such

tests.

5. Records of grout tests described herein shall be submitted to the Engineer/Engineer representative with twenty four (24) hours of testing.

PS 5.3.4.2 EXPLORATORY DRILLING LOG

The Contractor shall submit a technical log of the exploratory drill hole in a form approved by the Engineer/Engineer representative. The log shall, where applicable, include the following data (items marked with [C] to indicate core drilling, [P] to indicate percussion drilling):

a) Date and the time of beginning and end of drilling as well as the driller's name. [C,P]

b) Drill hole number. [C,P]

c) Location, coordinates, top and bottom elevation, inclination, direction and length of drill hole. [C,P]

d) Type and diameter of drilling bit or core barrel, make of drill rig and length and diameter of casing. [C,P]

e) Elevation of groundwater level, including date and time of measurement when available. [C,P]

f) Results of permeability tests and other drill hole tests. [C,P]

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. [C]

h) Length of each core run and the length, percentage or both of core recovered along with location and cause of core loss. [C]

i) Any changes in the character of the drilling water or mud, and in case of drilling water loss, the elevation or depth where this happened. [C,P]

j) The driller's interpretation and description of the nature of the formation(s) encountered in the drilling. [C]

k) Location and nature of cavities, seams, cracks, whether filled or open, soft or fractured rock and any other relevant information in connection with the purpose of the exploratory drilling. [C]

l) The use of additives to drilling water is subject to approval, and the Contractor shall submit notification and information on the chemical composition as well as a sample of such additive to the Engineer/Engineer representative at least 14 days prior to the proposed use.

PS 5.3.4.3 DRILLING EQUIPMENT

1. All drilling equipment shall be subject to Engineer/Engineer representative approval. It must be suitable for operation in open-air as well as in underground works, in any direction.
2. Rotary or percussion wet drilling equipment may be required, and only electric, or air-

driven tools will be accepted for works to be executed, underground and in galleries. Diesel or gasoline driven machines or equipment may be used only for open-air operation.

3. When coring is not required, Down the Hole (DTH) or roto-speed percussion wet drilling equipment can be used provided that the hole is smooth enough to allow the water tightness of the packer used for water test. All DTH equipment shall be of the Reverse Circulation (RC) type or preferably Water DTH hammers (WH). All drilling equipment shall use continuous water circulation to flush out drill cuttings. Use of dry drilling machines or dry drilling followed by water flushing is not permitted. Drilling equipment and methods shall be such as to minimize oversizing or caving-in of drill holes.

4. The Contractor shall have available at the Project Site both rotary and percussion drilling equipment. The diameter of drill holes for grouting, exploration, drainage and rock bolting shall be 46 to 165 mm, with the finally selected diameter as determined by the Engineer/Engineer representative in each case.

5. The Contractor shall provide sufficient water pump capacity and compressed air storage to ensure a continuous supply of water and air to all drilling and grouting operations at all times. The equipment shall be capable of maintaining a pressure in the water and air pressure supply lines.

6. Drilling equipment for grouting, rock bolting, spiling, canopy tubes, drainage and exploration shall be able to drill at any angle, upward or downward and to perform:

   a) exploratory hole (upto 100 mm core barrel) up to a length of 100 m;

   b) pilot holes (38-76 mm) up to a length of 100 m;

   c) holes (46-51 mm) for curtain grouting and consolidation grouting up to a length of 100 m;

   d) holes (152-165 mm) for 115mm OD canopy tube grouting up to a length of 15 m;

   e) holes for the installation of rock bolts, dowels and spiling/ forepoling; and

   f) drain holes (50-76 mm) up to 30 m long.

7. **EQUIPMENT FOR WATER PRESSURE TESTING:**

   a) Special emphasis shall be given to the control devices for pressure and volume of water pressure tests.

   b) Pressures and flow rates during pressure testing shall be monitored with electronic systems.

   c) The pressure applied shall be measured at the borehole head and transmitted to appropriate automatic recording instruments.

   d) Synchronized operation of pressure and discharge recorders must be ensured. For regular checking of pressure at the pumps, these shall be fitted with additional pressure gauge having an accuracy of 0.1MPa (1bar).

   e) All pressure gauge used shall permit accurate reading to within 0.1MPa (1bar) of the true value; gauge divisions and the top of the scale shall be adjusted to suit the applied pressure. Pressure and discharge recorders shall be of a type approved by the Engineer/Engineer representative and shall be checked against calibrated gauges at intervals as requested by the Engineer/Engineer representative.

f) The Contractor shall provide one complete set of pressure testing equipment per heading (with spares) to allow simultaneous testing at the various drilling and/or grouting locations.

g) Progressive cavity or helical rotor pumps shall be used for water pressure testing unless otherwise approved by the Engineer/Engineer representative.

h) Unless otherwise approved or directed, the pumps shall have a capacity of 300 litres per second at a pressure of 6000 kPa at the top of the hole. The pumping system shall be capable of maintaining any desired pressure without fluctuation and the pressure and discharge must be continuously adjustable.

i) Water pressure shall be measured by means of a pressure gauge with an accuracy of 0.5 bar and a range of 100 bar. The water meter shall be able to measure the discharge volume with an accuracy of 1 litre. Water meters as well as all pipes, hoses and couplings shall be designed to resist a pressure of 150 bar.

j) Water meters and pressure gauges shall be calibrated and certified by an independent laboratory prior to installation at the Project 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/Engineer representative for further checking purposes. Pressure gauges shall be installed close to the collar of the drill hole.

k) Packers shall consist of mechanically expanded rings or pneumatically expanded sleeves of rubber or other suitable material, which can be set tightly in a drill hole at any depth required. Packers shall be capable of withstanding pressures of up to 50 MPa without leakage. The Contractor shall keep at the Project Site an adequate supply of packers, of various sizes to suit the various hole diameters.

PS 5.4 EXECUTION OF DRILLING WORKS

PS 5.4.1 GENERAL

1. The starting direction of a hole shall not deviate more than 3 degrees from the specified angle, but, according to certain conditions, certain holes may be needed to be drilled within 2 degrees of the specification, and the location shall be within 0.150 m of that specified, except that the location of holes for rock reinforcement installation shall be within 100mm of that specified.

2. Holes to be specified by the Engineer/Engineer representative shall be sounded to their alignment at 5m intervals with a multi-shot or similar approved instrument if sunk deeper than 30m.

   Holes having a deviation of more than 3° from their intended alignment shall be stopped, filled with grout and re-drilled nearby at the Contractor’s expense. After the last grouted stage, the hole shall be filled with grout at low pressures.

3. Grout holes shall not be smaller than 46 mm diameter or as shown in the drawings or as approved by the Engineer/Engineer representative.

4. The use of rod dope, grease, oil, or other lubricants on drill rods is prohibited. No drilling water additives of any kind shall be used without written permission. The injection of cement grout to stabilize the drill holes shall subject to approval by the Engineer/Engineer representative.

5. All holes shall, immediately after drilling, be thoroughly washed out with water under pressure from the bottom of the hole. Water flushing shall continue until the waste water runs clear and no drill cuttings, rock fragments or other solid materials are found.

6. On completion of drilling and flushing of grout holes the Contractor shall immediately install grout nipples with caps or plug the holes with wooden plugs or steel caps and shall protect them from entry of dirt, muck, grout, surface water or any other material.

7. It may be necessary to install casing in portions of holes drilled for grouting. Any casing that is installed for the purpose of keeping the grout hole open for grouting shall be removed immediately prior to, or simultaneously with, the grouting process. Over lengths of the hole where grouting is required the casing left in place shall be perforated.

8. Unless otherwise directed, all holes drilled through concrete shall be reamed or re-drilled and filled as described herein these specifications under designation "***Closure of Holes and Clean-up***".

PS 5.4.2 DRILLING THROUGH CONCRETE

1. Drilling through concrete may be rotary drilling.

2. Drilling through concrete less than seven (7) days old is not permitted, except if stand pipes have been previously placed into the above considered concrete.

3. Where drilling is to be through reinforced concrete (except in tunnel concrete lining) or adjacent to piping or other embedded parts, then standard mild steel pipes for guides past the embedded parts shall be installed in the forms. The inside diameter of such a "guide sleeve" shall be sized so as to take the largest size bit to be used.

PS 5.4.3 DRILLING FOR CONTACT OR CAVITY GROUTING

a) The Contractor shall drill holes for contact or cavity grouting as shown on the drawings or whereas directed by the Engineer/Engineer representative.

b) The hole may be rotary drilled (46 mm min. diameter) through the concrete or shotcrete lining or through a pipe sleeve embedded in the concrete, and shall be drilled to a minimum depth of 0.3 m into rock.

c) Drilling of holes for contact or cavity grouting in any section of the tunnel structures shall not be started earlier than 28 days after placement of concrete or shotcrete at the particular location, unless otherwise directed by the Engineer/Engineer representative.

PS 5.4.4 DRILLING FOR CURTAIN AND CONSOLIDATION GROUTING

1. The Contractor shall drill the holes for curtain and consolidation grouting as shown on the drawings or where and as directed by the Engineer/Engineer representative.
2. The drill holes shall have a minimum diameter of 46 mm. Drill holes for grouting ahead of the face or the rock surrounding the excavated space, the drill hole lengths will typically be 5 to 40 m, exceptionally up to 50 m.
3. The location, direction and depth of each grout hole for curtain grouting or consolidation grouting shall be as directed by the Engineer/Engineer representative or as shown on the drawings. The order in which the holes are drilled and the manner in which each hole is drilled shall be as directed by the Engineer/Engineer representative.
4. Drilling through concrete less than seven (7) days old shall not be permitted, except if stand pipes have been previously placed into the above considered concrete.
5. In case of complete loss of water during drilling of hole to be injected, the drilling is to be stopped and the section grouted where the loss is observed.
6. Drilling for curtain grout holes or consolidation grout holes shall not commence until seventy two (72) hours after completion of cavity grouting within 10m.
7. In the downstage holes, or instructed by the Engineer/Engineer representative, set grout shall be re-drilled in order to resume next stage grouting. Holes which have been grouted shall not be re-drilled within twelve (12) hours of grouting
8. Holes drilled in soft rock or fractured formations shall be cased with a perforated steel pipe or cemented and re-drilled as required and approved. Where practicable, such casings shall later be removed. Casing shall only be allowed to remain permanently in place where approved by the Engineer/Engineer representative.
9. The drilling of grout curtain holes at the tunnel plug shall be performed through the pipes embedded for such purpose in the tunnel plug concrete.

PS 5.4.5 DRILLING OF DRAINAGE HOLES

1. Drainage holes shall be drilled during excavation or after placing of concrete or shotcrete lining in locations and at inclinations and directions as shown on the Drawing or as determined by the Engineer/Engineer representative. In addition to the drainage purposes, the holes may be equipped with pressure gauges to measure the water pressure.
2. Drainage holes shall be drilled by rotary or rotary-percussion drilling, and shall

have a diameter of 76 mm (NX size) and a length of up to about 30 m as shown on the Drawings or as directed by the Engineer/Engineer representative. Where required, these drill holes shall be cased. Casing shall be with-drawn after installation of drainage pipes.

3. Unless otherwise required, the drilling of drainage holes shall be executed only after all grouting works have been completed at a distance of 50m or a distance directed by the Engineer/Engineer representative where the geological conditions so require. Drain holes shall be drilled not sooner than seven (7) days after completion of all grouting.

4. Drain holes shall be flushed clean with water.

5. Low pressure water shall be circulated through drains in the vicinity of grouting operations to prevent possible grout build up inside the drains. After grouting in the area has been completed, the drains shall be washed clean of all grout. If plugging with grout occurs, the drain hole shall be rejected and a replacement hole drilled as directed.

6. PVC pipes (with or without perforation as needed) and wrapped with geotextile of a nominal internal diameter of 50 mm shall be installed where directed by the Engineer/Engineer representative. The pipes shall be "Schedule 40 PVC" pipes according to ASTM Specification D 1785 or an approved equivalent. Pipes shall be provided with couplings to achieve any required length.

7. The groundwater pressure shall be measured, where and when directed by the Engineer/Engineer representative, using a mechanical packer typically placed at a depth of 1.5 - 2 m in the drill hole and a pressure gauge. The Contractor shall provide pressure gauges, pipes and fittings which will allow the measurement of pressures up to 45 bar with an accuracy of 1.1%. Readings shall be performed at regular intervals until the pressure stabilizes. Pressures shall be recorded as directed by the Engineer/Engineer representative and results shall be made available to him. When pressure measurements are no longer required, the pressure gauges shall be removed.

PS 5.4.6 DRILLING AND PREPARATION OF HOLES FOR ROCK BOLTS, SPILING AND DOWELS

1. The diameter of each hole for rock bolts, spiling dowels shall be as specified herein these specifications for underground excavation works.

2. The length of drill holes shall be such as to receive the specified rock bolts, spiling or dowels and to provide for its satisfactory anchorage.

3. After drilling, each hole it shall be flushed with clean water and cleaned by blowing out all drill cuttings and debris with compressed air. The holes in rock which tends to swelling 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. The holes shall be capped until just prior to installation of rock bots, spiling or dowels.

4. If a rock bolt is not installed immediately after drilling the hole, and the hole has been left uncapped, the hole shall be washed and cleaned as stipulated above immediately prior to installing the rock bolt.

PS 5.4.7 DRILLING AND PREPARATION OF HOLES FOR CANOPY TUBES

1. The diameter of each hole for canopy tubes shall be up to 1.5 times the size of the canopy tube.
2. The length of the hole shall be such as to receive the instructed length of canopy tube.
3. After drilling, each hole in compact, washable rock shall be flushed with clean water and cleaned by blowing out all drill cuttings and debris with compressed air. The holes in rock which tends to swelling 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.
4. Holes drilled in unstable ground with a tendency to unravel or collapse shall be temporarily cased.
5. After drilling of each hole to receive canopy tubes and prior to drilling a subsequent hole, the canopy tube shall be installed in the hole in its final position.
6. Temporary casing installed in holes shall be withdrawn during the installation of the canopy tubes.

PS 5.4.8 DRILLING OF EXPLORATORY AND PILOT HOLES

1. The Contractor shall carry out exploratory drilling at locations and in a manner directed by the Engineer/Engineer representative at any time throughout the duration of the Contract. Such work shall, inter alia, include drilling for geological exploration by means of cored drill holes, which will mainly be performed in the tunnel to assess the stratigraphy and geological conditions ahead of the face. This will generally be achieved by drilling horizontal or inclined holes ahead of the face, or by drilling vertical cored holes in the crown or invert, depending on the dip, as directed by the Engineer/Engineer representative. Permeability testing may be carried out in these holes.
2. Exploratory holes with core recovery requested by the Engineer/Engineer representative shall be performed with rotary-type hydraulic fed core-drilling equipment using a 76 mm diameter (NX size)) or approved equivalent size, bottom discharge diamond bits and double / triple core barrel, equipped with standard core lifters providing core of minimum 45 to 47 mm diameter.
3. Drilling lifts shall be terminated and the cores removed from the barrel as often as is necessary to achieve the maximum core recovery. Drilling lifts shall not be longer than the length of the core barrel.
4. To forewarn of possible adverse geological conditions, but especially in the case of increasing water inflow (dripping, water bearing joints etc.), the Contractor shall

at his discretion drill horizontal or ascending percussion pilot holes ahead of the face to investigate the presence of a possible broken zone, fault etc., unless otherwise directed by the Engineer/Engineer representative. Such holes shall typically extend 50 m ahead of the face for Heading & Benching drives, and shall provide adequate overlapping (minimum 8 m) where continuous reconnaissance is required. During the execution of such holes, the penetration rate, the water colour, description of cuttings and water outflow shall be thoroughly recorded.

PS 5.4.9 FIELD PROGRESS RECORDS

Within twenty four (24) hours after completion of a core drilling, the Contractor shall submit in duplicate a complete log of the hole in a form approved by the Engineer/Engineer representative. The log shall include at least the following data:

a) location and coordinates

b) borehole number

c) type and diameter of boring

d) ground level

e) initial, intermediate and equilibrium groundwater levels with times and dates; note on colour and losses, etc.

f) description and state of weathering of rock and the levels of boundaries between different rock types

g) percentage of core recovery

h) fracture log

i) the results and levels of all in-situ testing

j) a record of the driller's observations on progress of boring, rate of penetration, type of bit and speed of rotation bit

k) water pressure test results

l) location of sample extraction (water / core material) for tests and change in strata

m) diameter of casing and depth to which taken

n) depth of termination of borehole

The Contractor shall inform the Engineer/Engineer representative as to all changes in drilling pressures, loss or gain of drill water, and all other pertinent data.

PS 5.4.10 LOGGING AND PRESERVATION OF CORES

a) The Contractor shall provide the logging of core samples based upon the Geological Society Engineering Group Working Party Report "The Logging of Rock Cores for Engineering Purposes", Quarterly Journal Eng. Geology. Vol. 3 1970 London or ISRM Suggested Methods.

b) Cores, whether from exploratory holes made by the Contractor for his own convenience or requested by the Engineer/Engineer representative, shall be handled and stored in fully labelled core-boxes in a satisfactory manner for future reference and safekeeping.

c) The Contractor shall provide strong (wood or sheet metal) 1.05 m long core boxes details of which have to be approved by the Engineer/Engineer representative. Each box shall hold cores from 5 m of hole and they shall be provided with fasten-able lids. All boxes shall be uniform in size.

d) The Contractor shall place the core in the box in the correct sequence after extraction from the core barrel. The core at the bottom of each lift shall be marked immediately after it has been placed in the box and a corresponding mark shall be printed on the side or partition of the core box and on the rock core. When core is not recovered, timber blocks of square cross-section shall be placed in the box by the Contractor. These timber blocks shall be cut to the same length as the core loses and placed in the positions for which the core was lost. If these positions cannot be determined, the blocks shall be placed at the top of the lift. A box shall not contain cores from more than one hole. Designation marks, hole numbers and elevations shall be placed on the boxes and along the line of cores as directed by the Engineer/Engineer representative. The covers shall be fastened securely to the core boxes, and the boxes shall be delivered to the Engineer/Engineer representative at a designated point in the vicinity of the Works.

e) Cores shall be colour photographed in the core boxes, one box per photograph, with labels clearly indicating the project name, drill hole number and initial and final depths of the drill hole covered by the core in each box. The photographs duly labelled and placed in albums shall be duly submitted to the Engineer/Engineer representative at the end of each month or such other period to be determined by the Engineer/Engineer representative.

f) The Contractor shall supply all core boxes and core loss blocks, and they will become the property of the Employer when the core has been permanently placed therein.

PS 5.4.11 WATER PRESSURE TESTING

1. Immediately before water pressure testing of any hole is started, the hole shall be thoroughly flushed with clean water to remove any accumulation of drilling sludge and cuttings by flushing through a water pipe, which shall be inserted to the bottom of the hole. Flushing shall continue until the return water is judged by the Engineer/Engineer representative to be clean.

2. The Contractor shall perform water pressure tests by the Lugeon test method in every stage of every consolidation, curtain and verification grout and exploratory holes or section of holes, as the drilling proceeds or after completion of a drill hole, as and where directed by the Engineer/Engineer representative. The test method shall be as described for packer tests in BS 5930, Clause 25.5.

3. The general procedure for water pressure testing shall be as follows:

   a) Before the packer is installed, the drill hole shall be thoroughly flushed and the Contractor shall check that the flow through the packer is unobstructed.

b) The water pressure test shall be carried out between a packer and the bottom of the hole or between packers in depth stages to suit the variation of jointing of rock. The in situ pressure head shall be measured and registered before and after each test.

c) The length of the test section of hole shall be 5 m or as directed by the Engineer/Engineer representative, plugged by single packer for tests carried out in the bottom section of hole and double packer for tests carried out in any part of hole.

d) The Water used shall be clean and comply with the requirements of ASTM C1602 (2012d)

e) Water is to be pumped into the section and pressure adjusted by stage to reach the constant effective pressure.

f) Water level above the packer is to be checked and recorded. Pressure losses due to friction in pipes and their fittings etc. shall be determined to the satisfaction of the Engineer/Engineer representative when the pressure is not taken directly from the packer.

g) The rate of flow shall be determined to an accuracy of 10 % for flows exceeding 1 litre/min, using an air vessel to smooth out fluctuations of pressure in case the pump is piston type. Progressive cavity type pumps shall preferably be used. The permeability as measured in the drill holes shall be expressed in Lugeon units, 1 Lugeon unit being equal to a water take of 1 litre per minute per linear metre of hole at a pressure of 1 MPa.

4. For selected primary holes, exploratory holes, check holes, instrument installation holes and when instructed by the Engineer/Engineer representative, multiple-pressure comprehensive water pressure tests are to be performed as described below.

Water shall be pumped into the hole through a header and pressure shall be applied in stages up to the maximum pressure. The maximum pressure shall be determined by the Engineer/Engineer representative depending on geological conditions, but shall in general not exceed 10 MPa above the in situ pressure head that the rock would experience in its design life. Where water-pressure tests are carried out in grout holes, the maximum pressure shall not exceed the maximum grouting pressure to be used. Unless otherwise directed, the pressure at the various stages shall be as shown in following Table 5.2:

Table 5.2 Gauge Pressures at Various Stages – Water Pressure Testing

Stage	Gauge pressure – in situ pressure head (bar)
1	2
2	5
3	10 or as directed

4	5
5	2

a) Discharge measurements shall be started only after a stable pressure has been established. For each stage of pressure, water absorption shall be measured two times for periods of 5 minutes each. The time for each stage of pressure test shall therefore be 10 minutes.

b) If during discharge measurements the rate of absorption or pressure changes, the test shall be extended until discharge and pressure remain constant over a period of 5 consecutive minutes.

c) If, due to high absorption, it is not possible to maintain the required pressure, the pump shall be operated at its maximum discharge rate for 10 minutes with the pressure measured at (1) minute intervals.

5. When directed by the Engineer/Engineer representative, abbreviated water pressure tests will be performed in holes immediately before grouting. Abbreviated water pressure tests shall be performed as follows:

a) For any test section, the maximum water pressures shall be 20 bar in maximum or the same as the maximum pressure to be used for grouting that section or as specified by the Engineer/Engineer representative.

b) The pressure shall be maintained constant for three (3) minutes and the rate of flow shall be measured and recorded at one (1) minute intervals unless otherwise approved by the Engineer/Engineer representative.

c) If the leakage is too great to enable the required pressure to be attained, then the discharge of the pump shall be maintained constant and the pressure recorded at one (1) minute intervals.

6. The Contractor shall prepare daily water pressure testing records for the Engineer/Engineer representative, on approved forms, of all water pressure testing carried out. For each test, the information provided shall include at least the following subjects:

a) identification of the hole,

b) level(s) of the packer(s),

c) level of water (if any) in the borehole before and after the test;

d) level of water (if any) above the packer during the test;

e) level of pressure gauge;

f) head loss between the pressure gauge and the tested section (in pipes, tees, bends, joints, valves);

g) pressure measured at the collar of the hole;

h) the volume of water injected at each pressure stage and the total quantity of water injected;

i) duration of each pressure stage of the test;

j) any observed flow from adjacent holes, joints or other openings, and

k) Test results by Lugeon values.

l) Plots of pressure and lugeon values for each test sequence plotted as bar graphs.

m) P/Q diagrams

n) Description of any unusual occurrences

PS 5.5 PRESSURE GROUTING

PS 5.5.1 GENERAL

The work shall consist of pressure grouting in underground excavations of tunnel & shaft, with the aim to improve specific properties of the rock mass, mainly strength, stiffness or watertightness, by drilling boreholes of suitable diameter, length and direction into the rock material, placing packers near the bore hole opening (or some other means of providing a pressure tight connection to the borehole), connecting a grout conveying hose or pipe between a pump and the packer and pumping a prepared cement-based or chemical-based grout by overpressure into the cracks and joints of the rock surrounding the bore holes.

The potential for groundwater inflows into tunnel & shaft excavations and the nature of impact upon both the tunnel construction and the surrounding area must be sufficiently understood before an effective grouting program can be developed. The work shall include measures for closing up the water bearing passages to prevent the flow of water into tunnel and or to concentrate the area of seepage into channel from where it can be easily drained out.
Grouting, particularly in zones near the surface, shall be accomplished with extreme caution to prevent uplift of the rock or excessive leakage at the surface.

The contractor shall caulk surface cracks that allow excessive loss of grout. Cracks may be caulked by mechanical means or with fast setting mortar. If necessary, grouting shall be temporarily suspended or the pressure shall be reduced to permit the caulking of leaks. Accelerators may be added to the grout for the same purpose if approved by the Engineer/Engineer representative.

If grout injected into one hole appears in adjacent holes, the interconnected holes shall be plugged temporarily with packers set just above the level at which the grout is entering. Holes grouted by interconnection shall be split spaced.

The quantity of grout prepared in advance shall be kept to a minimum. Grout that has remained in the mixer or holdover tank with or without agitation for more than an hour shall be discarded.

Grout temperatures shall be no lower than 10 degrees Centigrade. The grouted soil, rock, or concrete shall be no colder than 4 degrees Centigrade when grout is injected and for at least 48 hours thereafter. Insulation or heat shall be applied to the surface for 24 hours before grouting and 48 hours after if required to keep the soil, rock, or concrete above the minimum required temperature.

After grouting is completed, the contractor shall remove the grouting plant and all related parts, equipment, and supplies from the site. The cleanup includes unused materials and waste.

The work to be done under these Specifications shall include all labour, materials and equipment necessary to complete the job to the full extent of the Specifications, Drawings and /or Engineer/Engineer representative's satisfaction.

PS 5.5.2 DEFINITIONS

a) **Pressure Grouting**: Filling a void behind a liner or pipe with grout under pressure sufficient to ensure void is properly filled but without overstressing temporary or permanent ground support, or causing ground heave to occur.

b) **Backpack Grouting or Contact Grouting**: Secondary pressure grouting to ensure that voids have been filled between primary tunnel or shaft liners and the surrounding ground.

c) **Annular Grouting**: Filling the annular space between the carrier pipe and the primary tunnel liner, casing, or ground, by pumping.

d) **Ground Stabilization Grouting:** The filling of voids, fissures, or under-slab settlement due to caving or loss of ground by injecting grout under gravity or pressure to fill the void.

e) **Pre-excavation Grouting, or Pre-Grouting Strategy:** In this case, the boreholes are drilled from the tunnel excavation face into the virgin rock in front of the face and the grout is pumped in and allowed to set, before advancing the tunnel face through the injected and sealed rock volume. Such pre-excavation grouting can also be executed from the ground surface, primarily for shallow tunnels with access to the ground surface area above the tunnel.

f) **Post-Grouting Strategy:** For control of unacceptable water ingress and Improvement of ground stability, the drilling for grout holes and pumping of the grout material take place somewhere along the already excavated part of the tunnel.

g) **Consolidation Grouting:** In terms of tunnelling works, it refers to the structural enhancement of the ground in terms of its bearing capability. Typical fields of the consolidation grouting in rock mass are the stabilization of disintegrated or jointed rock.

h) **Sealing Grouting:** Rock mass grouting for filling of leakages or water bearing joint nets to block water ways in tunnelling works. Typical fields of application are grout curtains to shut off water inflows.

i) **Contact grouting** is done to fill the cavities/voids between concrete and rock mass on account of shrinkage of concrete and uneven over breaks.

j) **Compaction Grouting:** The typical method of grouting used to stabilize cover subsidence sinkholes. The primary difference between this technique and pressure grouting is that the grout material for compaction grouting is a thick, mortar-like material that is designed to displace soft soils and fill voids.

k) **Grout Take:** The volume of grout material that is required to treat a particular zone or project. Grout takes are typically estimated during the proposal phase of a project, however, the actual amount of grout required will only be determined after the project is completed.

l) **Pressure Filtration:** A measure of how easily water is removed or squeezed out of a grout under pressure. A high resistance to pressure filtration or a low-pressure filtration coefficient is desirable to ensure that the grout rheology is constant during the injection process.

m) **Hydrofracturing:** The fracturing of an embankment or underground stratum by pumping water under a pressure in excess of the tensile strength and minor principal stress.

n) **Packer:** An expandable mechanical or pneumatic device used to seal a hole or isolate portions of a hole.

o) **Stage**: One complete operational cycle of drilling, cleaning, pressure washing, pressure testing, pressure grouting, and grout cleanout within a zone. The depths of stages in any hole depend on conditions encountered in drilling that dictate where drilling should stop and grouting commence.

p) **Stage Grouting:** The grouting of progressively deeper zones in stages. Previously emplaced grout is removed before hardening, the hole is drilled to a deeper depth, and another stage is emplaced. Where upstage grouting is used, the hole is drilled to full depth and grouted in stages starting at the bottom of the hole and working upward. For downstage grouting, the hole is drilled for a single stage, which is then tested and grouted. After the grout in this stage has set, the hole is drilled to the next stage and grouted. This process is continued until the hole has reached its final depth.

q) **Stop Grouting:** The grouting of a hole beginning at the lowest zone (bottom) after the hole is drilled to total depth. Packers are used to isolate the zone to be grouted.

PS 5.5.3 SUBMITTALS

a) The Contractor shall make the following submittals to the Engineer/Engineer representative in accordance with all provisions and continuance of relevant para's of sub-clause *PS 5.3.4.1 – Submittals and Approvals* of these specifications.

b) Submit a description of materials, grout mix, equipment and operational procedures to accomplish each grouting operation. The description may include sketches as appropriate, indicating type and location of mixing equipment, pumps, injection points, venting method, flowlines, pressure measurement, volume measurement, grouting sequence, schedule, and stage volumes.

c) Submit a grout mix design report, including:

i. Grout type and designation.

ii. Grout mix constituents and proportions, including materials by weight and volume.

iii. Grout densities and viscosities, including wet density at point of placement.

iv. Initial set time of grout.

v. Bleeding, shrinkage/expansion.

vi. Compressive strength.

d) For cellular grout, also submit the following:

i. Foam concentrate supplier's certification of the dilution ratio for the foam concentrate.

ii. A description of the proposed cellular grout production procedures.

e) Maintain and submit logs of grouting operations indicating pressure, density, and volume for each grout placement.

f) Relevant Standards and recommendations of EN 12715, DIN 4093, American Petroleum Institute Test Procedure API RP 13B-1 and the ISRM (International Society for Rock Mechanics) report on rock grouting (ISRM 1996) may be referred.

PS 5.5.4 MATERIAL REQUIREMENTS

PS 5.5.4.1 GENERAL

1. Grouts used in hydraulic and underground construction / rehabilitation projects are generally categorized into i) suspension-type grouts, ii) emulsion-type grouts and iii) solution type grouts. The suspension-type grouts include clay, cement and lime, while the emulsion-type grouts include bitumen and the solution-type grouts include a wide variety of chemicals.

2. Within each grout family, there are primary grout subtypes Following are the subtypes of primary grout mixes, to be used in conformity with project specific requirements.

   Cement Grout

   a) Neat cement grout, with multiple admixtures including super-plasticisers and fluidifiers;

   b) Cement-sand grout, with admixture;

   c) Cement (with silica fume) grout with or without sand;

   d) Microfine-cement or Ultrafine-cement grout; and

Chemical Grout

a) These grouts are more correctly termed “colloidal,” “chemical solution,” or “solution” grouts.

b) Chemical grouts are injected into voids as a chemically reactive solutions, in contrast to cementitious grouts, which are suspensions of particles in a fluid medium. Chemical grouts initially behave as a fluid, but reacts after a predetermined time to form a solid, semisolid, or gel.

c) Chemical grouts each are unique in composition. They have the advantages of low viscosity, good injection ability, more resistant against wash out phenomena and expulsion of water.

d) They are truly solution grouts with no suspended solids, and having a high degree of penetrability into soils and rock. They can be injected into fine sands or microfractures. However, chemical grouts not only pose a health and environmental hazards but are also more expensive.

e) The chemical grout family includes sodium silicate, acrylic gels and polyurethane expansive foams. Although each parent grout type has primary grout spawns, this is where the commonalities end and the individual grout types split into their own unique characteristics.

f) Acrylates and acrylamides are highly penetrable in all mediums and form a gel when reacted. These materials are highly effective for water control because of their ability to set almost instantly within variable, but controllable periods of time. However, there are disadvantages, including shrinking and swelling during wetting and drying cycles.

3. The quantities of sand and admixtures used in Cement based grout will depend on the prevailing rock conditions.

4. Cement, sand, water and admixtures for use in grout shall conform to the requirements of Chapter 6 – Cement Concrete, of General Specifications, and relevant amendments in Supplementary specifications.

5. Cement for grout shall in general be either Ordinary Portland Cement Type – I, or Rapid Hardening Portland Type – III conforming to ASTM C150.

6. Cement used in pressure grouting shall have a minimum specific surface area of 5,400 cm^2 per gram as determined by the Blaine air-permeability method (ASTM C204) or as directed by the Engineer/Engineer representative. No cement particle shall be retained on BS Standard Sieve No. 200 (0.075 mm). If adequate grout penetration cannot be achieved with standard Type I or III cements, then microfine or ultrafine cement shall be used.

7. Cement grouts are considered to be suspended solids grouts, because they have particulates that comprise their composition which is derived from grinding Portland cement clinker. Portland cement grout generally has particulate sizes on average of 15 microns. Microfine cements range from 6 to 10 microns while ultrafine cements can have average particulate sizes of 3 to 5 microns.

8. Micro-cement for grout shall be milled from pure Portland cement clinker and shall have a minimum Blaine specific area of 900 m^2/kg with 95% of all particles < 10 µm

and with a maximum particle size of 15 µm.

- ACI Committee 552, Geotechnical Cement Grouting, defines microfine cement as a material in which **d_{max} < 15 µm.**
- According to the European Standard for grouting (SFS-EN 12715), microfine cements are characterized by a specific surface area >800 m^2 / kg and **d_{95} < 20 µm.**
- The Norwegian proposal divides two groups of micro-cements:

  d_{95} < 30 µm, Microfine Cement, and

  d_{95} < 15 µm, Ultrafine Cement
- In U.K. practice, ultrafine cements are characterized by **d_{max} ≤ 6 µm**

9. Application of admixtures like superplasticizers (for fluidity increase), dispersants, retarders, accelerators (applied in high flowing formations) are recommended to counter the wash out effects of the suspensions and clogging of the grouting pipes, especially in high water pressure or flowing water conditions.
10. Additives like bentonite (improves stability), slag, silica fume (to increase stability or to lower the pH-value of the grout), sodium silicate, fly ash or pozzolan may be added for improving the fluidity, stability and sulphate resistance of the grout. Fly ash used in grouting should contain less than 5% carbon. Up to 20 % of the cement may be replaced. Alternatively, Portland-Pozzolan cement may be used. Fly ash shall only be used if proved to be compatible with other grouting materials by testing prior to the start of grouting. Pozzolans and Fly Ash shall comply with ASTM C618 (2012e).
11. Where required, bentonite shall be added to the cement at a rate of 2 to 7 % by weight of cement. Bentonite shall be sodium montmorillonite with properties as specified by the American Petroleum Institute and specified in the following Table 5.3

Table 5.3: Properties of Bentonite

Property Description	Requirement
Wet Screen Analysis Residue on U.S standard sieve No.200	2.5 %, maximum
Moisture	10 %, maximum
Fan Reading	30, minimum at 600 rpm
Yield Point	3 x viscosity maximum
Filtrate	13.5 cc, maximum
Liquid Limit	> 350
Plastic Limit	> 28
Plasticity index	> 400

12. Properties of sodium silicate to be used as accelerator, if required for pressure grouting shall be as specified in the following Table 5.4

Table 5.4: Properties of Sodium Silicate to be Used as Accelerator

Property Description	Requirement
Specific gravity at 15ºC	more than 40 Be (Baume gravity meter)
SiO_2	28 to 30 % by weight
Na_2O	9 to 10 % by weight
Fe	less than 0.02 % by weight
Matter insoluble in water	less than 0.2 % by weight

13. Water used shall be clean and free from injurious amounts of oil, acid, organic matter, or other deleterious substances.

14. The minimum percentage of water required for complete hydration of cement is 30% when expressed by weight (45% by volume) of cement. Greater quantities of water are used in grouting than in concrete, as the water is the carrier of the products in suspension during injection. Potable water can be used in grout without any testing.

15. Groundwater or surface water testing is required to demonstrate that the water meets the requirements of ASTM C1602 (2012d), *Mixing Water Used in Production of Hydraulic Cement Concrete.*

16. Water shall not contain more than 2,000 ppm of suspended colloidal solids and no particles larger in size than the cement particles. The chloride content shall be less than 50 mg/l and the sulphate content less than 100 mg/l.

17. Water having a temperature above 30°C shall not be used in grouting operations. The use of water at a temperature not exceeding 30°C is designed to limit the temperature rise in the grout during the grouting operation. The Contractor's attention is drawn to the need to provide shelter from effects of hot weather and wind for the stored cement, water and grout lines and the other equipment handling the grout. Recommendations for hot weather concreting are contained in "Guide to Hot Weather Concreting - American Concrete Institute ACI 305R-10", and the Contractor shall adopt any of these recommendations applicable to grouting.

18. The Contractor shall submit details, for the Engineer/Engineer representative's approval, of the proposed source of the materials, test certificates or the results of the Contractor's tests and notes on any limitations in respect of the use of the materials for grouting on the works, with proposals to overcome those limitations where necessary.

PS 5.5.4.2 SAND

1. Sand shall conform to ASTM C33. Sand shall be either natural sand, composed of clean, hard, durable uncoated particles resulting from the disintegration of siliceous and/or calcareous rocks; or manufactured sand resulting from the crushing of boulders or shingle. Sand shall be clean and free of injurious amounts of organic impurities; deleterious substances.
2. Unless otherwise specified, the gradation shall be within the numerical limits e as specified in the following Table 5.5

Table 5.5: Sand Gradation for Grout

Sieve designation (U.S. Standard Square Mesh)	Percent passing by weight
16	100
50	20 – 50
100	10 – 30
200	0 – 5

PS 5.5.4.3 SILICA FUME

Silica fume may be added for improving the stability and penetrability of a grout. Silica fume for grout shall be micro fine powder, with an average particle size between 0.1 to 0.15 µm.

PS 5.5.4.4 ADMIXTURES

1. Chemical admixtures (superplasticizers) and fluidifers etc shall be added to grout mixes to produce Balanced, Stable High Mobility Grouts by modifying the flow and set characteristics (rheology) of grouts. Grout parameters, such as the rheological properties (i.e., yield stress and viscosity) and the injectability of cement grout, (i.e., coefficient of permeability to grout) govern the performance of cement-based permeation grouting in porous media.
2. Admixtures must be chemically compatible with the other components of grout formulations and with one another. Only admixtures tested prior to the start of grouting work and approved by the Engineer/Engineer representative shall be used. Manufacturer's certificates or guarantees will not be accepted as relieving the Contractor of his responsibility for the suitability of any admixture.
3. When chemical admixtures or grouts are required or proposed for use in grout, these shall be accompanied by the relevant manufacturer's certificate (including toxicity, health, safety and environmental certification), substantiating commercial use with satisfactory results in similar type of work. The manufacturer’s full

technical knowledge and support should be obtained in the use of admixtures such as at what point in the mixing sequence the admixture should be used. The storage, handling and usage shall strictly adhere to the manufacturer's instructions.

4. **Anti-Washout Agents**: Viscosity modifiers such as **diutan gum** provide resistance to washout. Additional resistance to washout can be achieved using commercially available anti-washout agents. These admixtures can be employed if flowing water is encountered when using cementitious grouts. These products are cellulose based and may have compatibility issues with other admixtures.

5. **Foaming Agents**: Foaming agents are used to lower grout densities. Grouts created using foam are often referred to as "foamed grouts," "aerated grouts," or "controlled low strength material".

   The dry admixtures are easier to use as they are simply added to the mixer as the final component. The wet foaming mixtures are less expensive, but require a foam generator. The dry mixes are applicable to batch-type mixing and placements, while the wet foaming agents are advantageous when large quantities are anticipated. Foamed grouts should not be used where the grout will be exposed to flowing water or the environment, as these grouts are typically less durable.

6. The use of toxic chemicals such as acrylamide shall not be permitted for use in the Works.

PS 5.5.5 GROUT MIX DESIGN

PS 5.5.5.1 GENERAL

a) Unless otherwise specified explicitly in these specifications and drawings, only Cementitious grouts shall be used in the underground works.

b) All types of cement-base grouts shall be high mobility grouts (HMG), balanced stable grouts with low water/cement ratios using multiple admixtures including super-plasticisers and fluidifiers. Low mobility grouts (LMG) can be used in the case of compaction grouting where it is necessary. Under high inflow / high pressure conditions, sodium silicate may be required as a flash setting additive. Sand or other type of filler may be used when required to fill large voids.

c) Grouts shall be designed to achieve the optimum combination of penetrability, durability and strength as required.

PS 5.5.5.2 DEFINITIONS

a) **Bingham Fluids**: Bingham Fluids are non-Newtonian fluids which do not follow **Newton's** law of viscosity and, thus, their viscosity, a ratio of shear stress (grouting pressure) to shear rate (flow rate of the grout) is not constant and is dependent on the shear rate. If enough force is applied to these **fluids**, their viscosity will change.

Bingham Fluids are basically **visco-plastic fluids** that possesses a yield strength which must be exceeded before the fluid will flow. There are different behavioural characteristics of non-Newtonian fluids including viscoelasticity, time-dependent viscosity, etc. In Cement based Grouts Cementitious suspensions behave as Bingham fluids.

b) **Newtonian Fluids:** Newtonian fluids obey **Newton's** law of viscosity. The viscosity is independent of the shear rate. **Newtonian fluids** have a constant viscosity that doesn't change, no matter the pressure being applied to the fluid. In other words, the ratio of the shear stress to the shear rate is constant throughout the fluid. Example: Water, air and gasoline.

c) **Visco-plastic fluids**: Grouts for which the viscosity changes with shear rate (flow rate).

d) **Yield Point.** The yield point or cohesion defines the minimum pressure required to start grout flowing and the pressure at which grout stops moving (refusal) within a fracture.

At any stress greater than the yield point, grout will continue to flow in the fracture. For a constant fracture width, the rate at which grout flows in the fracture is controlled by the pressure in excess of the yield point and the grout viscosity. As grout moves away from an injection hole, the pressure decreases due to head loss within the fracture. As the pressure experienced (or “felt”) by the grout farthest from the hole reduces, the flow rate continues to drop.

e) **Shear thickening & thinning:** Grouts where the viscosity increases with increasing flow rate (pumping rate) are identified as exhibiting shear thickening. Shear thinning behaviour refers to a grout for which the viscosity reduces with increasing flow rates.

f) **High Mobility Grouts (HMGs):** behave as a fluid and can be mixed, circulated, and injected with relative ease using normal grout mixing and pumping equipment. HMGs range from pourable to a thick consistency that is just barely able to be mixed and pumped with normal equipment. HMGs are commonly used for permeation grouting of coarse soils and fractured rock.

g) **Low-Mobility Grouts (LMGs):** are of a mortar-like consistency and exhibit both plasticity (stay together when deformed) and have high internal friction due to the high concentration of solids in the mix. With plastic type behaviour lacking enough fluidity, LMGs are not pourable. The best-known application of LMG is for compaction grouting, where the grout is injected into a soil for displacement and/or densification, resulting in a higher modulus and higher strength. The expanding property as a non-permeating bulb of plastic material, make LMG’s a best choice for void filling in karst terrain of tunnel works.

h) **Balanced Stable Grout:** The term refers to a grout mixture that is formulated to provide the desired rheological properties that also remain constant during the injection process. Stable grouts do not separate into distinct phases in the absence of agitation and do not undergo significant property changes until they begin to take a set.

With use of Additives, a balanced stable grout can be created (significantly reduced or zero bleed potential) with the desired rheologic properties that remain nearly constant during injection since the pressure filtration coefficient is low.

i) **Unstable Suspension Grouts**. Grouts which in the absence of continuous agitation, separates into two distinct phases (water and a very thick suspension). Unstable grout exhibits more than 5% bleed or sedimentation when placed in a graduated cylinder. At all locations except within the agitator itself, the properties of unstable suspension grouts are in a process of change throughout the grouting process.

j) **Rheology:** It is the science of deformation and flow of fluids. The rheological properties of Cementitious grouts change with time due to hydration of the cement. The rheology of cement grout is of prime importance in transporting, pumping, pouring and spreading of the material.

k) **Thixotropy:** The decrease of viscosity with time by application of shear and the recovery of viscosity when the material is at rest. Quick structural restore, or high thixotropy, of Cementitious grouts helps in controlling of water inrush in karst passages of underground works.

PS 5.5.5.3 DESIRED PROPERTIES OF CEMENT-BASED SUSPENSION GROUT.

Following are the achievable desired properties of a cement-based suspension grout:

a) Zero bleed, so that the fractures or voids that are filled during the injection remain filled.

b) High resistance to pressure filtration, so that the water-to-solids ratio remains constant during the injection.

c) Water repellent, so that the grout suspension does not dissociate when injected into water.

d) Resistant to particle agglomeration due to electrostatic and chemical interactions, to deter the development of macro-flocs (increase in grain size) from the hydration process during the period of injection.

e) Cohesion values consistent with the desired penetration distance. A low cohesion is desirable to maximize penetration from a given hole and limit the total drilling footage required. In karst or very high permeability formations, a mix or mixes with a high cohesion might be desirable to keep the travel distance within the intended treatment zone.

f) Viscosity compatible with the pumping pressures and low enough that an economical injection rate is achieved.

g) Thixotropic, so that the grout is resistant to washout after placement.

h) Well-graded grain size distribution of the cured grout (a well-graded structure of the cured grout reduces the matrix permeability and thus improves durability).

i) Long-term durability.

PS 5.5.5.4 GROUT MIX COMPOSITION, TESTING AND PRODUCTION

1. Type and Proportions of materials used in grout mixtures and any adjustments thereto during grouting operations shall be only as approved by the Engineer/Engineer representative. Proportions shall be varied to suit actual conditions encountered at Site.

   Grout mixes shall be balanced stable grout mixes. The use of additives in cement-based suspension grouts improve one or more properties of the grout, although, while adversely affecting other properties. The Contractor's Material Engineer/Engineer representative should have the proficiency in the design and proportioning of grout mixture with the use of admixtures to achieve the required properties.

2. Grout mix physical properties shall be based on requirements specified in these documents and /or as approved by the Engineer/Engineer representative, for marsh funnel viscosity, compressive strength, pressure filtrate, or the specific gravity, while the additive dosage shall be based on the weight of cement used.

   Whenever there is a change in bulk materials (i.e., cement from a new supplier or a new water source) on an ongoing project, the physical properties of the new mixes shall be verified through testing, and the material proportions and additive concentrations shall be modified to provide the desired properties.

3. Due to the variability of the grout components, a full-scale mix design program shall be carried out by the Contractor under the supervision of the Engineer/Engineer representative in the main laboratory before production grouting. The trial mix testing (Job Mix Formula) should use all the actual components and actual mixing and proportioning equipment intended for use in the production program, including the mix water.

4. Trial mix design & testing program of grout shall be started with a "medium" mix. The typical sequence of mixing when preparing stable grouts with multiple admixtures is to add the water to the mixer followed by the pre-hydrated bentonite slurry. (The bentonite slurry contains a significant portion of the mix water.)

   After the water and bentonite slurry, the cementitious materials are added. This includes the cement and any pozzolanic additives such as fly ash or silica fume. Once the cementitious materials have been added and mixed, the water reducer or superplasticizer is added, followed by any viscosity modifiers. Any accelerators or retarders are added at the time recommended by the material supplier, but these are generally added last.

   For very thick mixes, the superplasticizer might be added to the water before the cement. While adding the superplasticizer to the water in advance of the cement does facilitate mixing, a higher dose (up to two times) of superplasticizer will be required if added before the cement.

After the percentages of all the admixtures and additives have been determined, the water content is then systematically reduced to provide the range of apparent viscosities desired.

5. The grout mix design process for each kind of grouting work shall include the following tests, as described herein below.

    - Settling measured as the ratio between the volume of water appearing above the grout and the total volume in a 1 liter, 6 cm diameter graduated test cylinder, after 20, 40, 60, 80, 100 and 120 minutes and after setting. Setting time.
    - Viscosity with standard Marsh cone (4.75 mm dia). The Marsh funnel should be calibrated with water at least once during each shift.
    - Density, specific gravity.
    - Flexural and uniaxial compressive strength at 28 days.
    - Compatibility between the various components.

6. After the establishment of LJMF (Laboratory Job Mix formula), the mix design shall be tested on site under the supervision of the Engineer/Engineer representative, to investigate any changes in properties arising from differences in materials, mixing equipment, or procedures between laboratory testing and production grouting. This mix testing should use all the actual components and actual mixing and proportioning equipment intended for use in the production program, including the mix water.

    Baseline data for Production Job Mix Formula and Quality Control parameters shall be established jointly by the Engineer/Engineer representative and the Contractor, once the composition of the trial mix grout tested and adjusted satisfactorily with the prevailing geological formations.

7. During Production grouting, the properties of the grouts shall be measured regularly to ensure that grouts are being batched correctly and that mixes continue to be consistent with the site conditions as required under quality control and quality assurance procedures as stated in these specifications and/or approved by the Engineer/Engineer representative.
8. Any grout not injected within one hour of mixing shall be wasted.
9. Epoxy grouts shall be used for the grouting of fine joints and cracks which cannot be sealed by micro-cement.
10. Polyurethane (foam) may be used for open joints to stop or reduce water flows.

PS 5.5.5.5 MIX DESIGN CRITERIA

Design criteria for Balanced stable grouts shall be as follows or as directed by the Engineer/Engineer representative to suit Site specific conditions and grouting requirements.

a) **Setting time for grouting fractured rock**:

i. Initial set time 10 to 16 hrs

ii. Final set time 12 to 20 hrs.

Balanced stable grouts have a longer set time (whether initial gel or initial set) than neat cement grouts because the formulation of a stable grout with a fully dispersed structure delays the hydration process.

b) **Water-to-Cement Ratio (By Weight**):

Depending on the geology and the objective of the grouting, w/c of the starting mix shall be in the range is 3:1 (thinnest) to 0.6:1 (thickest).

The weight of cement shall include all cementitious materials including fly ash or silica fume.

c) **Bleed or Sedimentation** according to ASTM C940 less than 5% after 2 hrs.

d) **Viscosity:** To be adjusted for each specific work, apparent viscosities as measured with a marsh funnel shall be of a low range of 35–40 sec to a maximum of 60–70 sec with a tolerance on the specified viscosity of + or - 5 sec. A minimum 5-sec change in marsh funnel flow time should be provided, and a 10-sec change for thinner mixes.

e) **High resistance to pressure filtration**. Pressure filtration coefficient shall be < or = to 0.05 required at standard test duration of 30 min.

f) **Uniaxial compressive strength** after 28 days:

i. Contact and consolidation grouting, cavity grouting, steel linings and embedded items injections: > 9 MPa.

ii. Others works (curtain grouting): > 5 MPa.

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PS 5.5.5.6 MIX DESIGN PROPORTIONING

1. **Fly Ash.** Fly ash is designated as Class F or Class C based on the sum of the silicon, aluminium, and iron oxides. The benefits and detriments of the fly ash may depend on the fly ash source and should be checked if fly ash is to be used where heat of hydration, sulphate resistance, alkali-silica reaction, or expansion are critical to the grout performance.

Typical dosages by weight of **Portland cement** shall be

Class F fly ash: **10–30%**

Class C fly ash: **< 20%**

2. **Silica Fume**: The typical dosage is **5–10%** by weight of **Portland cement**.

3. **Bentonite**: The typical dosage is **2–5%** by weight of **cementitious material**.

Bentonite shall be added as a pre-hydrated suspension, typically hydrated a minimum of 12 hrs before use. When pre-hydrated bentonite is used, the amount of water in the pre-hydrated suspension must be considered in the batch calculations.

4. **Diutan Gum:** The typical dosage is **0.1 to 0.2%** by weight of **cementitious material.**

5. **Superplasticizer**. The typical dosage is **1.5 to 3%** by weight of **cementitious material**.

PS 5.5.5.7 TESTING GROUT PROPERTIES

1. The Contractor shall prepare and test the trial HMG mixes as directed b y the Engineer/Engineer representative, at least 28 days before commencement of grouting work. Materials for use in grout mixes shall be tested for compliance with the applicable requirements stipulated hereinabove in these Specifications for Grouting Materials.

2. Tests on proposed grout mixes shall be performed in the laboratory and during pre-production field testing prior to grouting and during field production grouting to demonstrate the grout properties. The Engineer/Engineer representative may direct changes be made to the grout mix, based on the results of sample testing.

3. The following tests should be carried out during laboratory testing phase, field pre-production phase and field production phase or as otherwise directed by the Engineer/Engineer representative:
   - Cohesion or gelation
   - Apparent viscosity
   - Bleed or sedimentation
   - Pressure filtration resistance
   - Washout resistance (as required and directed by the Engineer/Engineer representative)
   - Filler segregation
   - Specific gravity
   - Set time
   - Strength
   - Matrix porosity (as required and directed by the Engineer/Engineer representative)

Production Quality Control and Frequency of testing shall be as follows in Table:5.6:

Table 5.6. Quality control tests for HMG.

Test	Test Method	Equipment	Frequency
Apparent viscosity	ASTM D6910 or API Method RP 13B-1	Marsh funnel	Once per mix per day
Specific gravity	API 13B-1	Mud balance	Once per mix per day
Bleed	ASTM C940 (2010b)	Graduated cylinder	Once per mix per week
Pressure filtration coefficient	API 13B-1	API filter press	Once per mix per week
Set time	ASTM C191-92 (2008)	Vicat needle	Mix testing program only
Strength	ASTM C39/C39M	Grout Cylinders	Mix testing program only
Grout Gel Time and Cohesion Tests		YR-1 Rheometer and Steel plate (**100 mm x 100mm x 1mm)** cohesion meter	Mix testing program only

4. Sampling and testing will be supervised by the Engineer/Engineer representative according to the quality assurance plan for grouting activities.

5. During and simultaneously with the actual field production grouting operations the Contractor shall carry out tests on rheological properties of grout mixes from time to time during each shift to ensure that the grout is being properly formulated, proportioned and mixed, and that the desired properties have been achieved under ambient conditions, and that those properties have not changed during the holding period. Among other required testing data, the temperature of grout and that of the mixing water, the time at which the grout was mixed, the elapsed mixing time, the time and location at which it was sampled and the time at which the test was made shall be recorded. The grout sampling point should be representative of the grout that is being injected into the hole.

6. If a significant change in the cement source occurs, sampling and testing shall be repeated.

7. The Contractor shall prepare on approved forms records of these tests, which shall be submitted to the Engineer/Engineer representative on a daily basis.

PS 5.5.6 GROUTING EQUIPMENT

PS 5.5.6.1 GENERAL

a. The grouting equipment used shall be of a type, capacity and mechanical condition to suit the work to be carried out, as determined and approved by the

Engineer/Engineer representative, and shall consist of, but not be limited to, pumps, mixers, agitators, pressure gauges, flowmeters, pipes, fittings, material measuring devices, and all accessories and tools necessary to maintain a continuous supply of grout of suitable quantity. Automated recorders for pressure and volume of grout are required for all types of grouting works to be carried out.

b. The mixing and pumping equipment shall be installed in one or more central stations to enable continuous, undisturbed work, independent of weather conditions and to guarantee a constant mixture as required.

c. For the grouting operations in underground works, reliable communication system between the main working stations and the central grout mix and pump stations shall be provided.

d. Stand-by equipment for uninterrupted continuation of the work in case of break-down shall be provided. The distance between the grouting site and the pumps shall be limited to allow for continuous operation without risk of the pipes becoming clogged.

e. The arrangements shall be such as to ensure the continuous and uninterrupted flow of grout to the hole being injected. The grouting shall be carried out by a return flow system to guarantee continuous circulation of grout to the hole being injected and return surplus grout which is not accepted by the hole to the holding tank.

f. Special emphasis shall be given to the control devices for pressure and volume of grout and for water pressure tests.

g. The pressure applied shall be measured at the borehole head and transmitted to appropriate automatic recording instruments.

h. Synchronized operation of pressure and discharge recorders must be ensured. For regular checking of pressure at the pumps, these shall be fitted with additional pressure gauge having an accuracy of 0.1MPa (1bar).

i. The necessary spare parts to ensure continuous grouting operations as required shall be kept available at the Project Site.

j. Prior to the commencement of grouting work and during the work as specified or as requested at the end of such work, all pressure gauges, recorders and discharge meters shall be checked and calibrated.

PS 5.5.6.2 GROUT MIXERS AND AGITATOR SUMPS

1. Grout mixers shall be the mechanically operated, high speed, high shear “colloidal” double-drum Colcrete or Hany type with vortex action capable of thoroughly wetting and mixing cement and other admixtures to create a homogeneous suspension and operating at 1500 to 2500 rpm. Paddle type mixers shall not be allowed for mixing of grout.

2. Batching of grouting components shall be in the following order: water, bentonite slurry (if bentonite is used), cement, admixtures (time of addition in mixing

sequence of admixtures as per manufacturer's instructions) and sand (if used in the mix). Bentonite shall be premixed with water (hydrated) and batched as a slurry in specified proportions (2-4%) of the weight of cement. Sand will be added to the grout mix only when open formations are being grouted and for grouting anchor bars and rock anchor bolts, roof bolts and high strength anchors.

3. Additive and Admixture dispensers shall be provided at the mixers to measure and add correct amounts of additive or admixture directly into the mixer.

4. Mixers shall be provided with equipment for measuring weight and volume of mix components with an accuracy of 2% and a water meter, calibrated in litres, with a reset switch for zeroing after each delivery.

5. After mixing, the grout shall be discharged through a 5 mm mesh screen into an agitator sump, equipped with a stirring paddle with rotating speed of approximately 100 rpm to prevent settlement of the mix and at the same time not generate excessive heat. The tank should be equipped with two paddles together with a minimum of four baffles to prevent vortex formation. One additional paddle should be provided near the bottom of the tank to sweep the bottom of the tank. The stirring paddles shall be such as to guarantee complete circulation of the entire sump content. The agitator sump shall have at least 30 % more capacity than the mixer so that there is sufficient volume for one batch of grout to be pumped while the next batch is being mixed. The agitator discharge should be by pumping and not by gravity flow.

PS 5.5.6.3 GROUT PUMPS

1. All grout Pumps shall be Progressive cavity or helical rotor pumps allowing independent regulation of pressure and discharge arranged with interconnecting pipes and valves in such a way as to permit a stand-by pump to be brought into immediate service. The pumping equipment shall be capable of transporting grout into holes or grout connections in a continuous, uninterrupted flow at any specified pressure up to a maximum of 10.0MPa (**100kg/cm^2**), with only small fluctuations in pressure during pumping being permissible. A minimum of three pumps capable of pumping a sand-cement grout mix shall always be utilized. The grouting equipment shall be arranged so as to provide a supply line from the grout pump and a return line from the grout hole to the grout pump. They shall satisfactorily accommodate discharges from 2 litres per minute up to 500 lit/min, depending on the section to be grouted and on the purpose. High rates of water supply are required mainly for water pressure tests

2. Grout pumps (auger type pumps) for consolidation grouting and backfill/cavity grouting shall be capable of delivering a flow of 50 l/min of thick grout (w/c = 0.5) at the specified pressure and shall be able to achieve and maintain up to 10 MPa pressure.

3. Grout pumps for the installation of rock reinforcement shall be of the Speidel or worm type pump and shall be capable of delivering thick grout (w/c = 0.32 to 0.4) through 10mm diameter grout tubes to the bottom of the respective drillholes.

4. The pump, except for pumps used to deliver grout for rock reinforcement, shall be equipped with pressure and capacity control valves, which allow the independent setting of each, the maximum pressure and the flow. The pump shall automatically stop whenever the pre-set pressure is reached, and shall maintain that pressure without fluctuation.

PS 5.5.6.4 PRESSURE GAUGES AND FLOW RATE GAUGES

1. Automatic recording which records and indicate time, pressure and rates of absorption, shall be installed during grouting operations as directed by the Engineer/Engineer representative and shall be calibrated as approved by the Engineer/Engineer representative. Water and grout take shall be measured using magnetic flow meters and water and grout gauge pressure shall be measured using either electronic pressure transducers or dial type mechanical gauges. If dial type mechanical gauges are used the dial size should be greater than 100mm (4 inches). The gauges should cater for a variety of pressures ranges and should have a pressure range exceeding the pressure expected to be used for grouting.
2. Such recorders shall be of modern and sturdy design warranting reliable operation and exact recording of measurements. No grouting is permitted without the use of such instruments unless explicitly approved by the Engineer/Engineer representative. Particular attention of the Contractor is drawn to the fact that only records from such accurate automatic recording instruments will serve as the basis for payment of grout material quantities and time.
3. After each usage gauges shall be cleaned and recalibrated at frequent intervals. Accurate master pressure gauge for different pressure ranges shall be furnished to check periodically the accuracy of all gauges used.
4. All electronic pressure transducers shall be accurate to < 0.5 of full scale and mechanical pressure gauges shall be accurate to within 1% of the range.
5. The Contractor shall provide pressure gauges for both low and high pressure ranges **(0-1.5 MPa and 0-10.0 MPa).** Two gauges for the applicable range shall be provided on each grout line, one at the pump, the other at the connection collar at the hole.
6. Pressure gauges shall be calibrated and certified by an independent laboratory, prior to the commencement of each grouting work.
7. The Contractor shall arrange to have available on Site an adequate number of water meters and pressure gauges correctly calibrated so that water pressure testing and grouting operations are not held up at any time due to the lack of accurate, calibrated gauges.
8. Graduated water discharge meters shall be accurate to ± 5 %. Equipment for proportioning grout mixes based on the number of cement bags or weighing of cement from bulk silo, and dosing of bentonite and water shall have and maintain dosing accuracies of 2 % and 5 %, respectively. Manual batching shall in general not be allowed except where explicitly approved by the Engineer/Engineer representative.

PS 5.5.6.5 GROUT HEADERS AND CIRCULATION LINES AND EQUIPMENT ARRANGEMENT

1. Grout headers should include an arrangement of valves and pressure gauges to control the quantity of grout that flows into the hole, control the pressure the grout applied to the hole, bleed fluid off the hole during grouting and seal the hole after grouting is completed. Generally, the equipment at the header should include a pressure gauge or transducer to monitor the injection pressure, a flow meter, a diaphragm valve on the return line to control the injection pressure, a diaphragm valve and a ball or plug cock valve in the injection line and a bleed line with a ball or plug cock valve.
2. The grouting equipment shall be arranged in circulation loop system so as to pump grout from the agitator to the header via a supply line and to enable grout not needed to satisfy the demands of the hole to return to the agitator tank through a recirculation line from the header.
3. The supply and recirculation lines equipped with quick release couplings shall be able to sustain an internal pressure exceeding the maximum produced by the pump. The internal diameter of the lines shall be such that no appreciable sedimentation of grout will take place when pumping at the minimum discharge capacity of the pump. No manifolds shall be used.
4. The total length of pipe and hose between the hole being grouted and the pump shall be kept to a minimum.

PS 5.5.6.6 EMBEDDED PIPES AND FITTINGS FOR GROUTING

1. The Contractor shall furnish and install galvanized mild steel pipes for all grout connections set in concrete or rock.
2. Pipes for grouting shall also be set over springs, crevices in the rock, faults or other foundation defects, wherever directed by the Engineer/Engineer representative.
3. Standard mild steel pipes and all fittings for grouting shall be set firmly in rock or concrete where required. A standard coupling and wrapped nipple to facilitate removal of the pipe ends shall be attached to the grout pipe where embedded in concrete. The bond of these pipes in rock and concrete shall be 75cm in length, unless screwed to steel casings or directed otherwise by the Engineer/Engineer representative. Each pipe shall be anchored into the rock or concrete into which it is set and the space around the pipe shall be carefully sealed with grout or other suitable material. All pipes and fittings to be embedded in concrete shall be cleaned thoroughly of all dirt, greases, grout and mortar immediately before being embedded in the concrete or rock.
4. All grout pipes and accessories to be left embedded in concrete shall be carefully cleaned and protected against wearing or displacement while concrete is being poured. Both ends shall be protected to keep them from being filled with concrete during pouring of concrete. Grout pipes set in concrete shall end not less than 25 mm inside the finished surface of the concrete. When grouting is performed after the completion of concreting operations a standard coupling and wrapped nipple, to facilitate removal after grouting, shall be attached to the grout pipe and shall

extend outside the finished surface. The holes left upon removal of the wrapped nipples shall be filled immediately and completely with dry-pack mortar

PS 5.5.6.7 PACKERS

1. Packers are used to seal off or isolate a portion of grout hole that allows grout to be injected under pressure into a specified section of the hole. Packers are installed either at the top of the hole, also called the hole collar or at other locations along the length of the hole. The packers are set at the top of the hole for contact grouting. It is also most often installed at the collar of the hole for consolidation grouting operations, when the hole is grouted in single stage.
2. Holes are grouted using a single-packer or double-packer arrangements. In a single-packer arrangement the grout is discharged into the hole just below the location of the packers. In the double-packer arrangement, the grout is discharged into an isolated section of the grout hole located between an upper and lower packer. The single-packer arrangement is used in contact and most of the consolidation grouting operations. The double-packer arrangement is used to grout isolated sections in both consolidation and curtain grouting operations.
3. Common types of packers are double-tube packers, hydraulic packers, pneumatic packers or self-sealing packers, each used in accordance with the local rock conditions.
4. All packers used shall guarantee proper sealing of the respective borehole section and shall then be capable of withstanding pressures of up to **30 MPa** without leakage. The sizes of packers shall suit the various hole diameters and spacing of the expandable sleeves shall suit the stage lengths.
5. The type of packer used is subject to approval by the Engineer/Engineer representative, and the Contractor shall have all types required available on Site for immediate use.

PS 5.5.7 GROUTING OPERATIONS

PS 5.5.7.1 GENERAL

Grouting work and other pertaining operations in the Tunnel and Underground construction shall be carried out as approved by the Engineer/Engineer representative. The specified pressure for each particular hole or stage shall be as measured on the connection pressure gauge and not at the pump.

The procedures and grout mixes described below are general guidelines and may be altered in the field by the Engineer/Engineer representative to suit the conditions encountered and to meet the design objectives.

1. **Single-Stage Grouting:** The single-staged grouting will be performed by introducing the grout at the collar of the hole through a nipple or packer. The entire length of the hole is grouted in one operation.

2. **Multiple-Stage Grouting:** Multiple-stage grouting is performed by introducing the grout into a pre-determined section of a hole, blocked off by a packer. The grouting of the entire length of a hole is performed in successive stages, in either ascending or descending arrangement. Grout curtain rings at the tunnel plug shall be performed by multiple stage grouting.

   a) For an ascending grouting arrangement applied in stable ground, the hole is drilled to its full depth and flushed. Then the packer is placed at the top of the deepest section to be packer grouted, whereupon the section is water pressure tested, as directed before being grouted. The packer shall be kept in place until there is no further back-pressure and then moved to the top of the succeeding stage to be grouted and so on until the entire hole has been grouted.

   b) For a descending grouting arrangement applied in unstable ground, the grouting shall be performed in the downward sections from the collar of the hole. The hole shall be drilled to a pre-determined depth, corresponding to a grouting stage, and flushed. The packer shall be placed just above the section to be grouted, whereupon the hole shall be water pressure tested and grouted, as directed. The grout in the hole shall be flushed out before this hardens, but after it has attained its initial set. Then the subsequent stage of the hole shall be drilled and grouted. This procedure shall be continued until the entire hole has been completed.

PS 5.5.7.2 CONTACT AND CAVITY GROUTING

1. Low pressure contact or cavity grouting shall be carried out to fill all voids between concrete lining and concrete in the tunnel plug after cooling of the concrete, concrete permanent lining and primary lining, between the primary lining and the rock and between steel liner/penstock and concrete.
2. Water pressure testing will normally not be required prior to contact or cavity grouting.
3. Vent pipes for the release of air and water during grouting shall be provided at locations as directed or approved by the Engineer/Engineer representative.
4. Contact and cavity grouting shall be carried out at a relatively low pressure using neat cement or cement and admixture or cement sand grout as approved by the Engineer/Engineer representative and shall be continued until all voids are filled.
5. Cavity grouting should be done through drilling holes or steel grout pipes embedded in the concrete at crown of tunnel lining or plug concrete of overbreak cavities, or at closed space left between steel liner and second stage concrete.
6. Grouting in the tunnel crown area may require secondary grouting to completely fill all the void space due to overbreak. Such secondary grouting shall be done with expansive grout mixtures after the initial contact grout has been injected and set up.

7. Cavity grouting for tunnel crowns shall be carried out before any other grouting, which may be required, but not before the lining is at least 28-day age unless otherwise agreed by the Engineer/Engineer representative.

8. Grouting will be regarded as being satisfactory if the pressure can be maintained for at least 10 minutes without further grout take. 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.

9. Contact grouting shall be done at the highest safe pressure as directed but initially not exceeding 69 kPa (10 psi).

10. Grouting shall be initiated from the lower end and at the invert of a tunnel and the grout behind the liner displaced upward.

11. For shaft linings, grout holes or nipples shall be radially located and grouted from inside the shaft. Split spaced grout injection holes or nipples may be necessary in shaft liner grouting.

12. After completion of grouting, all grout pipe heads shall be plugged with hard mix mortar to make smooth surface.

PS 5.5.7.3 GROUTING BEHIND A STEEL LINER

1. This type of grouting, often called "skin" grouting, shall consist of placing neat cement grout in the annular space surrounding a steel liner or "can" to fill the void between the steel liner and the cast-in-place concrete final lining.

2. Grouting procedures are the same as those described in paragraph Contact Grouting with the following exceptions:

    a) Grout holes and sealing plugs shall be provided in the steel liner plates during fabrication. The pattern shall be as shown.

    b) Grouting equipment shall be such that sudden surges in pressure at refusal do not occur.

    c) Grout hole plugs shall be ground flush with the steel liner and finished smooth.

    d) After grouting is completed, the Engineer/Engineer representative will test the liner with hammer blows to determine if all voids are filled. If directed, additional grout holes shall be drilled and tapped to receive a nipple. The use of a cutting torch to cut-in and weld-on a nipple shall be prohibited.

    e) Any grout hole that is lost or damaged due to mechanical failure of equipment, inadequacy of grout supply, or Contractor error shall be replaced by another hole or holes at the Contractor's expense.

    f) The grouting of any hole shall not be considered complete until that hole refuses to take grout at a rate of less than 0.015 cubic meter of solids (cement) per 1/2 hour or 0.03 cubic meter of solids (cement) per 10 minutes at whatever grout mixture and pressure is being used.

PS 5.5.7.4 CURTAIN AND CONSOLIDATION GROUTING

1. Curtain and consolidation grouting of the rock shall be carried out in sections of the tunnel structures as shown on the Drawings or as directed. Additionally, consolidation grouting may be required during the excavation works, in order to consolidate the heading face or seal off inflow of groundwater. The curtain grouting will be carried out from the gallery formed in the concrete in the tunnel plug after completion of cavity grouting.
2. Consolidation grouting shall normally be performed in a single stage. However, certain geological conditions may necessitate multiple-stage grouting through a nipple or packer installed at the collar of the hole within the concrete in the tunnel plug and this is required in grout curtain rings at the tunnel plug. The grouting pressure for each stage shall be as determined by the Engineer/Engineer representative.
3. Grout shall normally consist of a water-cement slurry (w/c =0.5:1 to 1.5:1 by weight) with admixtures as applicable and directed. Grout to seal off the inflow of groundwater may also include a filler or a chemical as approved. The grouting pressure shall not exceed 10.0 MPa.
4. Grouting of a hole will be considered complete when the rate of grout take at the maximum grouting pressure is less than an amount set by the Engineer/Engineer representative, or otherwise directed.
5. Upon completion of grouting, the packer shall remain in the hole and the pressure maintained until the grout has attained its initial set.

PS 5.5.7.5 CONSOLIDATION GROUTING AROUND TUNNELS

For the tunnel galleries:

1. Consolidation grouting around the tunnel lining shall be performed after completion of the cavity grouting as follows or directed by the Engineer/Engineer representative:
   a) Holes shall be drilled in each case to a depth of 5m or more into rock as shown in the Drawings,
   b) Packer shall be set in the concrete lining, and grouted at that depth up to a maximum pressure equivalent to 150% of the design internal water pressure of the tunnel or other pressure decided by the Engineer/Engineer representative. The maximum grout pressure at bottom of the pressure shaft will be lower than 10MPa,
   c) Before grouting, abbreviated water pressure test shall be done

For the plug section of diversion tunnels:

2. The consolidation grouting shall be done after completion of the cavity grouting. Grouting pressure will be lower than 4MPa, or as directed by the Engineer/Engineer representative.

For the flushing tunnels:

3. Consolidation grouting around the tunnel lining shall be performed after completion of the cavity grouting as follows or directed by the Engineer/Engineer representative:

   a) Holes shall be drilled in each case to a depth of 3m into rock and packer shall be set in the concrete lining, and grouted at that depth up to a maximum pressure of 1 MPa;
   b) The holes shall then be drilled to a depth of 8m and grouted up to a maximum pressure of 2 MPa with a packer at a depth of 3m.

PS 5.5.7.6 CURTAIN GROUTING IN TUNNEL

1. The curtain grouting shall be performed after completion of the consolidation grouting.
2. The general purpose of curtain grouting is to achieve a permeability criterion of 3 Lugeon units. The build-up of the grouting curtain will be as shown on the Drawings or as directed by the Engineer/Engineer representative and shall be measured rock contact.
3. The grouting procedure will be concurrently adapted to the results of the water pressure test and test hole results and to observations made during the curtain grouting itself.
4. Initial details of suitable borehole directions, spacing, inclination and depth of curtain grout holes will be determined during performance of grouting tests at the locations of the tunnel plugs indicated on the Drawings, or as directed by the Engineer/Engineer representative. The curtains at tunnel plugs will generally be in the form of radial fans.
5. Curtain grouting shall be carried out using the following criteria, unless otherwise directed by the Engineer/Engineer representative.

   a) Curtain grouting shall generally be started by the drilling of primary holes. Secondary holes shall be located midway between the primary holes. Zones of third series holes (closure holes) may be necessary at the discretion of, and as ordered by, the Engineer/Engineer representative. No holes of subsequent series shall be drilled until grouting has been completed to the full depth in adjacent holes of the previous series. Locations of grout holes shall be as shown on the Drawings or as directed by the Engineer/Engineer representative.
   b) Grouting shall be carried out in stages adapted to properties of the rock (jointing, etc.) and the grout to be used, but the stage length shall not exceed 5m and shall be performed using the downstage method except where the Engineer/Engineer representative determines that the upstage method is acceptable.
   c) Packer shall be set in the concrete lining for the first stage (shallowest stage) of the hole.
   d) In downstage grouting, sufficient time shall be allowed for the grout to set before the next stage is commenced.

e) The water pressure test shall, where directed by the Engineer/Engineer representative, be carried out in stages before grouting. Permeability shall be measured in Lugeon units at the stage in the hole being tested. A stage needs not be grouted on its own, but may be included in the next stage where the permeability of the stage is less than 1 Lugeon or such permeability as directed by the Engineer/Engineer representative.

f) The grouting of each stage shall commence with a high mobility grout of the type most likely to penetrate the rock according to the jointing, etc. of the rock and of the results of the water pressure test, with the grout pressure being increased towards the maximum grout pressure described below.

g) Unless otherwise directed by the Engineer/Engineer representative, hydro-fracturing shall be avoided. The maximum grouting pressure shall be 1 to 1.5 MPa for the first stage and increasing as approved by the Engineer/Engineer representative for other deeper stages.

h) The viscosity of the grout shall then be increased if the pressure fails to increase to the required pressure per meter of depth whilst there is a high rate of take or be decreased if there is a rapid increase of pressure with a poor rate of take at high pressure. The viscosity of the grout shall be changed again, as appropriate, if the initial change of viscosity does not result in a satisfactory rate of take at the required pressure.

i) The Engineer/Engineer representative may instruct, as an alternative to changing the grout type, the technique of hydro-jacking to be adopted to increase the spread of the grout. The maximum grout pressure may be increased providing that surface heave is avoided. The hydro-jacking technique shall not be used in holes adjacent to the concrete lining.

j) During grouting, grout leaks shall be caulked, but if this cannot be achieved and the leaks are excessive, grouting shall be stopped and resumed later when the grout already injected into the leaking fissures has hardened. Precautions shall be taken to ensure that the grout does not enter other parts of the works such as drains. The Engineer/Engineer representative may order the establishment of level reference points, upheaval gauges, etc. to be observed as a check against uplift. Any possible movement shall be taken as an indication that the grouting pressure being used is excessive and it shall be immediately relieved.

k) Where grouting is practicable, the full grouting pressure shall be maintained constantly during injections. However, as a safeguard against rock or concrete displacement or while grout leaks are being caulked, the Engineer/Engineer representative may require the reduction of the pumping pressure or the suspension of pumping. After the grouting of the holes or connections is completed, the pressure shall be maintained by means of stopcocks or other suitable valve devices, until the grout has set sufficiently so that it will be retained in the holes or connections being grouted.

l) The grouting of a hole shall be considered complete (Grout refusal criteria) when the apparent lugeon value of zero is achieved at the maximum allowable pressure for that stage or as directed by the Engineer/Engineer representative. Pumping should be continued for at least 10 minutes at refusal. Upon completion, the packer shall remain in place and the pressure held for 15 minutes or until the excess pressure has dissipated. Unless otherwise specified by the Engineer/Engineer representative grouting of holes shall continue without interruption. The completed hole shall then be filled with thick grout.

PS 5.5.7.7 CANOPY TUBE GROUTING

Low pressure grouting shall be used to completely fill the canopy tubes and the entire annulus surrounding the tubes. For specific requirements refer to relevant item of work in these specifications.

PS 5.5.7.8 GROUTING CRITERIA FOR THE CONTROL OF WATER INFLOW AT FACE

1. Grouting ahead of the face will generally be considered in H&B drives when one or a combination of the following are encountered:

a) Sudden inflow exceeding 40 l/s occurs at the face, as jointly estimated by the Engineer/Engineer representative and the Contractor. In the case of disagreement, the flow from the face shall be measured 10 m behind the face using a method approved by the Engineer/Engineer representative.

b) Water inflow from a single pilot hole is larger than 10 l/s (assuming a 30 m pilot hole with 50 mm diameter). In such a case 2 additional pilot holes shall be drilled. If the total yield from three pilot holes exceeds 25 l/s, grouting (e.g., partial or full fan) shall be carried out as directed by the Engineer/Engineer representative.

c) Water inflow under high pressure is observed from pilot holes. The applicable pressure criteria will be determined by the Engineer/Engineer representative.

d) Unstable saturated ground ahead of the face is indicated by pilot holes or by significant worsening of conditions at the face.

e) The above criteria may be adjusted during construction by the Engineer/Engineer representative.

PS 5.5.7.9 CLOSURE OF HOLES AND CLEAN-UP

1. Upon completion of grouting and checking of any area, the holes shall be washed to remove all loose materials and laitance from grout. The Contractor shall then backfill the resulting voids left by the removal of the grout connections and loose material and the holes in the pipe sleeves with thick grout mix or dry-pack mortar to provide a smooth surface at least

equal to the undisturbed surfaces of the adjacent concrete or rock surface, as directed by the Engineer/Engineer representative.

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 pipes pushed down to the bottom of the holes and withdrawn slowly as filling proceeds after first blowing all water out of the holes.

3. If any hole shows signs of weeping water after being stemmed the hole shall be drilled out, re-grouted and re-stemmed without any additional payment.

4. Except otherwise requested by the Engineer/Engineer representative, all exploratory holes shall be backfilled starting from the end of the hole, with a thick grout. The collar shall be dry-packed upon completion of backfilling.

PS 5.5.7.10 CHECK HOLES

1. In order to check the effectiveness of grouting the Contractor shall drill additional percussion holes between one (1) and three (3) days after completing grouting in an area to enable water tests and possible supplementary grouting to be carried out. The number of holes required will be approximately 10 % of the holes and shall be spread over the grouted area as directed by the Engineer/Engineer representative.

2. Cored check holes to check the effectiveness of grouting operations shall be drilled as required by the Engineer/Engineer representative at any location, angle and depth within the range of the adjacent grout holes. The holes shall not be drilled until the grout is at least fourteen (14) days old.

3. Except as otherwise required by the Engineer/Engineer representative, check holes shall be grouted by the same method as for the grouting holes, to the same requirements as the original holes.

PS 5.5.7.11 AUXILIARY WORKS

Unless otherwise specified, all and any kind of works, materials, equipment, services, safety measures, etc., as well as, and if so, required by the Engineer/Engineer representative, all testing and sampling required for the completion of the drilling and grouting work shall be included in the unit price.

The following works, amongst others, shall be considered as being auxiliary works and being included in the unit rates:

a) all transportation of equipment to and from Site and any shifting of the same from one place of operation to another;

b) orderly disposal of any debris or spoil resulting from drilling, grouting or testing operations;

c) Supply of all flushing or other water at the working area and removal of surface water encountered at the place of operation;

d) all plant and equipment required for the adequate performance of the works;

e) lighting of the working area, as necessary;

f) all equipment for communication between the batching/mixing plant and the location of grouting activities.

PS 5.6 MEASUREMENT AND PAYMENT

PS 5.6.1 GENERAL

1. The Contractor will be remunerated for drilling and grouting in Tunnels and Underground Structures through the pay Items given in the Bill of Quantities. The unit prices and lump sums for these items shall cover all the Contractor's cost connected with drilling and grouting to the extent these costs are not covered by other pay items of the Works.

2. The unit prices for drilling and grouting in tunnels and underground structures shall include cost of mobilization of all necessary equipment, operation, maintenance during the works and demobilization at the end.

3. The estimated quantities given in the Bill of Quantities for drilling, water pressure testing and grouting are indicative only. The actual quantity will be determined by the conditions encountered in the course of the work. The Contractor shall not be entitled to additional payment beyond the unit prices indicated in the priced Bill of Quantities by reason of changes in the number and length of drillholes, grouted or un-grouted, by quantity of materials absorbed, by reason of the location of the drilling and grouting directed by the Engineer/Engineer representative, or by reason of the timing of the drilling and grouting works in relation to excavation, concreting and other activities.

4. No extra payment will be made for the following:

   a) drilling through steel ribs, steel lagging or reinforcing steel;

   b) installation and removal of grout stub pipes;

   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 the drilling of new holes to replace these;

   d) preparation and testing of trial mixes;

   e) the entire cost of cavity grouting, including the cost of furnishing and installing pipe and pipe fittings, of drilling holes, of hook-ups, and the cost of grouting materials in the tunnel plug concrete;

   f) pipes embedded in the concrete in the tunnel plug for drilling of grout curtain holes;

   g) grouting materials used in a mixture which have been prepared more than one hour prior to injecting or which have been lost due to improper handling or rejected due to improper mixing;

h) supply and injection of water;

i) plugging and caulking leaks during grouting;

j) protection of drainage system during grouting;

k) closure of the holes as specified and clean-up; and

l) preparation and submission of records and reports on grouting operations.

5. Measurement and payment will be made for the placing of grout including grouting materials as quoted in the Bill of Quantities.

6. Furnishing and installation of casing pipe shall be included in the respective unit rates.

7. Unit prices for grouting shall include drilling, cement, sand, silica fume and admixtures etc. entire cost of labour, equipment, processing, mixing, hooking-up to the hole, injecting grout, hole closures and clearing up based on the volume and or weight of materials injected as per specifications and drawings or as directed by the Engineer/Engineer representative.

8. Unit prices for grouting shall also include, the entire cost of supply, handling, transportation, storage and testing in accordance with the specification or as directed by the Engineer/Engineer representative.

PS 5.6.2 SPOT DRILLING OF 50 MM DRAIN HOLES UPTO 1.0 M LONG

a) Measurement for payment for drilling short drain holes will be by the number of holes drilled, in surface or tunnel excavations, as directed by the Engineer/Engineer representative.

b) Payment will be made at the unit price per hole 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.

c) If the Contractor intends to place short pipes for guides prior to sprayed concrete to avoid drilling through the welded wire fabric, the cost thereof shall be deemed to be included in the same unit price for drilling.

PS 5.6.3 SPOT DRILLING OF 50 MM DRAIN HOLES LONGER THAN 1.0 M.

a) Measurement for payment for drilling of drainage holes will be of the length of holes actually drilled in positions as directed by the Engineer/Engineer representative.

b) Payment will be made at the unit price per linear metre entered in the priced 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.

c) The unit price shall apply irrespective of the location, inclination or direction of the hole.

PS 5.6.4 SUPPLY AND INSTALLATION OF PVC PIPES 50 MM DIA.

a) Measurements for payment of PVC pipes installed in the drainage holes as directed by the Engineer/Engineer representative will be of the length of pipe as installed.

b) Payment will be made at the unit price per linear metre entered in the priced Bill of Quantities, which shall include the entire cost of supply and installation of perforated or un-perforated pipes, as well as all necessary couplings.

PS 5.6.5 SUPPLY AND INSTALLATION OF DRAIN HOLE CLOSURE DEVICES

a) Measurement for payment for the supply and installation of drain hole closure devices will be of the number installed.

b) Payment will be made at the unit price per piece entered in the priced Bill of Quantities, which shall include the supply and installation of all required accessories and sealing with mortar.

PS 5.6.6 SUPPLY, INSTALLATION AND REMOVAL OF PRESSURE GAUGES

a) Measurement for payment for the supply and installation of pressure gauges will be by the number of gauges installed.

b) Payment will be made at the unit price per piece entered in the priced Bill of Quantities, which shall include the supply, installation and removal of the pressure gauge, including pressure relief valve and all necessary pipe and fittings, grouting work around the drain pipe, and eventual re-drilling through the concrete lining and placement of commercial repair mortar when pressure measurements are no longer required.

PS 5.6.7 DRILLING OF PILOT HOLES WITHOUT CORE RECOVERY

a) Measurement for payment for drilling of pilot holes will be of the length of holes actually drilled.

b) Payment will be made at the unit price per linear metre entered in the priced Bill of Quantities, which shall include the entire cost of labour, equipment and materials for provision and setting-up drilling equipment, drilling of the holes and, reporting.

c) The unit price shall apply irrespective of the location, inclination or direction of the hole.

PS 5.6.8 DRILLING OF EXPLORATORY HOLES IN TUNNELS WORKS WITH CORE RECOVERY

a) Measurement for payment for drilling of exploratory holes in the tunnel will be by the length of holes drilled in positions as directed by the Engineer/Engineer representative.

b) Payment will be made at the appropriate unit price per linear metre of drillhole entered in the priced Bill of Quantities, which shall include the entire cost of labour, equipment and materials required for rotary drilling holes, core recovery, provision of core boxes, preservation and storage of cores, preparation of technical logs of the drillholes, and any assistance provided by the Contractor to the Engineer/Engineer representative during the geological logging and handling of core boxes.

c) The unit price shall apply irrespective of the location, inclination or direction of the hole.

PS 5.6.9 WATER PRESSURE TESTING

a) Measurement for payment for water-pressure tests will be of the number of tests satisfactorily performed, irrespective of size, length, or inclination of hole.

b) Payment will be made at the unit price per test entered in the priced 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/Engineer representative, and all costs associated with interruptions to the drilling caused by the intermittent nature of the testing work.

PS 5.6.10 CONTACT GROUTING:

(a) CONTACT AND CAVITY GROUTING IN TUNNEL;

(b) CONTACT GROUTING BETWEEN STEEL/PENSTOCK LINING AND CONCRETE;

(c) CONSOLIDATION AND CURTAIN GROUTING

1. Measurement for payment for contact, cavity and consolidation grouting shall be by the weight (kg) of cement consumed in the grout mix. The unit rate include setup, drilling through rock/ concrete, cement, sand, admixtures, plant & equipment, transportation, handling, labour and testing at locations shown on the Drawings or established by the Engineer/Engineer representative. The Contractor shall note that:

   a) Payment will be made at the unit price per kg cement entered in the priced Bill of Quantities, which shall include the entire cost of drilling, grout material, labour, equipment, washing out of the holes, maintaining the holes free from obstructions, reaming or re-drilling the holes after completion of grouting and filling with commercial repair mortar. The unit price shall apply irrespective of the location, inclination or direction of the hole.

b) When curtain grouting is carried out from the gallery in the tunnel plug concrete, no separate measurement for payment shall be made for drilling in tunnel plug concrete irrespective of whether the hole was actually drilled through the concrete or formed by other means. The cost thereof shall be included in the appropriate unit prices for drilling or concrete.

c) When drilling of the hole is carried out successively for multiple-stage grouting (both ascending and descending), the measurement for payment of will be based on the total weight of cement in kg injected. Any re-drilling required because of the Contractor's failure to clean the grout out of the hole before it has set shall be at the expense of the Contractor.

d) Measurement for payment for any required re-drilling and grouting where the grout has been allowed to set at the direction of the Engineer/Engineer representative will be of the actual weight of the grouting material.

e) No additional payment or allowance will be made for hindrance or delay caused by grouting operations or by drilling of grout holes.

CHAPTER NO. 06

UNDERGROUND SURVEYING AND PROFILE CONTROL WORKS

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ITEM PS – 6: UNDERGROUND SURVEYING AND PROFILE CONTROL WORKS

PS 6.1 DESCRIPTION

This chapter specifies requirements for all surveying works, above ground & underground and performing a careful and systematic checking of the final clearance of the primary tunnel lining in order to accommodate the designed nominal thickness of the inner (secondary) concrete lining without interfering with the clearance requirements of the underground structure.

General surveys and tunnel profile control works will not be paid separately. Costs for all the survey and profiling works shall be included in the unit rates of the Priced Bill of Quantities for underground excavation works.

PS 6.2 CONSTRUCTION REQUIREMENTS

PS 6.2.1 SURVEYING WORK

The Contractor shall provide all services for topographic survey and measurements as required for the execution of the works and performance of all obligations under the Contract. The Contractor shall clear and maintain sight lines to establish direct view between neighboring control points as necessary in the basic network. He shall secure and maintain all control points until his works are completed and he shall re-establish to the same standard any point damaged or destroyed during the construction period.

PS 6.2.2 SETTING OUT FOR THE WORKS

The Contractor shall check all GPS monuments, benchmarks and other relevant data in the basic networks established previously during the main dam & coffer dam joint survey's, to confirm co-ordinates, elevations, distances and directions, submit a report showing the results of control measurements and in writing approve their sufficiency for his works or propose corrections.

Based on these data, the Contractor shall establish all additional control points and benchmarks necessary to determine the exact alignment of the diversion tunnel. It is the Contractor's responsibility to maintain all control points. Control points shall be the center of a 12 mm diameter pin set to protrude 3 mm above the top of a 0.25 x 0.25 x 0.30 m deep concrete block, embedded 0.25 m into the ground. The level and/or other markings shall be painted on the surface of the concrete block as directed by the Engineer / Engineer representative.

The Contractor shall set out the lines and levels of surface excavation and earth works at intervals of not more than 25 m or as required for constructing the works. For the tunnel excavation the Contractor shall establish, and continuously extend, an all-time available

alignment and benchmark control system for checking the location of the working face and setting out the next round.
A properly maintained laser-based system shall be ensured throughout the underground excavation work.

Tunnel control surveys, based on the GPS basic control network, shall be carried out when the tunnel has been excavated through the curve and further 200 m of the straight alignment. A comprehensive report from such basic controls shall be presented to the Engineer / Engineer representative.

During excavation the Contractor shall use a continually operating laser-based guidance system. Geometric control shall take place as soon as possible after excavation, and before any application of shotcrete.

The Contractor shall put chainage marks on the tunnel wall at 10m intervals. The chainage marking shall be carried out with clearly visible spray paint, and the accuracy shall be within 250 mm.

The Contractor shall take full responsibility for the correctness and accuracy of his survey work and for the actions of the personnel engaged in it. He shall supply all such stakes, templates, ranges, gauges, precision survey instruments and other tools and materials required, and all labour necessary in setting out and checking any part of the work.

The Contractor shall submit comprehensive reports on all his survey and setting-out work, for control and approval by the Engineer / Engineer representative. Any approval by the Engineer / Engineer representative shall not relieve the Contractor of his full responsibility for the accuracy of measurements and for structures, and parts thereof, having positions and dimensions within the tolerances specified.

PS 6.2.3 METHOD OF PROFILE CONTROL FOR FINAL CONCRETE LINING

1. It is the Contractor’s responsibility to ensure that the minimum clearance for the final (inner) concrete lining, as shown on the drawings, is provided.

   In order to establish deviations from the theoretical profile the Contractor shall provide a gantry furnished with a template set to show the minimum profile required for the nominal thickness of the final concrete lining.

2. The Contractor shall submit full details of the design of the gantry (steel shutter) with its template and methodology with regard to the systematic checking of the geometry of the template during profiling operations, for approval of the Engineer/Engineer representative.

3. The gantry shall be designed to move along the rail tracks, laid on the footing beams, for the movement of the tunnel shutter and is to provide access for the

marking out of the areas of the initial lining which protrude into the minimum clearance zone. The gantry may also be designed as a working platform for the re-shaping of the initial lining should this prove to be necessary and for the surface preparation work outlined in these specifications.

4. The Contractor shall be solely responsible for the accuracy in setting out and the construction of the footing beams with their cast in fixings which will align the rail track at each side of the tunnel and on which the tunnel shutter will be mounted.

5. The Contractor may prefer to use advance surveying techniques and data processing to establish the final clearance profile. In which case he shall define a method of marking out areas of deviation from the theoretical profile to be approved by the Engineer/Engineer representative.

PS 6.2.4 EXECUTION OF PROFILE CHECKING

1. Immediately after completion of primary support installation of each excavation round, the Contractor shall perform a profile check and submit the records to the Engineer/Engineer representative.

2. The checking of the final clearance shall not proceed before the geotechnical measurements show that the radial displacements at any position of the tunnel have, in the opinion of the Engineer/Engineer representative, largely stopped or reduced to less than 4 mm per month.

3. The final clearance profile for the inner lining, after the completion of support works of the tunnel, after surface preparation as described in these specifications and after deformation as per para (2) above of this sub-clause, shall conform to the minimum clearance profile as indicated on the drawings.

4. For the shotcrete lining, a deviation of the theoretical excavation line shall be as described in these specifications and/or agreed by the Engineer/Engineer representative otherwise, due to overbreak, construction tolerance and deformation etc. The surface irregularities shall not exceed 100 mm over a length of three (3) meters.

5. Tunnel profile control shall be carried out either continuously by using a gantry furnished with a template or at least every 2.0 m by using advanced surveying techniques.

6. In case of an existing under-profile, the Contractor shall submit a proposal for the remedial works to the Engineer/Engineer representative for approval.

7. No reshaping (re-profiling) of the tunnel support shall be carried out without the approval of the Engineer/Engineer representative.

8. Any deviations from the theoretical clearance for the inner lining shall be made good as approved by the Engineer/Engineer representative, either by providing extra shotcrete or a thicker inner concrete in the case of excess clearance, or by reshaping any parts of the tunnel support protruding into the clearance profile. Contractor is responsible for these works without any extra payments.

9. Geotechnical measurements before, during and after the respective reshaping measures shall be carried out in compliance with the relevant design. The measurement points such as convergence bolts and/or extensometers shall be retained or substituted well in advance in order to establish "transfer - zero - readings" and it will not be paid separately.

10. Geotechnical measurement stations shall not be removed and abandoned without the approval of the Engineer/Engineer representative.

PS 6.2.5 TUNNEL PROFILING RECORDS

1. Records shall be kept for each stage of the remedial measures executed and shared with the Engineer/Engineer representative.

2. The final clearance profile shall be recorded at intervals and at points along the periphery of the tunnel in longitudinal direction, as proposed by the Contractor and approved by the Engineer/Engineer representative.

3. The recording can be executed by means of clearance profile measuring carriage equipped with sensors (contact method). In such a case, the protocol on the clearance profile shape shall be prepared for at least every 5 meter in the tunnel longitudinal direction or as approved by the Engineer / Engineer representative otherwise.

4. Alternatively, the clearance profile can also be recorded by introducing a non-contact method (manually or automatically). The protocol on the clearance profile shall be made for at least every 2 meter in the tunnel longitudinal direction. The clearance profile control shall be performed by the Contractor in compliance with the Engineer’s / Engineer’s representative instructions.

5. For the shotcrete lining, the final checking of the clearance profile after completion of re-profiling and surface preparation in compliance with these specifications shall be done in presence of the Engineer / Engineer representative.

PS 6.3 CONSTRUCTION TOLERANCES

PS 6.3.1 TOLERANCES FOR HORIZONTAL AND VERTICAL ALIGNMENT

The tolerance given below shall be the maximum permissible deviations from the specified dimensions, levels, alignments, positions etc., as shown on the drawings and /or otherwise agreed by the Engineer/Engineer representative.

In addition, at the interfaces with mechanical components, concrete surface be finished flush and shall also meet any additional tolerances required by the mechanical designs or works, respectively.

a) Determinations of center lines for alignment of tunnels shall meet the following criteria:

- 10 mm / Km horizontal and vertical offset of the tunnel axis
- max. 60 mm horizontal and vertical offset of the tunnel axis at the breakthrough points of the headings

b) Slopes and Slope displacements shall be measured with an accuracy of +5 mm.

PS 6.3.2 TOLERANCES FOR LINING

a) No reduction of the theoretical thickness of the inner lining is permitted unless approved by the Engineer/Engineer representative. To achieve this requirement, no support elements such as primary shotcrete, rock bolts, lattice girders and steel ribs etc. shall penetrate into the theoretical outer boundary of the inner lining, as shown on the drawings.

b) In the area of the invert and the foundation beams, no rock parts or rock peaks shall protrude into the theoretical excavation line.

PS 6.3.3 TOLERANCE FOR EXCAVATION LEVEL ON INVERT

a) For tunnel sections with no concreted invert arch, the Contractor shall excavate the bottom level of the invert with an accuracy of +0 to -100 mm related to the theoretical excavation line of the invert.

b) If the bottom excavation level, after cleaning mud, loose materials etc. is more than 100 mm below the designed theoretical excavation line, the Contractor shall backfill such areas up to the designed, theoretical level by means of sub-base material or as directed and approved by the Engineer/Engineer representative.

c) For tunnel sections with a concrete invert arch or shotcreted invert, no reduction of the designed, theoretical thickness of the concrete structure is permitted. Over-excavation must be compensated with structural concrete or shotcrete for the invert arch as specified. The inside face of the concrete invert arch shall deviate not more than ± 50 mm in elevation from the theoretical cross section.

CHAPTER -7

SECANT PILE WALL

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SECTION PS – 7.0 SECANT PILE WALL

PS 7.1 DESCRIPTION

This item of work shall consist of furnishing all materials, labor, tools, equipment, services and incidentals necessary to construct the secant piles in accordance with the Drawings, General / Supplementary Specifications, and these Particular Specifications. In the event that these specific specifications cause conflict or ambiguity with the general specifications, these particular specifications shall take precedence unless otherwise accepted, in writing by the Engineer/Engineer representative.

To decrease soil permeability and control seepage through the Dam foundation, Secant pile wall, to act as positive cut-off wall, shall be constructed by drilling a series of 1.0-meter Ø overlapping “primary” and “secondary” holes to the specified depth and filling with cement-bentonite (C-B) or cement-clay-bentonite (C-C-B) slurries. The primary piles shall be constructed first, followed by secondary piles, which are cut into the previously placed, unreinforced consolidated primary piles. The amount of overlap required between the adjacent piles is a function of the seepage cut-off design requirements and the installation tolerance that can be achieved.

The Contractor is deemed to have allowed, in the unit rate of the pile, for the implementation of all necessary measures, including the provision of all materials, labor and plant, for maintaining the stability of the sides of boreholes during secant pile installation and successful completion of the piles

PS 7.2 SUBMITTALS

28 days prior to proceeding for execution of work at site, the Contractor shall submit to the Engineer/Engineer representative for approval, the Construction Method Statement with specifically encompassing the qualification and experience of sub-contractor, as the secant pile cutoff wall installation requires a skilled and experienced contractor that understands drilling and concrete / C-B slurry placement methods.

The Contractor must understand that the successful performance of secant pile cutoff walls depends on continuity of the joints verticality and therefore shall be installed with tight tolerances. For such specialty work, the Engineer/Engineer representative shall review the sub-contractor's technical proposals for the job prior to award.

The Contractor's submittal for secant pile cutoff walls construction shall include the followings: -

a) **QUALIFICATIONS:**

- Onsite supervisor resume
- Previous C-B slurry / Concrete cutoff wall jobs of similar size and complexity
- The Contractor shall submit to the Engineer/Engineer representative for approval, written evidence to show that the persons who will be engaged in the works have had such experience.

b) **SECANT PILE CUTOFF WALL PLAN**:

- Bar chart construction sequence drawing that shows the dates of anticipated cutoff wall construction and completion.
- Anticipated production rates in linear feet / meter per day.
- Methods for ensuring alignment, depth, verticality, and overlap.
- Description of proposed drilling equipment and sequence of constructing the secant piles. Include secant pile diameters, width at overlapping intersection of piles, and methods of drilling through the specific materials at the site. Include methods of cleaning pile overlap joints. Include a description of proposed method to correct or replace secant piles that are deemed out of alignment tolerance or specified overlap requirements.
- Tremie equipment and tremie C-B slurry / concrete placement methodology.
- Methods to handle drilling slurry and slurry waste.

- Source of water for C-B slurry mix / concrete mix and water chemistry test results.

- If reinforced secant piles are required, the contractor must show how the vertical and lateral alignment of the reinforcement will be maintained during C-B slurry / concrete placement, type, and sequence of spacers.

The Contractor shall be responsible for the program and sequence of construction which is dependent on the rate of gain of strength of primary piles and which affects the time within which secondary piles can be formed. The C-B slurry / concrete mix may include additives to control the rate of gain of strength, particularly the primary piles.

Where the Contractor considers that alternative proposals for the C-B slurry / concrete mix are required then evidence of trial mixes should be provided to the Engineer/Engineer representative. The Contractor shall be responsible for the design of the self-hardening mix.

PS 7.3 TOLERANCES

a) POSITION

For efficient control of work (at cut-off level), the maximum permitted deviation of the pile center from the center point shown on the setting out drawings shall be +/-1 inch (25 mm) in any direction compared to an industry standard of +/-3 inches (75 mm) for layout based on surface staking.

b) VERTICALITY

Verticality tolerances of 0.5% (1 in 200) or stricter shall be adopted for secant piling drilling, compared with standard requirements of 1% to 1.5% (ACI 336.1) for drilled piers.

The contractor shall demonstrate to the satisfaction of Engineer/Engineer representative the pile verticality is within the allowable tolerance.

c) CORRECTION

Should piles be installed outside these tolerances affecting the design and appearance of the structure, the Contractor shall propose and carry out immediate remedial measure to the approval of the Engineer/Engineer representative at his own risk and cost.

PS 7.4 CONSTRUCTION REQUIREMENTS

PS 7.4.1 GENERAL

Successful secant piling projects require exceptional attention to drilling procedures, equipment, and quality control to ensure overlap is maintained. Drilling methods and equipment selection are integrally linked in the construction process.

The most critical aspect of constructing an effective secant pile cutoff wall is continuity of the wall. Very tight verticality tolerances are necessary to assure continuity especially in deeper cut-offs. This requires accurate drilling of each pile and the ability to achieve and verify accurate overlap of each secondary and primary pile. In addition to vertical accuracy, the lateral accuracy, as measured along the ground surface, is also important.

The Contractor is advised to use inclinometer at regular intervals for hole orientation checks or adopt **SONICaliper** or equivalent downhole survey techniques for verification of vertical accuracy. With the modern technology, the excavation wall can be profiled in wet or dry conditions. The sonar caliper (Soni Caliper) has the ability to virtually “see” foundation excavation shapes as constructed in water, polymers and other mineral slurries, giving the Engineer/Engineer representative, designer and contractor additional confidence that the end product is manufactured according to specification. The Soni Caliper can determine diameter, assess verticality, calculate volume and create images of the shaft or excavation. Using revolutionary software, it creates “as-constructed” images and calculations immediately after the shaft has been profiled. The type of instruments to be used for verticality assurance and control shall be subject to approval of the Engineer/Engineer representative.

1. **GUIDE WALL & SETTING-OUT**

   In order to ensure the alignment of wall and the extend of over cutting the primary piles and guiding the boring tools during initial boring works of bored hole, a guide wall or guide trench and templates shall be constructed at approximate 0.5m below the existing ground level prior to the commencement of boring works.

The location of permanent bored piles shall be set out and pegged by the Contractor's surveyor based on approved setting out drawings from the Engineer/Engineer representative and control points at site. The surveying details of each location to be recorded incorporating reduced level and coordinates.

Each individually surveyed pile position shall be protected from disturbance prior to commencement of boring works.

Two reference points to be installed equidistant at not less than 2.0m from the pile center location. A pilot hole of about 3-6metre deep shall be drilled at the pile location. The eccentricity and alignment of the pilot hole is then checked.

2. BORING

The Contractor shall carry out the works in accordance with the approved method statement.

The boring plant will be moved to the intended pile position for boring works. The kelly bar mounted with an auger is placed just above the pile point. The vertically of the Kelly bar shall be checked by means of a spirit's level and will be enhanced with the presence of the temporary guide wall. The auger is then lowered and boring operation commenced. During the boring operation, the bored hole shall be observed for its stability.

The bored hole shall also be filled with bentonite slurry as the drilling fluid; the bentonite is kept to within 0.4m from top of guide wall level in order to stabilized the bored hole. If hard material is encountered during the boring process, other coring tools may be utilized in order to penetrate into the hard stratum. The proposed drilling fluid mix design shall be submitted to the Engineer/Engineer representative for approval.

Excavations shall not be exposed to the atmosphere longer than is necessary and shall be covered at all times when work is not in progress. Pile excavated shall be cast within 24 hours unless otherwise agreed by the Engineer/Engineer representative. In the event of a rapid loss of drilling fluid from the borehole excavation and caused instability of bore, the excavation shall be backfilled without delay or other appropriate and approved remedial measures taken by the Contractor like installing temporary casing prior to resuming boring at that location.

The Contractor shall also carry out necessary grouting or sealing using suitable materials to control and prevent collapse of the boreholes or lost of drilling fluid or lost of C-B slurry / concrete during installation of secant piles.

If ground water is found in any hole in sufficient quantity or gushing out as to affect boring operations or excavations and removal of soil from the boreholes, or the sides of boreholes collapse, then a steel casing of appropriate size and length in conjunction with stabilizing fluid or other alternatives of sufficient strength shall be used to support the sides of the borehole and permit boring operations to proceed smoothly and safely. The temporary steel casing shall be driven into stable stratum if the bored bole is found to be unstable. The Contractor's boring equipment shall be able to sink a steel casing to support the sides of all boring.

Where the use of a temporary casing is required to maintain the stability of a bore, the bottom of casing shall be kept a minimum of 1 meter or more below the unstable strata to prevent the inflow of soil and the formation of cavities in the surrounding ground. The process of advancing the bore and the temporary casing shall be such that soil is not drawn into the bore from outside the area of the pile and cavities are not created outside the temporary casing.

The dimensions and quality of the casing shall be adequate to withstand without damage or distortion all handling, construction and ground stresses to which they will be subjected. The casings shall have an internal diameter not less than the specified pile diameter. They shall be free of significant distortion, of uniform cross-section throughout each continuous length and free from internal projections and encrusted concrete which might prevent the proper formation of piles. The joints of casings shall be reasonably watertight.

If temporary casings are damaged during installation in a manner which prevents the proper formation of the pile, such casings shall be withdrawn from the bore before pouring, repaired if necessary, or other action taken as may be approved to continue the construction of the pile.

Upon completion of boring, the bottom of the bored hole is thoroughly cleaned with the cleaning bucket prior to recycling of the bentonite. A submersible turbine pump attached to a tremie pipe is lowered to the bottom of the bored hole. The bentonite, loaded with soil particles in suspensions, is drawn off from the bottom of the bored hole and re-cycled through a recycling unit.

3. ROCK CORING

Rock coring shall means coring of sound bedrock using a coring bucket or approved method. The use of chisel shall not be permitted unless otherwise approved by the Engineer/Engineer representative.

When approved, the chiselling shall not cause loosening or collapse of borehole. Coring of rock other than the two items specified below shall not be considered as coring in rock, and will only be considered as boring in soil.

a) Rock socket length;

b) Cavity roof

Coring of inclined rock surface, limestone pinnacles, cavities and soil below boulder/floater shall be considered as boring in soils.

Socket length shall be measured from the flattened horizontal bedrock surface. This flat horizontal surface shall be probed using kelly bar or steel bar at a minimum of five positions over the borehole to confirm sound bedrock for socketing.

4. PRIMARY PILE

The primary piles shall be constructed first for the secant pile wall. The primary pile shall be filled with the specified strength & properties of C-B slurry or Concrete without any steel reinforcement.

5. SECONDARY PILE

The secondary piles shall be drilled in between the primary piles and overlap with the primary piles and poured with the specified strength & properties of C-B slurry / concrete after bored holes are properly washed / cleaned. The secondary pile formed by cutting into the primary piles to form the interlocking joint by using the specified coring tools. The boring process for the secondary pile shall only commence upon initial set of the primary piles or as approved by the Engineer/Engineer representative following the requisite slurry material testing in the laboratory.

Secondary piles boring adjacent to primary piles which have recently been casted and contain workable or partially set C-B slurry / concrete shall not be permitted.

For visual verification of piles continuity, a downhole video camera shall be used in every secondary hole to confirm that each side of the secondary secant pile hole properly intersect / overlap with the previously placed and consolidated adjacent primary secant pile.

6. REINFORCEMENT

Reinforcement cages, if specified in drawings, shall only be installed into the secondary piles as per the design requirement. Normally the reinforcement cages will be pre-fabricated on site; and upon completion of recycling the bentonite, the reinforcement cages will be lowered into the bored hole by means of as service crane. The reinforcement cages shall be equipped with round spacers to ensure that the specified minimum concrete cover to the reinforcement is maintained.

7. PLACING OF CEMENT-BENTONIT SLURRY / CONCRETE

C-B slurry / concrete shall be poured into the bored hole through tremie pipes. The tremie pipes are 270mm diameter and are made up of coupled section 0.5m, 1m, 2m, and 3m in length. As the level of slurry / concrete in the bored hole rises, the tremie pipe column is raised whilst always ensuring a minimum 2m embedment into the slurry / concrete in order to avoid bentonite inclusions.

C-B slurry is a self-hardening slurry which is prepared using a cement, clay and water slurry without the addition of soil. This slurry is typically a mixture of cement, bentonite and water (CB). The self-hardening slurry is used both as temporary excavation support during excavation and as final backfill after curing, with average compressive strengths of 15 to 30 psi. The tradeoff between the SB (Soil Bentonite) and CB methods is compressive strength for permeability, because cement-bentonite slurries achieve permeabilities in the **$1x10^{-6}$ cm/sec** range which is an order of magnitude more permeable than soil-bentonite backfill range of **$1x10^{-7}$ cm/sec.**

Before commencing the filling of the pile, the Contractor shall plan and reasonably demonstrate that a sufficient quantity of self-hardening C-B slurry mix is available to construct the pile in one continuous operation.

Removal of temporary casing, when used, shall be completed before the self-hardening mix within the casing loses its workability. No spoil, liquid or other foreign matter shall be allowed to contaminate the mix.

a) **WORKABILITY OF SELF-HARDENING MIX**
Self-hardening mixes shall be coherent and of a workability such that when in its final position and after all constructional procedures in forming the pile have been completed it shall remain sufficient workable.

b) **PLACING SELF-HARDENING MIX**

The self-hardening mix shall be placed using methods appropriate to the composition of the mix. These may include placing through a hopper attached to a length of tremie pipe and tremie methods in which case placement shall be in accordance with procedures outlined in these specifications. Other self-hardening mixes using proprietary methods shall be set out by the Contractor in his method of construction.

c) **TIME PERIOD FOR EXCAVATION AND PLACING SELF-HARDENING MIX**

The time period after a pile is excavated and before the self-hardening mix is placed shall not exceed 12 hours unless otherwise permitted. If temporary casing is used, this period shall start when excavation below the temporary casing commences.

8. EXTRACTING TEMPORARY CASING

All temporary steel casing shall be extracted immediately after the completion of pouring process. A Vibro-Hammer will be used to extract the temporary steel casing.

9. PRE-CAUTIONS

In the unlikely event of the sudden loss of bentonite slurry, the boring process shall be immediately stopped and backfilled the bored hole with soil by using the hydraulic excavator until the loss of bentonite slurry is stopped.

If a secant pile is deemed out of the vertical tolerance range or does not meet the specified minimum overlap requirements with the adjacent columns, the pile can be backfilled with lean concrete and redrilled. However, this method of re-drilling does not work in the holes, that are slurry supported and therefore temporary casing technique or other methods as approved by the Engineer/Engineer representative, shall be adopted.

10. **QUALITY MANAGEMENT**

The Contractor shall be responsible for quality control testing in accordance with these Specifications and the Engineer/Engineer representative will undertake quality assurance testing in accordance with these Specifications.

PS 7.5 MEASUREMENT AND PAYMENT

PS 7.5.1 MEASUREMENT

a) **PILE BORING**

The quantities to be paid for shall be the number of linear meters of primary and secondary pile shafts, measured along the axis from the pile tip elevation or the bottom of the excavation, including any rock-socketing, whichever is appropriate to the specified finished level of the pile head, completed and accepted by the Engineer/Engineer representative at the specified minimum OD), as shown on the contract documents.

Any additional pile lengths that may be necessary to suit the Contractor's method of operation or for any other reason shall not be included in the measurements.

Use of temporary casing for the convenience of preparing of boreholes and stability of walls, the same shall not be measured separately.

Repairs to the secant pile wall performed by the Contractor due to oversizing, over pouring, out of tolerance issues, excessive seepage, etc., as required by the Engineer/Engineer representative, shall not be measured for payment.

b) **POURING**

Placement of self-hardening C-B mix will be measured on a volume basis. The volume of C-B mix to be paid for will be the total number of cubic meters placed in the pile.

PS 7.5.2 PAYMENT

a) **PILE BORING**

The quantities of piling left in place and measured as provided above shall be paid for at the contract unit price per linear meter of piles as shown in the Bill of Quantities.

The pay items shall include full compensation for furnishing all labor, equipment, tooling, materials, and incidentals necessary to complete the drilling of the primary and secondary piles of the secant pile wall system. These pay items shall include full compensation for the installation and/or removal of guide walls, full depth temporary casing, and temporary working surfaces; for slurry and/or other drilling fluids; for the clearing and/or removal of known surface obstructions; for the lean concrete pouring and re-drilling of out-of-tolerance piles; drilling the boreholes for the drilled piles; for the handling and disposal of drill spoil, slurry, other drilling fluids, and waste concrete; for performing and providing monitoring and quality control services; and for providing all required documentation.

b) **POURING**

The quantities to be paid for shall be considered full compensation, for the furnishing and placement of all necessary self-hardening C-B mix in the primary and secondary piles, performing all relevant laboratory tests, labor, equipment, tools, fuel, welding, if needed, for performing and providing monitoring and quality control services; and for providing all required documentation, and other incidental expenses necessary to complete the item as directed by the Engineer/Engineer representative.

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CHAPTER -8

COFFERDAMS EMBANKMENT CONSTRUCTION

SECTION PS – 8 COFFERDAMS EMBANKMENT CONSTRUCTION

PS 8.1 DESCRIPTION

This Section of the Particular Specification applies primarily to the construction of the upstream and downstream cofferdam embankments. In the absence of information elsewhere in the Contract Documents, the principles outlined in the following Specification clauses shall deemed to be applicable to any other embankment constructed for the Project. Such embankment shall include, but not be limited to, river diversion cofferdams for other structures and road embankments.

The upstream cofferdam embankment, which will be later-on integrated with the Main Dam body structure, shall be constructed in accordance with the drawings, these Specifications and/or as directed by the Engineer/Engineer representative. The embankment shall comprise the following zones and features as shown on the drawings:

COFFERDAM BODY MATERIAL

a) Zone 3A: Transition Martial

b) Zone 3B: Rock Fill

c) Zone 1: Impervious earth-fill material (Main Dam clay core material)

The core of the cofferdam shall be constructed from sandy-gravel type material (transition material) which can be obtained from the main nullah bed and plunge pool excavations.

The outer most shell of the cofferdam body shall be of rock fill material, to provide stability to the cofferdam. Rip Rap material will prevent erosion of the upstream face by wave action. Both the materials which mainly composed of limestone will be obtained from the spillway, diversion tunnel and roadway excavations.

The main dam core zone will be extended to the upstream toe, underneath the rockfill zones – 3B and the U/s cofferdam structure. This arrangement of upstream impervious blanket will serve as a secondary safety measure for seepage control within the central riverbed reach of 95-meter length comprising of deeper overburden materials and will horizontally increase the seepage path, thereby further reducing the downstream pore water pressures and hydraulic gradient.

The upstream horizontal blanket of the impervious core zone (Zone-1) material shall be underlain by dual-zoned retention filter layers of 2A & 2B materials to safeguard against probable foundation erosion.

The thickness of the upstream impervious blanket under the U/s cofferdam shall be uniformly varied and adjusted from 10% of the maximum depth of the reservoir above the blanket at the dam inner filters and gradually reduced upstream to around 3% at the toe of cofferdam.

The upstream impervious blanket shall also be extended in future, if required under immediate remedial works due to any peculiar uncertainty in the limestone foundations.

COFFERDAM FILTER MATERIAL

Zone 2A: Fine Filter (Sand)

Zone 2B: Coarse Filter material

COFFERDAM UPSTREAM SLOPE PROTECTION MATERIAL

Zone 4: Riprap

Zone 2C: Geo synthetic membrane

The embankment shall be constructed to the lines and grades as shown on the Drawings provided that, at any time before or during construction, the Engineer/Engineer representative may vary the dividing lines between zones of the embankment and the position of the outside faces of the embankment.

The upstream face of the embankment and the downstream face of the embankment shall, when completed, present an appearance of uniform texture and general smoothness.

The Contractor's method and sequence of construction of the cofferdam embankment shall be in accordance with the proposals submitted with the Bid and with such modifications as are approved by the Engineer/Engineer representative from time to time.

At least 28 days before commencing any work on the embankment, the Contractor shall submit to the Engineer/Engineer representative a detailed method statement describing the proposed sequence of work.

PS 8.2 REFERENCE STANDARDS

ASTM D 422-63 – Standard Test method for particle size analysis of soils

BS 1377 Part 2, 4, 5, 7, 9: 1990 – Methods of test for soils for Civil Engineering purposes.

BS EN 1097-2 – Tests for mechanical and physical properties of aggregates. Methods for the determination of resistance to fragmentation.

BS 812-2 – Testing aggregates. Methods for determination of density

PS 8.3 SUBMITTALS

PS 8.3.1 SUBMITTALS BEFORE CONSTRUCTION

Not less than 56 days prior to the commencement of any quarrying and borrowing operation, the Contractor shall submit to the Engineer/Engineer representative for approval details of the proposed methods and procedures, as well as procedures and equipment that he intends to use to obtain material of the required quality, size and gradation as specified for each zone of the cofferdam's embankment.

All details, specifications and quantity of each piece of proposed equipment shall be indicated in a method statement, as well as the type and number of special equipment to be used in places inaccessible for the normal compacting equipment.

PS 8.3.2 SUBMITTALS DURING CONSTRUCTION

The Contractor shall submit all QC test results of construction materials, carried out by him prior to, and during the placement of the embankment material to the Engineer/Engineer representative. These test results shall be submitted as per schedule agreed by the Engineer/Engineer representative. In addition, quarterly reports summarizing the test results with format and content approved by the Engineer/Engineer representative shall be submitted by the Contractor.

The Contractor shall submit at monthly intervals the detailed embankment construction program, progress report and drawings depicting the embankment, including all work related to the instrumentation.

PS 8.4 GENERAL REQUIREMENTS

PS 8.4.1 FOUNDATION TREATMENT

The Engineer/Engineer representative will determine the suitability of each part of the foundation for placing embankment materials thereon.

Material shall not be placed in any Zone of the embankment until the foundation has been prepared in accordance with the appropriate provisions of this Specification and the Drawings and has been approved by the Engineer/Engineer representative.

Materials shall not be placed on any part of the foundation until that part has been dewatered, cleaned up, prepared and approved by the Engineer/Engineer representative.

Unless otherwise directed, all portions of exploratory trenches below the final excavation line shall be filled with material of the zone to be placed on that part of the foundation and shall be compacted as specified.

The Engineer/Engineer representative will generally direct that seams and other defects below the general level of the embankment foundation be excavated and filled or covered with the applicable materials specified, including hand grouting of open joints. The Engineer/Engineer representative may direct those seams and other defects be excavated and backfilled with concrete, or covered with shotcrete, and the abutment contact slopes be modified.

PS 8.4.2 MATERIALS

Material for construction of the embankment shall be obtained from the required excavations and borrow areas, as approved by the Engineer/Engineer representative.

Each load of material shall be placed in the embankment to produce the best practicable distribution of the material as determined by the Engineer/Engineer representative. For this purpose, the Engineer/Engineer representative may designate the locations in the embankment where individual loads shall be deposited.

If, during or after placement, material has become contaminated with material with topsoil or other objectionable material, the contaminated material shall be removed and replaced with material conforming to the specified requirements.

Fill adjacent to a concrete structure shall be placed and compacted with such equipment and in such manner that no damage is caused to the concrete structure.

The embankment shall be raised uniformly over the entire length of the embankment stage being constructed and no section of the embankment shall be higher than any other section without prior approval.

Where the Engineer/Engineer representative approves construction of any portion of the embankment to a higher elevation than an adjacent section, the slope between such sections along the cofferdam axis shall not exceed 1 vertical to 2 horizontal (1V:2H).

Immediately before placing materials against the sloping face of an already placed section, the sloping face shall be stripped to sufficient depth to remove those surface materials which are contaminated or do not meet the requirements of this Specification for moisture content and density and those materials in all zones which have, in the opinion of the Engineer/Engineer representative, been adversely affected by exposure to water or weather.

If, after such stripping, the surface of the exposed material is, in the opinion of the Engineer/Engineer representative, too dry or smooth to bond properly with newly placed fill, it shall be moistened and scarified to provide a satisfactory bonding surface before new fill is placed upon it. During compaction of new fill, the compaction equipment shall completely overlap the contact surfaces.

PS 8.4.3 RAMPS

Where temporary ramps are constructed on or in the embankment they shall be filled or removed upon completion of the embankment to leave the outside faces of uniform appearance and to the lines, grades and dimensions shown on the Drawings or directed.

Where ramps are constructed within the embankment shoulders, all material within the ramps shall be placed in accordance with the requirements of the Specification for each Zone. The side slopes of ramps shall not be steeper than 1 vertical to 2.0 horizontal in Zones 1 (Impervious clay core material).

As the remainder of a Zone adjacent to ramps is placed, the side slopes of the ramps shall be cut back a minimum of 1 m to remove any loosened or segregated material and the resulting material combined with new material before re-compaction in the relevant zone.

The Contractor will not be entitled for any additional payment for construction, maintenance and dismantling of access ramps and the cost thereto deemed to include in other items relevant to the work in the Bill of Quantities.

PS 8.4.4 STAGED CONSTRUCTION OF COFFERDAM EMBANKMENT FOR RIVER DIVERSION PURPOSES

The Contractor shall construct the embankment in stages, where necessary, to comply with his approved method of river diversion. Construction of embankment stages shall be restricted by the requirements in this Clause.

The Contractor shall limit the number of embankment stages to the minimum required for river diversion purposes only.

The slope of the completed stages perpendicular to the dam axis shall not be steeper than 1 vertical to 2.0 horizontal (1V:2H).

As a minimum level of protection, surfaces of the completed stages that may be exposed to river flow shall be protected against damage by methods such as:

a) Placing rip-rap or mattresses against the face of the completed embankment stages to provide protection to the completed embankment stage during floods.

b) Reinforcement and gridded mesh

Temporary protection to the surface of the completed embankment stages shall be removed prior to commencement of the adjoining stage.

Immediately before placing materials against a section of the sloping face of the completed embankments stages, the face shall be cut back to remove the material, which has dried out or no longer satisfies the specified density requirements or as and where directed. The Contractor shall carry out field density and moisture content tests to prove the existing material has been cut back sufficiently. The Contractor shall ensure that good bonding of all materials is made across the joint between the stages. As a minimum, the Contractor shall cut benches equal to one layer thickness into the existing stage surface to allow bonding and compaction across the joint, unless otherwise approved.

PS 8.4.5 TOLERANCES

After compaction, materials in the embankment shall not encroach into adjacent zones further than allowed by the tolerances specified in Table 8.1 measured perpendicular to the dam axis, and in a horizontal plane from the dividing line shown on the Drawings or adjusted by the Engineer/Engineer representative.

Table 8.1: Tolerances on Dimensions of Zones

Line	Tolerance	
	Towards dam axis	Away from dam axis
Outside faces of dam embankment:		
All relevant Zones	Zero	600 mm

Abrupt changes will not be permitted in the dividing lines between zones.

Except as otherwise approved or as specified, the differential height between adjacent zones, measured at the dividing line between zones, after compaction, shall be maintained within the limits specified in Table 8.2.

Table 8.2: Tolerances on Differential Height

Elevation	Tolerance	
	Minus	Plus
Elevation of Zone 3A	Zero	Zero

Portions of the embankment constructed to a higher level than the general level of the zone on the section of embankment under construction shall be constructed to the same general height in the direction parallel with the axis of the dam.

PS 8.5 CONSTRUCTION REQUIREMENTS

PS 8.5.1 ROCKFILL/ RANDOM FILL IN ZONE 3B

Rockfill/ Random fill in Zone 3B of the upstream coffer dam shall be of the same gradation as that of the Main dam and shall consist of a well graded mixture of particles of moderately to slightly weathered rocks, obtained from required excavations for the diversion channel, diversion tunnels, spillway, rock quarry, or other approved sources. After compaction, Rockfill/ Random fill shall be free draining such that it will not retain pools of water. The particles of rock shall not break down significantly during compaction. Such material shall be placed in layers not exceeding in thickness than the approximate average size of the rocks except that no layer shall exceed 0.8 meter of loose measurement and compacted by a vibratory roller.

The selection and initial processing of the Rockfill/ Random fill in Zones 3B shall be as given by the required properties in Table 8.3

Table 8.3: Required Properties of Zone 3B Random fill

Item	**Zone 3B**
Approved degree of weathering	Moderately to slightly weathered.
Approved rock strength	UCS = 30 MPa
Maximum thickness of layer after compaction	0.5 m

Size of largest particle	Up to 2/3rd to 3/4th of the compacted layer thickness
Maximum percentage fines less than 0.075 mm after compaction	5
Maximum percentage clay less than 0.002 mm after compaction	2

PS 8.5.2 MATERIALS PLACEMENT

Each load of material shall be placed in the cofferdams to produce the best practicable distribution of the material as determined by the Engineer/Engineer representative. For this purpose, the Engineer/Engineer representative may designate the locations in the cofferdams where individual loads shall be deposited.

If, during or after placement, material in any Zone has become contaminated with material from another Zone or with topsoil or other objectionable material the contaminated material shall be removed and replaced with material conforming to the specified requirements.

Fill adjacent to a concrete structure shall be placed and compacted with such equipment and in such manner that no damage is caused to the concrete structure.

Each cofferdam shall be raised uniformly over the entire length of the stage being constructed and no section of the cofferdam shall be higher than any other section without prior approval.

Where the Engineer/Engineer representative approves construction of any portion of the cofferdam to a higher elevation than an adjacent section, the slope between such sections along the axis shall not exceed 1 vertical to 2 horizontal. Benches of 2 m minimum width shall be formed along the limit of the raised section.

Immediately before placing materials against the sloping face of an already placed section, the sloping face shall be stripped to sufficient depth to remove any surface materials which are loose or do not meet the requirements of this Specification in any other way.

PS 8.5.3 TESTING

The Contractor shall carry out field density tests of 3A & 3B (Rockfill/ Random fill) materials using the methods appropriate for the material grading. The Contractor shall be guided by BS 1377 Part 9:1990 or ASTM equivalent as to which test is the most appropriate for the material, or shall be directed by the Engineer/Engineer representative. Field density tests shall involve methods such as water replacement, sand replacement and nuclear densometer methods. All tests shall be carried out in accordance with BS 1377 Part 9: 1990. The methods of testing shall be approved by the Engineer/Engineer representative.

The Contractor shall carry out field percolation tests using the open pit method described in BRE Digest 365. This test may be combined in the hole excavated for water replacement density tests, if carried out. Otherwise, a pit shall be excavated at least 1 m square in plan and two-layer thicknesses deep. The pit shall be filled with water without unnecessary delay, but in a controlled manner to avoid excessive erosion/ damage to the pit. The percolation rate shall be determined as the distance the ponded water surface falls in the pit over a measured time. The Contractor shall establish a secure datum over the pit to accurately measure the water surface drop. The test shall be continued for a minimum of 1 hour, unless the pit has drained dry or the Contractor has been otherwise directed. Measurements of the time taken for each 100 mm vertical drop in water surface elevation shall be made. The Contractor shall backfill the pit with Rockfill/ Random fill from the Zone tested and shall compact the material to the density requirement as specified for the remainder of the Zone.

The frequency of field density testing on Zone 3B materials of upstream coffer dam shall be as those specified in these specifications for the Main Dam materials.

Representative tests for the rate of percolation shall be carried out by the Contractor as shown in following Table 8.4:

Table 8.4: Frequency of Pit Percolation Tests on Zone 3A & 3B Materials

Zone	Frequency
3A & 3B	1 test per Zone 3A & 3B

Additional tests may be required if, in the opinion of the Engineer/Engineer representative, there is a change in material properties.

PS 8.5.4 TRIAL SECTION- PLACEMENT AND COMPACTION

PS 8.5.4.1 GENERAL

1. A trial embankment shall be constructed at a location agreed upon or as directed by the Engineer/Engineer representative. The objectives of the embankment are the following:
   - to assess the performance of the compaction equipment;
   - to assess the different methods of laboratory and field density determination;
   - to verify the appropriateness of the specified compaction equipment;
   - to verify the specified layer thickness and number of passes of the compaction equipment to produce the required field density;
   - to determine the effects of moisture conditioning; and
   - to determine the gradation and rate of percolation of the compacted Rockfill/ Random fill.
2. Trial embankments will be required for Zone 3A & 3B. The Contractor shall use fill material with the required properties. The fill shall be representative of the type and source approved for embankment construction. Construction methods for the trials, including compaction equipment, methods of conditioning and placement methods, shall be as specified for embankment construction.

PS 8.5.4.2 METHOD

1. The Contractor shall carry out the trials in a planned and controlled manner using personnel experience in earthworks and earthworks testing. Unless otherwise directed, the following approach shall be used:
   - Prepare a level area of 25 m by 30 m minimum dimensions for the trial embankment by stripping to a formation of completely weathered rock;
   - Establish a grid system sufficient to lay out a square grid at 1.5 m centers in each direction. The minimum number of grid points shall be an area with 4 lines of points in one direction and 5 lines of points in the other direction, giving a total of 20 grid points. The intention is to provide two ‘lanes’ of fill placement, each with 2 lines of grid points by 5 lines long, to allow for placement of fill

at two different moisture contents. The innermost gridlines for the two separate lanes shall be 3 m apart;

- Survey the foundation levels at each grid point;
- Spread the first layer of fill (Layer No. 1) at the thickness given in Table 8.8. The fill shall be spread over an area sufficiently large to allow for the top and last layer (Layer No. 4) to have a plan area of at least 12 m by 17.5 m, allowing for side slopes less than 1V:2H on all sides (notwithstanding access ramp). The Contractor shall provide suitable means of accurately controlling the layer thickness;
- One lane shall be placed at the moisture content representative of the material as excavated from the material source ('Lane 1'). The other lane shall be placed with 150 liters of water added to each cubic meter of Rockfill/ Random fill, unless otherwise directed;
- Perform one pass of the specified roller without vibration over the whole area, to smooth out the surface;
- Re-establish the grid and level survey all grid points to establish the loose lift thickness;
- Perform compaction as specified for embankment construction in 2 pass intervals up to a total of 10 passes. The roller shall travel at a constant speed over the whole area of fill placed, not just along the lines of grid points. Care shall be taken to ensure that only the set number of passes are given to any one area and that the wheels of the roller or tracks of the tractor do no disturb grid points, where possible;
- Level survey the grid points after each set of 2 passes, re-establishing the grid on the fill surface if necessary; and
- Repeat the process for each of the required layer thicknesses given in Table 8.8. Each subsequent layer shall be placed on the preceding layer.

2. The Contractor shall provide for access ramps at both ends of the fill trial, at least 5 m beyond the last grid lines required for surveying. In addition, a minimum of 3 m of fill shall be placed and compacted all-round the limits of the grid. Levels taken on fills shall, if necessary due to surface undulation, be taken using a levelling rod fitted with a 0.3 m square base that can freely rotate about the base of the rod. Levels shall be determined within an accuracy of ± 3mm.

3. The Contractor shall repeat the trials if they are not carried out to the satisfaction of the Engineer/Engineer representative, at no additional cost to the Employer.

PS 8.5.5 SLOPE PROTECTION

PS 8.5.5.1 UPSTREAM SLOPE – RIP RAP

The upstream slope shall be protected with excavated rock (Zone 4) material whereas the downstream slopes shall be protected with cobbles and boulders as shown on the Drawings or as directed by the Engineer/Engineer representative.

At no point shall there be more than 5m vertical height between the stone pitched slope and the current level of embankment.

The work shall consist of furnishing hand-set pitching laid dry to stabilize slopes or as a protection against water or other erosion to form a flat or cured surface as directed by the Engineer/Engineer representative. All materials regardless of type or kind shall be placed as per the lines and levels called for on the plans.

The Excavated rock/ stones shall comprise good, hard and durable broken boulders or pieces of rock. These shall be sound, dense, resistant to the action of air and water and suitable in all respects for the purpose intended. These shall conform to the following specifications. The depth of the stones and their weight shall be as under;

Stones ranging in weight from a minimum sixty (60) kg to a maximum of one hundred (100) kg, with at least 50 percent by weight of the stones weighing more than eighty (80) kg.

The bed upon which excavated rock (pitching) shall be laid, shall be firm or compacted of approved granular material of specified thickness and to the required grades and lines as shown on the plans or as directed and approved by the Engineer/Engineer representative.

The stones shall comprise roughly dressed and shaped, set on their edges with their longest dimension at right angles to the flow of water. These shall be securely bedded, breaking bond closely packed with any interstices locked and filled by selected stone spalls hammered in. The pitching specified in plans shall be placed by dumping and spreading in layers by hand or other methods approved by the Engineer/Engineer representative all to secure a stable mass.

The ends of pitched areas shall be protected from undermining by the use of edge stones at least twice the general size and weight set on end. In large or slope areas of pitching, key stones shall be provided at the rate of one per square meter, at least one and a half times the general size and weight, set on end.

The pitching to the batters of the earth works and diversions of waterways shall be carried down in trench to such a depth as will ensure a sound footing for the lowest course. Subsequent to pitching the trench shall be backfilled to normal ground level with approved, well compacted suitable material.

PS 8.6 MEASUREMENT AND PAYMENT

No separate measurement and payment will be made for complying with the requirements of Particular Specification Section 8 – Cofferdam Embankment Construction and the cost thereto shall be deemed to include under relative items of Construction of Main Dam Embankment.

CHAPTER -9

FURNISHING, DELIVERING AND LAYING STEEL PIPE AND APPURTENANCES

SECTION PS – 9.0 FURNISHING, DELIVERING AND LAYING STEEL PIPE AND APPURTENANCES

PS 9.1 DESCRIPTION

This specification covers the Contractor's duties and responsibilities for detailed designing, fabrication, manufacturing, transport, installation, erection, shop and site welding of 1.0-meter diameter mild steel pipe including fittings and appurtenances where required, protective coatings, testing and commissioning for the conveyance of raw water from the Dam site to Water Treatment Plant to be laid in, on or above ground or to be fixed on or built into other parts of the works, complete in all respects and in accordance with these specifications and Bill of Quantities.

The work shall include furnishing of all labor, materials, equipment, for excavation, sheeting, shoring, dewatering, pipe laying, jointing, testing, backfilling and any other work that is required or necessary to complete the installation as shown on the Drawings and as specified herein.

Except as specified otherwise, the requirements for protection, installation, subsequent pressure testing and flow measurement, shall apply to pipes, valves, flow meters and the like.

This Particular Specification shall be read in conjunction with the drawings, American National Standards Institute and American Water Works Association Specification ANSI/AWWA C200-97 for Steel Water Pipe 150 mm and Larger and American Petroleum Institute, API 5L Specification for Line Pipe.

All the pipes fabrication, welding, coating works shall be done in accordance with applicable AWWA standards or equivalent, and shall be completed to the satisfaction of the Engineer/Engineer representative.

Excavation and backfilling of pipe trenches shall be carried out as specified in the relevant sections of General specification for pipes.

PS 9.2 MATERIALS

MS welded Pipes shall be fabricated from mill certified hot rolled steel plates conforming to ASTM Designation A36.

Mild Steel pipe of size1000 mm diameter,8mm thickness shall be Straight seam full penetration butt-welded carbon steel pipe with fabrication according to AWWA C200.Fabricated fittings shall be according to AWWA C208.

A heat analysis of the steel used for the pipes shall be provided in accordance with Clause 3.2 of API 5L. Check analyses on the finished pipe shall be taken in accordance with Clause 3.3 and 3.4 of API 5L. The chemical analysis shall be in accordance with ASTM standard.

Standard length straight pipes shall be the maximum which the pipe manufacturer can produce by his normal processes and which can readily be transported to Site. Shorter lengths of pipe shall be supplied as necessary to enable changes of grade or direction to be made using joints capable of angular deflection as specified below.

Pipes shall be manufactured to the tolerances given in Section 6 of API 5L.

Pipes shall be subjected to non-destructive testing of welds in accordance with Section 9 of API 5L and shall be hydraulically tested at the place of manufacture in accordance with Section 5 of API 5L.

The exterior & interior surfaces of steel pipe and fittings to be installed underground shall be coated in accordance with AWWA Standard C203, or in accordance with AWWA Standard C214. If coated in accordance with AWWA C214, then the fittings will be coated in accordance with AWWA Standard C209.

The exterior surface of steel pipe and fittings to be installed above ground shall be cleaned, primed and painted, all in accordance with AWWA Standard C203, Section 1.2, Paragraph 3.

The following joint type as approved shall be permitted:

1. Butt-joint end preparation for pipe continuously field welded shall be according to AWWA C206 where shown on the Drawings.
2. Lap joints for pipe continuously field welded shall be according to AWWA C206 where shown on the Drawings.
3. Bell and spigot joints shall be according to AWWA C200 where shown on the Drawings.

Unless otherwise specified, special fittings and appurtenances shall be of the same material as the pipe.

Steel welding electrodes shall conform to the requirements of American Welding Society Specification AWS A5.1, "Specification for Mild Steel Covered Arc-Welding Electrodes," and/or as provided on drawings, except that they shall be uniformly and heavily coated (not washed) and shall be such a nature that the coating will not chip or peel while being used with maximum amperage specified by the manufacturer.

The Contractor shall provide the Engineer/Engineer representative with an affidavit from the manufacturer that the pipes materials, valves, fittings, meters and any other products or materials furnished under the Contract comply with all applicable provisions of these specifications, and that the items supplied comply with the relevant ASTM/BS/BS-EN/AWWA/ ISO 9000 series of quality standards or other recognized and acceptable international standards.

PS 9.3 CODES AND STANDARDS

The following codes and standards, for the design, fabrication/manufacturing, painting and installation of pipeline, valves, bends, manholes etc., shall be referred to as required.

1. **ASTM International (American Society for Testing and Materials)**

- ASTM A36 Standard Specification for Carbon Structural Steel
- ASTM A53 Standard Specification for Welded steel pipe
- ASTM A139 Electric-Fusion (Arc)-Welded Steel Pipe (NPS 4 and Over).
- ASTM A283 Standard Specifications for Low and Intermediate Tensile Strength Carbon Steel Plates.
- ASTM A333 Seamless and Welded Steel Pipe for Low-Temperature Service.
- ASTM A530 General Requirements for Specialized Carbon and Alloy Steel Pipe.
- ASTM A865 Threaded Couplings, Steel, Black or Zinc-Coated (Galvanized) Welded or Seamless, for Use in Steel Pipe Joints.
- ASTM A1005 Steel Line Pipe, Black, Plain End, Longitudinal and Helical Seam, Double Submerged-Arc Welded.
- ASTM A1006 Steel Line Pipe, Black, Plain End, Laser Beam Welded

2. **British Code of Practice**

- BS 534 Steel pipes, joints and specials for water and sewage.
- BS 2569: Part 1 Sprayed metal coatings: protection of iron and steel by aluminum and zinc against atmospheric corrosion.
- BS 2971 Class II arc welding of carbon steel pipework for carrying fluids.
- BS 3601 Carbon steel pipes and tubes with specified room temperature properties for pressure purposes
- BS 4129 Welding primers and welding through sealants, adhesives and waxes for resistance welding of sheet steel.
- BS 4147 Bitumen-based hot-applied coating materials for protecting iron and steel, including suitable primers where required.
- BS 4515 Welding of steel pipelines on land and offshore.
- BS 5500 Unfired fusion welded pressure vessels.
- CP 2010: Part 2 Design and construction of steel pipeline on land.

3. **American Water Works Association (AWWA)**

- AWWA M11 Steel Pipe- A Guide for Design and Installation
- C200 Steel Water Pipe 6 inches (15 cm) and Larger
- C203 Coal Tar Protective Coatings and Linings for Steel Water Pipeline- Enamel and Tape- Hot Applied.
- C205 Cement-Mortar Protective Lining and Coating for Steel Water Pipe- 4 In. (10 cm) and Larger- Shop Applied.
- C206 Field Welding of Steel Water Pipe.
- C208 Dimensions for Steel Water Pipe Fittings.
- C209 Cold Applied Tape Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipelines.
- C210 Coal-Tar Epoxy Coating System for the Interior and Exterior of Steel Water Pipe.
- C213 Fusion-Bonded Epoxy Coatings and Linings for Steel Water Pipe and Fittings
- C214 Tape Coating Systems for the Exterior of Steel Water Pipelines.

- C222 Polyurethane Coatings and Linings for Steel Water Pipe and Fittings

4. **American Society of Mechanical Engineers**
   - ASME Section IX-Welding and Brazing Qualifications

5. **Society for Protective Coatings (SSPC)**
   - SSPC-SP 10 Surface Preparation Specification

6. **American Welding Society (AWS)**
   - AWS D1.1:2008 Structural Welding Code-Steel

PS 9.4 CONTRACTOR SUBMITTALS

PS 9.4.1 GENERAL

Within 30 days of the Notice to Proceed, the Contractor shall submit to the Engineer/Engineer representative for approval, technical product literature including the name of the pipe and fitting suppliers and a list of materials to be furnished, completely detailed working drawings and schedules of all MS pipe and fittings required, prior to each shipment of pipe, submit certified test reports that the pipe for this Contract was manufactured and tested in accordance with the ASTM and ANSI/AWWA Standards specified hereinabove.

The Contractor submissions shall include but not limited to: -

- Typical drawings of standard items
- Detail drawings of special items.
- Pipe, fittings and joint details including manufacturer, pressure/temperature ratings, material properties and thickness and lubricants.
- Design details of flanges outside the range of Reference Standards.
- External and internal protection and lining system details.
- Method of boxing out and building pipes into structure walls.
- Method for control of line and level of pipeline during installation.

- Welding procedure details including plant, method, weld materials, air testing of joints and names of welders.

- Thermal fusion jointing details including method, tools and equipment, procedure, testing programme and jointers' names, training and experience.

- Manufacturers' calculations, catalogues and data sheets.

The Contractor shall check all dimensions and quantities on the drawings or schedule given to the Contractor by the Engineer/Engineer representative, and shall notify the Engineer/Engineer representative of all errors therein which the Contractor may discover.

Upon completion of the work, the Contractor shall furnish to the Engineer/Engineer representative all such record or as-built work as directed by the Engineer/Engineer representative. No separate payment will be made for this work, compensation for such work shall be deemed included in other items.

PS 9.4.2 RECORDS TO BE KEPT

The Contractor shall keep detailed and up-to-date records in a form to be approved by the Engineer/Engineer representative of all pipes, fittings and pipeline appurtenances, the quantities of each type, size and class which have been: -

a) ordered during the course of the Works;

b) delivered during the course of the Works;

c) declared on delivery to be faulty, damaged or deficient;

d) broken, damaged or lost during the course of the Works;

e) repaired;

f) laid or installed.

Each week the Contractor shall provide the Engineer/Engineer representative with an up-to-date copy of the above records.

PS 9.4.3 CERTIFICATES OF TESTS

The Contractor shall forward to the Engineer/Engineer representative the following certificates, where relevant:

a) works tests on pipes and fittings;

b) material tests;

c) inspection;

d) welder qualification tests;

e) Non-destructive tests on completed welds.

All MS welded pipe and fittings shall be from a single manufacturer. The pipes to be installed under the project will be inspected at the foundry for compliance with these Specifications by the Engineer/Engineer representative. The Contractor shall require the manufacturer's cooperation in these inspections. The cost of foundry inspection of all pipe approved by the Engineer/Engineer representative,plus the cost of inspection of disapproved pipe will be borne by the Contractor.

Pipes shall not be shipped from place of manufacturer to site until completion of tests has been carried out to the satisfaction of the Engineer/Engineer representative

Inspection of the pipe will also be made by the Engineer/Engineer representative after delivery. The pipe shall be subject to rejection at any time on account of failure to meet any of the Specification requirements, even though pipes may have been accepted as satisfactory at the place of manufacture. Pipe rejected after delivery shall be marked for identification and shall immediately be removed from the job.

PS 9.4.4 METHOD AND PROGRAMME OF PIPELINE TESTING AND CLEANING

The Contractor shall submit for the approval of the Engineer/Engineer representative details of his proposed methods and programme for pipeline testing and cleaning (including details of test and cleaning equipment).

PS 9.5 CONSTRUCTION REQUIREMENTS

PS 9.5.1 FURNISHING AND DELIVERING STEEL PIPES AND APPURTENANCES

PS 9.5.1.1 GENERAL:

It is the intention of this part of the specifications to describe the materials and workmanship entering into the fabrication, shop testing and delivery of the items for an electric – fusion (ARC) welded steel main, 1000 mm diameter, 8mm thickness with all necessary appurtenances.

PS 9.5.1.2 WORK INCLUDED:

The Contractor shall furnish and deliver the steel pipe and appurtenances indicated on the drawings. Steel pipe and plate steel specials, shall comply with the requirements of these specifications and the American Water Works Association Standard for Steel Water Pipe 150 mm and Larger, ANSIIAWWA C200-97; where there may be a conflict between the AWWA Standard and these specifications, the Engineer/Engineer representative’s decision shall prevail.

PS 9.5.1.3 FIRST CLASS MATERIAL AND WORKMANSHIP

1. These specifications are intended to assure main water pipeline facilities from Dam site to Water Treatment Plant of great permanence and of maximum degree of reliability of service.

2. All materials, fixtures, fittings, supplies and equipment furnished under this contract shall be new, of standard, first grade quality, and of the best workmanship and design. No inferior or low grade, or obsolete articles will be approved or accepted, and all work of assembly, installation and construction shall be done neat, first class and workmanlike in manner. The apparent silence of the specifications as to any detail, or the apparent omission from them of a detailed description concerning any work to be done and materials to be furnished, shall be regarded as meaning that only the best practice is to prevail and that only the best material and workmanship is to be used; and interpretation of these specifications shall be made upon that basis. Should any conflict occur in or between the drawings and specifications, the Contractor shall be deemed to have estimated on the most expensive way of doing the work unless the Contractor shall have asked for and obtained a decision in writing from the Employer before the submission of the Contractor’s bid, as to what shall govern.

   In asking for prices on, or placing orders for, materials, fixtures, fittings, supplies and equipment intended for use or installation under this contract, the Contractor shall provide the manufacturer or dealer with such complete information from these specifications as may in any case be necessary and/or agreed in principle by the Engineer/Engineer representative, and in every case the Contractor shall quote in full to each such manufacturer or dealer the text of this paragraph, as well as the text of such other portions of the specifications as are appropriate.

The chemical and physical tests, including the optional tests, called for in the ASTM, and other specifications cited in this contract shall be made as specified, unless otherwise approved. The following statement shall appear on the face of every purchase order issued by the Contractor for work to be incorporated in this contract and the Contractor shall instruct approved manufacturers or dealers to place this statement on purchase orders issued by them for such work:

“This order is subject to inspection by Employer and Engineer/Engineer representative and shall not be processed until inspection instructions have been issued by the Engineer/Engineer representative.”

3. Whenever the characteristics of any required material are not particularly specified, such approved material shall be used as is customary in first class work of the nature for which the material is employed. The Contractor shall install any proprietary articles in full compliance with all recommendations of the manufacturers of such articles. Materials or equipment furnished for identical service or use shall be the product of one manufacturer, except as otherwise approved by the Engineer/Engineer representative.

PS 9.5.1.4 GEOMETRY OF PIPE:

To determine the definite horizontal and vertical alignment of the pipeline, the Contractor shall excavate test pits along the line of the work and prepare a pipe geometry. Based on field survey data and pipe geometry, the Contractor shall prepare the shop drawings and the schedule(s) of straight pipe, including random lengths and closure pieces, and of all bends and fittings, required to complete the work, and submit them to the Engineer/Engineer representative for approval.

PS 9.5.1.5 CHANGES IN ALIGNMENT AND GRADE:

The contract drawings illustrate the alignment and grades of the pipes based upon the existing substructures as shown on these drawings, and the work will be laid out approximately as shown thereon. Corrections in alignment and grades may be necessary as the trench is excavated. Test pits shall be done to minimize these corrections. Changes in the alignment or grades, from those shown on the contract drawings, and alterations of pipes, either in the shop or in the field, due to such changes in alignment or grade shall be made by the Contractor at his own expense.The Engineer/Engineer representative is the only one who shall make the determination to change the alignment or grade.

PS 9.5.1.6 CURVES AND OTHER SPECIALS:

Wherever changes in line or grade of the pipes make angles necessary, they shall be formed by cutting and beveling the ends of a sufficient number of courses to produce the desired total deflection or curvature. All bends less than 2-1/2 degrees shall be made up of straight pipe with miter cuts at the ends, these cuts being made in the shop. Closure or filler pieces of odd lengths shall be furnished and delivered by the Contractor as required and approved. The Contractor shall take careful measurements to determine the dimensions and curvature of all bends, closure pieces and other specials required, and shall be responsible for the accurate detailing and fabrication of same so that they will fit in the work. The shop drawings for all pipes, reducers, bends and other specials shall be submitted for approval of the Engineer/Engineer representative before fabrication.

PS 9.5.1.7 RESERVE CLOSURE PIECES AND BENDS:

If called for by a note on the contract drawings, the Contractor shall furnish, deliver and have in reserve, in advance of the delivery of the other pipe, certain random lengths or closure pieces and bends to be used at locations where unexpected obstructions or other difficulties may arise, requiring their immediate use to avoid leaving the trench open at such locations for long periods, or otherwise delaying the completion of the pipe line. The number and dimensions of such closure pieces and bends to be furnished shall be as given on the drawings or as directed by the Engineer/Engineer representative.

Any pipe, bend or special which is not called for in the drawings, or which is not required in the finished work, but which may have been delivered, shall at the finish of the contract, remain the property of the Contractor, or revert to him, and shall be promptly removed by him from the site of the work.

Where a piece of pipe has been cut, the remaining section may be incorporated in the work by the Contractor, provided the length is not less than 2.5 meter.

Sections less than 2.5 meter in length may be used, with the approval of the Engineer/Engineer representative.

PS 9.5.1.8 COATING AND LINING:

All steel pipe, specials, and fittings, fabricated of steel and lining plate, shall be lined on the interior and coated on the exterior as hereinafter described herein below "Lining and Coating of Steel Pipe and Appurtenances in the Shop and in the Field".

PS 9.5.1.9 MATERIALS:

Steel for plates of welded pipe shall be manufactured by one or more of the following processes: open hearth, basic-oxygen or electric furnace and shall fulfill the requirements of a carbon steel from the following table:

TYPE OF STEEL *	GRADE	YIELD POINT Psi (Min:)	TENSILE STRENGTH Psi
A36	---	36,000	58,000 to 80,000
A 135	B	35,000	60,000 min
A 139	B C D	35,000 42,000 46,000	60,000 min. 60,000 min. 60,000 min.
A 283	C D	30,000 33,000	50,000 to 70,000 60,000 to 75,000
A 572	42 50 60	42,000 50,000 60,000	60,000 min. 65,000 min. 75,000 min.
A 570	33 36 40 45 50	33,000 36,000 40,000 45,000 50,000	52,000 min. 53,000 min. 55,000 min. 60,000 min. 65,000 min.

***** The type of steel chosen by the Contractor to be used on this project shall conform to the minimum yield strength(s) and pipe wall thickness(es) as designated on the contract drawings. In the events of uunusual field conditions, the Contractor may require special designs. In these cases, pertinent calculations shall be submitted by the Contractor to the Engineer/Engineer representative for approval before commencing fabrications.

Pipe shall be furnished to meet the requirements specified herein these documents for longitudinal straight seam and circumferential girth seam manufactured electric-fusion arc welded product.

All materials shall be suitable for 150 pounds per square inch (psi) minimum working pressure unless otherwise indicated.

All specimens and records shall be furnished including analyses and tests made, as provided in the these specifications for Engineer/Engineer representative review and record.

The Contractor shall notify the Engineer/Engineer representative in writing at least five (5) days in advance of the date of rolling, sampling and testing of the plate. The Engineer/Engineer representative will then determine whether the Engineer/Engineer representative will be represented by a Senior Engineer/Engineer representative during the fabrication and test, or will, in lieu thereof, accept certified copies of the mill tests and analyses. Duplicate samples shall be furnished to the Engineer/Engineer representative whenever required. Two copies of mill test reports of all materials shall also be submitted to the Engineer/Engineer representative.

PS 9.5.1.10 THICKNESS:

a) **GENERAL**

Unless otherwise noted on the drawings, the thickness of steel plates for pipe and fittings which may be ordered by weight, shall be as follows:

Nominal Size of Pipe		Thickness		Nominal Weight	
inch	**mm**	**inch**	**mm**	**Lb / Sq-Ft**	**Kg / Sq-m**
30 and 36	760 and 900	3/8	9.5	15.3	74.7
48 to 72	1200 to 1800	1/2	12.7	20.4	99.6
-do-	-do-	5/8	15.9	25.5	124.5
-do-	-do-	3/4	19.1	30.6	149.4
-do-	-do-	7/8	22.2	35.7	174.3

b) **PIPE WALL THICKNESS ALLOWANCE**

Wall thickness as determined by design formulas shall be increased to provide for:

- Corrosion allowance;
- Tolerances for threading and machining, thinning allowance when pipe is to be bent;
- Pipe manufacturer's manufacturing tolerances

c) The following Corrosion and erosion allowances are specified as minimum requirement:

Material	Corrosion Allowance	Remarks
Carbon steel and alloy up to 9 Cr-Mo in dry service	1.6 mm	
Carbon steel and alloy up to 9 Cr-Mo in wet service	3.2 mm	
Galvanized steel	1.6 mm	
Stainless steel	0 mm	
Non-Metal such as GRP, HDPE, PVC, Non-metal lined, etc.	0 mm	

PS 9.5.1.11 DIMENSIONS:

Pipe fabricated for lap fillet welded field joints shall be made with alternate inside and outside courses without reduction in the thickness or in the nominal diameter which is the inside diameter of the inside course; with a clearance between the laps of the pipe of 1/8" (3 mm) maximum and 1/16" (1.5 mm) minimum, measured on the diameter, and similar to that shown on Drawing.

Pipe for lap fillet welded field joints may also be fabricated by cold expanding one end to form a bell or by shop welding a steel sleeve on one end, the inside and remaining outside joints being made in the field as shown on Drawing.

Pipe shall be not less than 30 ft. (9.0 meter) long except where shorter lengths are required and be manufactured by the electric-fusion (arc)-welded straight-seam welding method using rolled plates. All longitudinal seams, splice seams, and shop girth seams shall be butt-welded. The welding procedure chosen must be approved by the Engineer/Engineer representative before any production starts.

When the straight-seam manufacturing method is chosen, pipe 30" (760 mm) in diameter shall be made with one longitudinal seam. Pipe 36" to 48" (900 mm to 1200 mm) in diameter may be made with two longitudinal seams. Pipe 60" (1500 mm) and larger may be made with three longitudinal seams. On 900 mm to 1200 mm diameter pipes, the plate shall subtend a minimum arc of 150 degrees. On pipe 1500 mm in diameter and larger, the minimum arc shall be 100 degrees.

PS 9.5.1.12 FABRICATION:

All shearing, rolling, punching, fitting, welding and other shop operations shall be done in a shop having adequate facilities to produce sufficient pipe per daytime shift to enable the Contractor to fulfill the time requirements of this contract. Pipe fabricated from plate shall be cold rolled to the proper curvature for its entire length. The variation of the radius of curvature from the specified radius shall be held within the generally accepted limits of good workmanship.

There shall be no flat area along the longitudinal seams; the plate shall be crimped in a suitable press before rolling, or other special forming shall be employed to meet this requirement.

All surfaces to be welded shall be thoroughly freed from rust, scale and dirt before welding. Joint edges shall be smooth, uniform and free from defects that adversely affects proper welding. Surfaces and edges that are torch cut or air-arc gouged shall be· ground to remove slag and oxidation and be of the proper shape and contour for welding.

The longitudinal edges of the MS plate shall be shaped by press or by rolling to the true pipe radius. Hammering the edges to shape is not permitted. The plate shall then be properly formed and may be tacked preparatory to welding.

Mark bottom and top center lines on each and every pipe.

Grind inside longitudinal or spiral welds flush to the surface for a minimum distance of 50 mm from the ends of the pipe.

Longitudinal, splice and circumferential shop joints shall be double butt welded, with complete penetration by a method subject to the approval of the Engineer/Engineer representative. Peripheral joints of pipe and special fittings shall be accurately aligned and retained in position so that edges meet and surfaces coincide within 1/8" (3 mm). The welds shall be central to the seam with complete penetration and, with automatic welding; the weld reinforcement shall not extend more than 1/8" (3 mm). above the plate surface. The weld bead lying within the area of the contact surfaces of the field joint shall be ground flush with the plate.

Circumferential (girth) seams shall not be less than 2.5 meter apart for straight pipe, unless otherwise approved or directed by the Engineer/Engineer representative. The butt-welding joints used in the shop for these seams shall have the outside surface of the pipe coincide within one-sixteenth 1/16 of an inch (1.5 mm), and the adjoining plates within one-eighth 1/8" of an inch(3 mm), at the closest points.

The straightness of a 12-meter length of pipe shall not deviate more than plus or minus 13 mm from a straight line.

The roundness tolerances shall be as follows:

The circumference shall not be smaller than one-sixteenth (1/16) of an inch (1.5mm) or greater than one-eighth (1/8) of an inch (3mm) from the true circumference. Each of the diameters when measured on the zero, 120-, and 240-degrees axes shall not vary more than 3/16" (4.76mm) from the true diameter.

The inside of the pipe shall be prepared for the lining process, with cleaning of welds and weld spatter.

Unless otherwise specified, the ends shall be to the following standard:

Ends Type	Standard	Remarks
SW / SCRD	ASME B16.11	SW: Socket welding SCRD: Screwed (ends)
BW	ASME B16.25	Butt weld
Flanged	ASME B 16.5 and ASME B16.47 Series ‘B7 Taylor Forge/AWWA	
Threaded	ASME B1.20.1 (NPT, Taper Threads)	

PS 9.5.1.13 WELDING RODS, ELECTRODES, AND FILLER METALS:

All welding materials shall comply with the ASME Boiler and Pressure Vessel Code, Section II Material Specifications, Part C - Welding Rods, Electrodes, and Filler Metals or equivalent. Materials and procedures shall be such quality as will insure thorough full penetration and sound weldments. Any welding rod, electrode, flux, filler metal that shows undesirable properties during welding shall be rejected.

Welding rods for manual welding shall be of the low hydrogen type, conforming to AWS/ASME Designations E7018, E6018, E7016, or E6016 or as provided on drawings and required for the particular steel being used. Provision shall be made to store these electrodes in a dry place at the job or field site and to keep them free from moisture at all times until used.

The welding procedure specification (WPS), the procedure qualification record (PQR), and the welder/welding operator performance qualification tests (WPQ) in the shop or field shall be indicated on the shop "drawings as part of the general notes and must be approved by the Engineer/Engineer representative before any production can proceed.

Welding procedure specification (WPS) shall be drafted with the aim to provide direction for making production welds which will meet the code requirements. WPS should be made available for reference and review by the Engineer/Engineer representative representatives. It should also be made available with welding supervisors, welders actually involved in production of the weld.

The intended purpose of Welding procedure specification (WPS) and Procedure Qualification Record (PQR) is to determine that the welding operation proposed for fabrication are capable of producing welds with required properties for intended application with the assumption that the welder performing the welding procedure qualification test is a skilled workman. Procedure Qualification test is to establish the properties of the weldment and not the skill of the welders.

The welding procedures shall be qualified in accordance with the American Welding Society standard qualification procedures as given in: AWS 82.1, Welding Procedure and Performance Qualification, and AWS 010.9, Specification for Qualification of Welding Procedures and Welders for Piping and Tubing or ASME Section IX of the Boiler and Pressure Vessel Code.

PS 9.5.1.14 SPECIAL FITTINGS:

The design of bends and special fittings shall be subject to the approval of the Engineer/Engineer representative before fabrication. The term, special fittings, as used in this paragraph shall mean any bend or fitting of plate steel of which one or more peripheral joints are made in the shop, or any plate steel reducer. In general, the angle subtended by any one segment of a bend shall not exceed 15 degrees, and no circumferential (girth) seam shall intersect another. The radius of any bend, unless otherwise required and approved, shall be not less than two and a half (2-1/2) times the nominal diameter of the pipe. One out of every 10 bends or specials shall have a specimen cut out of each weld and tested, as per the requirements of “Test for Approval of Pipe” as specified herein below

- Fittings shall have dimensions as given in Standard AWWA C208 (R89), except where such dimensions conflict with these specifications or as directed by the Engineer/Engineer representative.

- Two miter cuts (i.e., one shop welded joint) is permissible for a maximum deflection of 15 degrees.
- Miter cuts for shop welded joints shall not exceed 7-1/2 degrees.
- Two shop-welded joints, (i.e., one intermediate segment) are required for angles greater than 15degrees, but not exceeding 30 degrees.
- Three shop-welded joints (i.e., two intermediate segments) are required for angles greater than 30 degrees, but not exceeding 45 degrees.
- Four shop welded joints (i.e., three intermediated segments) required for angles greater than 45 degrees, but not exceeding 60 degrees.

No separate payment for bends will be made and the cost thereto shall be deemed to include in the unit price bid per linear meter of the MS pipeline works.

PS 9.5.1.15 FIELD JOINTS:

Field joints, unless otherwise indicated on the drawings, shall be butt welded joints and in full conformance with AWWA C206. Welders in charge shall have the qualification stipulated in JIS Z 3801 (Japanese Industrial Standard) or AWS 010.9 and AWS 82.1.

Surfaces and edges to be welded shall be free from scale, rust and other foreign material. Edges that have been torch cut or air-arc gouged shall be ground to remove slag and oxidation. All edges must have the proper bevel and miter configuration as given by the Engineer/Engineer representative, approved welding procedures and as per AWWA Standard for Field Welding of Steel Water Pipe, ANSl/AWWA C206-91.

Welded joints in trench may be of the parallel short sleeve, spherical spigot and socket type with a circumferential full strength fillet weld both internally and externally. Welding gap tolerances shall be as specified on drawings. Full-strength fillet welds shall have a throat thickness not less than 0.7 times the thickness of the pipe to be welded.

Where pre-jointing of straight runs of pipe outside the trench is adopted, full-penetration butt welds executed by manual or automatic procedures to the approval of the Engineer/Engineer representative may be used. Butt welds shall have a throat thickness not less than the thickness of the pipe wall.

During welding, the pipe ends shall be securely held by an approved method ensuring a correct and uniform root gap.

At closing lengths where two plain ended pipes are to be joined by a welded collar joint, the gap between the two pipe ends shall not exceed 75mm and the collar shall be placed centrally over the two ends to be jointed. The end of each pipe shall be welded to the sleeve collar using circumferential full-strength fillet welds both internally and externally. Where a split collar is used, the two halves shall be drawn together by tie bolts until the gap between them is less than 3mm. The four circumferential welds shall then be made, after which the tie bolts shall be removed and the longitudinal seam between the collar pieces welded. The tie bolt lugs shall then be cut off and the attachment points smoothed before the welds are tested.

After completion of welding at each joint, magnetic crack detection tests shall be carried out on all fillet welds made and 100% radiographic examination carried out on all butt welds made. Alternately, as agreed by the Engineer/Engineer representative, Butt Welds may be inspected / tested either by Magnetic Particle (MT) or Ultrasonic Testing (UT) methods. All such tests shall be carried out by the Contractor in the presence of the Engineer/Engineer representative.

Where butt joints are being welded mechanically, the Engineer/Engineer representative may permit the proportion of weld radiographically examined to be reduced to 20% if and when and for as long as he is satisfied with the results being obtained. Where necessary, welds shall be repaired in accordance with Section 10 of API 5L. Weld repairs shall not be made more than once at any position on the joint.

Before starting the welding of pipe joints on Site, the Contractor shall submit for the Engineer/Engineer representative's approval details of the plant, methods and materials he proposes to use, including make and size of electrodes, number of runs, current strength, and arrangements for air testing of individual joints.

The Contractor shall submit the qualification of the proposed welders for the steel pipe jointing for the approval of the Engineer/Engineer representative. The Engineer/Engineer representative may request the Contractor to conduct special test welding session to verify the capability of the welders. The Contractor shall, when requested by the Engineer/Engineer representative make the necessary arrangement for such testing for joint welding at his own cost.

The Contractor should require the welding subcontractor to be qualified for the project, having a minimum experience of three separate projects exceeding the welding of 1200 mm dia. pipes, 1500 meter long and must provide a statement of qualification acceptable to the Engineer/Engineer representative. The Contractor shall ensure to hire a reputable company for undertaking the welding job and shall disallow piece work compensation for individual welders. Welded steel joints should be regularly inspected by an experienced and well qualified inspector in accordance with AWWA C206 to verify conformance to the Specification.

PS 9.5.1.16 FLANGED JOINTS:

Flanges for flanged joints, where called for or as indicated on the drawing, shall be standard steel hub or ring slip-on flanges in accordance with AWWA C207-94 (or latest revision thereof) Class E. Flanges shall be made from: -

- seamless forgings which meet the requirements of the Standard Specification for Forgings, Carbon Steel, for General-Purpose Piping, ASTM Designation A181-87, Class 70 or
- the Standard Specification for Forgings, Carbon Steel, for Piping Components, ASTM Designation A105- 87.

Flanges may also be cut as a single piece from steel plate conforming to the requirements of AWWA Standard for Steel Pipe Flanges for Waterworks Service - sizes 100 mm. through 3600 mm. ANSl/AWWA C207-94.

Flanges shall be either flat faced; that is, without projection or raised face as approved by the Engineer/Engineer representative and shall be welded front and back with continuous fillet weld size equal to the pipe wall thickness. Flanges shall be spot faced or back faced at the rear; such facing shall not reduce the minimum flange thickness by more than 1.5mm. The spot or back facing shall be in accordance with MSS (Manufacturers Standardization Society) Standard Practice SP-6-1985, Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings and MSS Standard Practice SP-9-1987, Spot Facing for Bronze, Iron and Steel Flanges.

Dimensions of flanges shall conform to Class E hub-type or ring-type slip on flanges in accordance with ANSl/AWWA C207-94 except for the bolt holes on insulated flanged joints. For insulated flange joints the bolt hole diameters shall be 3.0 mm larger than the table values for flanges of pipes more than 400 mm diameter.

Blind flanges shall be as per AWWA C207-94, Class E, ring slip-on type. Blind flanges shall be flat-faced.

Each flanged joint shall be drilled and tapped with a 6.0 mm hole for subsequent air testing as directed by the Engineer/Engineer representative.

Center gaskets shall be full-faced rubber with cotton cloth insertor epoxy/glass, 3.0 mm thick, with bolt holes and bolt circle to match the AWWA Standard Class E Type flanges for pipe 750 mm and larger in diameter. Material for gaskets shall be cotton cloth-reinforced SBR rubber or equal as approved by the Engineer/Engineer representative.

Bolts, nuts and washers for un-insulated joints shall be carbon steel to meet the requirements of the Standard Specification for Carbon Steel Bolts and Studs, 60000 PSI Tensile Strength, ASTM Designation A307-90, Grade B for bolts; ASTM A563-90, Grade A for nuts; and ASTM F844-90 for washers. The bolt head and nut shall be of the heavy hex series in accordance with the dimensions shown in ANSI 818.2.1 for heavy hex bolts; ANSI 818.2.2 for heavy hex nuts. Two washers per bolt (one on the inside head and the other on the nut) will be required. The washers shall be in accordance with ANSI B18.22.1, Type A, Table 18 (wide). All bolts and nuts shall be threaded in accordance with ASME 81.1-1989 (Revision of ANSI 81.1-1982) Unified Inch Screw Threads, Course Thread Series (UNG), Class 2A and 2B fit respectively and all surfaces shall be free of mill scale.

For insulated joints, bolts and studs shall be stainless steel Type 304 and meet the requirements of the Standard Specification for Alloy-Steel and Stainless-Steel Bolting Materials for High-Temperature Service, ASTM Designation A193/A193M-90, Grade B8A. Class 1A with a Class 2A thread fit. The thread bolt shall be the heavy hex type in accordance with the dimensions of ANSI 818.2.1-1981 and the Heavy Hex Screws Series. All bolts and studs up to 25 mm diameter shall be threaded with the coarse thread series (UNG) and with the 8-pitch thread series (8UN) when 28 mm and larger in diameter, except where tapped holes for flanged butterfly valves have UNG threads.

Nuts, for insulated joints, shall be Type 303 stainless steel and meet the requirements of the Standard Specification for Carbon and Alloy Steel Nuts and Bolts for High-Pressure and High Temperature Service, ASTM Designation A194/A194M-90, Grade 8FA, Class 1A, with a thread fit of Class 2B and with a machined washer face. The nuts shall also be the heavy hex head series in accordance with the dimensions of ANSI 818.2.2 and shall have thread pitch compatible to the mating bolt or stud. The threads shall be cleaned and lubricated with a thread lubricant before packaging the nuts for shipment by the manufacturer.

Washers, for insulated joints, shall be Type 304 stainless steel and comply with the chemical and physical requirements of ASTM Designation A193/A193M-90, Grade B8A, Class 1A material. The required washer diameter that matches a particular size bolt shall be used

All stainless-steel threaded fasteners and washers shall be cleaned free of all scale and shall have a bright finish, and be passivated in accordance with approved procedures as given in the Standard Practice for Cleaning and Descaling Stainless Steel Parts, Equipment, and Systems, ASTM Designation A380-88. All stainless-steel fasteners shall be made up, during both shop and field assembly, with a thread lubricant. The thread lubricant shall have properties that will prevent seizing and galling between the male and the female threads, reduce the torque required to tighten the fasteners, permit ready disassembly after many years of service in damp locations, and prevent contamination at the bearing surface of heads, nuts, and flanges. The thread lubricant shall be readily applied by brushing or dipping, have no detrimental effect on the gaskets used.

All bolts, carbon steel and stainless steel shall have a sufficient machined chamfer to ensure a sound starting thread. The Engineer/Engineer representative shall be notified in sufficient time prior to all tension tests and heat treatments so that arrangements can be made for QA personnel to witness the tests and heat treatments. If proper notification is not given, the tests and heat treatments may be disapproved. One test shall be made for each diameter of each heat. Steps shall be taken to ensure that heats are traceable.

Certified test reports and mill certificates are required for each material heat incorporated under this work. One chemical check is required for each heat of steel and two percent (2%) of the nuts; washers and bolts shall be checked for dimensional compliance in the presence of the Engineer/Engineer representative.

For all threaded fasteners the Contractor shall furnish a complete chemical analysis of each heat, made and certified by an approved laboratory, and shall furnish a certified statement of the heat treatment procedure.

PS 9.5.1.17 FLANGE JOINT HYDROSTATIC TEST IN SHOP:

Before being coated, each flanged lap fillet welded joint on the inside and outside of the pipe shall be painted with soap suds and tested with air at a pressure of 40 psi applied through the 6.0 mm tapped hole inside the pipe.

Any defect in the weld, indicated by air leak forming bubbles, shall be repaired by chipping out a section of weld not less than one inch (25 mm) either side of the defect and replacing the removed section. If, in the opinion of the Engineer/Engineer representative, the number of defects disclosed by the test are such as to indicate that the entire circumferential weld is defective, the entire weld shall be chipped out and replaced. Caulking of welds will not be permitted. All joints, in which welding repairs have been made, shall be retested. After testing, the 6.0 mm hole shall be welded shut. After satisfactory completion and acceptance of each welded joint, the coating, electrical testing and wrapping of the joints may be completed. Similarly, outlet connections and manholes welded in the field shall be air tested.

PS 9.5.1.18 TEST FOR APPROVAL OF PIPE:

Qualification tests shall be conducted prior to approval of the welding, coating and wrapping processes. For the purpose of these tests, all equipment required for rolling, welding, testing, cleaning, coating and wrapping pipe shall be installed and ready for operation in the shop or shops where the pipe is fabricated and coating applied.

Charpy V-Notch Impact Tests shall be performed on every heat of pipe coil. The samples shall be removed from the welded pipe when the weld test samples are removed as described hereinafter. The samples shall be machined in a set of three transverse specimens in accordance with ASTM A370 and tested at the temperatures shown and meet the following minimum requirements:

Test Temperature	Ft-lbs.
30° F	25
0° F	15

When using sub size samples (i.e., pipe thickness of less than 12.7mm) as specified in ASTM A673, the following minimum requirements shall be met:

Test Temperature	Ft-lbs.
30° F	19
0° F	11

Should the average ft-lbs of the three samples not meet the above requirements when tested at both temperatures, all the pipes manufactured from that heat shall be rejected.

A specimen of weld shall be cut from each of three pipes fabricated for approval of the welding process. One specimen shall be cut from each longitudinal seam or spiral seam, and one from each circumferential butt-welded seam, with the opening left with rounded corners.

Each specimen shall be large enough to furnish four companion test pieces, two for bending and two for tension. Each of these test pieces shall be at least 350 mm long, with weld running crosswise at its center, and shall be machined to a width of 37.5 mm. The weld reinforcement may be removed from each bending specimen. The welding process shall be approved if--

(a) The base metal tensile strength reached at failure shall meet the minimum requirements of **sub-clause PS – 9.5.1.9** of these specifications, for the carbon steel material used to fabricate the pipe.

(b) The tensile stress at failures that occur in the welds or heat-affected zones shall exceed 75,000 psi.

(c) To determine tensile strength, the ultimate load in pounds us divided by the cross section of the test piece, measured adjacent to the weld.

(d) Two test pieces are bent cold 180 degrees around a 62.5 mm diameter pin, with the weld in the center of the bend. The bend-test pieces shall be considered as having passed if no cracks or other open defects exceeding 3.00 mm measured in any direction is present in the weld metal or between the weld and base material after the bending. The direction of bending of one piece shall be towards the center of the pipe and· the other piece bent away from the center of the pipe.

If any of the pieces fails in its respective test, whether tensile or bending, approval of the welding process will be withheld and the pipe will not be accepted.

If the welding process is approved, patch plates of the same material shall be lap fillet welded inside and outside over the openings and the three lengths of pipe shall be tested in the hydrostatic press, as provided in **sub-clause PS – 9.5.1.20** of these specifications. Patch plates shall lap openings by at least 50.00 mm and welds tested by air pressure and soap solution. Welds shall be 7.94 mm minimum. Flush patches, double butt-welded, may be used, provided the pipe or special fitting is hydrostatically tested thereafter in conformance with **sub-clause PS – 9.5.1.20** of these specifications.

Complete records of the results of the bending and tensile tests shall be available at all times to the Engineer/Engineer representative at the point of fabrication.

These three lengths of pipe shall be then sandblasted, lined, coated, and wrapped by the mechanical means outlined in these specifications. The lining, coating, and wrapping process shall be approved if the requirements of the specifications are met.

The preliminary tests may be omitted with the approval of the Engineer/Engineer representative, where the process has been previously approved and not changed in any respect in the interim.

One length chosen at random out of every 20 lengths of straight pipe shall have a specimen of each welded seam cut out and tested. The specimen shall pass the tests outlined above, and patch plates installed as outlined above. Straight pipe shall vary from 9.00 meter to 12.00 meter in length.

The fabricator's attention is called to the inspection provisions in the lining and coating specifications, when the lining and coating is done in a plant other than that in which fabrication and testing take place.

PS 9.5.1.19 WELDERS TO BE QUALIFIED:

Welders and welding operators shall have sufficient experience in welding ferrous metals. In addition, all assigned welders shall be qualified by an approved laboratory prior to welding.

The Welder/Welding Operator Performance Qualification Test (WPQ) for field joint welding shall be performed as described herein below after the proposed welding procedures are approved by the Engineer/Engineer representative. The qualifying test can be done on a test plate or on a pipe in accordance to ASME Boiler and Pressure Vessel Section IX, governing pressure pipe welding as specified in ASME Section IX, QW-461.9 (Performance Qualification - Position and Diameter Limitations) and QW-202.1 (Type of Tests Required). The welding qualifications shall be based on the type and position(s) of welds to be performed and sizes of pipe on the project and shall be according to QW-461.9 and QW-202.1. The minimum qualifying weld position on plate is 4G and on pipe is 5G. The welding procedures will be qualified only if two tensile and four guided-bend test specimens are prepared and tested as specified in QW-150 and QW-160, and are accepted as specified in QW-153 and QW-163. The welder will be qualified if the test required as mentioned in QW-302 meets the requirements prescribed in QW-160. Alternately, welders may elect to be qualified for the combination of 2G, 3G and 4G on a test plate and 6G on a test pipe which will not restrict welders to the type of welding, welding position or size of pipe.

The tests shall be made at the Engineer/Engineer representative's approved testing laboratory and a written report of each test specimen shall be furnished to the Engineer/Engineer representative. The cost of equipment, materials and labor for all tests shall be entirely borne by the Contractor.

The Welder/Welding Operator Performance Qualification Test (WPQ) for shop welding shall be a vertical (3G) uphill groove weld in accordance with the Welding Procedure Specification (WPS) as specified in Section IX, 1989 ASME Boiler and Pressure Vessel Code in fabricating the carbon steel pipe. This WPS shall reference the supporting Procedure Qualification Record (PQR) which is the complete record of the welding data used to weld the test coupon and pipe. The format of the PQR, the WPS, and the WPQ are shown in Section IX of the Code. The test coupon shall be large enough for two tension specimens and four guided bend test specimens and the welder shall be qualified if the tests are positive as for field joint welding. A chemical analysis of the weld filler metal shall also be included for carbon, silicon, and manganese. There shall be at least one set of weld-test specimens taken of each size, grade, and wall thickness from work performed by each welding machine and each operator.

All qualifying weld procedures and tests for both the field and shop shall be witnessed by the representatives of the Engineer/Engineer representative and the approved laboratory.

PS 9.5.1.20 HYDROSTATIC TEST IN SHOP:

Before being coated, each completed straight pipe shall be tested and made tight at the shop under a hydrostatic pressure not less than that determined by the following formula:

$$P = \frac{2ST}{D}$$

Where:

P = minimum hydrostatic test pressure (psi)
NOTE: When the diameter and the wall thickness of the pipe are such that the capacity of the testing equipment is exceeded by these requirements, the test pressures may be reduced as approved by the Engineer/Engineer representative.

S = stress in pipe wall during hydrostatic test (psi), which shall be 0.75 times the specified minimum yield point of the steel used.

T = wall thickness (in.)

D = outside diameter (in.)

The test pressure shall be held for sufficient time to observe the weld seams. There shall be no leaks. Plate and/or welds shall be struck with a sledge of the weight specified in the ASTM Specification applicable for the material being used.

Special fittings shall be tested and made tight under a hydrostatic pressure of 150 lbs. per square inch, unless otherwise directed by the Engineer/Engineer representative.

Cracks in the weld not more than three inches (75 mm) in length may be repaired by welding, provided all the weld metal is removed at the sides of the crack and far enough beyond the end of the crack to ensure that sound metal has been reached. If any pipe under hydrostatic test develops more than one crack or a single crack more than three inches (75 mm) in length, the entire weld will be rejected.

All repaired pipe shall be subjected to the hydrostatic test specified above, and any completed pipe failing to meet the requirements on the third test will be rejected.

A general sweating of the weld under the hydrostatic test shall cause rejection of the complete pipe; peening with hammer or other tool will not be permitted. Hammer or similar marks on a weld, other than that authorized by the Engineer/Engineer representative, will be sufficient ground for rejection.

PS 9.5.1.21 GAUGING:

The ends of all pipe shall be measured with a circular gauge before leaving the shop, to ensure a proper fit and roundness at the joint, in accordance with **sub-clause PS – 9.5.1.12 of these specifications.**

PS 9.5.1.22 OUTLET CONNECTIONS:

Outlet connections shall be fabricated from carbon steel as specified herein below.

a) Plate steel for the outlet saddle may be Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates, ASTM Designation A283-88, Grade C or Grade D.
b) Pipe outlets, from 150 mm to 600 mm in diameter inclusive, shall be fabricated from pipe produced in a pipe mill according to the Standard specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless, ASTM Designation A53-88a, Type S Seamless, Grade B.
c) Pipe outlets 750 mm and larger shall be of the same material as the main pipe section. Flanges shall conform to requirements **sub-clause PS – 9.5.1.16 of these specifications.**
d) The cutting of pipe for inserting valves, fittings, or closure pieces shall be done in a neat and workmanlike manner, without damage to the pipe, so as to leave a smooth end at right angles to the axis of the pipe. Outside edge of cut pipe shall be beveled and smoothed to avoid damage to the gasket. Avoid damage to the lining.

Before being coated, each flange, reinforcement collar and manhole saddle shall be hydrostatically air tested in accordance with **sub-clause PS – 9.5.1.17 of these specifications.**

PS 9.5.1.23 CONNECTIONS, MANHOLES, REINFORCING RINGS:

Manhole, blowoffs, and lateral connection fittings to the pipe shall be as shown on the drawings or as directed by the Engineer/Engineer representative. Unless otherwise ordered or permitted, the jointing and the cutting of outlets in the steel pipe for all connections for branches, and blowoffs shall be done in the field after the pipes are in place in the trench. The Contractor, if he so desires for construction purposes, may increase the number of manholes beyond those shown on the drawings or ordered, but no additional payment will be allowed for such extra manholes. He shall place additional temporary manholes and operate portable blowers through such manholes or pass holes as may be necessary to secure adequate ventilation within the pipeline and safeguard persons working therein. Additional manholes may be made by cutting an opening of approved size in the pipe, which is to be enclosed and made watertight by welding a steel plate, not less than 12.7 mm thick, to the pipe. The details of all such additional manholes shall be submitted for the approval of the Engineer/Engineer representative before they are made.

Reinforcing rings, bead bands, lugging bands, collars and flanges shall be provided and attached in an approved manner on all reducers and on all-steel pipes where connections are made to cast iron pipe.

Steel Specials shall be firmly jointed to the pipe by welding, and required apertures through the pipe plates shall be cut out neatly. While work is being done inside the pipe, the flanges of all manhole frames shall be protected by a heavy disc of durable wood securely bolted in position. Between the flange and the wood disc, there shall be a double layer of burlap saturated with heavy mineral grease.

PS 9.5.1.24 STAMPING, MARKING AND SHIPPING OF PIPE:

Before starting shop welding, each pipe and special shall be given a running number stamped clearly on the inside of each end, approximately 150 mm from each end and 150 mm from the longitudinal seam. Where "bell and spigot" pipe is used, the running number shall be stamped at the spigot end only.

Before leaving the shop, each length of pipe and special that conforms with the above specifications shall be plainly marked in paint on the inside and near the end of the pipe and special, with the identifying piece number corresponding to that shown on the geometry drawing.

On the top center line of pipe, at the bolting up hole, an arrow shall be painted on the outside of the pipe to indicate the direction of field assembly. Any curve or special, which cannot be completely fabricated in the shop, shall be match marked to facilitate assembling in the field.

A detailed schedule in quadruplicate, on forms approved by the Engineer/Engineer representative, shall be given to the QA Inspector for each shipment of pipe, specials and appurtenances. These forms, numbered consecutively, shall indicate each day's total shipment.

To assure roundness of pipe at joints, all pipe and fittings shall be braced horizontally and vertically at both ends during storage and shipping. All pipe is to be rounded before bracing is installed.

Heat numbers on the steel plate used for fabrication shall be painted on the plate in a position to be visible at the inside of the spigot end of the pipe after rolling.

Stamped-on running numbers shall be encircled with a paint to spot location of the number.

The Engineer/Engineer representative shall be furnished a report, daily giving:

1. Heat numbers of plates used that day for making pipe or specials.

2. Running numbers of all rolled pipe or specials:

    a) fabricated on that day,
    b) rounded and ring tested on that day,
    c) belled on that day,
    d) hydrostatically tested on that day, and
    e) lined, coated and wrapped in that day.

3. Running numbers of all straight pipe taken for making specials on that day.

PS 9.5.1.25 HANDLING OF FABRICATED PIPE:

During handling, loading, transportation and unloading, more than ordinary care shall be taken to prevent injury to the pipe. Loading and unloading shall be done carefully, with each pipe at all times under perfect control. Under no condition shall a pipe be dropped. All dunnage, skids, and blocks must be padded with a layer of carpet and shall be placed under each pipe in the shop, storage yard and during transportation. The pipe shall be securely wedged during transportation and elsewhere, as required. Stulling of the pipe ends shall be accomplished with 4" x 4" wooden cross braces during transportation to the installation site. The braces shall be so placed that they do not encroach or mar the corrosion prevention coating at the internal surface of the pipe. Pipe must be carried or lifted by the use of nylon slings or carpet padded forks to protect all exterior coating from damage. Coated pipe shall be shipped with nylon tie-down straps located approximately over the stulling as required to maintain roundness of pipe to 4.76 mm. In case any pipe is indented or deformed, it shall be resumed to the proper shape if such repairs can be made acceptable; otherwise, it will be rejected and shall be replaced with a new pipe. Wire rope slings and chain slings, padded or otherwise, shall not be used to lift coated pipe.

PS 9.5.1.26 APPURTENANCES:

Gate valves to be furnished shall comply with AWWA C509 Standard Specifications, as shown on the drawings or as indicated in the Bill of Quantities. The connections may be either flange ends, or hub and flange ends.

Butterfly valves to be furnished shall comply with AWWA C504 Standard Specifications for Rubber-Seated Butterfly Valves 600 mm, 750 mm, 900 mm, and 1200 mm Class 250B with Square Nut Drive.

Flanges on all appurtenances shall be in accordance with the design / Drawing, Insulated Flange Joints for Reduction or Electrolysis in Main pipelines. Flanges shall be full raised faced and drilled in accordance with ANSI/ASME B16.5-1975 Class 150 Stainless Steel Flanges, except where necessary to be drilled 1/8-inch (3 mm) larger to accept Mylar insulating sleeves, and either faced or spot faced at the rear, unless otherwise noted. For flange fasteners see–**sub-clause PS – 9.5.1.16 of these specifications**.

Gaskets shall be full-faced rubber with cotton cloth insert, 3.00 mm thickness as specified in **sub-clause PS – 9.5.1.16 of these specifications**.

PS 9.5.1.27 INSPECTION FACILITIES:

The Contractor shall ensure that the fabricator of the pipe shall have available for the Engineer/Engineer representative's representative a desk and a locker for clothes for his exclusive use; and clean toilet and wash-up facilities shall also be available.

PS 9.5.1.28 SAFETY EQUIPMENT FOR QA INSPECTOR:

The fabricator shall furnish the Engineer/Engineer representative's representative, a "hard" hat, safety goggles and such other safety equipment as may be necessary to protect him from injury while he is performing his inspection functions on the premises.

PS 9.5.1.29 INSPECTION OF PIPE FABRICATION:

The pipe fabrication shall be done in a shop having adequate facilities to produce sufficient pipe per normal eight (8) hour daytime shift to enable the Contractor to fulfill the time requirement of this contract.

Pipe fabrication on Saturdays, Sundays, Holidays or during overtime periods on weekdays is prohibited, unless specifically permitted by the Engineer/Engineer representative.

The Contractor's attention is also hereby directed to **sub-clause PS – 9.5.3.1;para (2) of these specifications.**

The pipe fabricator shall schedule all work in accordance with the above conditions.

PS 9.5.2 LAYING STEEL PIPES AND APPURTENANCES

PS 9.5.2.1 WORK INCLUDED:

The Contractor shall lay, test and make tight the line of steel pipe indicated on the drawings. The work of laying the steel pipe also includes the air test of pipe joints, the cleaning of the line in preparation for coating or covering, the final cleaning of the inside of the steel pipe, and filling of the line with Raw Dam water in preparation for placing it in service.

Any pipe, bends, or specials, which are not called for in the Bill of Quantities or on the drawings or which are not required in the finished work but which may have been delivered, shall, at the finish of the contract, remain the property of the Contractor or revert to him and shall be promptly removed by him from the site of the work.

All pipes and fittings shall be handled and installed in accordance with the applicable section of AWWA Manual M11 and the requirements described herein.

PS 9.5.2.2 TEST PIT AND BENCH MARKS:

Before the actual pipe laying operations are commenced, the Contractor shall excavate test pits and take all necessary field measurements to prepare a main pipeline geometry for approval of the Engineer/Engineer representative, indicating horizontal and vertical alignment and appurtenance locations that conform to these specifications, requirements of the drawings and to field conditions. Alignment and appurtenance locations shall be indicated by stationing, elevations (datum: mean sea level) and deflection angles. and all topographical and subsurface information identified and located shall be shown on the geometry drawing. In addition, the relationship of the main pipeline to significant field features (e.g., road curbs, crossing streams, subsurface structures, buildings lines, etc.) shall be indicated by stationing and/or dimensioning. All reference points shall be clearly documented so that they may be re-established at any time.

Reference bench marks, at least one per kilometer, shall be fixed before the work of laying the pipe line is started. These bench marks should be fixed a little away from the field of work and should be securely fixed in cement concrete.

PS 9.5.2.3 HANDLING OF PIPES AND SPECIALS:

During loading, transportation, unloading, and lowering into the trench, more than ordinary care shall be taken to prevent injury to the pipe or the wrapping. The pipes and specials shall be handled in such a manner as not to distort their circularity or cause any damage to their coating. Pipe and specials shall be suspended on at least two (2) slings of fabric, nylon or leather, each not less than 150 mm in width, of ample strength to support the weight of the pipe or special, with each pipe or special under perfect control at all times. Additional slings shall be used to suspend pipe longer than 12.0 meter, subject to approval. Chain slings and wire rope slings regardless of padding are specifically prohibited for use in lifting coated pipe.

Pipes under no condition shall not be thrown down from the trucks nor shall they be dragged or rolled along bard surfaces. In case any pipe is indented or deformed, it shall be returned to the proper shape if such repairs can be made acceptably, otherwise it will be rejected and shall be replaced with a new pipe.

A dent is a depression producing a significant alteration of the curvature of the pipe shell. The depth of a dent is measured as a gap between the lowest point of the dent and the curvature of the pipeline. All dents exceeding 2 percent of the outer diameter of the pipe should be removed. Dents shall be removed by cutting out a cylindrical portion of the pipe and replacing the same with an undamaged piece of the pipe. Insert patching may be permitted by the Engineer/Engineer representative if the diameter of the patch is less than 25 percent of the nominal diameter of the pipe. Repairs by hammering with or without heating shall not be permitted. Any damage to the coating shall also be carefully examined and rectified.

Pipe stored on the ground, awaiting installation in the trench, shall be placed on burlap bags filled with sand to prevent damage to pipe coatings.

PS 9.5.2.4 TRENCH EXCAVATION:

1. GENERAL

The pipe shall be laid to accurate line and grade and the excavation and backfill so performed that the pipe will be firmly imbedded. No timber blocking will be permitted for the purpose of maintaining line and grade; sand bags or other approved means may be used for this purpose. There shall be at least a 450 mm clear distance between the pipe and the sides of the trench.

Where the trench is in rock, no rock shall project nearer than 150 mm to the bottom or 200 mm to the side of the pipe, and before laying, the bottom of the trench shall be filled with clean earth thoroughly compacted to the level of the underside of the pipe.

Where the trench is in fresh fill or in soil of low bearing power, the pipe, where and as directed, shall be laid on concrete cradles, supported on a continuous reinforced concrete mat or on a concrete pile caps which in turn shall be supported on approved piles, where and as ordered by the Engineer/Engineer representative.

Where the trench is in a material which, in the opinion of the Engineer/Engineer representative, is not suitable to give a proper bed or support for the pipe, the Contractor shall, where directed, excavate 150 mm below subgrade and fill to grade with clean earth or sand thoroughly compacted to the underside of the pipe.

Unless otherwise indicated on the plans or in the specifications, the length of trench which may be opened between the point where backfilling is completed and the point where excavation of the trench is commenced shall, in general, not exceed 150 meter; this length, however, may be increased or reduced with the approval of the Engineer/Engineer representative and in accordance with his direction, depending upon the density of the population and the degree of the traffic congestion along the route of the pipe line, and the requirements of other Govt deptts, traffic, etc.

As part of the work under the excavation items, and at no extra cost to the Employer, the Contractor shall build all drains and do ditching, pumping, bailing and all other work necessary to keep the excavation clear of sewerage and extraneous water during the progress of the work and until the finished work is safe from injury. The contractor shall provide all necessary pumping equipment for the dewatering work, as well as operating personnel, POL, power, etc. all at no extra cost to the Employer. All water pumped or drained from the work shall be disposed of in a manner satisfactory to the Engineer/Engineer representative. Necessary precautions against flooding shall be taken.

The Contractor shall take special care of the existing sub-surface facilities likely to be encountered during the execution of work which require special precaution for their protection, such as sewers drain pipes, water mains, conduits, electric cables, communication cables and the foundations of adjacent structures. The Contractor shall be responsible for the damage to any such facility and shall repair the same at his expense whether or not this facility has been shown on the drawings.

The lane adjacent to the trench shall be used for trucks and equipment. The excavated material shall not be placed on the road, pedestrian tracks, drains, etc., except when permitted by the Engineer/Engineer representative. No pipe or appurtenances shall be left un-guarded at site overnight.

2. **MATERIALS ON PRIVATE PROPERTY**

No excavated material or materials of construction shall be placed by the Contractor or for the Contractor upon private property, unless by written permission of the owners or lessees thereof. Any such material placed without written permission will be removed by the Contractor, and all damages to said property remedied by the Contractor at the Contractor’s own cost and expense.

Unless such materials are removed and such damage remedied by the Contractor within forty-eight (48) hours after serving upon the Contractor of a written notice by the Engineer/Engineer representative to do so, the Engineer/Engineer representative shall be at liberty to dispose of such materials, and to remedy such damage and deduct the expense thereof from the moneys due or to become due under this contract. Copies of all written permissions shall be given to the Engineer/Engineer representative prior to the placement of any material on private property.

3. **SAFE AND HEALTHFUL WORKING CONDITIONS**

The Contractor shall provide working conditions that are as safe and healthful as the nature of the construction operation permits. All such safe and healthful working conditions shall be in accordance with OSHA requirements and regulations. Main pipeline construction that require proper lighting in order to comply with OSHA shall be lighted with electric lights in sufficient number to insure proper work and inspection.

The Contractor shall keep the air in the main pipeline in which work is being performed in a condition suitable for the health of the workers. A sufficient supply of fresh air shall be provided at all times in all places underground. Provisions shall be made for the testing and monitoring of gases and for the quick removal of gases and dust created by operations in the pipeline. Should natural ventilation prove inadequate, ventilation plants of ample capacity shall be installed and operated while the work is going on and at such other times as is required to produce conditions hereinbefore specified. No separate payment will be made for the providing of safe and healthful working conditions. The cost for the above work shall be deemed included in the prices bid for all items of the contract.

PS 9.5.2.5 LAYING PIPES:

1. **LAYING OF PIPES BELOW GROUND**

After the trench has been excavated as required, the pipe, specials, gate valves and other appurtenances shall be delivered to the site and placed at once in the trench. Unless otherwise permitted, no pipe or appurtenances shall be left un-guarded on the site overnight and none more than six hours before laying.

When the pipe is on the filled sandbags, it shall be thoroughly cleaned, inspected and the coating, if applied, shall be removed from the surfaces that are to be in contact at the joints. This requirement, however, is not to be taken to apply to the priming solution used to protect the contact surfaces. When suspended above the trench, all abrasions of the coating and wrapping which will be inaccessible after laying, shall be satisfactorily repaired as approved by the Engineer/Engineer representative. The patch wrapping shall be securely bonded and shall lap the damaged portion at least 100 mm. The pipe shall then be lowered into place upon the subgrade excavated accurately to the desired elevation of the pipe and laid to the required line and grade without blocking.

After the pipe is lowered, it shall be laid in correct line and level by use of levelling instruments, sight rails, Total Station etc. Care shall be taken to see that the longitudinal welded joints of the consecutive pipes are staggered by at least 30° and should be kept in upper third of the pipeline, if there are two longitudinal joints they should be on the sides. While assembling, the pipe faces shall be brought close enough to leave a uniform gap not exceeding 3 mm. The spiders from inside and tightening rings from outside or other suitable equipment should be used to keep the two faces in shape and position till at least one run of welding is carried out.

If the prepared bed is damaged for any reason, the pipe shall be raised and the bed made good before pipe laying is continued. The open end of the pipeline shall be securely closed with a tight fitting plug or cover whenever the work interrupted for any reason. The interior of each pipe after being laid shall be thoroughly cleaned. Any pipe that is not in true alignment both vertical and horizontal or experience any undue settlement after laying shall be taken up and re-laid correctly by the Contractor at his own expenses when so ordered by the Engineer/Engineer representative.

Each pipe and fitting shall be laid true to alignment, curve and gradient in accordance with the drawing or as directed by the Engineer/Engineer representative. The minimum cover and the minimum gradient shall unless otherwise stated not be less than one meter and 1:400 respectively. The pipes shall be laid to even gradients and sight rails shall be provided for this purpose at intervals not exceeding 50 meters and at changes of direction and grade. Pipes and fittings supposed to be exposed at culvert or bridge crossings and in manholes or chambers shall be painted in accordance with these specifications and / or as directed by the Engineer/Engineer representative.

Pipe shall not be dragged on the trench bottom in making joints. Wire rope slings and chain slings, regardless of padding, shall not be used. After placing the pipe in the trench, special effort shall be given to make up each field joint promptly and the Contractor shall provide an adequate force of men and appliances to meet this stipulation. Every effort, including use of interior jacks and braces, shall be made to keep the pipe round within limits set in **sub-clause PS – 9.5.1.12 of these specifications.**

Any underground water encountered in the pipe trench shall be pumped out regularly and the water level be kept below the sockets when joining. In no case shall pipes and/or fittings be jointed before being lowered into its final destination in the trench. Any damage occurs to the pipes through failure of the Contractor to comply with these conditions shall be made good at the Contractor's expenses.

2. LAYING OF PIPES ABOVE GROUND

The procedure for handling the pipes and for lowering and assembling the pipes underground as described hereinabove should be followed for lifting and laying the pipes on supports or on ground. The pipeline may be allowed to rest on ground if the soil is non-aggressive. The ground should, however, be dressed to match the curvature of the pipe shell for an arch length subtending an angle of 120° at the centre of pipes.

Alternatively, the pipeline should be laid either on saddle or roller and rocker supports as provided in drawings or as specified by the Engineer/Engineer representative.

a) **Expansion Joints**

For all pipelines laid above ground, provision for expansion and contraction on account of temperature variation should be made either by providing expansion joints at predetermined intervals or by providing loops where leakage through expansion joints cannot be permitted. Where expansion joints are provided, it is necessary to create restraining points on the pipeline to ensure proper functioning of these joints. The pipe laying work should preferably start from the restrained points on either side working towards center where the expansion joint should be fitted last. Spacing of expansion joint depends on local conditions. Provision of expansion joint at intervals of 300 m on exposed steel pipeline is generally recommended. Expansion joints should always be provided between two fixed supports or anchorages.

b) **Anchorages**

The pipe shall be anchored by concrete anchor blocks or other means to resist unbalanced water pressures and temperature stresses. The Contractor shall submit proposal for the Engineer/Engineer representative's approval, for provision of anchorages to pipe during construction and in service where floatation could occur.

PS 9.5.2.6 WELDED JOINTS:

Welded field joints shall be either butt welded or lap fillet welded as shown on the drawings and /or as approved by the Engineer/Engineer representative.

Surfaces and edges to be welded shall be free from scale, rust and other foreign material. Edges that have been torch cut or air-arc gouged shall be ground to remove slag and oxidation. All edges must have proper bevel and miter configuration as given by welding procedures approved by the Engineer/Engineer representative and AWWA Standard for Field Welding of Steel Water Pipe, ASNI/AWWA C206-88.

Field welding shall be done in such a way as to avoid burning the protective coating on the pipe except in the immediate vicinity of the weld.

All butt welds shall be subjected to a 100% radiographic test. All fillet welds shall be subjected to air tests where appropriate and to magnetic particle tests.

All manual and field welding shall be done by the Shielded Metal Arc Welding (SMAW) method. The electrodes shall conform with the requirements of the Specification for Covered Carbon Steel Arc Welding Electrodes, SFA-5.1, ASME Boiler and Pressure Vessel Code, Section II, Material Specifications, Part C - Welding Rods, Electrodes, and Filler Metals, classification number E7016, E7018, E6016, or E6018, or as required for the particular steel being used. Welding Electrodes shall be the same as those used for welding procedure qualification. A copy of the Engineer/Engineer representative approved Welding Procedure Specification, as specified hereinabove, shall be kept at the field-welding site to allow the QA / QC Inspectors to monitor the field welding parameters and methods. The welding current shall be within the range recommended by the manufacturer of the electrodes used and the Engineer/Engineer representative approved welding procedure specification (WPS). The Contractor shall control the storage and handling of the electrodes to maintain their low-hydrogen (moisture) characteristics as recommended by the electrode manufacturer.

The electrodes shall be kept in cans covered and stored in a dry place, and kept dry until used. A portable holding oven shall be at the field-welding site to facilitate keeping the low-hydrogen electrodes dry. Electrodes not used after a day's production shall be stored in a hermetically sealed container.

Reconditioning and drying or electrodes that have absorbed excess moisture shall not be allowed and those electrodes so exposed shall be rejected.

PS 9.5.2.7 FILLET WELDED LAP JOINTS:

Lap joints shall be made with a double, continuous 5/16" (7.94 mm) minimum fillet weld, with full penetration into the ·base metal. Each joint shall be properly prepared and cleaned for welding. Welding shall be in accordance with the Welding Procedure Specification WPS approved by the Engineer/Engineer representative and a copy shall be at the work site during welding. Welds up to 3/8" (9.53 mm) may be made in a single pass. If made in more than one pass, all slag or flux remaining on any bead of welding shall be removed before laying down the next successive bead. Any cracks or blowholes that appear on the surface of any bead of weld shall be removed by chipping, grinding or gouging before depositing the next successive bead. There shall be no under cutting of the base metal. All slag shall be removed from finished welds and the welds shall show workmanlike appearance, uniform section, and freedom from porosity and trapped slag.

All outlet connections and manholes shall be welded with continuous, double lap, fillet weld.

The holes used in aligning the pipe shall be satisfactorily plug welded after the completion of each joint, or closed by the insertion of a 7/8" (22.23 mm) diameter cold panhead rivet, 7/8" (22.23 mm) long, and welded inside and outside.

PS 9.5.2.8 TEST OF FILET WELDED LAP JOINTS:

After the welding of a circumferential field joint is completed, the inside and outside of the joint shall be painted with soap suds and tested with air at a pressure of 40 psi applied through the 1/4” (6.35 mm) hole at the top of the pipe. Any defect in the weld, indicated by air leak forming bubbles, shall be repaired by chipping out a section of weld not less than one inch (25.4 mm) either side of the defect and replacing the removed section.

If, in the opinion of the Engineer/Engineer representative, the number of defects disclosed by the test are such as to indicate that the entire circumferential weld is defective, the entire weld shall be chipped out and replaced. Caulking of welds will not be permitted. All joints, in which welding repairs have been made, shall be retested. After field-testing, the 1/4” (6.35 mm) hole shall be welded shut. After satisfactory completion and acceptance of each welded joint, the coating, electrical testing and wrapping of the joints may be completed. Similarly, outlet connections and manholes welded in the field shall be air tested.

PS 9.5.2.9 FIELD JOINTING TO KEEP UP WITH PIPE LAYING:

The work of making the field joints and outlet connections, etc., shall keep up as closely as possible to that of the pipe laying gang so ·that, except where otherwise permitted, not more than five joints shall intervene between the last joint that is made and the pipe that is being laid.

If, at any time the Engineer/Engineer representative is of the opinion that the Contractor is not advancing the various portions of the work at a satisfactory rate, then the Contractor shall, under the direction of the

Engineer/Engineer representative, temporarily suspend the pipe laying or any other portion of the work, to permit the other portions of the work to be advanced sufficiently to justify the resumption of the work suspended.

To minimize the effect of ambient temperature effects on expansion joints valve chambers during construction, joints immediately outside the chambers shall be welded last before final backfilling. A "make-up" sleeved and welded joint may be introduced by the Contractor for this purpose at his option.

PS 9.5.2.10 PROTECTION OF PIPE COATING:

The Contractor shall at all times take every precaution to prevent injury to the coating and wrapping of the pipe and appurtenances by workmen or trespassers. During the laying and jointing of the pipe, or at any other time while it is exposed, no person shall be permitted to walk on or in the pipe wearing boots or shoes with hobnails or other attachments that will injure the coating. Dropping of tools and other materials on the pipe, dragging of heavy objects over them, and other acts that would mar the coating and wrapping, shall be prevented. The ends of completely coated pipes in the storage yard, unless otherwise permitted, shall be stopped by an approved head or barrier of wood or metal with apertures not more than 100 mm wide. Unless pipes delivered to the site from the storage yard are to be immediately placed in the trench, the ends shall be similarly protected, and the heads or barriers shall not be removed until the pipes are about to be laid. Each day at the close of work, and when laying is not in progress, the exposed ends of the pipe in the trench shall also be protected in this way. Ends of pipe, if any, when it becomes necessary to cover with earth before making connection to adjacent piping, shall be closed by suitable timber bulkheads before the trench is backfilled.

PS 9.5.2.11 FLOATING:

The Contractor shall take every precaution against the floating of the pipe due to water flowing into the trench, or through flushing or puddling. In case of such floating, he shall replace the pipe at his own expense, making wholly good any injury or damage which may result. The responsibility for the movement of the pipe, due to water flowing into the trench, shall rest entirely upon the contractor and no claim shall be made by or will be allowed to him for the expense of repairing the damage resulting therefrom, due to the deficiency, or alleged deficiency, in the capacity of the natural drainage or sewers or drains in the vicinity to carry off storm water flow, or for any other reason.

PS 9.5.2.12 COMPLETION OF LINING AND COATING:

After satisfactory completion and acceptance of the field test, the Contractor shall remove any water from the section and shall clean all of the interior surface. All abrasions and other damage to interior lining shall be cleaned, dried and repaired. The coating and wrapping shall then be completed at all field joints and at all jointed appurtenances shall be primed and coated on the exterior and the interior, as hereafter specified, except that the coating and wrapping may be applied by hand. Wrapping shall be bonded firmly and smoothly, to lap adjacent layers by at least 25.4 mm.

After completion of wrapping, the section of trench over the field joint shall be backfilled as hereafter specified.

PS 9.5.2.13 ELECTRICAL TEST OF INTEGRITY OF COATING:

Following the repair and completion of coating, all of the interior lining and exterior coating shall be again tested electrically for flaws, such as cracks, pin holes, holidays and thin spots. All imperfections revealed by the inspection and test shall be immediately covered by an additional full thickness of hot enamel as has been used or as approved by the Engineer/Engineer representative for other coating systems**.**

PS 9.5.2.14 MAINTAINING PIPE UNDER PRESSURE:

In addition to the requirements for field testing stipulated above, the Contractor shall fill with water and maintain, under hydrostatic pressure any portion or portions or the whole of the pipe line as frequently, and for such lengths of time, as may be directed by the Engineer/Engineer representative, in order to keep the pipe as closely as practicable to a circular cross-section and unchangeable in shape when concrete is being placed about the steel pipe, when backfilling is being rammed or puddled and until it is acceptably consolidated, and when loads, other than from backfilling could, in the opinion of the Engineer/Engineer representative, unduly distort the pipe. Any flanged joint which shows evidence of leakage after the introduction of hydrostatic pressure shall be completely disassembled and reassembled at the contractor's own cost and expense.

PS 9.5.2.15 CONCRETE BACKING AND VAULTS:

The Contractor shall place a suitable backing of concrete, reinforced, if and as directed, of such dimensions as may be ordered or shown on working plans to be furnished, at all bends and other locations in the pipe line, where, in the opinion of the Engineer/Engineer representative, unbalanced pressures may exist or develop which will tend to cause movement in the pipe line, while the pipe is under normal or test pressure.

Vaults, manholes and footings shall be constructed around and under valves in accordance with the drawings, or as may be otherwise directed by the Engineer/Engineer representative.

PS 9.5.2.16 BACKFILLING TRENCH:

The Contractor shall take such borings or excavate such test pits as he may deem necessary to schedule his operation, consistent with the need of having an adequate supply of satisfactory backfill material available along the pipeline so that he may proceed with undue interruptions, and no payment, other than hereinbefore provided, will be allowed the Contractor for delays or other expenses incurred because the satisfactory backfill is not available at the proper time and place; and no other allowance will be made to the Contractor for disposing of the unsatisfactory excavated material.

The satisfactory backfill material shall be placed in layers not more than 200 – 300 mm in thickness and thoroughly compacted by mechanical tamping or other approved means, with particular attention paid to placing and compacting under the pipes and compacted to minimum ninety (90) percent of the maximum dry density determined as per AASHTO T-191 Method, so that on each side of the pipe there shall be thoroughly compacted material at least as wide as the external diameter of the pipe except insofar as undisturbed material obtrudes upon this width.

Each layer shall be moistened, if dry, and then compacted by tamping with mechanical hammers or by hand tamping with heavy iron tampers to the densities as specified under relevant item of work in the General Specifications. This method of filling and compacting shall be continued until the backfill material has reached an elevation of twenty 200 mm above the top of the pipe.

Extra caution should be exercised, where a backfilling machine is employed; the trench shall be backfilled by hand and mechanically tamped for the first 300 mm of cover to prevent injury to pipe from stones in the backfill. No material used for backfill shall contain any stone for fill up to at least 300 mm over the pipe. Above that point, no stones larger than three 75 mm will be permitted, and no stone shall come within 150 mm of the pipe.

The backfilling with sandy material shall be thoroughly consolidated by flushing, using a hose at least 37.5 mm in diameter, to which shall be attached a flushing pipe at least 25 mm in diameter, to which shall be inserted into the backfill to approximately the depth of the center line of the pipe. The flushing pipe shall be inserted in the backfill at such points and for such time as in the opinion of the· Engineer/Engineer representative will result in a satisfactory consolidation of the backfilling. This flushing shall be carried on either during or after the completion of the backfilling, or at both times, as may be directed by the Engineer/Engineer representative. For the period following the flushing, during which, in the opinion of the Engineer/Engineer representative, the backfilling is too soft to safely permit vehicles passing over it, the Contractor shall barricade the trench in a manner satisfactory to the Engineer/Engineer representative. Where either the nature of the material to be used in the backfilling or the subsurface condition is such as, in the opinion of the Engineer/Engineer representative, to make it inadvisable to use the flushing method of consolidating the backfill, the backfill shall be consolidated by mechanical tamping. On unpaved village tracks, the Contractor shall use such material for surfacing the trench as will result in the restored surface being equal to the original surface for the purpose of carrying vehicular traffic.

Any rock that is excavated from the trench, that is of a size in excess of that allowed to be placed in the backfilling, shall be immediately separated from the material that is to be used for backfilling the trench, and shall be promptly removed from the work.

If the pavement along the sides of the trench is or becomes undermined, the Contractor shall break down and remove such pavement, together with the pavement foundation, loose earth and rock, before placing the temporary pavement, and he shall place and compact the necessary backfilling and relay the pavement so undermined.

Where the roadway or sidewalk in which the trench is excavated is surfaced with Asphaltic material; such asphaltic surfacing shall be restored by the Contractor to the satisfaction of the Engineer/Engineer representative without any additional cost to the Employer.

PS 9.5.2.17 TEMPORARY PAVING:

Except as herein provided, in all roadway areas having an improved pavement, as soon as the trench has been backfilled, the contractor shall place temporary pavement over the trench. The temporary pavement shall be of the following type:

Plant mixed hot binder mixture, 100 mm minimum thickness after compacting one layer, as designated in this project “General Specifications” for Asphalt paving mixtures design and compaction.

The material and workmanship shall comply with the requirements of these General Specifications and /or as directed by the Engineer/Engineer representative.

Temporary pavement in roadway and/or sidewalk areas shall be maintained by the Contractor until replaced by the permanent pavement, permanent pavement base, and permanent sidewalk.

Should a settlement occur or other defect develop in temporary pavement during these periods, which in the opinion of the Engineer/Engineer representative may cause hazards or undue inconvenience to pedestrian or vehicular traffic, the Contractor shall immediately restore such pavement to proper grade or otherwise repair the defects.

Where stone or concrete paving blocks are removed by the Contractor during pipe laying operations, such blocks shall be properly stored at the site of the work and shall be re-laid / fixed at a location and in the manner, as directed by the Engineer/Engineer representative, after completion of backfilling works.

PS 9.5.3 LINING AND COATING OF STEEL PIPE AND APPURTENANCES IN THE SHOP AND IN THE FIELD

PS 9.5.3.1 GENERAL:

1. All steel pipe and fittings furnished for use in the Main line system shall be lined and coated as specified on drawings unless specifically noted or instructed otherwise. This section of the particular specification shall be read in conjunction with **Clause: 25.4.13 – Painting, Chapter – 25 Iron Works, of General Specification**.
2. The Project technical documents and drawings are mutually explanatory. In the event of any dispute arising as to the true intended meaning of these Technical Specification’s, the Engineer/Engineer representative shall interpret the same and his interpretation shall be

accepted as final and binding upon all parties concerned

3. The term lining in these specifications shall mean the application of primed liquid epoxy conforming to the requirements of NSF/ANSI Standard #61 and approved for potable water line use by NSF(American National Sanitation Foundation) to be either a high solids polyamine epoxy or 100% solids polyurethane to the interior of the pipe, fittings, special sections, connections or appurtenances, and the term coating in these specifications shall be understood to mean the wrapping and coating of the exterior of the pipe, fittings, special sections, connections or appurtenances with the materials herein specified as follows:

   a) The interior shall be lined with epoxy NSF #61 approved or polyurethane NSF #61 approved as per coating specifications of manufacturer, and unless specifically noted otherwise, the exterior shall be coated with primed hot coal-tar enamel and shall be wrapped with glass-fiber felt reinforced tape in accordance with the American Water Works Association Standards for Coal-Tar Protective Coatings and Linings for Steel Water Pipelines--Enamel and Tape--Hot-Applied, ANSl/AWWA C203- 91, as hereinafter described; or

   b) The exterior shall be coated and/or the interior shall be lined in accordance with the American Water Works Association Standard for "Liquid Epoxy Coating Systems for the Interior and Exterior of Steel Water Pipelines, AWWA C210-84", as hereinafter described; the interior shall be lined with cement-mortar or epoxy NSF #61 approved or polyurethane NSF #61 approved as per manufacturers specifications.

   c) The exterior shall be coated and wrapped with fabricated multilayer cold applied polyethylene tape in accordance with the American Water Works Association Standard for 'Tape Coating Systems for the Exterior of Steel Water Pipelines, ANSl/AWWA C214- 89", as hereinafter described; or

   d) The exterior shall be coated and wrapped with cold applied primer and prefabricated tape in accordance with the American Water Works Association Standard for Cold-Applied Tape Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipelines, ANSl/AWWA C209-84, as hereinafter described.

2. Coating of pipe and specials in a plant other than that in which fabrication and testing take place, will be permitted under the following conditions:

   a) No fabrication or testing of pipe is to be done unless a QA Inspector is at the fabricating plant.

   b) No coating of pipe under this contract is to be done unless a QA Inspector is at the coating plant.

3. Pipe lying in storage after final inspection for a period of more than three (3) months before installation in the ground shall be subject to re-inspection, including the use of the holiday detector for determining any defects. Such pipe shall be repaired, if required, as directed by the Engineer/Engineer representative.

PS 9.5.3.2 QUALIFICATIONS OF COAL TAR ENAMEL APPLICATOR:

1. The Contractor's coating applicator will be considered as qualified to perform work in the shop on a straight pipe after he has complied with the following:

   a) He shall have under suitable cover a manufacturer's plant approved by the Engineer/Engineer representative capable of coating steel water pipe in accordance with the American Water Works Association Standard for " Coal Tar" Protective Coatings and Linings for Steel Water Pipelines--Enamel and Tape--Hot-Applied, ANSl/AWWA C203-91" for the sizes called for in this contract.
   b) He shall have been continuously engaged in this business for a period of not less than 5 years during which time he shall have successfully lined, coated and wrapped sufficient lengths of pipe and hydraulic related structural steel components to demonstrate his abilities for qualification.

2. The Contractor's coating applicator will be considered as qualified to perform work in the shop on specials and fittings after he has complied with the following:

   a) He shall have a physical plant under suitable cover.

   b) He shall have been engaged in this type of work either as the head of his own business, or in a supervisory capacity with a concern doing this type of work for a period of at least five (5) years.

c) He shall undertake a qualification test to be taken by the Engineer/Engineer representative. This test shall consist of coating a section of steel pipe in accordance with industry standard specifications. This section will be inspected and tested by the Engineer/Engineer representative and, if found satisfactory, the applicator will be declared qualified.

d) He shall employ experienced help for this work if the applicator is acting in the supervisory capacity and not doing the work himself.

e) Should subsequent inspections reveal that the applicator is consistently doing work of an inferior nature, he will be disqualified from the work by the Engineer/Engineer representative.

3. The coating applicator will be considered as qualified to perform work in the field on joints and touching-up of defective areas after he has qualified with the following:

a) He shall have been engaged in this type of work either as the head of his own business, or in a supervisory capacity with a concern doing this type of work, for a period of at least five (5) years.

b) He shall undertake the qualification test described hereinabove in **sub-clause PS – 9.5.3.2;para – 2 (c) of these specifications.**

c) He shall employ experienced help for this work if the applicator is acting in a supervisory capacity and not doing the work himself.

d) Should subsequent inspections reveal that the applicator is consistently doing work of an inferior nature, he will be disqualified from the work by the Engineer/Engineer representative.

4. The applicator for coating specials, and for work in the field on joints and "touch-up" should have the following equipment:

a) Tar kettle with metal paddle agitators.
b) Thermometer.
c) Thickness gauge.
d) Hand daubers.
e) Approved electrical testing equipment for holiday detection.
f) Penetrometer testing equipment available for sample testing by the Contractor, if required in the opinion of the Inspector.
g) Heating torches.
h) Grinders.
i) Paint Sprayers.
j) Paint brushes and rollers.
k) Sand paper.
l) Mixing equipment.

PS 9.5.3.3 MATERIALS FOR PRIMER, COAL-TAR ENAMEL, GLASS-FIBER FELT, AND WHITEWASH:

1. **Primer:**

The primer shall be of the fast-drying synthetic type complying with the following:

Fast-drying synthetic primer shall consist of chlorinated rubber; synthetic plasticizer, and solvents, suitably compounded to produce a liquid coating which can be readily applied cold by brushing or spraying and which will produce a suitable and effective bond between the metal and subsequent coating of coal-tar enamel.

The primer shall have good spraying and brushing properties and a minimum tendency to produce bubbles during application. The primer shall dry hard to the touch when applied as recommended.

2. **Coal Tar Enamel:**

This enamel shall be composed of a specially processed coal-tar pitch combined with an inert mineral filler. No asphalt of either petroleum or natural base shall be acceptable as part of the ingredients. The enamel shall have the characteristics of Type II shown in Table – I.

TABLE – I

Characteristics of Coal – Tar Enamel Type –II

TEST	MINIMUM	MAXIMUM
Softening point, ASTM D36	220°F (104°C)	250°F (116°C)
Filler (Ash), ASTM D2415,% by weight	25	35
Fineness filler, through 200 mesh, ASTM D546, % by weight	90	--
Specific gravity at 77°F (25°C), ASTM D71	1.4	1.6
*Penetration-AWWA C203, Sec. 2.8.1		
i) At 77°F (25°C), 100-g weight, 5 sec.	10	20
ii) At 115°F (46.1°C), 50-g weight, 5 sec.	15	55
High-temperature test at 160°F (72°C) (sag), AWWA C203, Sec. 2.8.9	--	1/16 in. (1.6 mm)
Low-temperature test at -10°F (-23.3°C) (cracking), AWWA C203, Sec. 2.8.10	N/A	N/A
	--	None
Impact test at 77°F (25°C) 650-g ball, 8-ft. drop, AWWA C203, Sec. 2.8.12		
i) Direct impact, disbonded area	--	10 in^2 (6452 mm^2)
ii) Indirect impact, disbonded area	--	2 in^2 (1290 mm^2)
Pee! test, AWWA C203, Sec. 2.8.11	No peeling	

* For static conditions,

- above 5°F (-15°C), use enamel with 5-10 penetration at 77°F (25°C);
- below 5°F (-15°C) and above -10°F (-23°C), use 10-15 penetration; and
- below -10°F (-23°C) and above -20°F (-29°C), use 15-20 penetration enamel.
  (Static conditions are those conditions under which the pipe is not being handled).

Sampling and test procedures shall be in accordance with Sections 2.6, 2.7, 2.8 and 2.9 of the American Water Works Standard for Coal-Tar Protective Coatings for Steel Water Pipelines-- Enamel and Tape--Hot-Applied, ANSIIAWWA, C203-86 or latest revision, except that all tests will be at the expense of the Contractor in laboratories approved by the Engineer/Engineer representative.

In addition, and witnessed by the Engineer/Engineer representative's QA Inspector, samples shall be taken from the kettles during the coating operations according to the following schedule:

a) From each kettle, one sample shall be taken prior to commencing work; one at mid-day, and one at the end of the working day.

b) No recharging of the kettles will be allowed until the samples are taken.

c) The samples taken shall be tested by the coater and shall not have a loss of penetration at 77°F - 100 gram, 5 seconds, exceeding seven (7) points from the material certified by the manufacturer as supplied in the drum.

d) Except that, during the coating operation, the penetration of the enamel applied to the pipe shall not be less than ten (10) during the period of October through April, and eight (8) during the period of May through September.

e) At the end of each working day, the kettles shall be drained of the enamel; and such drained enamel shall not thereafter be used for coating the pipe.

3. **Whitewash Formula:** All whitewash to be used shall be mixed as follows:

a) **Ingredients:**

50 gal. water

1 gal. boiled linseed oil

150 lb. processed quicklime

10 lb. salt

b) **Mixture:**

Lime and oil shall be slowly added simultaneously to the water and mixed thoroughly. The mixture shall be allowed to stand for not less than 3 days before it is used

4. **Glass-Fiber Coal-Tar Saturated Felt:**

The wrapper shall be composed of a glass-fiber felt with suitable binder, the whole saturated with a distilled. coal-tar to produce the following characteristics in the finished felt:

a) **Appearance:**

The finished tar-saturated glass-fiber felt shall have a smooth, uniform surface, free from visible defects. When unrolled at temperatures of 32°-100°F (0°C – 38°C), it shall not stick to such an extent as to cause tearing.

b) **Weight per 100 sq. ft.:**

Exclusive of all comminuted surfacing or sand which has been added to prevent sticking in the rolls, the weight shall be not less than 12 lb/100 sq. ft. nor more than 15 lb/100 sq. ft. The weight of the base glass-fiber mat, before coating, shall not be less than 1.7 lb/100 sq. ft.

Test Method:

In accordance with the requirements of the Standard Methods of Sampling and Testing Bitumen-Saturated Felts and Woven Fabrics for Roofing and Waterproofing, ASTM Designation D146-78a (Reapproved 1986).

c) **Breaking Strength:**

Average after test samples from the inside of the roll have been aged in free air for at least 2 hrs. at 77° ± 2°F (25°C ± 1°C):

i With fiber grain (longitudinal), not less than 35 lbf/in. (6130 N/m) of width.
ii Across fiber grain (transverse), not less than 27 lbf/in. (4730 N/m) of width.

Test Method:

In accordance with the requirements of the Standard Test Methods for Tensile Properties of Thin Plastic Sheeting, ASTM Designation D882-88.

d) **Pliability:**

Average after test samples from the inside of the roll have been aged in free air for at least 2 hrs. at a temperature of 77 ± 2°F (25°C ± 1°C): No cracking of felt when bent over a 1-in. mandrel at 77°F.

Test Method:

Five 6-in.(150 mm) strips shall be cut with the fiber grain as shown at D-1 to D-5 (Fig. 1 of the ASTM specification D146-78a (Reapproved 1986) and immersed in water at 77°F (25°C) for 10-15 mins. These strips shall be bent through 130° at a uniform speed, in approximately 2 sec., around a mandrel with a diameter of 1 in.

e) **Saturation:**

Average after test samples from the inside of the roll have been aged in free air for 2 hrs. at a temperature of 77 ± 2°F (25°C ± 1°C): The saturation by extraction shall be not less than 22 percent nor more than 32 percent of the weight of the extracted felt.

Test Method:

ASTM D146-78a (Reapproved 1986) Sec. 16, omitting correction for entrained carbonaceous materials, calculated as follows:

$$\frac{\text{wt. of extracted saturant x 100}}{\text{wt. of extracted felt (as defined)}} = \text{\% saturation}$$

f) **Loss on Heating:**

The loss on heating shall be not more than 10 percent according to the following test method:

Test Method:

Cut two samples, 6 in. (150 mm) wide by 12 in. (300 mm) long, of saturated felt, weighing each strip and suspend by wire hooks for 2 hrs. in an oven maintained at 200°F ±5°F (93°C ± 2.5°C) Care shall be taken to see that the felt does not touch the oven side or other samples of felt and that localized overheating of the samples does not take place. Remove from the oven, cool in a desiccator, and weigh. Compute the percentage of toss in weight based upon the original weight of the sample, minus the weight of surfacing. The average of the result on the two samples shall be reported as the loss on heating.

PS 9.5.3.4 SHOP APPLICATION OF EPOXY PRIMERS AND COAL-TAR ENAMELS:

1. **GENERAL:**

The Contractor shall furnish all labor, equipment and material required, shall prepare all surfaces to be coated, and shall apply the primer and coal-tar enamel to all exterior surfaces to be coated.

2. **PREPARATION OF SURFACES:**

a) Before blasting, all oil and grease on the surfaces of the metal shall be removed thoroughly by flushing and wiping, using “Xylol (Xylene)," or other suitable solvents and clean rags. The use of dirty or oily rags or solvent will not be permitted. All other foreign matter not removable by blasting shall be removed by suitable means. All metal surfaces shall be thoroughly cleaned by blasting. Blast-cleaning operations shall remove all rust, scale, and other impurities from the surface, exposing base metal over all, presenting a grayish matte appearance, in accordance with the requirements of the Steel Structures Painting Council, Surface Preparation Specification No.10, Near-White Blast Cleaning, SSPC- SP10. Blasted surfaces that rust before a priming coat has been applied shall be cleaned of all rust by buffing or wire brushing or, at the discretion of the Engineer/Engineer representative, shall be re-blasted. Adequate air separators shall be used to remove effectively all oil and free moisture from the air-supply to the blaster.

b) After cleaning, the pipe shall be protected from and maintained free of all oil, grease, and dirt that might fall upon the pipe from whatever source until it has received its final enamel coat. Any pipe showing pits after beginning of blasting shall be set aside immediately, pending examination by the Inspector for approval, reconditioning or rejection.

3. **PRIMING:**

The primer shall be as specified in **sub-clause PS – 9.5.3.3; para – (1) of these specifications**, and the application shall be as follows:

a) All blasted steel surfaces shall be cleaned of dust and grit and shall be primed immediately following blasting and cleaning. The surfaces shall be dry at the time the primer is applied, and no primer shall be applied during rain or fog unless protected from the weather by suitable housing.

b) At the option of the Contractor, the application of the primer shall be by hand brushing, air gun spraying, or spraying-and-brushing, and shall be in accordance with instructions for application as supplied by the manufacturer of the primer. The apparatus to be used shall be approved by the Engineer/Engineer representative. Spray gun apparatus to be used shall include a mechanically agitated pressure pot and an air separator that will remove all oil and free moisture from the air supply.

c) The use of coal-tar primer that becomes fouled with foreign substances or has thickened through evaporation of the solvent oils will not be permitted.

d) After application, the priming coat shall be uniform and free from floods, runs, sags, drips, holidays, or bare spots. Any bare spots or holidays shall be recoated with an additional application of primer. All runs, sags, floods, or drips shall be removed by scraping and cleaning and the cleaned area retouched, or, at the discretion of the Inspector, all such defects shall be remedied by re-blasting and re-priming. Suitable measures shall be taken to protect wet primer from contact with rain, fog, mist, spray, dust, or other foreign matter until completely hardened and enamel applied.

e) In cold weather when the temperature of the steel is below 45°F (7°C), or at any time when moisture collects on the steel, the steel shall be warmed to a temperature of approximately 85°-100°F (30°C - 38°C) for sufficient time to dry the pipe prior to priming. To facilitate spraying and spreading, the primer may be heated and maintained during the application at a temperature of not more than 120°F (49°C).

f) The minimum and maximum allowable drying time of the primer between application of primer and application of coal-tar enamel shall be in accordance with instructions issued by the manufacturer of the primer unless otherwise directed by the Engineer/Engineer representative. If the enamel· is not applied within the maximum time after priming, as required by the manufacturer or as directed by the Engineer/Engineer representative, the pipe shall be re-primed with an additional light coat of primer, or, at the discretion of the Engineer/Engineer representative, the entire prime coat shall be removed by re-blasting and the pipe re-primed.

4. **PREHEATING OF PRIMED PIPE:**

a) At all times during cold weather when pipe temperature is below 45°F (7°C), or during rainy or foggy weather when moisture tends to collect on cold pipe, enameling shall be preceded by warming the pipe.

b) Warming shall be done by any method which will heat pipe uniformly *to* recommended temperature without injury to primer. Steel temperature of pipe shall not exceed 160°F (71°C).

c) After heating and while pipe is at its highest temperature, inside lining enamel shall be applied. Coating of the outside of the pipe with coal-tar enamel shall proceed immediately after the spinning operation is completed, while the pipe is still warm from preheating and centrifugal casting.

5. **COAL-TAR ENAMEL APPLICATION:**

Coal-tar enamel coating to be used for the exterior coating shall be in accordance with **sub-clause PS – 9.5.3.3; para – (2) of these specifications.** The application shall be as follows:

a) The coal-tar enamel shall be heated in approved heating kettles equipped with accurate and easily readable thermometers. In addition, for recording thermometers, such thermometers shall be installed on the heating kettles as directed by the Engineer/Engineer representative and at the expense of the Contractor. Such thermometers will be checked and adjusted by the Engineer/Engineer representative whenever necessary. The charts therefrom shall constitute a basis for acceptance or rejection of any enamel because of improper heating and/or handling.

b) The operating and/or supply kettles shall be provided in sufficient numbers so that the coal-tar enamel may be heated and coordinated with the application procedure. No enamel shall be held in the operation kettles at application temperatures for a longer period than recommended by the manufacturer. The enamel heated in supply kettles shall not exceed the temperatures and melting periods recommended by the coating manufacturer. Operating kettles shall not be used as a continuous source of supply by adding un-melted enamel during the time they are in use but shall be completely emptied of one charge and cleaned, if necessary, before the next charge of un-melted enamel is added; except when mechanically agitated kettles are used. In the practice of field patching, the Engineer/Engineer representative may permit continuous use of a heating kettle not exceeding 50-gal. capacity. Kettles shall be covered with hinged lids which may be securely fastened down and shall be tightly closed during the heating and application of enamel except for necessary loading and stirring.

c) The coal-tar enamel shall be maintained moisture and dirt free at all times prior to, and at the time of, heating and application.

d) In loading the kettles, the enamel shall be broken into pieces suitable for the heating equipment used.

e) In heating the coal-tar enamel, the charge shall be melted and brought up to application temperature as rapidly as possible without injury to the enamel. The temperature at which the enamel will be applied shall be in accordance with the recommendation furnished by the manufacturer. The hot enamel shall be thoroughly stirred at intervals not exceeding 15 min. regardless of whether the enamel is being used from kettles or is being held ready for use. Iron paddles shall be used for stirring; wooden paddles will not be permitted.

f) The maximum allowable temperature to which enamel may be heated and the maximum allowable time that the enamel may be held in the kettles an application temperature shall be in accordance with the instructions supplied by the manufacturer.

g) Coal-tar Enamel that has been heated in excess of the maximum allowable temperature, or that has been held at application temperature for a period in excess of that specified, shall be condemned and rejected. Fluxing the enamel will not be permitted.

h) Excess enamel remaining in a kettle at the end of any heat shall not be included in a fresh batch in an amount greater than 10 percent of the batch. Kettles shall be emptied and cleaned frequently as required. The material removed in cleaning the kettles shall be dumped and wasted.

6. **APPLICATION OF COAL-TAR ENAMEL TO EXTERIOR SURFACES:**

a) The primed steel surface to be enameled shall be dry and clean at the time the enamel is applied. Any damage occurring to the primer coat shall be repaired by retouching before application of the enamel.

b) External enamel shall be applied by pouring on the revolving pipe and spreading to the specified thickness. Enamel shall be applied so each spiral resulting from the spreading operations shall overlap the preceding spiral, producing a continuous coat free from defects. The thickness of coating shall be 3/32 in.(2.3 mm), and the allowable variation in thickness shall not exceed ±1/32 in (0.8 mm). ·

c) The enameled pipe shall not be rolled or supported on its enameled surface until thoroughly cooled and hardened.

d) For application to specials and other shapes, refer to **sub-clause PS – 9.5.3.4 of these specifications**.

e) Exterior enamel coating shall be electrically tested as per **sub-clause PS – 9.5.3.4;para – (11) of these specifications**, before wrapping is applied.

7. APPLICATION OF COAL-TAR ENAMEL AT END OF PIPE SECTIONS:

a) When pipe sections are to be joined together by field welding, the protective materials shall be left off the outside surfaces at the ends a distance of 4 inches (100 mm) for the primer and of 9 inches (230 mm) for the final coating and wrapping, to permit the making of field joints without injury to the lining and coating.

b) When pipe sections are to be joined together with mechanical couplings, the enamel shall be left off the exterior of the pipe a distance back from the ends of 1 in. (25 mm) more than one- half the overall length of the assembled coupling. The interior lining shall extend to the pipe end.

c) For joints other than specified herein, the length of pipe to be left bare at ends shall be in accordance with instructions supplied by the Engineer/Engineer representative.

8. SPECIALS - CLEANING, AND COATING:

The results of cleaning and coating of specials shall be equivalent to the results of similar work on straight pipe sections. Methods deviating from the prescribed procedure shall require approval by the Engineer/Engineer representative. If the shape precludes spinning, the exterior coating shall be applied by hand daubers as follows:

a) All surfaces shall be double coated by applying the enamel with hand daubers. The brush strokes of enamel shall be made in the direction of flow. All brush strokes of enamel shall overlap and form a continuous coating. The daubing may be done by the double-lap or “shingling" method. The work shall be done in a workmanlike manner, and no indiscriminate smearing of the enamel will be permitted. On all welds the strokes of the first coat of enamel shall be applied along the weld.

b) Enameling buckets shall be filled from the heating kettles with ladl8S or from spigots attached to the kettles and shall not be dipped for filling. Buckets shall be kept clean and free of dirt at all times and shall not be set directly upon the ground or on enameled surfaces but shall be set upon suitable pads or blocks. Buckets shall not be allowed to accumulate excess chilled enamel but shall be kept clean.

c) Enamel shall not be used from the enameling buckets below the minimum temperature specified by the manufacturer.

d) All drips and splashes of enamel on primed surfaces shall be carefully scraped off before the hand brushed coat of enamel is applied. This pertains particularly where overhead hand enameling is necessary inside of pipe or specials.

e) Hand-enameling daubers or mops shall be of the size best adapted for the work and shall be subject to the approval of the Engineer/Engineer representative. Daubers shall be made of the best grade of Tampico Fiber set in solid hardwood handles. Sweeps, or knot daubers shall not be used. Long hand horseshoe daubers will be acceptable for large areas and flat work. Mops shall be made of top quality waterproofer's yarn looped, with strand lengths of 6” to 8" (150 mm to 200 mm).

9. **FITTINGS:**

All fittings such as manholes, service connections, air valves, and blowoff connections shall be protected with primer and coal-tar enamel, and the same application procedure shall be employed as specified in **sub-clause PS – 9.5.3.4;para – (8) of these specifications.**

10. **APPLICATION OF GLASS-FIBER COAL-TAR SATURATED FELT:**

Fiberglass felt shall be mechanically applied in a continuous end-feed machine or in a lathe-type machine or by approved field felt application equipment.

a) External enamel and glass-fiber felt wrapper shall be applied to the revolving pipe so as to produce a coal-tar enamel coating to a thickness of 3/32 in. (2.38 mm) and the allowable variation in the enamel thickness shall not exceed ±1/32 in. (0.8 mm) The fiberglass felt shall be definitely and positively bonded to the enamel. The enamel coating shall be continuous and free from defects, skips, or holidays.

b) The glass-fiber felt as specified in **sub-clause PS – 9.5.3.3;para – (4) of these specifications** shall be of suitable width for smooth, spiral application and shall be of approximately uniform width. The overlap of the felt shall be not less than 1/2 in.(13 mm) The glass-fiber felt shall be applied neatly and smoothly and shall be free ·of wrinkles and buckles. The second layer (when required) of coal-tar enamel and glass-fiber coal-tar saturated felt shall overlap the first layer by 50% producing a continuous coat free from defects, skips or holes. The thickness of this layer shall be 3/32 in.(2.3 mm), and the allowable variation in thickness shall not exceed ±1/32 in.(±0.8 mm) The second glass-fiber coal-tar saturated felt layer shall have a 1/32 in.(0.8 mm) minimum cover of hot coal-tar.

c) Over the bonded glass-fiber felt wrapper shall be applied a coating of whitewash following final inspection as specified in **sub-clause PS – 9.5.3.4; para – (12) of these specifications.**

11. **ELECTRICAL INSPECTION:**

The Contractor shall conduct electrical inspection of all of the coating by means of an approved electrical flaw detector delivering approximately 10,000 V at low amperage. Before final shop acceptance of coal-tar enamel coating, the entire interior and exterior surfaces of all coated pipe. shall be tested, and all defects found shall be satisfactorily repaired by and at the expense of the Contractor.

a) **General:**

When applying coating system to pipelines the main goal is to apply a continuous film to help prevent structural deterioration throughout the life of the structure. Unaddressed discontinuities (i.e., pinholes and holidays) can result in undercutting corrosion of the substrate, where the integrity of the structure could be prematurely compromised.

Holiday or pinhole detection is used to detect voids in the applied coating.

Pinholes are tiny voids, or pin-sized holes that penetrate through a coating, but may or may not penetrate to the substrate. Pinholing can be caused by numerous factors, but essentially is the inability of the coating to thoroughly wet-out the surface.

Holidays are skips or misses in a coating layer and are typically an error caused the applicator rather than the coating itself. Holidays are more prevalent for complex structures where it may be more difficult to access surfaces.

Pinholes and holidays are of much greater concern when coating or lining performance cannot be easily observed, such as a buried pipe or the interior of a tank or vessel. These voids and misses can be detected by performing holiday detection, then repaired before the coating system is put into service.

The inspection process shall be performed after application of the final coat of a system; performing holiday detection after each coat is not recommended as surface contamination may interfere with adhesion of subsequently applied coatings. Also, holiday detection is intended for use with new coatings applied to metal substrates. Its use on a coating previously exposed to an immersion condition can result in damage to the coating or produce erroneous detection of discontinuities due to permeation or moisture absorption of the coating. Deposits may also be present on the surface causing telegraphing (current traveling through a moisture path to a discontinuity, giving an erroneous indication) or current leakage across the surface of the coating due to contamination. Employing high voltage detection on previously exposed coatings can generate possible spark-through, which will damage an otherwise sound coating. Although a low voltage tester can be used without damaging the coating, it may also produce erroneous results.

b) **Types of Holiday Detection**

There are two main types of holiday detection; wet-sponge (low voltage) and spark (high voltage).

Low voltage detection is typically used to inspect coatings that are less than 20 mils (0.508 mm) thick.

High voltage detection is used to inspect coatings greater than 20 mils (0.508 mm) thick. High voltage detection can be used on coatings between 10 (0.254 mm) and 20 mils (0.508 mm) in thickness provided the voltage is calculated correctly and can be precisely set on the detector.

For either method (low of high voltage), the substrate must be electrically conductive, and the coating must not be conductive. Coatings that contain conductive pigments (zinc, aluminum flake, etc.) cannot be tested using these methods.

The following standards for electrical inspection of coatings shall be invoked, as directed by the Engineer/Engineer representative:

- ASTM D5162-15 "Standard Practice for Discontinuity (Holiday) Testing of Nonconductive Protective Coating on Metallic Substrates," and ASTM G62-14 "Standard Test Methods for Holiday Detection in Pipeline Coatings."

- NACE International (National Association of Corrosion Engineer/Engineer representatives) SP0188 "Standard Practice – Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates".

- ISO 29601 "*Paints and Varnishes* — Corrosion Protection by Protective Paint Systems — Assessment of Porosity in a Dry Film."

The underlying procedures and requirements of when to use each type of detector are the same, but the procedures vary when describing testing of coatings greater than 20 mils thick (spark testing); specifically, variations in adjusting required voltage for the different thicknesses.

Tables are provided in each of the test methods that contain suggested inspection voltages. For example, ASTM D5162 provides a range of 19.7 to 307.1 mils (0.500 to 8.00 mm) coating thickness that is linear (2,700 to 30,000 volts). NACE SP0188 provides a range of 8 to 185 mils (0.200 to 4.7 mm) coating thickness that is linear to a suggested voltage testing range of 1,500 to 15,000 volts.

The Contractor is advised that proper selection based on coating thickness, set-up (voltage setting for high voltage detection) and operation helps ensure proper testing without adversely affecting the dielectric insulating properties of the coating.

12. **USE OF WHITEWASH ON EXTERIOR:**

Outside surfaces of all pipe and specials shall be given a coat of water-resistant whitewash immediately following final inspection. Before whitewashing coated and wrapped pipe, it shall have completely cooled. Kraft paper may be used in lieu of a whitewash coating on the outside surface of the pipe in accordance with AWWA Standard for Coal-Tar Protective Coatings and Linings for Steel Water Pipelines--Enamel and Tape--Hot-Applied, ANSl/AWWA C203-91 Section 2.5.

PS 9.5.3.5 FIELD PROCEDURE AND ENAMELING:

1. **TRANSPORTING AND HANDLING ENAMELED PIPE:**

a) Protected pipe at all times shall be handled with equipment such as stout, wide belt slings and wide padded skids designed to prevent damage to the coating. Bare cables, chains, hooks, metal bars, or narrow skids shall not be permitted to come in contact with the coating. All handling and hauling equipment shall be approved by the Engineer/Engineer representative before use.

b) In truck shipments, the pipe shall be supported in wide cradles of suitable padded timbers hollowed out on the supporting surface to fit the curvature of pipe, and all chains, cables, or other equipment used for fastening the load shall be carefully padded. For smaller diameter pipe, sand or sawdust filled bags may be used instead of hollowed out timbers.

2. **HANDLING ENAMELED PIPE IN FIELD OR AT TRENCH:**

a) Pipe shall be stored along the trench side, supported on wooden timbers placed under the uncoated ends to hold the pipe off the ground.

b) Pipe shall be hoisted from the trench side to the trench by means of a wide belt sling. Chains or cables, no matter how well padded, tongs, or other equipment likely *to* cause damage to the enamel coating will be not be permitted. Dragging or skidding the pipe will not be permitted. The Contractor shall allow inspection of the coating on the underside of the pipe while suspended from the sling. Any damage shall be repaired before lowering the pipe into the trench.

c) Where the trench traverses rocky ground or ground containing hard objects that would penetrate the protective coating, a layer of screened earth or sand not less than 3 in. (75 mm) in thickness shall be placed in the bottom of the trench prior to installation of pipe, or as otherwise specified or directed by the Engineer/Engineer representative.

d) At all times during erection of the pipeline the Contractor shall use every precaution to prevent damage to protective coating on the pipe. No metal tools or heavy objects shall be unnecessarily permitted to come in contact with the finished coating. Workmen will be permitted to walk upon the coating only when necessary, and in case of such necessity the workmen shall wear shoes with rubber or composition soles and heels. This shall apply to all surfaces, whether bare, primed, or enameled. Any damage to the pipe or the protective coating from any cause during the installation of the pipeline and before final acceptance by the purchaser shall be repaired as directed by the Engineer/Engineer representative, and at the expense of the Contractor.

3. **WELDED FIELD JOINTS ; COAL-TAR ENAMEL COATING:**

a) The primer and coal-tar enamel used shall be the same material as used for coating the pipe.

b) Interior: After field pressure testing, exterior surface of welds of field joints shall be cleaned. Primer shall then be applied and allowed to dry according to the coating manufacturer's instructions. Completion of lining of field joints shall be compatible with the lining used and accepted Standard Practice. The requirements of this paragraph are applicable only to those sizes of pipe 30 in. (750 mm) and larger, into which it is possible to enter for cleaning and applying primer.

c) Exterior: After field pressure tests have been completed, joints shall be cleaned and primed. When the primer is dry, the field joints shall be manually coated and wrapped to the specified thickness. Enamel shall overlap the coating on each side of the field joint to form a continuous external coating free from defects.

d) All hand enameling shall be done in accordance with the procedure outlined in paragraphs under **sub-clause PS – 9.5.3.4;para – (8) of these specifications**, and heating of enamel for field application shall be done in accordance with the procedure outlined in paragraphs under **sub-clause PS – 9.5.3.4;para – (5) of these specifications.**

e) All field coating work shall be thoroughly inspected in the presence of the Engineer/Engineer representative by the Contractor, using an electrical flaw detector, and any flaws or holidays found shall be repaired by the Contractor.

f) Once each day a standard peel test shall be taken by the Engineer/Engineer representative from the outside of one field joint before wrapping. The joint selected shall be one done during that day.

The test procedure shall be as follows:

With a knife-edge, cut two parallel lines through the enamel to the steel approximately 3/4 inch (19 mm) apart and approximately 4 inches (100 mm) in length. With the edge of the knife blade, cut under the enamel strip at one narrow end and loosen the enamel from the plate the full width and back about 1/2 inch. (12.7 mm) Place the blade under the loosened end and with a firm grip on the enamel between the blade and a finger, apply a slow upward pull on the strip.

(a) If the strip peels only 1/8 inch (3 mm), the test shall be recorded "no peel" and the coating made that day are acceptable.

(b) If the strip peels more than 1/8 inch (3 mm), the test shall be recorded "unacceptable peel”.

If (b) occurs, all other coated joints made during the working day represented by the tested coated joint shall be similarly tested. Any joint showing the same condition shall have the coating removed, and a new coating reapplied, all at the expense of the Contractor.

4. **MECHANICAL COUPLINGS-CLEANING, PRIMING, AND COATING:**

At the point of manufacture, all couplings shall be cleaned, then primed with the primer specified by the manufacturer of the coating used on the pipe. The couplings and the exposed pipe ends shall be reprimed in the field. When the primer is dry, these exterior surfaces shall be coated with the AWWA coal-tar enamel coating recommended by the manufacturer of the coating used on the pipe. The coating shall be capable of conforming to the normal movement of the buried pipe without cracking.

5. **MAIN PIPELINE BULKHEADS**:

The Contractor shall be aware that main pipeline bulkheads shall be lined and coated as herein specified for the interior and exterior surfaces of the main pipe section.

6. **FINAL INSPECTION BEFORE BACKFILLING:**

All phases of the installation work shall be done in such a manner so as to prevent any damage to the main pipeline lining and coating. Prior to backfilling any section of the main pipeline, these surfaces shall receive a final visual inspection, and an overall electrical flaw inspection using an approved "holiday detector". Any defects noted shall be repaired and the surfaces retested until satisfactory results are obtained. The holiday detector shall deliver 10.000 V to 12,000 V at low amperage.

7. **BACKFILLING:**

Backfilling shall be conducted at all times in such a manner as to prevent damage and abrasion to coal-tar enamel exterior protection of pipe.

PS 9.5.3.6 INTERIOR LINING AND EXTERIOR COATING WITH APPROVED EPOXY AND POLYURETHANE COATINGS:

The interior lining and the exterior coating shall be in accordance with the American Water Works Association Standard for Liquid Epoxy and Polyurethane Coating System for the Interior and Exterior of Steel Water Pipelines, AWWA C210-84, or equivalent and/or as approved by the Engineer/Engineer representative. This standard covers the material and application requirements of a liquid epoxy coating system that will provide long term protection from corrosion to both interior and exterior of steel water pipe, special sections, welded joints, and connections installed underground under normal conditions. The lining system must also have been approved for use in contact with potable drinking water in accordance with the ANSI/National Sanitation Foundation Specification Standard ANSI/NSF 61-1992. This lining system shall consist of a liquid two-part chemically cured rust-inhibitive epoxy primer and one or more coats of a liquid two-part epoxy finish coat. The coating system may alternatively consist of two or more coats of the same epoxy coating without the use of a separate primer. The first coat of this alternate system shall be considered as the primer.

The Contractor shall observe strict adherence to the manufacturer's directions for preparation and application of the epoxy coating system as specified on drawings, in the Bill of Quantities and / or as approved by the Engineer/Engineer representative. The coated film shall not contain any blisters or cracks and shall be uniform without runs or sags. The coating shall be worked into angles and crevices formed by joining members. After coating it shall not be easily chipped or peeled by penetration with a knee joint.

PS 9.5.3.7 QUALIFICATIONS OF EPOXY AND POLYURETHANE APPLICATOR:

1. The Contractor’s coating and lining applicator will be considered as qualified to perform work in the shop or in the field on straight pipe, special sections, welded joints, couplings, venturi tubes, regulators, valves, expansion joints, fittings and connections after he has complied with the following:

   a) He shall have under suitable cover a manufacturer's plant approved by the Engineer/Engineer representative capable of cleaning, blasting, lining and coating steel pipe and appurtenances in accordance with American Water Works Association Standards, Steel Structures Painting Council Specifications, and National Association of Corrosion Engineer/Engineer representatives Standards.

   b) He shall have been engaged in this type of work either as the head of his own business, or in a supervisory capacity with a concern doing this type of work for a period of at least five (5) years.

   c) He shall take a qualification test to be given by the Engineer/Engineer representative. This test shall consist of lining and coating a section of steel pipe in accordance with standard Engineering practices and / or as specified exclusively by the Engineer/Engineer representative. This section will be inspected and tested by the Engineer/Engineer representative and, if found satisfactory, the applicator will be declared qualified.

   d) He shall employ experienced help for this work if the applicator is acting in the supervisory and not doing the work himself.

   e) Should subsequent inspections reveal that the applicator is consistently doing work of an inferior nature, he will be disqualified from all the project works.

2. The applicator for coating pipe and appurtenances, and for work

in the field on joints and "touch- up" should have the following equipment:

a) Sufficient epoxy components that have not exceeded shelf life.
b) Mixing kettle with metal paddle agitators.
c) Thermometer and timer.
d) Thickness gauge, both wet and dry.
e) Hand daubers and spray equipment.
f) Approved electrical testing equipment for holiday detection.
g) Approved cleaning materials and sand blast cleaning equipment.
h) Exhaust fans for adequate health and safety precautions.

PS 9.5.3.8 MATERIALS FOR PRIMER, EPOXY AND POLYURETHANE:

1. **PRIMER:**

The primer shall be supplied by the epoxy manufacturer approved by NSF or equivalent for use in potable water mains and shall consist of a two component epoxy system of bisphenol, an epoxy resin and a polyamide resin catalyst, in a solvent which will produce, without heat application, an effective bond between the metal steel surface to be protected and the next coat to be applied. The primer shall comply with all code and regulatory requirements regarding safety and environmental protection in effect at the location of use.

2. **EPOXY FINISH COATS**:

a) The topcoat shall consist of a two-part liquid epoxy to be used over the epoxy primer. The mixing ratio of the two components shall be as specified by the manufacturer. The characteristics and performance properties of the topcoat shall conform to the requirements in accordance with the American Water Works Association Standard for Liquid Epoxy Coating Systems for the Interior and Exterior of Steel Water Pipelines, AWWA C210-84 as stated in Table – II.

TABLE – II

Characteristic and Performance Properties

Primer	Minimum	Maximum	Method
1. Sag of wet film		None	Sec.5.3.2.1
Top coat	Minimum	Maximum	Method
1. Sag of wet film		None	Sec.5.3.2.1
Coating system	Minimum	Maximum	Method
1. Penetration at 140°F (60°C)		0.001 in. (0.025 mm)	Sec.5.3.2.2
2.Impact resistance at 75°F ± 2°F (24°C ± 1°C)		Pass	Sec.5.3.2.3
3. Cathodic disbondment		1.5 $in.^2$ (967.5 mm^2)	Sec.5.3.2.4
4. Hot water resistance 24 hrs at 208°F ±4°F (98°C ±2°C)	Pass		Sec. 5.3.2.5
5. Water extractables		0.5 $mg/in.^2$ (0.00078mg/mm^2)	Sec. 5.3.2.6
6. Taste and odor	Pass		Sec. 5.3.2.7
7. Immersion	Pass		Sec. 5.3.2.8
8. Adhesion	Pass		Sec.5.3.2.9

b) Pipe, appurtenances, mechanical couplings, flanges, and expansion joints shall be coated externally with the epoxy primer and liquid epoxy finish coat system. Both primer and finish coat(s) shall be spray-applied in accordance with the manufacturer's recommendations. Application by airless spray is the preferred method.

3. **SPECIFICATION OF 100% POLYURETHANE COATINGS AND LININGS FOR STEEL PIPE:**

a) **SCOPE:**

This specification covers a plural component 100% solids polyurethane coating system for use as an internal lining or external coating for steel pipe.

b) **MATERIAL:**

The coating/lining material shall consist of a 100% solids polylsocyanate resin and polyol resin that meets the performance requirements AWWA standard C210- 84 as described in Section 2.2 that has the following properties:

PROPERTY	REQUIREMENT
% Solids	100%
Dry-to-touch time	60 seconds @ 70°F
Mix Ratio	1 :1

c) **SURFACE PREPARATION:**

All surfaces to be coated or lined should be cleaned to a near white metal finish (SSPC-SP10) with an angular profile of at least 2.5 mils (0.0635 mm) All surfaces to be coated shall be completely dry, free of moisture, dust, grease or any other deleterious substances at the time the coating or lining is applied.

d) **THICKNESS:**

The required thicknesses are as follows for the respective applications:

APPLICATION	MINIMUM FILM THICKNESS	NOMINAL FILM THICKNESS
Internal Potable Water	15 mils (375 microns)	18 mils (450 microns)
Line Pipe	15 mils (375 microns)	18 mils (450 microns)
Field Joints	15 mils (375 microns)	18 mils (450 microns)
Valves	20 mils (500 microns)	25 mils (625 microns)
Fittings	20 mils (500 microns)	25 mils (625 microns)
Slip Bore	50 mils (1250 microns)	--
Stock Pipe	25 mils (625 microns)	--
Other Internal	depends on chemical and abrasive content and floor rates	

e) **COATING APPLICATION:**

A heated, plural component airless spray pump (1:1 ratio) is to be used to" apply the coating in one coat, multi-pass operation. No primers are to be used with this coating system.

f) **REPAIR AND FIELD TOUCH-UP:**

Repair and touch-up materials should be compatible with the main coating system and applied according to the manufacturers recommendations.

g) **INSPECTION:**

Holiday inspection shall be conducted as described in AWWA C210, Section 5.3.3.1. The testing may be conducted any time after the coating has reached sufficient cure.

PS 9.5.3.9 SHOP AND FIELD APPLICATION OF PRIMER AND EPOXY SYSTEM:

1. **GENERAL:**

The Contractor shall furnish all labor, equipment and material required, shall prepare all surfaces to be coated, and shall apply the NSF approved primer and either epoxy and polyurethane exterior surfaces to be coated.

2. **PREPARATION OF SURFACES:**

a) Before blasting, all oil and grease on the surfaces of the metal shall be removed thoroughly by flushing and wiping, using “Xylol (Xylene)" or other suitable solvents, and clean rags. The use of dirty or oily rags or solvent will not be permitted. All other foreign matter not removable by blasting shall be removed by suitable means. All metal surfaces shall be thoroughly cleaned by blasting. Blasting-cleaning operations shall remove all rust, scale, and other impurities from the surface, exposing base metal over all, presenting a grayish matte appearance, in accordance with the requirements of the Steel Structures Painting Council, Surface Preparation Specification No.10, Near-White Blast Cleaning, SSPC-SP10. Blasted surfaces that rust before a priming coat has been applied shall be cleaned of all rust by buffing or wire brushing or, at the discretion of the Engineer/Engineer representative, shall be re-blasted. Adequate air separators shall be used to remove effectively all oil and free moisture from the air-supply to the blaster.

b) After cleaning, the surfaces shall be protected from and maintained free of all oil, grease, and dirt that might fall upon it from whatever source until it has received its final epoxy coat. Any surface showing pits or cracks after beginning of blasting shall be set aside immediately, pending examination by the Inspector for approval, reconditioning or rejection.

c) The use of epoxy or polyurethane epoxy that becomes fouled with foreign substances or has thickened through evaporation of the solvent oils or began to harden will not be permitted.

d) After application, the coatings shall be uniform and free from floods, runs, sags, drips, holidays, or bare spots. Any bare spots or holidays shall be recoated with an additional application of primer. All runs, sags, floods, or drips shall be removed by scraping and cleaning and the cleaned area retouched, or, at the discretion of the Inspector, all such defects shall be remedied by re-blasting and re-priming. Suitable measures shall be taken to protect wet coatings from contact with rain, fog, mist, spray, dust, or other foreign matter until completely hardened.

e) In cold weather when the temperature of the steel is below 55°F (13°C), or at any time when moisture collects on steel, the steel shall be warmed to a temperature of approximately 85°-120°F (30°-49°C) for sufficient time to dry the surface prior to priming or coating. To facilitate spraying and spreading; the mixed epoxy may be heated and maintained during the application at a temperature of not more than 75°F (24°C). The temperature of the mixed epoxy and the steel surfaces at the time of application shall not be lower than 55°F (13°C).

3. END PREPARATION OF PIPE, SPECIAL CONNECTIONS AND APPURTENANCES:

a) Pipe section with butt or lapped joints to be joined by field welding shall not be coated within 2-1/2in. ±1/2in. (64 mm ±12.7 mm) of the area to be welded. This requirement applies to both the inside and outside surfaces of the pipe. Coating material on the holdback, bevel, or band is not acceptable. When rubber gasketed joints or mechanical couplings are used, the coating may extend to the ends of the pipe; but the coating thickness on the pipe surfaces that receive rubber-sealing gaskets shall not exceed what is recommended by the manufacturer of the coupling.

b) Nuts, bolts, and other items of mechanically threaded system parts used in conjunction with connections, couplings and attachments that must be assembled and operated in the field shall be left uncoated, except as shown on the approved drawings or specifications.

c) Flange faces, spot faces on flanges and bolt holes shall be coated with one smooth coat of epoxy with a dry film thickness of approximately three (3) mils (0.0762 mm).

4. **ELECTRICAL AND THICKNESS INSPECTION:**

The Contractor shall conduct electrical inspection of all of the coating by means of an approved electrical flaw detector. Either wet sponge or high-voltage equipment shall be used and the voltage settings and procedures must be in strict accordance with National Association of Corrosion Engineer/Engineer representatives Standard Recommended Practice for Discontinuity (Holiday) Testing of Protective Coatings, NACE RPO 188-88, or equivalent alternate standards and procedures as specified in **sub-clause 9.5.3.4; para (11) of these specifications.**

After coating each pipe section and fitting shall also be tested for thickness in accordance with the epoxy or polyurethane manufacturer's recommendation with an approved thickness gauge. The total system coating shall provide in two or more coats a total dry film thickness of not less than 14 mils (0.356 mm) nor more than 25 mils (0.635 mm). Any defects noted from the testing procedures shall be repaired and the coatings retested until satisfactory results are obtained.

PS 9.5.3.10 FIELD PROCEDURE:

a) **TRANSPORTING AND HANDLING COATED PIPE AND APPURTENANCE:**

Similar to **sub-clause 9.5.3.5; para (1), sub-para's (a) to (d)** of these specifications.

b) **HANDLING EPOXY AND POLYURETHANE LINED AND COATED PIPE IN FIELD OR TRENCH:**

Similar to **sub-clause 9.5.3.5; para (2), sub-para's (a) to (d)** of these specifications.

c) **WELDING FIELD JOINTS - EPOXY AND POLYURETHANE LINED AND COATED:**

Refer to **sub-clause 9.5.3.9; para (3), sub-para's (a) to (c)** of these specifications.

d) **MECHANICAL COUPLINGS**:

Refer to **sub-clause 9.5.3.9; para (3), sub-para's (a) to (c)** of these specifications.

e) **MAIN PIPELINE BULKHEADS**:

Similar to **sub-clause 9.5.3.5; para (5)** of these specifications.

6. **FINAL INSPECTION BEFORE BACKFILLING**:

Similar to **sub-clause 9.5.3.5; para (6)** of these specifications.

7. **BACKFILLING:**

Backfilling shall be conducted at all times and in such a manner as to prevent damage and abrasion to the exterior coating of the pipe.

PS 9.5.3.11 CANAL OR RIVER CROSSING AND CULVERT CROSSINGS

The Contractor shall furnish all labor, equipment and materials and perform all incidental work required to install canal or river crossings and culvert crossings as shown on the drawings or as specified or as otherwise directed by the Engineer/Engineer representative.

The Contractor shall dig test pits near the bridge and/or the bank of the canal prior to installation of pipe crossing the canal. In the event of underground structures and/or utilities are not in the same locations as indicated on the

Drawings that may cause changes in the pipe routing, position of form of pipe support structures and other related works, then the Contractor shall prepare drawings showing detail of the changes and submit them to the Engineer/Engineer representative for approval. The Contractor shall pursue the directions of the Engineer/Engineer representative on this matter and any damage resulting from not carrying out said direction including the costs in changing the method of construction of the approach pipe laying shall be borne by the Contractor.

Steel used for pipe supports and incidental works of canal crossing shall be of structural steel. Concrete thrust blocks and supports shall be constructed at fittings or bends where indicated on the Drawings or as directed by the Engineer/Engineer representative.

The Contractor shall submit the proposed method and details of the construction to the Engineer/Engineer representative for his approval. Approval of such details shall not relieve the contractor from the responsibilities under the Contract. The Contractor shall take extreme care to protect bridges, surrounding structures and utilities from damage. Vehicular and pedestrian traffic shall be maintained at all times as well as utility services. Costs or charges resulting from damage thereto shall be borne by the Contractor.

The Contractor shall provide support to the pipes with proper concrete structures where pipe trenching is not practical or pipes are to be installed in swampy areas. The installed pipe shall be levelled as shown on the Drawings and an air valve shall be installed at the highest point of the pipe or at the end point of the pipe or at the tail water end as shown on the Drawings. Necessary trench cut off walls and rubble pitching shall be provided for crossing of pipeline outside of the culvert and under the invert level as shown in the drawing.

PS 9.6 FURNISHING. DELIVERING AND INSTALLING PIPE APPURTENANCES

PS 9.6.1 GENERAL

This section of specification covers the requirements of materials selected for appurtenances of 1000 mm Ø MS pipeline, to be used on this project

All pipe fittings, packing, jointing material and valves, shall be new and conform to Section C of AWWA Standards. All pipe material, solder and flux shall be lead free (less than 0.2% lead in solder and flux and less than 8.0% lead in pipes and fittings).

Piping components shall be required 100% Radiography Test to weld area with a weld joint efficiency of 1.00.

All codes and standards specified below refer to the latest revision of that standard under the same specification number or to the superseding specifications under a new number.

AMERICAN SOCIETY OF MECHANICAL ENGINEER/ENGINEER REPRESENTATIVES (ASME)

ASME B31.3	Process Piping
ASME B16.5	Piping Flanges and Flanged Fittings
ASME B16.9	Factory-Made Wrought Steel Buttwelding Fittings
ASME B16.10	Face-to-Face and End-to-End dimensions of Valves
ASME B16.11	Forged Fittings, Socket-Welding and Threaded
ASME B16.20	Metallic Gaskets for Pipe Flanges-Ring Joint, Spiral Wounds and Jacketed
ASME B16.21	Nonmetallic Flat Gaskets for Pipe Flanges
ASME B16.25	Buttwelding Ends
ASME B16.34	Valves-Flanged, Threaded, and Welding End
ASME B16.47	Large Diameter Steel Flanges, NPS 26 through NPS 60
ASME B18.2.1	Square and Hex Bolts and Screws (Inch Series)
ASME B18.2.2	Square and Hex Nuts (Inch Series)
ASME B46.1	Surface Texture (Surface Roughness, Waviness, and Lay)

AMERICAN PETROLEUM INSTITUTE (API)

ANSI/API SPEC.5L	Specification for Line Pipe
API 594	Check Valves : Flanged, Lug, Wafer and Butt-Welding
API 598	Valve Inspection and Test
API 599	Metal Plug Valves - Flanged and Welding Ends
API 600	Steel Gate Valves – Flanged and Butt-Welding Ends, Bolted Bonnets
API 603	Corrosion-Resistant, Bolted Bonnet Gate Valves-Flanged and Buttwelding Ends
API 607	Fire Test for Soft-seated Quarter-turn Valves
API 608	Metal Ball Valves-Flanged, Threaded, and Welding End
API 609	Butterfly Valves: Double Flanged, Lug- and Wafer-Type

AMERICAN WATER WORKS ASSOCIATION (AWWA)

AWWA C221-18	Fabricated Steel Mechanical Slip-Type Expansion Joints

AWWA C207-18	Steel Pipe Flanges for Waterworks Service—Sizes 4 In. Through 144 In. (100 mm Through 3,600 mm)
AWWA C226-19	Stainless-Steel Fittings for Waterworks Service, Sizes 1/2 In. Through 72 In. (13 mm Through 1,800 mm)
AWWA C227-17	Bolted, Split-Sleeve Couplings
AWWA C228-19	Stainless-Steel Pipe Flange Joints for Water Service—Sizes 2 In. Through 72 In. (50 mm Through 1,800 mm)
AWWA C500-19	Metal-Seated Gate Valves for Water Supply Service
AWWA C504-15	Rubber-Seated Butterfly Valves
AWWA C507-18	Ball Valves, 6 In. Through 60 In.(150 mm Through 1,500 mm)
AWWA C508-17	Swing-Check Valves for Waterworks Service, 2-In. Through 48-In. (50-mm Through 1200-mm) NPS
AWWA C509-15	Resilient-Seated Gate Valves for Water Supply Service
AWWA C510-17	Double Check Valve Backflow Prevention Assembly
AWWA C512-15	Air Release, Air/Vacuum, and Combination Air Valves for Water and Wastewater Service
AWWA C518-18	Double-Disc Swing-Check Valves for Waterworks Service 2-in. Through 48-in.(50-mm Through 1,200-mm) NPS
AWWA C519-18	High Performance Waterworks Butterfly Valves – 3 In. (75 mm) through 60 In. (1,500 mm)
AWWA C541-16	Hydraulic and Pneumatic Cylinder and Vane-Type Actuators for Valves and Slide Gates
AWWA C542-16	Electric Motor Actuators for Valves and Slide Gates
AWWA C561-14	Fabricated Stainless-Steel Slide Gates

AMERICAN SOCIETY FOR TESTING MATERIALS (ASTM)

ASTM A182 / A182M	Standard Specification for Forged or Rolled Alloy and Stainless-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
ASTM A231	Specification for Steel Casting, Austenitic, for High-Temperature Service

ASTM A240 / A240M	Standard Specification for Chromium and Chromium Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications (**Grade: 316 & 316L)**
ASTM A276	Specification for Stainless and Heat-Resisting Steel Bars and Shapes
ASTM A351 / A351M	Standard Specification for Castings, Austenitic, for Pressure-Containing Parts
ASTM A995 / A995M	Standard Specification for Castings, Austenitic-Ferritic (Duplex) Stainless Steel, for Pressure-Containing Parts

BRITISH STANDARD (BS)

BS 1868	Steel Check Valves (Flanged and Butt-Welding Ends) for the Petroleum, Petrochemical and Allied Industries
BS 1873	Steel Globe and Globe Stop and Check Valves (Flanged and Butt- Welding Ends) for the Petroleum, Petrochemical and Allied Industries
BS 5155	Butterfly Valves
BS 5163	Pre-Dominantly key operated Cast Iron Gate Valves for Water Works Purposes
BS 4504	Circular Flanges for Pipes, Valves, and Fittings
BS EN ISO 17292	Metal Ball Valves for Petroleum, Petrochemical and allied industries
BS EN ISO 12266-1	Industrial Valves – Testing of Valves
BS EN ISO 12266-2	Industrial Valves – Testing of Valves

MANUFACTURERS STANDARD SOCIETY (MSS)

MSS SP-6	Standard Finishes for Contact Faces of Pipe Flanges and Connecting & End Flanges of Valves and Fittings
MSS-SP-25	Standard Marking System for Valves, Fittings, Flanges and Unions

MSS SP-42	Class 150 Corrosion Resistant Gate, Globe, angle and Check Valves with Flanged and Butt Weld Ends
MSS-SP-44	Steel Pipeline Flanges
MSS-SP-53	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Component - Magnetic Particle Examination Method
MSS-SP-54	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Component - Radiographic Examination Method
MSS-SP-55	Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components - Visual Method for Evaluation of Surface Irregularities.
MSS SP-61	Pressure Testing of Valves.
MSS SP-67	Butterfly Valves
MSS-SP-75	Specification for High Test Wrought Butt Welding Fittings
MSS-SP-80	Bronze Gate, Globe, Angle and Check Valves
MSS-SP-97	Integrally Reinforced Forged Branch Outlet Fittings-Socket Weldings, Threaded and Buttwelding Ends
MSS-SP-110	Ball Valves, Threaded, Socket Welding, Solder Joint, Grooved and Flanged Ends
MSS-SP-93	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Component – Liquid Penetrant Examination Method

PS 9.6.2 MATERIALS AND MANUFACTURE

All valves shall be of size and type as shown on the drawings or in the Bill of Quantities. All valves shall be from one manufacturer, unless approved by the Engineer/Engineer representative in exceptional circumstances.

1. VALVES ENDS

Valve ends shall be of flanged ends except where otherwise specifically called out on the bill of quantities. Where flanged ends are used, mating dimensions and drilling; Bolts and nuts shall be in accordance with **sub-clause PS 9.5.1.16 "Flanged Joints"** of these specifications.

2. **VALVE MARKING**

All valves shall have the direction arrow for opening; the name or mark of the manufacturer; the name of the organization ; the valve size; year of manufacture; number of turns to open, and the working pressure for which they are designed cast in raised letters upon an appropriate part of the body. In addition, valves designed for one-way flow only shall have a direction arrow cast on the body.

3. **PROTECTIVE INTERIOR COATING FOR ALL VALVES**

Ferrous surfaces in the water passages of the valves excluding those surfaces manufactured of corrosion resistant material shall be non-toxic epoxy resin. The minimum coating thickness shall not be less than 100 microns.

4. **PROTECTIVE EXTERIOR COATING FOR BURIED VALVES**

All buried valves excluding those manufactured of corrosion resistant material shall be provided with an exterior protective coating against corrosive soil in accordance with AWWA or DIN standards K115 or BS 5163: 1974 or approved equivalent standards. The minimum coating thickness shall not be less than 200 microns**.**

5. **DIRECTION TO CLOSURE**

The manufacturer of the valve shall ensure its closure by clockwise turning of the wrench nuts and open by counter clockwise turning by the valve operators.

6. **SUBMITTALS**

The Contractor shall submit descriptive information and evidence that the materials and equipment the Contractor proposes for incorporation in the Work is of the kind and quality that satisfies the specified functions and quality.

The Contractor's submittal shall include manufacturer's certified drawings showing the principal dimensions, construction details and materials used for all parts of the valve and full details of valve stem extensions, including material, dimensions, fabrication, torque limits, method of connection to the valve and valve box and stem guides when required to avoid buckling, for approval of the Engineer/Engineer representative.

a) **Samples, Inspection and Testing Requirements**

All tests and inspections called for by the applicable standards shall be performed by the manufacturer. Upon request, results of these tests shall be made available to the purchaser.

b) **Other Requirements**

Each submittal shall be accompanied by:

(i) Complete data covering:

- the operator, including type and size, model number, etc.,
- the name and address of the manufacturer's nearest service facility,
- the number of turns to fully open or close the valve.

(ii) detailed instructions for calibrating the limit stops for open and closed positions, and

(iii) any other information, that may be necessary to operate and maintain the operator.

(iv) Complete dimensional data and installation instructions for the valve assembly as it is to be installed, including the operator.

(v) Complete replacement parts lists and drawings, identifying every part for both the valve and operator.

7. MAINTENANCE MATERIALS

The Contractor shall supply the following materials for use of the Employer as replacement parts for the valves furnished under this Contract in quantities of:

i. For every five (5) gate valves of the same size and type or fraction thereof:

1 set stem seal

1 pc stuffing box gasket with O-Ring

1 pc bonnet gasket with O-Ring

1 pc stem

1 pc operating nut

ii. For every five (5) butterfly valves of the same size and type or fraction thereof:

1 pc shaft seal
1 pc rubber-sealing ring
1 pc thrust bearing
1 pc operating nut

When each type of valve to be installed is less than five (5) sets, each one (1) set of the materials specified above shall be provided. No separate item is incorporated in the Bill of quantity for the maintenance material. Costs of these maintenance materials shall be deemed to be included in the unit rate of each type of valve in the relevant item.

8. **TEE-HANDLE VALVE KEYS, EXTENSION SPINDLES AND LIFTING KEYS**

The Contractor shall supply twelve (12) tee-handle valve keys of sufficient length (inclusive ex- tension spindles where required) for the operation of buried/below ground valves. The length of the key shafts shall vary according to the valve depths but shall project approximately one meter (1m) above ground level. Tee-Handle shall be of galvanized mild steel. The Contractor shall obtain Purchaser prior approval before ordering these materials.

The Contractor shall also supply twelve (12) lifting keys suitable for manhole covers and sur- face boxes.

PS 9.6.3 FURNISHING, DELIVERING AND INSTALLING TRIPLY-ECCENTRIC BUTTERFLY VALVES (EITHER LAMINATED OR SOLID METAL SEAT TYPE)

1. **FUNCTIONAL REQUIREMENTS**

Butterfly valves shall give tight closure against unbalanced water pressure in either direction. The unbalanced water pressure shall be the design pressure rating of the valve. The manufacturer's preferred direction of flow for the valve shall be clearly marked on it.

Valve shall be double flange stainless steel resilient seated type and shall be suitable for maximum velocity of 3 m/sec and for throttling service. Valve body shall be designed to withstand the maximum working pressure specified and the maximum differential pressure of 0.6 Mpa. Minimum thickness of valve body shall be calculated without exceeding a working stress equivalent to 20% of the tensile strength of the material used.

Shaft shall be either a one-piece unit extending completely through the valve disc, or of the "stub shaft" type, which comprises two separate shafts inserted into the valve disc hubs. If "stub" construction, each stub shaft shall be inserted in to the valve disc hubs for a distance of at least 1.5 times the shaft diameter. Valve shaft shall be of high yield strength Austenitic stainless steels of type 304 or 316. Allowable torsional sheer stress, not exceeding 25% of yield strength of material used shall be applied for de- sign of valve shaft diameter.

Valves shall be of such design that the valve discs will not vibrate or flutter when operated in a throttled position. Valve discs shall be secured to the shafts by means of keys or pins so arranged that the valve discs can be readily removed without damage thereto. All keys and pins used in securing valve discs to shafts shall be stainless steel or Monel. Valve discs shall be stainless steel or ductile iron, ASTM A 536, Grade 65-45-12 (448-310-12); seating edge shall be stainless steel or other corrosion resistant material.

Valve shafts shall be constructed of wrought stainless steel or Monel. The ends of the shaft shall be permanently marked to indicate the position of the disc on the shaft.

A shaft seal shall be provided where shafts project through the valve bodies for actuator connection. Shaft seal shall be designed for the use standard V-Type packing; O-ring seals; O-ring loaded U-cup seals; or a pull-down packing. If O-rings are used, they shall be contained in a stainless steel or bronze removable recesses. If stuffing box and pull-down packing are used, the design of the valve and stuffing box assembly shall permit adjustment or complete replacement of packing without disturbing any part of the valve or actuator assembly except packing gland follower. Gland or gland assemblies shall be made of stainless steel or bronze. Packing shall be made of resilient, non-metallic material suitable for potable water service, which shall not contain asbestos material.

The valve seat shall be replaceable and be formed of approved resilient material. Seats shall be of a design that permits removal and replacement at the site of installation. The valve seat shall be securely clamped into a machined groove in the valve body or to the edge of the disc by seat retention members or other equivalent retention device, in such a manner as to prevent leakage of water under the seats and to hold the seat securely in position during opening and closing of the valve disc. The seat retention members shall be of stainless steel and shall be securely fastened to the body or disc with stainless steel fasteners. When all the seat retention members are in place, the finished edges shall fit closely and the surface shall be smooth with all fastenings set flush in the water passage so as to offer the least resistance possible to the flow of water through the valve.

Valve seats which extend over the face of the flanges to secure the seat in place, or which require sur- face grinding and/or hand fittings of the disc; or designs, which require the adjoining pipe flange to retain the seat in place and resist line pressure, shall not be supplied.

Valve disc shall be made of stainless-steel casting and shall be of design with no external ribs transverse to the flow. The design of disc shall withstand full differential pressure across the closed valve disc without exceeding the working stress, equivalent to 20% of tensile strength of the material used. Disc edges shall be machined with rounded corners and shall be polished to a smooth finish. The valve disc shall rotate through an angle of 90 degrees from the fully opened to the fully closed position and the seat shall be of such design as to allow the valve disc to seat at an angle normal to the axis of the pipe when the disc is in the fully closed position. Adjustable mechanical stops shall be provided in the valve body to prevent over-travel of the valve disc in both the open and closed positions

Unless otherwise indicated, valves shall be provided with manual operators with vertical stems and 2 inches (50 mm) square operating nut turning clockwise to close and equipped with a valve disc position indicator. All keys or pins shall be stainless steel or Monel. Buried valves shall have the valve stems extended or adjusted to locate the top of the operating nut no more than 24 inches (0.6 meter) below finish grade.

Unless otherwise indicated, motorized butterfly valves shall be equipped with 230/460 volt, 3-phase reversing motor operators, extended as required to locate the center line of the operator shaft approximately 4 feet to 4 feet, 6 inches (1.2 to 1.4 meters) above finish grade. Operators shall be equipped with cast iron or malleable iron manual override hand wheel with a valve position indicator, local push button controls, lighted status/position indicator, torque and travel limit switches and all switches, relays and controls (except external power and signal wiring) necessary for both local and remote operation.

2. PERFORMANCE REQUIREMENTS

Unless otherwise indicated, valve operators shall be sized to seat, unseat, open and close the valve with 150 psi (1 megapascal) shutoff pressure differential across the disk and allow a flow velocity of 16 feet (4.9 meters) per second past the disc in either direction.

Motorized valve motors shall be capable of producing at least 140 percent of the torque required to operate the valves under conditions of maximum non-shock shutoff pressure without exceeding a permissible temperature rise of 1310F over 1040F ambient (55 degrees Celsius over 40 degrees Celsius ambient); they shall have a duty rating of not less than 15 minutes and shall be capable of operating the valve through 4½ cycles against full unbalanced pressure without exceeding the permissible temperature rise. Motors shall be suitable for operating the valve under maximum differential pressure when voltage to motor terminals is 80 percent of nominal voltage. Motor bearings shall be permanently lubricated and sealed.

3. MEATAL SEAT TYPE

a) DESCRIPTION:

This section of the specification is applicable for installing and testing of high pressure offset seat butterfly valves with its appurtenances.

b) APPLICALE STANDARDS:

The following standards shall apply:

- ASME B16.47: Large Diameter Steel Flanges, NPS 26 through NPS 60
- ASME B16.34: Valves-Flanged, Threaded, and Welding End

- ASME/FCI 70-2: Control Valve Seat Leakage.
- MSS-SP-25: Standard Marking System for Valves, Fittings, Flanges and Unions
- MSS SP-68: High Pressure-offset Sear Butterfly Valves.
- API 609 : Butterfly Valves: Double Flanged, Lug- and Wafer-Type

c) DESIGN REUIREMENT:

(i) Valves shall be High Performance Butterfly with offset seat and eccentric shaft. They shall be capable of Class IV sealing in either flow direction**.**

(ii) Valve seat shall be both self and pressure energized.

(iii) Valves shall have retained top and bottom bearings.

(iv) Shaft design shall be single or dual piece.

(v) Retainer rings must be recessed in the body so that the line gasket prevents any potential external leakage.

(vi) Valves shall have internal stop to prevent disc over-travel.

(vii) Valves shall be of make and model as approved by the Engineer/Engineer representative.

d) MATERIALS:

(i) Valves shall be constructed of new material.

Carbon steel valves shall be constructed from materials below**:**

(ii) Body–ASTM A105 or A216 Gr. WCB.

(iii) Disc–ASTM A182 F316 or A351 Gr. CF8M.

Stainless steel valves shall be constructed from materials below:

(iv) Body–ASTM A182 Gr. F316 or A351 Gr. CF8M.

(v) Disc–ASTM A182 Gr. F316 or A351 Gr. CF8M.

(vi) Shafts shall be ASTM A564 type 630 H 1150, or 316 SS.

e) ACTUATOR TYPE

(i) MSS SP-91-2009 Guidelines for manual operation of valves

(ii) Right-hand sets shall be furnished unless otherwise specified.

(iii) Shall be Gear operated type and manufactured in accordance to MSS SP-67, MSS SP-25 and API-609.

(iv) Worm Gear with 50 mmm Square Nut & Handwheel

f) INSPECTION AAND TEST

(i) Valves shall be hydrostatically shell tested per ASME B16.34 and MSS SP-61.

(ii) Valves shall be seat tested per ASME/FCI 70–2, Class IV

4. SOFT SEAT TYPE

a) APPLICALE STANDARDS:

The following standards shall apply:

- ASME B16.47: Large Diameter Steel Flanges, NPS 26 through NPS 60
- ASME B16.34: Valves-Flanged, Threaded, and Welding End
- ASME/FCI 70-2: Control Valve Seat Leakage.
- MSS-SP-25: Standard Marking System for Valves, Fittings, Flanges and Unions
- MSS SP-68: High Pressure-offset Sear Butterfly Valves.
- MSS SP-61: Pressure Testing of Steel Valves
- API 609: Butterfly Valves: Double Flanged, Lug- and Wafer-Type
- BS 5155 Specification for Butterfly valves.
- AWWA C504-10 Rubber Seated Butterfly valves., 75 mm through 1800mm

b) DESIGN REUIREMENT:

(i) Valves shall be High Performance Butterfly with offset seat and eccentric shaft. They shall be capable of sealing against full differential pressure in either flow direction.

(ii) Valve seat shall be both self and pressure energized with an elastomeric core. The self-energizing member shall be isolated from the line media.

(iii) Valves shall have retained top and bottom low friction bearings.

(iv) Shaft design shall be single or dual piece.

(v) Retainer rings must be recessed in the body so that the line gasket prevents any potential external leakage.

(vi) Valves shall have internal stop to prevent disc over-travel.

(vii) Valves shall be of make and model as approved by the Engineer/Engineer representative.

c) MATERIALS:

(i) Valves shall be constructed of new material.

Carbon steel valves shall be constructed from materials below**:**

(ii) Body–ASTM A105 or A216 Gr. WCB.

(iii) Disc–ASTM A182 F316 or A351 Gr. CF8M.

Stainless steel valves shall be constructed from materials below:

(iv) Body–ASTM A182 Gr. F316 or A351 Gr. CF8M.

(v) Disc–ASTM A182 Gr. F316 or A351 Gr. CF8M.

(vi) Shafts shall be ASTM A564 type 630 H 1150, or 316 SS.

d) SEAT MATERIAL / O-RING

(i) Seat Seal (Soft seated) shall be of EPDM, RPTFE or Polyethylene (UHMWPE)

(ii) Seat O-ring shall be of RTFE / Silicone

(iii) Metal Seat shall be of PTFE Encapsulated 316 Stainless steel (50-50)

e) ACTUATOR TYPE

(i) Operating gear for butterfly valves shall be of the fully enclosed type. Valves shall be suitable for operation by one man at all pressure conditions that can apply. A valve position indicator shall be provided for butterfly valves in chambers. For hand wheel type operating system, the indicator shall be clearly visible form the hand wheel operating position. Where a containing chamber is not shown, butterfly valves shall be specially adapted for buried use. In-line valves shall be operated by means of a hand wheel with gearing to prevent rapid closure of the valve. Gear ratios shall be at least 20:1.

(ii) MSS SP-91-2009 Guidelines for manual operation of valves

(iii) Right-hand sets shall be furnished unless otherwise specified.

(iv) Worm Gear with 50 mmm Square Nut & Handwheel shall be manufactured in accordance to MSS SP-67, MSS SP-25 and API-609.

f) INSPECTION AAND TEST

(i) Valves shall be hydrostatically shell tested per ASME B16.34 and MSS SP-61.

(ii) Valves shall be seat tested per MSS SP-61. No leakage is permitted for resilient seated valves

g) FLANGE COMPATIBILITY

Butterfly valve shall be designed to fit between flanges in compliance with MSS SP-44 Class 150; Dia: 760 mm to 1200 mm and ASME B16.47 flanges.

h) PRODUCT IDENTIFICATION

(i) Every valve furnished and installed at site shall have a metal identification tag attached to the valve body. Information includes the figure number, the size and pressure class, the materials of construction, and the operating pressures and temperatures.

(ii) Every valve furnished and installed at site shall be hydrostatically tested before it is shipped. The metal tag shall also include a serial number unique for each valve to be recorded by the Manufacturer Quality Control Department. The test results and material certification data, shall be provided to the Engineer/Engineer representative before installation / fixation, for individual traceability and verification of every valve furnished.

i) CONSTRUCTION METHODS:

The Contractor shall furnish, test, deliver and install butterfly valves and actuators complete and ready for operation as specified herein, to the sizes and at the locations shown on the drawing and as directed by the Engineer/Engineer representative.

The butterfly valves together with all adjacent appurtenances (bypass, expansion joint or coupling) shall be housed in chambers which shall be constructed by the Contractor in accordance with the Drawings.

5. **EXPANSION JOINTS:**

Expansion joints shall be installed as specified on drawings. Expansion joints will be of the slip type with limiting rods, Dresser Style 63, Type Ill or Baker Expansion Joint, Type 3, Series 403 or approved equal. Slip pipe shall be stainless steel. Contractor shall have to submit detailed shop drawings to the Engineer/Engineer representative for approval.

All internal and external steel surfaces of each expansion joint, except the slip pipe, shall be cleaned and sand blasted in full accordance with Steel Structures Painting Council Specifications SSPC-SP5, White Metal Blast Cleaning. Since these surfaces will be required to function satisfactorily in submerged service, the Contractor is. specifically advised that Commercial or Near-White blast cleaning will not be acceptable.

Immediately after cleaning, such surfaces shall be primed and later finished with two coats of a National Sanitation Foundation (NSF) approved material specifically formulated for water pipelines and applied in accordance with the manufacturer's instructions. After assembly, defects in coating shall be rectified.

6. **BOLTED, SPLIT SLEEVE TYPE RESTRAINED COUPLING:**

Where shown on the drawing or directed by the Engineer/Engineer representative, the Contractor shall furnish, deliver and install Victaulic Depend-0- Lok, Fixed x Fixed, Type 2RC Restrained Coupling, 250-psi minimum, or approved equal, in lieu of an expansion joint. The coupling shall be installed as per manufacturer’s recommendations and as directed by the Engineer/Engineer representative.

7. **BY-PASS FOR BUTTERFLY VALVE:**

The Contractor shall install the external by-pass as indicated on the Drawing for the valve chamber for 1000 mm diameter Butterfly Valves.

PS 9.6.4 FURNISHING, DELIVERING AND INSTALLING MISCELLANEOUS VALVES

PS 9.6.4.1 IRON-BODY GATE VALVES

Resilient-seated gate valves shall conform to AWWA C-509-01 and 09

Reduced-wall, resilient-seated gate valves shall conform to AWWA C-515-09

Metal-seated gate valves including tapping valves, shall conform to AWWA C-500-09.

a) **Stem Seals:**

All valves shall have approved O-ring type stem seals. At least two O-rings shall be in contact with the valve stem where it penetrates the valve body.

b) **Operation:**

All valves shall have non-rising stems with a 2-inch (50 mm) square operating nut, or with a spoke type handwheel when so ordered, turning clockwise to close.

c) **Gearing:**

Gate valves in 40-inch (1000 mm) sizes shall be geared and when necessary for proper bury depth and cover, shall be the horizontal bevel-geared type enclosed in a lubricated gear case.

d) **Bypass:**

Unless otherwise indicated on the Drawings, metal-seated gate valves shall be equipped with a bypass of the non-rising stem type which meets the same AWWA standard required for the main valve.

e) **Valve Ends:**

Valve ends shall be push-on, flanged or mechanical joint, as indicated or approved.

f) **Gear Case:**

All geared valves shall have enclosed gear cases of the extended type, attached to the valve bonnet in a manner that makes it possible to replace the stem seal without disassembly and without disturbing the gears, bearing or gear lubricant. Gear cases shall be designed and fabricated with an opening to atmosphere so that leakage past the stem seal does not enter the gear case.

g) **Valve Body:**

Double disc gate valves in 40-inch (1000 mm) and larger sizes installed in the horizontal position shall have bronze rollers, tracks, scrapers, etc.

PS 9.6.4.2 AIR RELEASE, AIR/VACUUM. AND COMBINATION AIR VALVES

a) **GENERAL**

Valves shall be combination air-release, air-vacuum units having small and large orifice units contained and operating within a single body or assembled unit confirming to AWWA C512-15.

The small orifice system shall automatically release small volumes of air while the pipe is operating under normal conditions. The large air-vacuum orifice system shall automatically exhaust large volumes of air while the pipe is being filled and shall permit immediate re-entry of air while being drained.

Valves shall be rated for at least 150 psi (1 megapascal; maximum) normal service pressure.

b) **MATERIAL REQUIREMENTS**

Valve exterior bodies and covers shall be cast iron or reinforced nylon.

Internal bushings, hinge pins, float guide and retaining screws, pins, etc., shall be stainless steel, bronze, nylon, or Buna-N rubber.

Orifice seats shall be Buna-N rubber.

Floats shall be stainless steel, nylon, or Buna-N rubber, rated at 1,000 psi (6.9 megapascals).

Air valves unless otherwise specifically indicated on the bill of quantity shall be of the following type and size depending on the size of pipeline in which they are installed.

Pipe Size (mm)	Nominal Size of Air Valve (mm)		Type of Air valve
	Body size	Flange size	
400 – 600 DI	100	100	Double Orifice with flanged inlet and an isolating ball valve.
800 – 1200 DI	150	150	Double Orifice with flange inlet and an isolating ball valve.

c) **SINGLE ORIFICE TYPE**

Single orifice type air valves shall be designed to automatically operate so that they will exhaust accumulated air under pressure while the pipe is flowing full of water.

d) **DOUBLE ORIFICE TYPE**

Double orifice air valves shall be designed to automatically operate so that they will:

(i) Positively open under internal pressure less than atmospheric pressure to admit air in bulk during pipeline draining operation;

(ii) Exhaust air in bulk and positively close as the water is flowing full of pipe, under low head, fills the body of the valve during filling operation;

(iii) Not blow shut under high velocity air discharge; and

(iv) Exhaust accumulated air under pressure while the pipe is flowing full of water.

Air valves Shall be performance tested to ISO 5208 at the shop.

- Seat test 1.1 x working pressure
- Body test 1.5 x working pressure

No leakage shall be allowed.

Coating of air valve shall be same as coating for gate valve.

e) **HIGH SPEED AIR VALVE (QUICK TYPE)**

Where shown on the drawing, high speed (quick type) air valve conforming to JIS B2063 Class 4 or equivalent DIN standards shall be used. The valve shall have flanged end and to meet the maximum operating pressure of 16 kgf/sq. cm. Dimension of flange shall conform to the requirement of the pipe flange.

The valve shall be a float actuated air valve with their inlets flanged. Valve bodies, covers, bonnets and stuffing boxes shall be of ductile iron conforming to ASTM A536 65-45-12, or BS2789 500/7, or equivalent.

PS 9.6.4.3 FLOW METERS - ELECTROMAGNETIC TYPE

1. **GENERAL**

The electromagnetic flow meter shall be designed to measure the flow rate and total flow of potable water pumped or delivered to the particular system. The water meter shall be constructed in modular form in order to facilitate expansion of its measuring capabilities in the future. The sensor and transmitter incorporated in this compact design shall form on mechanical unit. Interior of the flow meter shall contain an ap- propriate lining materials that ensure non-deposition of iron that may present in the delivered potable water. Necessary electrical and electronic circuits shall be inbuilt in the flow meter to prevent the deposition of iron on the exposed parts of electrodes in combination with selection of suitable materials for electrodes. The bulk flow meters shall in general be located in the following areas.

- Pumping main from WTP to Storage Reservoirs
- Delivery main from Reservoirs to distribution system
- Pumping main from Booster Station to delivery main
- Transmission main bifurcation junctions

The Contractor shall furnish, test, deliver and install flow meters complete with all instrumentation, recorders and appurtenances to the sizes and at the locations shown on the drawing and as directed by the Engineer/Engineer representative.

The flow meters together with all required appurtenances shall be housed in chambers which shall be constructed by the Contractor in accordance with the drawing or as directed by the Engineer/Engineer representative:

2. FUNCTIONAL REQUIREMENTS

- There shall be no flow obstructions in the measuring tube. No pressure loss, lower requirements for straight pipe sections;
- There shall be multiple choices of sensor lining and electrode materials;
- The converter shall have Low power consumption, stable zero point and high accuracy. The flow range shall reach 1500:1;
- The converter and the sensor shall be separated;
- The converter shall have at least 16-bit high-performance microprocessor. 2x16LCD display. Convenient parameter setting. Reliable programming;

- The flowmeter shall have two-way measuring system with three totalizers inside. Forward total, reverse total, and difference total. Should display positive and negative flow; have variety of outputs: current, pulse, digital communication, HART;
- The converter shall adopt surface mount technology (SMT). With self-check and self-diagnosis function.
- The measurement shall not be affected by changes in fluid density, viscosity, temperature, pressure and conductivity;

3. STANDARD SPECIFICATIONS OF MAGNETIC LARGE DIA. PIPE FLOW METER

Accuracy:	± 1.5% measured value standard ± 1.0% measured value special ± 0.5% measured value high precision
Conductivity:	5μs/cm
Measuring range:	Recommended use range: 0.5m/s～10m/s continuously adjustable Use range: 0.2m/s～15m/s continuously adjustable
Medium temperature:	-20℃ to +150℃
Ambient temperature:	-20℃ to +60℃
Fluid pressure:	≤ 1.6MPa
Protection level:	Sensor Converter IP67 IP67 IP68 IP67
Material quality:	The probe material shall be 304 stainless steel, the electrode material shall be 316 stainless steel, and the insulation layer shall be PTFE or equivalent
Electrical Interface:	M20×1.5,1/2″ NPT
Display method :	Standard two-line LCD display, which shall display instantaneous and cumulative flow at the same time.
Power supply:	220VAC 50HZ 24VDC

Signal output:	1. The switch value can be set as: pulse output (1000HZ); High/low flow alarm; ATC alarm; Flow direction indication; error alarm; 2. Current output: 4-20mA output.
Configuration method:	1. Configure on-site through three manual keys. 2. On-site configuration via remote control. To 3. Perform on-site configuration through the handheld communicator.

PS 9.6.4.4 MISCELLANEOUS ITEMS

1. **BOLTED, SPLIT SLEEVE TYPE RESTRAINED COUPLING:**

Where shown on the drawing or directed by the Engineer/Engineer representative, the Contractor shall furnish, deliver and install Victaulic Depend-0- Lok, Fixed x Fixed, Type 2RC Restrained Coupling, 250-psi minimum, or approved equal, in lieu of a bolted, sleeve-type coupling with external restraint system. The coupling shall be installed as per manufacturer's recommendations and as directed by the Engineer/Engineer representative.

2. **FURNISHING, DELIVERING AND INSTALLING FLANGE BOLTS, NUTS AND WASHERS**:

All flange bolts, nuts, and washers for insulated flange joints for valves, outlets, and tie-ins shall be stainless steel as per **sub-clause PS 9.5.1.15 “Flanged Joints”** of these specifications.

In addition, carbon steel flange bolts, nuts, and washers for all non-insulated flange joints shall be as per Section 15 of the aforementioned specification and shall be coated with a fluoropolymer coating meeting the 1,000-hour salt spray requirements of ASTM 8117. The fluoropolymer coating shall be **of *Tripac* make,** or **equal as** approved **by the Engineer/Engineer representative**.

3. **STANDARD VALVE CHAMBERS:**

The Contractor is advised that the dimensions and layouts of the various components within the standard chambers may differ from those shown on the standard drawings. The Contractor shall verify all dimensions and accordingly alter roof slabs and/or chamber dimensions for operational access to the valves. Shop drawings detailing all alteration work to the roof slabs and/or chamber shall be submitted to the Engineer/Engineer representative for review and approval prior to chamber construction. The cost for this alteration work shall be deemed included in the appropriate bid items provided in the contract. No additional or separate payment will be made for this alteration work.

For regulator valve chambers, the opening for the manway access (casting where the steps are located) shall be on the side (determined by pipe centerline) of the chamber where the regulator control components and sump pit are located. Regulator valve chambers must be located completely within a sidewalk or shoulder area and not within roadway areas.

Any relocation of chambers due to field conditions must be approved by the Engineer/Engineer representative.

The design and locations of washouts shall be illustrated on the Drawings to be approved by the Engineer/Engineer representative. Exact positioning shall be determined with regard to topography and to the approval of the Engineer/Engineer representative. At least 3.0 meter of the washout pipe-work, inclusive of the isolating valve, measured from the center line of the pipeline, shall be laid at the same time as the pipeline and suitably capped to prevent ingress of foreign material. The minimum gradient for the washout pipe-work shall be 1 in 100.

PS 9.6.4.5 CONSTRUCTION METHODS;
SETTING VALVES, DRAINS AND AIR RELEASES.

Unless otherwise indicated, main line valves, drain valves and piping, air and vacuum release assemblies and other miscellaneous accessories shall be set and jointed in the manner described hereinabove for cleaning, laying, and jointing pipe.

Unless otherwise indicated, valves shall be set at the locations shown on the Drawings and such that their location does not conflict with other appurtenances such as curb ramps.

Valves shall be installed so that the tops of operating stems will be at the proper elevation required for the piping at the location indicated above.

Valve boxes and valve stem casings shall be firmly supported and maintained, centered and aligned plumb over the valve or operating stem, with the top of the box or casing installed flush with the finished ground or road pavement, and installed with the top of the box or casing approximately 6 inches (150 mm) below the road subgrade which are excavated for paving construction or where such excavation is scheduled or elsewhere as directed by the Engineer/Engineer representative or designated representative.

Drainage branches or air blowoffs shall not be connected to any sanitary sewer or submerged in any stream or be installed in any other manner that will permit back siphonage into the main line system. Every drain line and every air release line shall have a full-sized independent gate valve flanged directly to the main. Flap-valves, shear gates, etc., will not be accepted.

PS 9.7 MEASUREMENT AND PAYMENT

PS 9.7.1 MEASUREMENT

The quantity to be paid for steel pipes of required diameter, thickness and material shall be the calculated theoretical number of metric tons of pipes as determined by standard Engineer/Engineer representativeing practices with density of steel as 7850 kg/m^3, density of water as 1000 kg/m^3 and from the linear meters as measured along the axis of the pipe in place from the start to end regardless of depth and irrespective of the number of joints, outlets or closure pieces, but excluding the lengths of valves or other appurtenances, placed, completed, successfully tested and accepted at locations as shown on the Drawings.

The length shall be measured along the centerline at mid height of the pipe from end to end of the pipe.

All Lining and coating of pipes shall be done according to the details provided on drawings and shall be measured and paid separately.

The quantity of Butterfly valves, Global valves, Air & Vacuum valves, Expansion joint assembly, Flow meters etc., measured for payment shall be the number(s) of each of these items actually furnished, delivered, installed and tested by the Contractor and approved by the Engineer/Engineer representative.

PS 9.7.2 PAYMENT

The payment for delivery pipe shall constitute full compensation for all the works the cost of all labor, materials, plant, equipment, samples, fabrication; inspection and testing; furnish, deliver and lay straight steel pipe as shown or specified, including all bridging; cleaning; welding; jointing; connections; preparation, submittal and approval of all required shop drawings and designs; obtaining all necessary permits; furnish and install all other items necessary to complete this work; replacement of defective pipes and accessories; do all other work necessary and incidental thereto in order to complete this work all in accordance with the plans and specifications and as directed by the Engineer/Engineer representative.

No payment shall be made for pipes which are damaged in transit or laying.

No separate payment will be made for preparation of the geometry (including field measurements and test pits within the contract specified trench limits), the pipe-laying schedule and the fabrication drawings and the cost thereto shall be deemed included in the various contract items.

No extra payment will be made for flushing-out stop connections, sampling outlet connections, and miter cuts on steel pipe made up in the shop, but payment therefore shall be included in the unit price of steel pipe.

No extra payment will be made for flanges including bolts and all accessories on straight pipe, reducers, bends, special castings, spool pieces or piping adjacent to expansion joints, but payment thereof will be deemed to be included in the unit price of straight steel pipe.

No extra payment shall be made for insulated flange joints indicated on the standard and contract drawings, but payment thereof will be deemed to be included in other items of piping works.

Payment for expansion joint or coupling shall be made at the unit bid price for " Furnishing, Delivering Installing, Testing, Commissioning Expansion Joint / Couplings for Butterfly Valves Including 150 mm By-Pass

Outlet", and shall include the pipe with the 150 mm bypass outlet between the expansion joint and valve.

The quantity of butterfly valves measured for payment shall be the number of butterfly valves of each size actually furnished, delivered and installed by the Contractor and approved by the Engineer/Engineer representative.

The contract price for "**Furnishing, Delivering and Installing Butterfly Valve with By-Pass Arrangement and Outlet, Complete**" shall be the unit price bid for each size of butterfly valve furnished, delivered, installed and accepted by the Engineer/Engineer representative and shall cover the cost of all labor, equipment, materials, plant, samples, tests and commissioning required and necessary to furnish, deliver and install butterfly valves in the manner specified herein. No separate or additional payment will be made for any costs associated with the work of furnishing, delivering and installing butterfly valves.

The contract price for "**Furnishing, Delivering and Installing Flow Meter Tube and Appurtenances, Complete**" shall be the unit price bid for each size of flow meter furnished, delivered installed and accepted by the Engineer/Engineer representative and shall cover the cost of all labor, equipment, materials, plant, samples, tests and insurance required and necessary to furnish, deliver and install flow meters in the manner specified herein. No separate or additional payment will be made for any costs associated with the work of furnishing, delivering and installing flow meters.

Payment for the chamber including concrete, reinforcing steel, structural steel, miscellaneous steel, manhole steps and pipe-to-wall penetration seals, thrust restraints, etc., shall be made to the Contractor under the appropriate bid items.

Excavation, backfilling and compaction required in the installation of pipes shall be measured separately for payment under relevant item of work.

No separate payment will be made for trench dewatering, maintenance etc., and the cost thereto shall be deemed to be included in the relevant pay item.

CHAPTER NO. 10

INSTRUMENTATION

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ITEM PS-10: INSTRUMENTATION

PS 10.1 DESCRIPTION

This work shall comprise furnishing, installation, testing, commissioning, regular calibration and maintenance of an automated monitoring system, for the dam, spillway and other ancillary structures, as shown on the drawings or as directed by the Engineer/Engineer representative.

The automatic monitoring system, encompassing the automated data acquisition system (ADAS), data transmission system (DTS) and data processing & management system (DPMS), shall include installation of piezometers (vibrating-wire type, hydraulic twin-tube type, and porous-tube type), pneumatic total pressure cells (TPC), strong motion seismograph, internal vertical movement (IVM) device, inclinometer-cum-magnetic extensometer, crest extensometer monuments, structural measurement points, embankment measurement points, multi-point borehole extensometers, appropriate electrical service interconnections, all associated operating & control equipment and systems etc., construction of gauge houses / terminal structures for implementation & management of data and visualization for remote monitoring, in accordance with these specifications and to the details & at the locations shown on the drawings or as directed by the Engineer/Engineer representative.

The Contractor shall be responsible for all specialist works and support works of dam instrumentation job, including furnishing of all materials, equipment, special tools, instrumentation engineers, supervisors, labors and other items required to complete the instruments installations, data collection, processing, presentation, interpretation and reporting etc.,

The Contractor shall be responsible for factory calibrations and quality assurance before shipment of all measurement devices, and for performing acceptance tests to ensure correct functioning when instruments are first received at the site, in accordance with the manufacturer's guidelines and existing international standards for quality control and regulations such as ISO, US National Bureau of Standards and others relating to metrology.

In case of missing of instrumentation partly or fully for some structures, foundation and surroundings, in the bidding and/or construction drawings and if it deems necessary by the Engineer/Engineer representative at any time during the execution of the Contract, the provision of the instrumentation for that structure as directed by the Engineer/Engineer representative shall be Contractor's responsibility.

The Contractor shall be responsible for monitoring the performance of the dam and allied structures for the duration specified in the Contract documents and shall submit daily, weekly, monthly instrumentation reports, at frequencies detailed in these specifications, or as directed by the Engineer/Engineer representative.

PS 10.2 SUBMITTALS

1. Prior to procurement of proposed instruments, the Contractor shall submit to the Engineer/Engineer representative for approval, all order lists, detailed drawings and specifications for specialist and support works, including detailed step-by-step installation procedures, "Drilling program plan" for the installation of the instruments, the number and location of each instrument, general

description of the methods that will be used to install the instruments, description of the instruments construction details, plan and cross sections showing the location of the proposed instruments and instruments schematic.

The approval of order lists and installation details by the Engineer/Engineer representative shall in no way relieve the Contractor of responsibility for the correctness of such lists and details. Any expenses incident to the revisions of material furnished in accordance with such lists and details to make it comply with the drawings shall be borne by the Contractor.

2. The Contractor shall furnish in duplicate to the Engineer/Engineer representative confirmation that products shipped meets or exceeds the standards set forth in these specifications. This shall be in the form of a written document / certification from the manufacturer attesting to the specific instrument meeting the standards.

3. The Contractor submittals shall also include experience details of the manufacturers, quality assurance checklists, warranties, instruction manuals, shipping documents, and instrument samples for review and approval of the Engineer/Engineer representative

PS 10.3 MATERIAL REQUIREMENTS

PS 10.3.1 ACCLIMATISATION AND POWER RATING

All instruments and associated equipment shall be suitable for operation in the climate and conditions at Dam site.

All electrical equipment shall operate on 220 V to 240 V single phase 50 Hz power supply.

All steel parts furnished shall be either hot dip galvanised with long term corrosion protection coating or stainless steel of first grade quality.

PS 10.3.2 SIGNAL CABLES AND EARTHING WIRES

All cabled instruments shall be supplied complete with the required length of cable. Splicing of cables on the site shall be avoided wherever possible. No splicing of cables on site may be performed without the prior approval of the Engineer/Engineer representative.

The general cable routes shall be shown on the drawings. Each instrument located in fill shall be supplied with enough cable for its required length in the trench, an additional “snaking” allowance of 10 metres of slack for every 100 metres of cable run, and an additional 5 metres at the gauge house / terminal structure.

All instrument cables shall be of the armoured, heavy duty; polyethylene insulated type suitable for direct placing in concrete or fills and shall have the following characteristics:

a) Cables shall be of dual windings composed of one layer of chloroprene or neoprene covered with rubber and metallic tubes for protection. The cables shall have distinctly coloured cores.

b)	No. of core:	4
c)	Conductor nominal section:	0.5 mm^2
	• composition	20/0.18 mm
	• outer diameter	1.0 mm
d)	Strand diameter approx.	5.1 mm
e)	Thickness of	
	• Separator	0.5 mm
	• Rubber	0.5 mm
	• Chloroprene sheath	1.3 mm
	• Armouring steel	0.3 mm
	• Anticorrosive vinyl	2.5 mm
f)	Finished outer diameter	approx. 19.7 mm
g)	Conductor resistance at 20°C	39.8 ohm/km
h)	Test voltage	1000 V/min
i)	Insulation resistance, at 20°C	400 M ohm/km
j)	Approx. weight	≤ 450 kg/km

All cables shall be shielded, with individual drain wires for electrical noise protection.

All cables shall be heavy duty water blocked by the use of petroleum jelly and bitumen or other means, and shall be capable of elongation in excess of 20% before failure.

All earth wires shall consist of 19/1.53 mm bare hard drawn copper conductors.

At joints, connection of conductors, armour, and shielding wires shall be made using self-insulating mechanical connectors (crimping sleeves). Individual conductor connections shall be staggered. No solder shall be applied to the conductor joints without the approval of the Engineer/Engineer representative. Individual connections at a particular joint shall be isolated by taping.

At joints, the insulating layers shall be joined by vulcanising unless the use of self-adhering synthetic rubber tape is approved by the Engineer/Engineer representative. A rubbery polyurethane resin compound shall be applied around the connection, and the connecting part shall be covered subsequently with protecting tape.

Cable joints shall provide adequate insulation, mechanical protection, and protection against water and humidity. The Contractor shall demonstrate that joints will remain fully watertight against the external water pressures expected at the various cable locations.

The tapes for connecting parts shall satisfy the specifications provided in Table 10.1

Connection of cables to instruments shall be made with stainless steel cable glands. Each gland shall be designed for a tensile load of 12 KN. Water blocking shall be provided through heavy duty neoprene gaskets and O-rings, in order to protect the instrument from both water pressure outside the cable/gland and any internal pressure within the cable caused by inadvertent cuts in the cable sheath.

The Contractor shall supply samples of all cables, jointing kits, glands, and earth-wires to the Engineer/Engineer representative for approval.

Table 10.1: Requirements for Cable Tapes

REQUIREMENTS	SELF-ADHERING TAPE	PROTECTING TAPE
Thickness	More than 0.5 mm	More than 0.2 mm
Width	More than 15 mm	More than 19 mm
Dielectric strength	More than 2 kV/1 min	More than 5 kV/1 min
Volume inherent resistance	More than 1 x 1015 ohm/cm	More than 2 x 1012 ohm/cm
Tensile strength	More than 0.07 kg/cm^2	More than 0.7 kg/cm^2
Elongation	More than 200%	More than 100%
Bond strength	-	More than 3.0 kg

PS 10.3.3 PROTECTIVE SURROUNDS

The Contractor shall construct as required, during the installation of instruments in the dam, protective surrounds in accordance with the approved procedures. Such protective surrounds shall be placed and compacted as approved by the Engineer/Engineer representative.

Protective surrounds in the dam body shall be constructed and subsequent confinement material shall be placed without disturbing the instrument installations. Material adjacent to protective surrounds shall not be compacted by vibrating or tamping rollers until one complete layer of material has been placed above the surround.

Where required, provide a bed of sand-rich, concrete (max 19mm aggregate size), or mortar and embed and cover, provide cable trenches or notches or openings in the Dam structure and provide metal cable and trench covers where required to provide adequate protection to instruments and cables in trench; notches or openings.

PS 10.3.4 ELECTRICAL POWER SUPPLIES

The primary sources of electrical power for fully automated monitoring system, including the automated data acquisition system (ADAS), data transmission system (DTS) and data processing and management system (DPS) shall be mains power, batteries, portable generators, and solar system. Mains power shall be the preferred source in controlling of environmental conditions such as temperature and humidity. Mains power shall be 220 -240 volts AC, 50 hertz single phase as a standard.

Portable instruments shall be powered with rechargeable batteries. Alternative power supplies shall be adopted, when batteries cannot provide sufficient power economically and when the site is too remote for mains power, including diesel or gasoline generators, and solar power.

The quality and reliability of mains power, if varies considerably within the project area, then conditioning shall be adopted as per direction of the Engineer / Engineer representative. Undervoltage, overvoltage, and transients shall be cured by a combination of lightning protection equipment, circuit breakers, and power line conditioners. The problem of power outages shall be addressed by use of uninterruptable power supplies (UPS).

When opting for solar power, either the system shall be sized on winter needs, entailing significant overcapacity in summer, or additional batteries shall be provided for winter use. For high-capacity solar power, specialized batteries shall be used to smooth the variations in power supply.

Use of either type of generators entails maintenance and refuelling costs, but diesel units shall be preferred because of reduced maintenance and more safety of stored fuel than gasoline. Diesel generators shall be designed to produce 220 volts AC, with convertors added to reduce the power output to a convenient DC voltage of 12 volts.

PS 10.3.5 LIGHTNING PROTECTION

The Contractor shall provide lightning protection to all monitoring instruments and the data logging, storage and processing ADAS facilities.

The lightning protection facilities shall not have fuses to be replaced, shall be of the self-resetting type, and shall operate without any power supply.

The Contractor shall submit to the Engineer/Engineer representative for approval, details of the proposed lightning protection facilities, which shall include a general description, circuit diagrams, details of the proposed lightning protection facilities, and proposed testing and commissioning procedures.

The Contractor shall supply and install a system, at each electrical instrumentations site, to protect the instrumentations from lightning damage that may occur from one of or a combination of the following modes:

a) **Direct:** by the interception of lightning on exterior metalwork or other exposed conductors.

b) **Indirect:** by the interception of lightning on other structures or services connected to the dam/structure.

c) **Inductive:** by a lightning strike to the ground that induces a transient in conductors, the dam/structure, or services connected to the dam/structure.

Protection against external disturbances shall be ensured through transient protection and shielding. Surge arrestors shall be used to protect the instruments from being damaged due to massive surge current and high intensity electromagnetic fields. Shielding methods shall be used to protect the measurement signal coming from the instruments from being altered or distorted due to electrical noise, caused by external factors. Primary causes of noise are radio frequency interference (RPI) and electromagnetic interference (EMI) from sources, like power lines, electrical generators and motors, commercial TV, radio or radar stations, defective fluorescent signs, electronic navigation systems, nearby thermostats and other switch closures, welding, and dirty terminals of power line transformers.

Grounding for efficient lightning protection and shielding shall be designed and implemented in compliance with the manufacturer's recommendations. Sophisticated transient and surge protection devices combined with a poor grounding system will be just good-for-nothing.
In a situation with number of piezometers to be connected to the data acquisition system, junction boxes shall be used. Individual piezometers, shall have individual transient protections (ITP) and grounding system, and shall be connected to the junction boxes, and then linked to the data acquisition system by a multi-conductor cable.

Grounding rods shall be installed at each borehole collar where ITPs are located, at the junction boxes and at the data acquisition system.

Omission of ITPs in instrumentation layouts shall not be allowed. ITPs should be located on the ground surface and should be as close to borehole collars as possible, since lightning surcharges travel at the ground surface and not at depth.

Grounding rods should be a minimum of 3 meters long. Use up-to three rods at important locations, such as the data acquisition system, to provide a good ground network.

The soil resistivity factor shall be taken into account in designing the grounding system. Before designing the grounding system, measurement of the soil resistivity shall be conducted by Wenner 4 - Point Test or equivalent, involving four probes spaced at equal distances to determine the profile of the soil resistivity at various depths.

In addition to the type of soil, influence of temperature and moisture level on soil resistivity shall also be considered. Soil resistivity is impacted by change in season or weather patterns and therefore grounding system performance. Soil with low resistivity during humid, warmer seasons may have a higher resistivity during cold (freezing as an extreme) or dry seasons.

The cable shield shall be grounded at one end only and not at the two ends. As such, there should be three different cable sections between the piezometer and the data acquisition system; from the piezometer to the ITP, then to the junction box and finally to the data acquisition system. For each of these three cables, one shield end shall be grounded and the other end shall not. From the instrument to the data acquisition system, the grounded end shall be on the data acquisition side.

In case of junction box, the shields from cables between the ITPs and the junction box shall be connected to the ground at the junction box. Similarly, the multiconductor cable running from the junction box to the data acquisition system shall also be shielded to the ground at the data acquisition system end. Multiconductor cable shall preferably have individual shield for each conductor pair and an overall shield and they shall all be grounded to the same point. Additionally, if the cable has a metallic armour, central or overall, this armour shall also be connected to the same ground as the other shields.

More-over, multi-stage transient protection shall be incorporated in the data acquisition system to protect its entries from transients that would come along the connection cables.

The VSAT (Very Small Aperture Terminal) systems, accelerograph and micro-seismic recording systems shall also have adequate lightning protection and earthing.

PS 10.3.6 SURVEY MONUMENTS, SURFACE MOVEMENT AND CREST SETTLEMENT POINTS

PS 10.3.6.1 GENERAL

The Contractor shall supply, install and survey all survey monuments, surface movement and crest settlement points including pipes, pipe fittings, survey pins, and concrete as shown on the Drawings or approved by the Engineer/Engineer representative. The Contractor shall also supply approved survey targets in required quantity, as directed by the Engineer/Engineer representative, for temporary mounting on the survey pins.

The Contractor shall supply and install at least 9 survey monuments at the dam site and/ or as approved by the Engineer/Engineer representative.

The Contractor shall also procure and install stationary light reflectors (prisms) on the surface deflection points for permanent use on the downstream face of the Dam or spillway. Stationary light reflectors shall also be provided for temporary use on the

surface deflection points located on the upstream face of the dam during construction.

For the Dam, surface movement and crest settlement points are termed berm deflection points and crest deflection points, respectively. Survey monuments are referred to geodetic pillars.

PS 10.3.6.2 MATERIALS AND INSTALLATION

Pipe and fittings for surface movement and crest settlement points shall be galvanised mild steel in accordance with this Specification. The survey pins shall be threaded stainless steel with integral stainless steel base plates, with protective stainless-steel caps, all to suit the fitting of the approved survey targets and of shape and size as approved.

For surface movement points and crest settlement points in the Dam, the pipes shall be not less than 2 m long and 150 mm diameter with 250 mm protruding above the surrounding surface. The pipe shall be filled with concrete after installation and the survey pin shall be secured in a recess left in the concrete using an approved non-shrink grout or epoxy mortar as shown on the Drawings or as directed by the Engineer/Engineer representative. The threaded survey pins shall be set truly vertical and the base plates truly horizontal.

Geodetic Pillars, surface movement points and crest settlement points shall be constructed as shown in the Drawings or as directed by the Engineer/Engineer representative.

The Contractor shall carry out all work necessary for the installation of surface movement and crest settlement points within 1.5 m of the required position as shown on the Drawings and shall complete the installations as soon as practicable after placement of the fill in the locations at which surface settlement points are required.

Surface movement points and crest settlement points shall be installed as soon as practicable after placement of dam body materials and construction of the dam crest wall.

Geodetic pillars shall be constructed at approved locations on each abutment and in the vicinity of the downstream toe of the Dam as shown on the Drawings or as directed by the Engineer/Engineer representative. The pillars shall be constructed of 300 mm to 500 mm diameter galvanised steel pipe or reinforced concrete and shall be 1.3 m long, set in a reinforced concrete base one metre square and set into the ground at least 1.5m. The top of the concrete base shall be level with the surrounding ground and the top of the pipe shall finish 1.2 m above the ground. If galvanized pipe is used, the pipe shall be filled with reinforced concrete and a mounting plate, which should also be suitable for mounting a total station survey instrument, shall be set in a recess left in the concrete with an approved non-shrink grout or epoxy mortar. The survey mounting plate shall be set truly vertical and horizontal. The top of the galvanised pipe and survey mounting plate shall be covered by a lockable galvanised steel cover. The geodetic pillars shall be installed as soon as practicable and the date that each has been completed shall be neatly engraved in the concrete base. The detail of the geodetic pillar and mounting plate may be changed as required by the Engineer/Engineer representative.

Survey monuments for the Dam shall be as shown on the Drawings.

Immediately after installation of any geodetic pillar survey point or pillar, its position and level shall be precisely surveyed and co-ordinates calculated to the nearest 5 mm and this data reported to the Engineer/Engineer representative in writing.

The light reflectors (prisms) shall be suitable for long distance triangulation between the survey monuments and the reflectors. Each reflector shall be installed such that a clear sight is provided between the relevant survey monuments and the reflector

PS 10.3.7 OPEN STANDPIPE (CASAGRANDE) PIEZOMETERS

PS 10.3.7.1 GENERAL

The Contractor shall drill 100 mm diameter holes and install flush coupled PVC casing complete with a ceramic low air entry filter element and covers over the holes as approved by the Engineer/Engineer representative.

The depth of the holes shall extend at least 300 mm below the end of the ceramic tip when the tip is located with its centre at the intended measurement point in the ground.

The Contractor shall construct each open standpipe piezometer as early as practicable providing it will not unnecessarily obstruct the construction of the Works.

PS 10.3.7.2 MATERIALS

a) The PVC casing shall meet the requirements of these Specifications and be capable of being installed without deformation. The external diameter of the casing shall be of a size such that it will allow sufficient clearance for installation of the pipe and tip and shall not be less than 75 mm and shall be of heavy gauge rigid PVC and joints in the tubing shall be screwed and cemented with no reduction in the internal bore of the tube.

b) The ceramic low air entry filter element shall have a pore diameter in the order of 60 microns and permeability in the order of 0.3 mm/s. The ceramic tip shall be 300mm long and a minimum of 38 mm to 50 mm diameter.

c) The covers over the top of the groundwater observation hole shall be constructed from 100 mm diameter galvanised steel pipe, and fitted with lockable galvanised steel caps. The steel pipe shall finish not less than 300 mm above ground level and be concreted into the ground to a minimum depth of 500 mm. The top surface of the concrete shall be neatly finished, at least 400 mm square and inscribed with the date of its installation.

d) A tape-type water level indicator for locating the level of standing water in standpipes or boreholes shall comprise a water-sensitive probe, suitable for passing down the standpipe supplied for Casagrande piezometers, together with a graduated cable. It shall indicate by a light and buzzer when the probe touches the surface of the water. Water level meters shall be designed to exclude the possibility of false readings being obtained due to shorting of the probe against the wet sides of the standpipes or boreholes. The probe will be 16mm in diameter. Each water level meter shall be fully portable and supplied complete with cable drum, winding mechanism and 100m of unjoined flat tape calibrated in metres and centimetres. Water level meters shall be capable of measuring water levels to an accuracy of +2.5cm.

PS 10.3.7.3 INSTALLATION

The standpipe piezometer holes of minimum diameter 100 mm shall be drilled to the full-length using bits and methods adapted to the material being drilled so that caving of holes is minimised. Immediately after each hole has been drilled the standpipe piezometer shall be installed for the full length of the drilled hole. Drilling mud shall not be used.

Piezometers tips shall be saturated by immersion in clean water for approximately 15 minutes prior to installation. Air bubbles shall be removed by gently tapping the filter element.

The Casagrande piezometer tip shall be placed centrally in the borehole in a pocket of clean washed sand extending 300mm below and 300mm above the tip. It shall be held in a vertical position while the sand is carefully tamped around the tip. If the hole is dry, sufficient water shall be added to just saturate the sand. Above the sand the hole shall be sealed with bentonite pellets and water to form a plug 300mm deep. The remainder of the hole shall be filled with grout.

Where a piezometer tip is to be placed above the level of the bottom of the borehole; the hole shall be filled with bentonite cement grout, placed by tremie pipe, up to 600mm below the level at which the tip is to be placed. When the grout has set the hole shall be sealed with bentonite pellets and water to form a plug 300mm deep. The sand pocket and the piezometer shall then be placed as specified above. The remainder of the hole shall be sealed with grout.

After the piezometer tip and standpipe have been placed in the hole but before final backfilling with grout, a water level meter probe shall be lowered to the bottom of the standpipe to ensure that the pipe is not obstructed.

At the surface of the ground the standpipe shall be capped with a lockable cover as described above. All such covers shall be supplied with a stout rust-proof padlock of secure design together with two keys. All padlocks protecting instruments shall be opened by a master key, two of which shall be provided.

Immediately following installation of the standpipe, the Contractor shall grout in the covers and after the grout has set, survey the cover tops.

PS 10.3.7.4 ELECTRIC PIEZOMETER

The Contractor shall supply and install Electric piezometers in the Dam body at the locations as shown on the drawings or directed by the Engineer/Engineer representative.

The Instrument shall comply with the following minimum requirements

- Measuring Range: 1 to 300 meters of Column;
- Full scale: 0.35 – 700 bar absolute and relative;
- Pressure Sensor Material: AISI 316L, or equivalent;
- Overcharge: 3 x F.S;
- Operating temperature: -40/+125 °C;
- Power supply: 8-28 V DC;
- Output: 4-20 mA;
- Non linearity: +/- 0.1% F.S;
- Repeatability: +/-0.01% F.S;
- Total thermal error: <0.04% / °C;
- Long-term stability: 0.1 % F.S /1year;
- Insulation: >100 MΩ;
- Material: stainless steel 316 fully watertight or equivalent;
- Diameter 19 mm to 22 mm;
- Length 150 mm to 190 mm

The Accessories and related components shall include Data-logger with integrated modem for data transmission, Compensation Cable for absolute measurements of piezometric pressure, Junction Boxes for the connection of different instruments, Multi-polar Cable for the connection of different sensors to one cable, Portable Readout Unit, Portable Data-logger, Multichannel Data-logger and Multiplexer for the connection of different sensors to the data-logger.

The data-logger shall be included in the body of the sensor.

PS 10.3.7.5 VIBRATING WIRE PIEZOMETER

The vibrating wire piezometers shall be of heavy-duty type and have the following characteristics:

a)	Measuring range	-3.5 to 250 mH_2O;
b)	Accuracy	+/- 0.1 % of Full Scale (FS);
c)	Resolution	0.025 % FS;
d)	Over range capacity	200%;
e)	Temperature range	-20 °C to + 80°C;
f)	Thermal effect on Zero	less than 0.02% of FS per °C

Dam body piezometers shall be heavy duty type specifically designed for installation in the concrete gravity dam and fitted with low air entry filter with robustly constructed thick-walled housing, robust, water-blocked signal cable and heavy-duty seals. Foundation piezometers shall have low air entry filters with 40 to 60-micron pores. Filters shall be ceramic and shall be removable for saturation prior to installation.

Piezometers used in impervious fill or soil shall have high air entry filters with 0.5 to 2 micron pores and be of similar robust construction as above.

The piezometer transducer shall be designed for long-tem stability and reliability. An operational life of at least 30 years or more is required. It shall be unaffected by cable length and shall exhibit a very low volume change to pressure.

The piezometer body shall be hermetically sealed and fabricated from stainless steel or ferro-manganese bronze. Only piezometers manufactured with electron beam welding will be considered.

The overall diameter of the piezometer shall be 32 mm to 38 mm with a length of approximately 200 mm. The vibrating wire piezometer shall have an in-place check feature for zero drift and calibration.

The piezometers shall be installed in the dam foundation or boreholes as shown on the Drawings or as directed by the Engineer/Engineer representative

For installations in foundation boreholes, the following procedures shall apply:

- After the hole has been prepared, the piezometer tip shall be placed and embedded in a sand layer of dimensions as shown on the Drawings or as directed by the Engineer/Engineer representative.
- This layer shall be sealed off from the other water bearing areas with bentonite pellets to a depth as shown on the Drawings or directed by the Engineer/Engineer representative.
- For dam body piezometers installed at shallow depth in trenches, the instruments shall be placed in preformed holes prepared using a suitable hole forming tool. Each instrument shall be carefully covered by the manufacturer recommended material.
- Dam body piezometers in shallow boreholes shall be installed in a similar manner to that described above for foundation piezometers.
- The ends of the cables shall be adequately protected and sealed until the connections are made in the gauge houses / terminal structures or switchboxes.

PS 10.3.8 WATER LEVEL MEASURING GAUGES

PS 10.3.8.1 MANUAL GAUGES

The Contractor shall supply and install water level measuring gauges at the Dam and Spillway and other structures in the locations as shown on the drawings or directed by the Engineer/Engineer representative.

The height range to be covered by the gauges shall be between the 2m below reservoir minimum drawdown level to maximum water level and intake sill level and service deck level.

The gauges shall be enamelled ironware with melamine resin coating, and shall be subject to the approval of the Engineer/Engineer representative. The principal division shall be in meters above sea level which will be further divided into centimetres. The lettering shall be every 10 cm with large, clearly legible letters.

The Contractor shall set the gauges by accurately levelling from a designated benchmark. The gauges shall be fixed to the concrete walls using stainless steel expansion or chemical grout bolts.

PS 10.3.8.2 ELECTRONIC RESERVOIR WATER LEVEL RECORDER

The Contractor shall furnish and install pressure meter type water level recorder(s), as approved by the Engineer/Engineer representative, in Spillway and Intake Structure of Dam. The recorders shall be able to monitor water levels with rang compatible with the reservoir max: / mini: elevations as shown on the drawing having an accuracy of 1 percent.

PS 10.3.9 SEEPAGE MEASURING WEIRS

The Contractor shall construct seepage measuring weirs at the locations shown on the Drawings or as approved by the Engineer/Engineer representative.

At the downstream toe of the dam, the seepage measuring weirs shall consist of V-notch weir plates formed with 6.3 mm thick, 316 S31 stainless steel plate, set into the gallery drains, as shown in the Drawings or as directed by the Engineer/Engineer representative, together with installation of a stick gauge for measurement of weir flow.

PS 10.3.10 METEOROLOGICAL STATION AND RAINFALL GAUGES

The Contactor shall supply and install a Meteorological Station at the dam site to measure rainfall, temperature, wind and evaporation. Each instrument will be supplied with an automatic reading and data logging system.

The meteorological station shall be provided during Site establishment and shall be located close to the construction site, but outside the range of disturbing traffic and dust. The meteorological station is a permanent station and it shall monitor the environmental conditions. An autonomous power supply shall be provided by the Contractor.

The Contractor shall procure, install and commission all required instruments of the meteorological station, which shall record continuously the environmental conditions at the Site. The Contractor shall also provide a twice daily monitoring on water levels of the stream during the project duration.

The meteorological station shall monitor the ambient air temperatures, global solar radiation, wind speed, the barometric pressure and relative humidity on an hourly basis. The precipitation shall be monitored at 15 minutes intervals.

Instruments shall comply with the following minimum requirements:

a) Temperature measurement:

- Range 0°C to +50°C
- Accuracy ± 0.5°C

b) Relative humidity:

- Range up to 100 %
- Accuracy ± 2.5 %

c) Global solar radiation:

- Range 0 to 1400 W/m^2
- Accuracy < 5 % of measured value

d) Wind speed:

- Range up to 35 m/s
- Sensibility < 1 m/s

e) Automatic rainfall gauge with compensator:

f) The gauge shall have the following characteristics:

- Sensitivity: 0.5mm/pulse (for tipping bucket type) or better.
- Measurement range: Up to 150mm/hr.
- Accuracy: 5% for entire measuring range.
- Size: 200mm diameter.
- Min. Installation Height: 1000mm.
- Cross area 200 cm^2
- Resolution 0.2 mm precipitation

g) The rain gauge shall be installed in a secure compound, and a windscreen shall be provided around the gauge.

h) The rain gauge shall be supplied with a battery-powered data logger, complete with a PCMCIA memory card capable of storing at least 6 months of data. The data logger shall allow readings to be taken at pre- set intervals ranging from 1 minute to 24 hours. The gauge shall also be suitable for direct connection to a PC.

i) The meteorological station shall also include:

- Autonomous power supply through solar panel and battery
- Data Logger

Installation details shall be according to the manufacturer's recommendations.

PS 10.3.11 FOUNDATION WATER PRESSURE MEASUREMENT SYSTEM IN SPILLWAY GALLERIES

The Contractor shall supply and install the water pressure measuring system in the spillway galleries as shown on the Drawings or as directed by the Engineer/Engineer representative.

The water pressure measuring system shall consist of bourdon tube gauges, shut off valves, manifolds and pipes all as shown on the Drawings. The characteristics of the bourdon tube gauges shall be as follows.

a) Dial size – 100 mm minimum.

b) Measurement range – 0 to 2.5 MPa

c) Accuracy – 0.25% FS

The Contractor shall install all piping, water flushing system (wash headers), drainage system and measuring gauges as shown on the Drawings or as directed by the Engineer/Engineer representative. All pipe locations, elevations and measurement points in the foundations shall be surveyed accurately and recorded on drawings and submitted to the Engineer/Engineer representative.

The measuring system shall be maintained free of blockage during grouting of the foundation in the vicinity of each measuring system by continuous flushing with water through the wash headers. After completion of the flushing operation, the Contractor shall plug and seal the flushing system in such a manner as to allow measurement of the water pressure in the foundation of the dam and spillway. He shall then install the pressure measurement gauges, valves etc so that pressure measurement can be carried out and test the system and take initial readings as described above for record and submission to the Engineer/Engineer representative.

PS 10.3.12 STRONG MOTION ACCELEROGRAPHS

PS 10.3.12.1 GENERAL

For the digital recording of ground and structure response motions and accelerations caused by earthquake events, strong motion accelerographs shall be installed as approved by the Engineer/Engineer representative at:

- The Dam crest, midway down the dam downstream face and both abutments and in free field area rock outcrop.
- At other locations, as shown on the Drawings or as directed by the Engineer/Engineer representative.

The Dam body instruments shall be located one at each abutment, and one at the centre of the dam crest, one midway on the downstream face and one on a free field rock outcrop approximately a minimum distance of 3 times the height of the dam (approx. 640m) away from the toe of the dam. All dam instruments shall be aligned in the same direction, usually with the instrument long axis parallel to the long axis of the dam.

The Contractor shall supply and install a seismic recording system, including low-noise strong motion triaxial (mutually perpendicular vertical, longitudinal and transverse) force-feedback accelerometers with centralized digital recording and evaluation system.

The seismic recording system shall operate on a standard 240 volt, 50Hz AC current power source. For a direct current operation, a suitable 12 V battery charger and a 12 V DC sealed lead-acid battery for internal installation shall be provided.

The system shall have the following features at a minimum;

- 3+1 sensor channels.
- 24-bit Delta Sigma converter, one per channel.
- Built in GPS, Built in PTP.
- Capable of Recording and Communicating Multiple sample rates.
- Capable of Multiple data formats and telemetry protocols.
- Ultra-low latency real time data output for earthquake early warning.
- Capability to off load data automatically. Parallel recording (mirroring) of data.
- Wireless communication via Wi-Fi.
- Streamlined Station Maintenance capability.
- Extensive state of health monitoring, system status and diagnostics.
- Application Programming Interface (API).
- IP security through SSH and SSL.
- Transient and EMI/RFI protection on all connections.
- Operating environment

  Temperature (-) 20ºC to (+) 70ºC

  Humidity 0 to 100% RH

The accelerograph shall measure and record accelerations in three orthogonal directions synchronously using GPS timing or other method. The system shall have the following characteristics.

CHANNELS

Channels – 3 +1 sensor channels w/internal sensor

Sensor Type – Triaxial Force-balance accelerometer, orthogonally oriented, internal.

Full Scale Range –User selectable ± 1g, ± 2g or ± 4g

Band width – DC to 200 Hz

Dynamic Range – 155 dB +

The accelerograph shall be fitted with a calibration system enabled on user command and of step applied to feedback type, shall be housed in corrosion resistant watertight enclosure and shall be capable of operating within a temperature range of -20°C to + 100°C. Lightning protection shall be provided.

The accelerograph shall store at least one year of continuous data recorded at least at 200 samples per second, which can be downloaded electronically onto a suitable data system. Software shall be provided to allow the data to be processed and acceleration time-histories plots to be produced to be produced for each accelerometer on a PC. An appropriate hardware and software shall be provided for downloading and transferring data stored in the seismic recording system. The data acquisition and recording system shall have the following characteristics.

DATA ACQUISITION

a) Type – Individual 24 bit Delta Sigma converter per channel.

b) Dynamic range – 200 sps at approx 127 dB-100 sps at approx. 130 dB

c) Frequency response – DC to 80 Hz @ 200 sps

d) Sampling rates – 1 to 5000 sps

e) Acquisition modes – Continuous, triggered, time windows

f) Output data format – 24 bit signed in user selectable format

g) Real time digital output – Ethernet or RS – 232 output of digital stream

TRIGGER

a) Trigger Type – IIR Bandpass filter

b) Trigger selection – Independent selection for each channel

c) Threshold trigger – Selectable from 0.01% to 100% of full scale

d) Trigger voting – Internal, external and network trigger votes with arithmetic combination

e) Additional trigger – STA/LTA, Time Window

TIMING

a) Type – Oscillator digitally locked to GPS or PTP

b) Shared timing – a minimum of at least 3 ports for shared timing for multiple local units

c) Timing – less than 1 μs (1 microsecond) of UTC with GPS or PTP

STORAGE

a) Data slot – Internal SDHC Card Slot – with minimum 32 GB

b) System slot - Internal SDHC Card Slot – with minimum 8 GB

c) Recording Capacity – Minimum 42 kB per channel per minute of 24-bit data @ 200 sps

1. The Time Base of the accelerograph shall have the following characteristics.

   Type – GPS Receiver/Clock plus a disciplined oscillator

2. The accelerograph shall be provided with a precise levelling system to ensure accurate alignment.
3. The accelerograph shall be protected by a secure vandal proof lockable enclosure (terminal box) as shown on the Drawings or as directed by the Engineer/Engineer representative.
4. The central recording system shall be installed in the nearest monitoring terminal. All cables from the accelerograph shall be connected to the recorder.
5. An independent work station shall be provided for data storage together with spares for at least 2 years.
6. State-of-the-art laptops (latest generation) with related software shall be supplied for data retrieval.
7. Adequate earthing and lightning protection shall be provided at the locations where each accelerograph is located.
8. The Contractor shall install and commission all equipment and provide necessary training and training documentation and operation and maintenance manuals for the equipment.
9. The Contractor shall submit all details of the seismic recording system including capabilities, manufacturer's specifications for approval by the Engineer/Engineer representative.

PS 10.3.12.2 MICRO-SEISMIC NETWORK

A micro-seismic network with the following specification shall be supplied and installed in the project area.

a) Six Triaxial Short Period Seismometers.

b) The system shall have the following features at a minimum;

- Range between 0.1Hz to 50 Hz
- Peak response 1 Hz
- Dynamic range > 130 Db
- 6 Channel, 24-bit High resolution recorder/digitizer
- DC Power system together with solar panels

c) Adequate earthing and lightning protection shall be provided at the locations where each seismometer is located

d) The Contractor shall install and commission all equipment and provide necessary training and training documentation and operation and maintenance manuals for the equipment.

The Contractor shall submit all details of the seismic recording system including capabilities, manufacturer's specifications for approval by the Engineer/Engineer representative.

PS 10.3.13 MISCELLANEOUS ITEM'S

PS 10.3.13.1 AUTOMATIC DATA ACQUISITION SYSTEM

Remote data acquisition systems shall be installed, as approved by the Engineer/Engineer representative, at the following locations:

- Dam Gauge Houses (Terminal Structures);
- Dam Spillway and instrumentation galleries;
- Spillway Slopes;
- Other locations/structures as directed by the Engineer/Engineer representative

1. The ADAS shall have a node driven system architecture. Nodes shall share communications capabilities equally without a master controller. Each node shall be capable standalone operation and be capable of being programmed to collect data and make alarm notification decisions on its own. The nodes shall be capable of being configured to allow two-way communication between units and of initiating access to a shared communication system. The system shall be capable of detecting alarm conditions locally without requiring polling from centralized host computers.
2. Communication between nodes shall be accomplished by several wireless and hardwire methods to ensure reliability.
3. The ADAS shall include signal conditioning capability for the mix of instruments that are to be monitored.
4. A CR1000 or latest model measurement and control system, as manufactured by Campbell Scientific, or equivalent shall be installed at each location of instrument installation in major structures or as directed by the Engineer/Engineer representative. The system shall be capable of simultaneously interrogating sensors, performing control functions, and transmitting data. The CR10 shall have sufficient internal memory for 1000k readings.
5. The CR1000 or latest model data logger or equivalent shall be supplied with an adequate number of multiplexers to cater for the number of instruments connected to each gauge house/terminal structure. Where vibrating wire instruments are present in a structure, a vibrating wire interface shall be installed between the data logger and the multiplexer(s). Signal cables from all electrical instruments shall be connected to the data loggers unless specified or directed otherwise by the Engineer/Engineer representative.
6. The CR1000 or latest model systems or equivalent systems shall be housed in secure, weatherproof boxes and provided with AC mains power supply and a 12-volt battery for backup power supply.
7. Wired links for data retrieval shall comprise a direct link to a laptop PC via a serial interface and interface cable, and a fibre optic modem and fibre optic cable routed from the data logger to the Dam Services Building as shown on the Drawing. Removable data storage in the form of a PCMCIA card writer shall also be provided for data retrieval during dam construction.

PS 10.3.13.2 PORTABLE READOUT UNITS

The Contractor shall supply portable readout units suitable for reading all vibrating-wire instruments.

The readout units shall be powered by DC batteries and be light, robust and durable.

The readout unit shall be capable of being set to a resolution of up to 0.01% of full scale (FS).

The readout unit shall be capable of storing the calibration coefficients of around 500 vibrating wire sensors.

Each readout shall allow readings to be stored in RAM memory, with each reading being time stamped, and assigned a reference number either manually or in automatic increments. The minimum static RAM shall be 1 GB.

The readout shall be capable of displaying the temperature of the transducer directly in °C from the thermistor incorporated in the sensor.

The readout units shall have the following provisions:

a) Digital reading

b) Storage of last reading

c) RS-232 interface to transmit readings to a computer.

Management software shall be provided to allow transfer of sensor calibration information and data between the readout and the computer.

PS 10.3.13.3 COMPUTER HARDWARE AND SOFTWARE

The Contractor shall supply a computer station including printer, plotter and all hard and software required to retrieve and handle all monitoring data acquired. The computer shall be located in the administration centre for the project.

The desktop computer shall meet the following minimum requirements:

a) **Model:** Desktop

b) **Processor:** Intel® Core i7 7700K quad core processor (4.5 GHz, 8MB Smart Cache, Bus Speed 8 GT/s DMI3) or equivalent or better latest generation processor

c) **Ram:** 16 GB 2133 MHz DDR4 RAM or better specification

d) **Hard disk:** 4.0 TB 7200 rpm SATA 6.0 Gb/s or better specification

e) **Optical Drive:** DVD +/- Double Layer Drive (Read/Writable) with Super Multi Drive LightScribe Tech or better specification

f) **Graphic Card:** Nvidia GeForce GTX 1080 Ti or better specification

A 19-inch wide TFT monitor, standard keyboard, PCMCIA data card reader, and optical scroll mouse shall also be supplied.

A custom software package shall be provided for the data logging system. The software shall be used to write and compile monitoring programmes, to transfer the programmes to the data loggers, and to retrieve data. The software shall also perform data reduction and processing for real-time graphical presentation, and also generate trend plots, profile plots and alarms. The software shall allow data to be exported into other software programs for further analysis.

The computer shall be installed with Microsoft latest Widows operating system, and loaded with the Microsoft Professional 2021 or latest suite of applications. All software shall be fully licensed.

The Printer shall be HP Office Jet Pro 8000 Printer or equivalent approved by the Engineer/Engineer representative.

The Plotter shall be HP Design jet 5500mm Printer or equivalent approved by the Engineer/Engineer representative.

PS 10.3.13.4 SWITCHBOXES

Permanent or temporary switchboxes, as required, shall be mounted in Dam & spillway structures, gauge houses / terminal structures or at temporary read out points.

They shall be of weather proof and dust proof construction and all metal parts including terminals shall be of rust proof material.

Each switchbox shall permit the connection of 12 vibrating-wire sensors to the readout unit.

PS 10.3.13.5 GAUGE HOUSES / TERMINAL STRUCTURES

The Contractor shall construct concrete gauge houses / terminal structures as approved.

The Contractor shall install at the required location in each gauge house / terminal structure all the instrumentation, measuring and servicing equipment relevant to that gauge house / terminal structure, and make all necessary connections to the installed instruments, including the permanent electrical wiring and earthing plate for ancillary equipment.

The Contractor shall supply and install the following items in the gauge houses / terminal structures as approved or otherwise by the Engineer/Engineer representative:

a) Floor drain cover, galvanised pipe for floor drain, vent pipe and entrance pipe for electrical supply;

b) Galvanised pipe with flared ends in accordance with this Specification;

c) Aluminium entrance doors complete with supporting frame and anchors in accordance with this Specification;

d) Aluminium framed fixed glass louvre windows;

e) 150 mm PVC ventilation ducts and electric exhaust fans and switches of an approved type suitable for tropical conditions;

f) Other required equipment as approved.

All concrete gauge houses / terminal structures shall be painted externally with an approved silicone-based water repellent paint and internally with an approved acrylic paint as specified in this Specification unless specified or directed otherwise by the Engineer/Engineer representative.

The Contractor shall complete each gauge house / terminal structure and instrument boxes at least twenty-one (21) days before the anticipated date of installation of instruments which will be connected directly to the gauge house / terminal structure.

The Contractor shall provide an approved temporary 240 V A.C. single-phase electric power supply plus earth to each gauge house / terminal structure from the time of completion of each gauge house until the permanent power supply has been commissioned. The Contractor shall also supply a sufficient quantity of de-aired water to each gauge house during construction.

All gauge houses / terminal structures shall be constructed as shown on the Drawings.

PS 10.4 CONSTRUCTION REQUIREMENTS

PS 10.4.1 INSTRUMENTS AND ANCILLARY ITEMS

The instrumentation to be supplied, installed, calibrated, tested, commissioned and maintained with respect to above stated parameters shall include:

b) Geodetic pillars, Surface movement and crest deflection points;

c) Groundwater observation wells;

d) Standpipe piezometers;

e) Water level measuring gauges;

f) Seepage measuring weirs;

g) Meteorological Station;

h) Rainfall gauges;

i) Foundation pressure measurement system;

j) Electrical instrumentation for pore pressure measurements, stress meters, no stress strain meters, strain gauges, temperature monitoring devices, total pressure cells and joint meters;

k) Combined Strong motion accelerographs/ Seismographs;

l) Micro-seismic recording stations;

m) Automatic data acquisition system;

n) Portable read-out units;

o) Computer hardware and software;

p) Inclinometers;

q) Submersible Tiltmeters;

r) Hydrostatic settlement cells;

s) Water Pressure Measurement System including Gauges;

t) Gauge houses / Terminal structures

PS 10.3.3 QUALITY OF INSTRUMENTATION

Instrumentation shall be supplied only by manufacturers who have been specialised in manufacture of dam and reservoir and slope instrumentation during the last 20 years or more.

Instrumentation shall be obtained from manufacturers with a worldwide reputation in the field of Civil Engineering instrumentation;

All instrumentation, cabling and protection etc to be used on the Dam shall be heavy duty type.

All instrumentation shall have operational ranges, accuracies and sensitivities which are consistent with the expected measurement requirements.

All instrumentation for use on the project shall be of proven make and construction and have a history of durability, reliable and stable performance on projects in the past 10 years or more.

The transducers or sensors of instrumentation must have proven longevity in similar environments to the Project. Cables, tubes or pipes that connect the transducer, sensor or instrument to the readout unit must be able to survive the life of the project under imposed pressure changes, deformation, water, sunlight and chemical effects such as corrosion and electrolytic breakdown.

PS 10.3.4 APPROVAL OF INSTRUMENTATION, PROCUREMENT AND INSTALLATION PROCEDURES

1. The Contractor shall procure, install and commission the different instruments complete with accessories, installation devices and manuals after the approval of the instrumentation specifications by the Engineer/Engineer representative.

2. The Contractor shall, with due cognizance of the time required to order and supply the instruments, but not later than 90 days after the Order to Commence, submit to the Engineer/Engineer representative for approval details of all the instruments proposed for installation and equipment and materials he intends to purchase. These will be consistent with the general information on the instrumentation submitted by the Contractor with his Bid as well as any modifications agreed to mutually between the Engineer/Engineer representative and the Contractor and shall include:

    a) a detailed description of the instrumentation including the ancillary measuring equipment he proposes to install;

    b) a detailed layout of the instruments and cabling system and routing, based on the relevant drawings;

    c) evidence of the successful performance of the instrumentation he proposes to install, which have been installed and operated for a period of at least 10 years in other dams, spillways and powerhouses and their foundations and surrounds;

    d) samples of all instrumentation, cabling, tubing, valves and fittings proposed to be used.

e) detailed procedures prepared by the manufacturers of the instrumentation for the installation, testing and operation and maintenance of the instruments;

f) details of the layout of all the equipment and accessories to be installed in each switchbox and gauge house;

g) details of protective surrounds, recesses in concrete & earthfill structures, cable shafts, etc. proposed for the installation of instrumentation and switchboxes; and

h) the experience of the supervisor and technicians who will install the instruments.

3. During the execution of the works, the Contractor shall submit to the Engineer/Engineer representative for approval any further details regarding the instrumentation that the Engineer/Engineer representative may require.

4. Not less than 28 days before the anticipated date of installing any instrumentation, in any particular location, the Contractor shall submit to the Engineer/Engineer representative for his approval

   a) the proposed installation procedure

   b) details of the ongoing construction work in the vicinity of the instrument installation

   c) the programmed sequence of events for the installation including details on:

   - the instrument(s) to be installed and their location(s),
   - calibrating and zero measurements,
   - personnel in charge, labourers, construction equipment and material to be used.

   d) within 15 days after the submission of the details, the Engineer/Engineer representative will give his approval with such modifications as may be deemed necessary.

5. Details of the construction procedures to be employed in the dam placing operations in the vicinity of the instrument installation and the programmed sequence of events for this work including details of all labour, construction plant and materials to be used.

6. The installation of instruments may interfere with the overall construction progress. The Contractor shall make provision for such interferences in his construction planning. The Contractor will not be entitled to any compensation or extension of the Time to Completion by reason of any such delays, including repair and replacement of damaged instruments.

7. No materials shall be purchased prior to the Engineer/Engineer representative’s approval. However, approval by the Engineer/Engineer representative of the Contractor’s proposals and drawings or data shall not relieve the Contractor from his sole responsibility to meet all the requirements of the Contract.

8. The Contractor shall prepare surveys and as-built drawings of all installed instruments and submitted to the Engineer/Engineer representative for approval.

PS 10.3.5 SKILLED PERSONNEL

The Contractor shall, after seeking formal approval of the Engineer/Engineer representative, employ only skilled technicians with more than 10 years' experience on installation and monitoring of instrumentation, trained by the Manufacturer and/or Supplier for the installation and monitoring of instruments and the recording and evaluation of the measurements.

The whole of the instrumentation work shall be under the direct supervision of a senior supervisor with at least 15 years of experience on dam, concrete structure and slope monitoring instrumentation, approved by the Engineer/Engineer representative, and employed by the Contractor who is well experienced in the installation of all types of instrumentation and who understands the purpose and function of all instruments being installed, is experienced in the field of dam, spillway and other concrete structure's and construction control and understands the anticipated behaviour of the relevant structures.

Installation and calibration shall be carried out only by skilled technicians, acceptable to the Engineer/Engineer representative, well experienced in the installation of the instruments in dams and powerhouses and who have a sufficient knowledge of the purpose and function of the particular instruments being installed.

The Engineer/Engineer representative has the right to ask for the replacement of any of the technicians or the supervisor if he deems it to be necessary with respect to the proper installation, testing and monitoring of the instrumentation.

PS 10.3.6 INSTRUMENTATION's MATERIAL TESTING AND STORAGE

The Contractor shall store, test and calibrate as required, transport, install, commissioning and maintain all the procured instrumentation (including all cabling, auxiliaries, readout units). The Contractor shall furnish and install cabling conduits, necessary supports for the cable leads, the basic reading station facilities, cabinets, panel boards, power and lighting facilities and all other components necessary for a complete installation and functioning.

The Contractor shall supply the type and number of instruments (including spares) as indicated on the Drawings and Specifications or as directed by the Engineer/Engineer representative.

All instrumentation shall be tested and calibrated in the factory under conditions simulating "as installed at site" temperatures, pressures environmental conditions etc. for each such instrument. The Contractor shall provide copies of such test and calibration certificates to the Engineer/Engineer representative. These instruments shall also be tested at site and if deemed necessary, recalibrated in the presence of the Engineer/Engineer representative before installation, at Contractor's cost.

The Contractor shall have all ancillary equipment, parts, fittings and materials as well as specifically required tools available for the instruments.

All instrumentation shall be stored on site, before installation, in a secure, weatherproof and lockable building and fitted with facilities for testing and partial assembling of the instrumentation.

PS 10.3.7 INSTALLATION

Installation procedures shall be planned well in advance of scheduled installation dates. The Contractor shall issue method statements (step-by-step procedures) to the Engineer/Engineer representative for the drilling methodologies, installation of the individual measurement devices, cabling and protection, making use of the instrumentation manufacturers' instruction manuals and the state-of-the-art knowledge.

The Contractor shall:

a) Excavate pits and trenches in dam body or provide notches and openings and trenches in the spillway, concrete structures for the installation of the instruments, cables and tubes;

b) Provide all proposed installation and protection measures for internal instruments during construction of the dam, spillway, powerhouse and all ancillary structures and places.

c) Assemble the instruments and calibrate and install them in the presence of the Engineer/Engineer representative at locations as indicated in the Drawings or as directed by the Engineer/Engineer representative.

d) The installation shall preferably be performed during daylight hours. If the installation has to be performed during night time or in enclosed space or structures, the Contractor shall provide sufficient lightning to ensure proper execution of the installation work;

e) The instrument function and cable connections shall be tested immediately after installation to ensure fully effective function.

f) Protect the installed instruments and cables or tubes against damage. Where necessary he shall expose all temporarily buried instruments to continue the installation or connections;

g) Install and connect cables and tubes, with sufficient slack, in the maximum practicable length to the instruments and install them in horizontal, vertical and inclined section without joints as determined by the Engineer/Engineer representative.

h) Combine single cables with multiple cables as appropriate and, where permitted and approved by the Engineer/Engineer representative, splice and couple cables and tubes in accordance with the Manufacture's recommendations;

i) Keep the open ends of all incomplete lines of tubing and casing plugged, sealed and protected;

j) At all times during installation keep the insides of casing and tubes free from foreign matter; and

k) Protect all cables, tubes etc. from degradation due to ultraviolet light by storing in an adequate building or, during construction, by covering with suitable material,

l) Determine the exact location and elevation by topographic survey to locate the instrument before and immediately after the installation of the instrument. Its co-ordinates shall be calculated to an accuracy of 10mm. The data shall be reported to the Engineer/Engineer representative immediately in writing.

m) Tag all cables and tubes with identification tags approved by the Engineer/Engineer representative at intervals of approximately 15 m horizontally or at such closer intervals as necessary to provide continuous identification.

n) All materials and works shall be in accordance with the relevant parts of the Specification.

The Contractor shall install all instrumentation in accordance with the manufacturer's instructions.

The instrumentation shall be put into operation at the earliest practical time during construction in order to obtain information relating to the performance of the structure, its foundation and abutments.

Initial readings, i.e., commissioning of the installed instruments shall be carried out under the Engineer/Engineer representative's supervision to assess the proper installation and function of the instruments.

PS 10.3.8 CARE OF INSTRUMENTATION

The Contractor shall protect all instruments from damage and displacement during the progress of the work and for the duration of the Contract Period. If, as determined by the Engineer/Engineer representative, there has been any damage to, or displacement of the instruments and connections during the progress of the work, they shall be repaired or the instrument replaced immediately to the satisfaction of the Engineer/Engineer representative at no additional costs to the Employer.

As soon as practicable after each instrument has been installed / buried or drilled in its protective surround and covered with a lid of concrete as the case may be, the instrument shall be checked to verify it is functioning correctly. Any such instrument which is not functioning correctly shall be immediately removed and replaced. Such checks shall continue to be carried out regularly by the Contractor so that damaged or defective instruments can be replaced at the earliest possible time.

The Contractor shall be fully responsible for the maintenance and repair of all instrumentation for the duration of the contract period.

PS 10.3.9 READING INSTRUMENTS

An initial set of readings on all instruments installed at any particular elevation will be taken immediately by the Contractor after the Contractor has completed their installation. Until the completion of the monitoring terminals the Contractor shall read the instruments by means of a portable measuring device, which can be connected to a PC with relevant software for data evaluation. Software shall be capable of converting units to standard metric units.

The Contractor shall program his work to allow the reading of the instruments as soon as possible after their installation.

The Contractor shall read the instruments at regular intervals. The Contractor shall inform the Engineer/Engineer representative when will the reading of the instruments take place.

The Contractor shall retain a qualified and experienced Engineer/Engineer representative to monitor all instrumentation and preserve records of readings in digital form from the time of their installation until the Taking Over of the Works at the end of the Period of Maintenance.

The Contractor's engineer shall read all instrumentation related to the Dam and appurtenant structures, as listed in Table 10.1, at intervals no greater than those stated in the table. When abnormal readings are observed the reading shall be repeated and both results shall be recorded together with an explanation. All data will be recorded in a Surveillance Manual which shall be submitted to the Engineer/Engineer representative on a weekly basis and any abnormal readings shall be reported immediately to the Engineer/Engineer representative.

Table 10.1: Frequency of Instrument Readings

Instrumentation	For a month after installation	Commencement of Impounding	After impounding Commencement to Issue of Completion Certificate
Surface and crest deflection points	weekly	weekly	monthly
Groundwater observation wells	weekly	weekly	weekly
Water level measuring gauges	daily	daily	daily
Seepage measuring weirs	weekly	daily	weekly
Piezometers	daily	daily	weekly
Total pressure cells	daily	daily	weekly
Long-base strain gauges	daily	weekly	weekly
Hydrostatic settlement cells	daily	weekly	weekly
One dimensional joint meters	daily	weekly	weekly
Three dimensional joint meters	daily	weekly	weekly
Total pressure cells	daily	weekly	weekly
Inclinometers	daily	weekly	monthly
Rainfall	daily	daily	daily
Reservoir level	daily	daily	daily

All other instruments shall be monitored and recorded as required for the safety of the Works and to obtain the information necessary for design purposes. The frequency shall be agreed with the Engineer/Engineer representative.

The Contractor shall maintain instruments in satisfactory operation and maintenance during the dam, spillway and powerhouse construction and for the required Period of Maintenance.

PS 10.3.10 OPERATION AND MAINTENANCE MANUAL AND TRAINING OF EMPLOYERS STAFF

The Contractor shall furnish operation and maintenance manuals for all the instrumentation installed in the Works.

The manual shall include comprehensive as-built information for all instrumentation installed in the Works.

The manual shall include all necessary reference and calibration data furnished by the manufacturer of each item of instrumentation and shall include all necessary safe operation and maintenance instructions.

The Contractor shall train a selected number of Employer’s staff in reading, calibrations, operating and maintaining the instruments without additional cost to the Employer.

PS 10.5 MEASUREMENT AND PAYMENT

Unless otherwise specified, the unit and lump sum prices for the supply and installation of instrumentation entered in the priced Bill of Quantities shall comply with the Works requirements of this Section.

The Unit and lump sum prices shall include, but not limited to the followings:

1. The supply, installation, calibration, testing, surveying, repairing and maintaining of all sensors, including protective steel covers, switchboxes, a nominal length cable for each sensor, tubes and tube protections, required to perform the specified measurements;
2. The supply of an adequate number of ancillary and read out equipment required for the performance of the Works specified in this Specification, including back-up equipment;
3. The unit prices shall also include for forming all necessary recesses in dam body and concrete structures, all necessary excavation, preparation, temporary and permanent protection of instruments and ancillary equipment by surrounding with selected material or by other approved method;
4. The Contractor shall include in his unit prices any additional readout equipment's, which may be necessary for reading the instruments he proposes to use; and
5. Payment of items for "supply and install" shall be made when the respective instrument is, in the opinion of the Engineer/Engineer representative, fully installed, commissioned, tested and ready for use.

Unless otherwise specified, the unit prices for the reading of instrumentation entered in the priced Bill of Quantities shall include the following:

a) All costs associated with reading the instrumentation, including all measures required to maintain access to the various readout locations for the period specified or agreed by the Engineer/Engineer representative;
b) All costs associated with the keeping of records, as set out in this Specification.
c) All costs associated with the collating and preparation of data gathered in the field and the attendance of the daily monitoring meetings.

CHAPTER 11
INTAKE TOWER STEEL STRUCTURES

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ITEM PS – 11.0 INTAKE TOWER STEEL STRUCTURES

PS 11.1 DESCRIPTION

This section of specification covers the Contractor's duties and responsibilities for detailed designing, fabrication, manufacturing, transportation, installation, erection, shop and site welding of different structural steel components at the Intake Tower including hydraulic steel structures, steel access bridge and their fittings, appurtenances where required, protective coatings, testing and commissioning for the safely withdrawing of water from the reservoir and then to discharge this water into the withdrawal conduit of MS pipe, through which it reaches the Water Treatment Plant, complete in all respects and in accordance with these specifications, drawings and Bill of Quantities.

The work shall include furnishing of all labor, materials, equipment, for fabrication, welding, coating, testing of different structural steel components in accordance with **Chapter – 16: Road and Bridges**; Section – 16.6.9 Steel Structures and **Chapter – 25: Iron Works** of General Specifications (***Technical Specifications for Workmanship; MRS-2019***), and shall include any other work that is required or necessary to complete the installations as shown on the drawings and as specified herein to the satisfaction of the Engineer/ Engineer Representative.

All materials incorporated in the equipment shall be new, unused and of first-class quality, free from defects. Materials and Proprietary items shall be selected taking into consideration customary use for type and class of equipment having regard to strength, the durability and best engineering practices.

The Contractor shall also maintain the intake structure equipment's and structural steel components during the maintenance period.

If provisions of this section are found in conflict with the requirements of the specific sections of general specification, then the Engineer's / Engineer representative decision in the matter shall prevail and binding upon all parties concerned.

For convenience in illustration in the Tender Documents, certain equipment, articles, materials, or processes have been designated by trade name or catalog name and number. Such designation shall be deemed to be followed by the words "or equal".

PS 11.2 HYDRAULIC STEEL STRUCTURES

1. **GENERAL**

   The equipment included in the scope of work shall be as per general description given hereunder and as shown in the appended drawings, suitable for operating functions as defined. It shall be simple in design and give long trouble-free service with minimum maintenance. Any item which is essential for the efficient performance of the equipment but not specifically mentioned in these specifications shall be considered included in the scope of supply of the contractor.

a) One set of vertical slide type gate of clear span of 1146 mm for Intake is proposed. The gate is to be operated under un-balanced head condition with the help of individual manually operated stem rod hoists of adequate capacity. The gate and embedded parts shall be designed to withstand an un-balanced Hydro static head of 37.0m or more corresponding to maximum surge level.

b) One set of sliding type stop-logs of clear span of 2000 mm consisting of almost twenty-seven equal size sections as non-interchangeable units shall be provided. The stop-logs shall be designed to withstand an un-balanced hydrostatic head of 37m or more corresponding to maximum flood level. The stop-log sections are to be operated with the help of power operated under-running single girder crane and a lifting beam of adequate capacity.

c) One set of fine trash-rack at the entrance of intake tower is proposed. The trash-rack shall be designed for a deferential water head of 3 m. The trash-rack shall be cleaned manually.

d) Electrically operated, under running single girder gantry crane of 5-ton capacity provided to be fixed on a concrete gantry structure at intake tower deck.

2. WORK TO BE DONE:

It is required that the contractor shall:

- Design, procure material, fabricate, deliver at site, store, erect and conduct test trial run to the satisfaction of Engineer/ Engineer Representative. The equipment, its material, accessories, supplies and services must be complete in every respect in accordance with these specifications and drawings as set forth in these bidding documents.
- Furnish a complete set of maintenance tools needed for Lubrication, adjustment and normal maintenance of each item of the equipment. These tools shall be neatly mounted in heavy duty cabinets or proper tool kit provided with locks. The price for each set of maintenance tools shall be included in the Contractor’s quoted bid price of the representative B.O.Q items.
- Furnish a complete sets of erection supplies. The price of erection supplies shall be included in the Contractor’s quoted bid price for the equipment / structure to which, it belongs. Erection supplies shall consist of the following

quantities in excess of the total quantity required for the site assembly for each type of the equipment.

(A) Erection Supplies

Erection Supplies	Excess Quantity (Percentage)
Bolts, screws, studs, nuts, washers and similar parts that are to be places and/or removed during field installations	5
Electrodes for field welding	25
Expansion anchor or other anchors	10
Lubricating grease or oil	20

- Furnish the basic spare parts for equipment supplied. The cost of the following basic spare parts for gate equipment shall be included in the corresponding equipment cost:

(B) Basic Spare Parts

Description	Slide Gates for Intake Tower
J. type seal (ft.)	As per Tender Drawings
L-type Seal (ft.)	-
Wedge type seal (ft.)	As per Tender Drawings
Rubber block for lower corner (sets)	02
Self-lubricating /Lubricate bushes and washers (one seal contain one bush and two washers)	2 sets for each type
Roller Bearing	2 sets for each type
Wire rope along with Sockets and turn buckles	-

All spare parts shall be interchangeable with and of the same material and quality as the original parts. All spare parts shall be treated and boxed as required to preserve them against rusting etc., during storage. Boxes shall be clearly marked for identification of the parts they contain.

3. DEFINITIONS:

Whenever the following technical terms appear in these specifications or drawings, these shall be understood to have the following meanings:

"DRAWINGS": means the drawings furnished by the Engineer representative or any modifications of such drawings approved in writing by the Engineer representative.

“INTAKE”: Structure placed at the beginning of an outlet-works waterway (power conduit, water supply conduit), the intake establishes the ultimate drawdown level of the reservoir by the position and size of its opening(s) to the outlet works. The intake may be vertical or inclined towers, drop inlets, or submerged, box-shaped structures. Intake elevations are determined by the head needed for discharge capacity, storage reservation to allow for siltation, the required amount and rate of withdrawal, and the desired extreme drawdown level.

"GATE": The movable or moving parts of a gate serving to close one opening.

“BULKHEAD GATE”: A gate used either for temporary closure of a channel or conduit before dewatering it for inspection or maintenance or for closure against flowing water when the head difference is small, e.g., for diversion tunnel closure.

“FIXED WHEEL GATE (*FIXED ROLLER GATE*, OR *FIXED AXLE GATE*)”: A gate having wheels or rollers mounted on the end posts of the gate. The wheels bear against rails fixed in side grooves or gate guides.

“SLIDE GATE (SLUICE GATE)”: A gate that can be opened or closed by sliding in supporting guides.

“GATE CHAMBER (VALVE CHAMBER)”: A room from which a gate or valve can be operated, or sometimes in which the gate is located.

"GATE EQUIPMENT": All equipment to be furnished under the Contract which includes gates and all accessories, including embedded parts, hoisting/operating system arrangement, decks, access ladders, spare parts, erection & maintenance tools and all appurtenances including supplementary equipment. The word "Equipment" wherever used instead of "Gate Equipment" shall mean as Gate Equipment.

"GATE UNIT”: The completely operational group of equipment parts that are required and sufficient to close one opening. A gate unit will normally include one gate, one hoist with hoisting deck, one set of embedded parts, access ladders and all required appurtenances.

“STOPLOGS”: Large logs, timbers, or steel beams placed on top of each other with their ends held in guides on each side of a channel or conduit / intake tower, so as to provide a cheaper or more easily handled means of temporary closure than a bulkhead gate.

“TRASH-RACK”: A device located at an intake to prevent floating or submerged debris from entering the intake.

“GANTRY CRANE”: A fixed or traveling bent-supported crane for handling heavy equipment.

"HOIST”: A device serving to move (open and close) a gate, including all related equipment necessary to assure safety.

"EMBEDDED PARTS": The group of parts of a gate, stop-log, trash-rack etc., which is to be embedded in concrete or otherwise permanently attached to the civil work, such as frames, seal plates, sill beams, bearing plates and rails. All welding pads, erection studs and anchorages to be furnished by the Contractor are also considered embedded parts except as otherwise noted.

"HOISTING/OPERATING DECK": A steel structure consisting of beams, chequered plates, required to install the hoists/operating system and related equipment.

4. **DESIGN REQUIREMENTS:**

a) **VERTICAL SLIDE TYPE GATE**

The gate shall be vertical lift, slide type and having skin plate & seals on the downstream side designed to withstand full static head corresponding to maximum surge level as indicated in the data given hereafter. The lowering/raising of gates shall be under balanced head conditions. For operation of gates, stem rod hoists shall be provided.

The gates shall be of fabricated steel construction consisting of downstream skin plate, horizontal girders and vertical stiffeners spaced according to design loads, end vertical girders. Side & top seals shall be of bronze material. The seals shall be fastened to gate using stainless steel bolts/counter sunk screws and nuts.

The gates shall operate within fabricated steel gate frames embedded in concrete. Gate is controlled by manually operated stem rod hoist. The hoists shall be installed on hoist bridge supported above top of piers.

DATA:

i)	Type of Gate	:	Vertical lift slide type with downstream skin plate and downstream seals,
ii)	No. of gates	:	1
iii)	Clear width of opening	:	1146 mm
iv)	Sill level	:	El. 588m
v)	Max. Flood water level	:	628.0 m
vi)	Normal Conservation Level	:	617.0 m
vii)	Design head	:	29 m
viii)	Type of side & top seals	:	Bronze bar.
ix)	Type of bottom seal	:	Bronze bar
x)	Position of skin plate & side seal	:	Down Stream
xi)	Operation	:	Lowering / raising under balanced head conditions by stem rod hoist.

b) **INTAKE TOWER STOP-LOGS**

Provision to close the water intake of intake tower by stop-logs has been made to facilitate repair and maintenance of Slide Gate and intake tower itself. For this purpose, stop-log grooves have been provided on downstream of intake trash-rack.

A set of stop-log panels shall consist of twenty-seven sections of almost equal height. Each stop-log unit shall be capable of self-closing i.e., by gravity under its own weight. Embedded metals/parts for stop-log panels shall be provided in the channel more than the normal conservation water level. Stop-log units when not in use shall be supported on dogging latches provided near the top of the structure.

The stop-log is a vertical lift, slide type of fabricated steel construction and shall be formed by two vertical end girders between which horizontal girders are spaced according to design loads and the downstream face is covered with a skin plate.

The stop-log in two non-interchangeable of equal size units is provided with two lifting lugs. Stop-log units shall be provided seals on downstream side. Side seals shall be of rubber music note type and bottom seal of rubber wedge type. The seals shall be fastened to the stop-log unit using stainless steel bolts and nuts.

Stop-log unit shall be provided with two guide shoes on each side. The stop-log units shall be handled by a monorail hoist using a lifting beam capable of grappling and ungrappling of stop-log unit under water. The lifting beam shall be attached to the hoist at two points.

Fabricated steel frames shall be provided in the flushing bay to receive the stop-log. The frames shall consist of side and bottom seal seats, tracks i.e., load carrying faces to bear the thrust pads fixed on the stop-log units and guides on both sides. Faces of seal seats and tracks shall be of corrosion resisting steel.

The Mono-rail Hoist shall be installed on concrete column structure at top of intake tower. Alignment pins shall be provided between consecutive units of the Stop-logs for their alignment during placement.

DATA:

i)	Type of Stop-log gate	:	Vertical lift, slide with downstream skin plate and downstream seals, non-regulating type i.e., not to be kept at partial opening.
ii)	No. of stop-log panels sets required	:	One
iii)	Clear width of opening	:	2000 mm
iv)	Sill level	:	El.591.0 m
v)	Max Flood level	:	El.628.0m
vi)	Normal Conservation Level	:	El.617.0m
vii)	Type of side seals	:	Rubber, music note Type
viii)	Type of bottom seal	:	Rubber, wedge Type
ix)	Position of skin plate & seals		Down Stream
x)	Operation	:	Lowering / raising under balanced head conditions by Mon-rail Hoist. & Lifting Beam of adequate capacity

c) **FINE TRASH-RACKS**

The vertical fixed type fine trash-rack shall be required to be installed in the main entrance of intake tower to prevent entry of bed load and debris directly into the Intake tower and indirectly into the delivery pipe. These shall be of fabricated steel construction consisting of trash-bars supported on horizontal bars, which in turn shall be supported on end channels/members to bear against the downstream face of slots. Trash-racks shall be split into units of equal height except the top panel for easy handling. The units shall be interchangeable and each unit shall have two lifting points. The trash-racks units shall be handled by Mono-rail Hoist using a lifting beam/sling capable of grappling/ungrappling under water. Cleaning of trash-racks shall be done manually by lowering the cleaning bucket up-to the TR cleaning platform at normal conservation water level.

Alignment pins shall be provided between consecutive units of the trash-racks for their alignment during placement.

Data:

Clear width of opening	:	2000 mm
Clear height of opening	:	40,200 mm
No. of openings	:	One
Sill level	:	El.591.0m
Max Flood Level	:	El. 628.0m
Top of trash rack	:	El. 631.20 m
Clear spacing between trash bars	:	85 mm
Min. thickness of Trash-rack Bars :	10 mm	
Differential head for design	:	3 m
No. of sets of trash-racks required	:	One set (up to the top deck level)
Operation	:	Lowering / raising by Mono-rail Hoist

d) **STEM ROD HOISTS (FOR INTAKE GATE)**

For vertical lift slide type gate, one manually operated stem rod hoist is proposed. The capacity of the hoist to meet the operation requirements and shall be worked out by contractor and shall be 20% more than all the forces opposing the raising of gate. The hoists shall be designed to conform to DIN or US Corps manual or other equivalent International Standards. The hoists shall be installed on the top grating of intake tower. The hoists shall be capable to perform the operation of crack opening of the gate under maximum unbalanced head conditions and shall also take care of down pull, if any, in this operation.

A clear walkway for the operating/maintenance personnel of 1.0 m width shall be provided on either side of the hoist.

The hoists and their components shall be simple in design and rugged in construction so as to give trouble free operation with minimum maintenance. These shall be suitable for out-door service. The driving unit shall comprise of a gear box, brake, reduction unit, necessary shafts, bearings and flexible couplings. The driven unit shall comprise of two stem rods, reduction units, shafts, couplings and bearings.

The design of hoist mechanism shall be based on the gate opening / lowering speeds mentioned in the above paras. The gates shall fall under their own weight so as to effect closure of the delivery pipe.

e) **5 – TON UNDER RUNNING SINGLE GIRDER GANTRY CRANE**

A 5-ton (electrically operated) under running single girder gantry crane shall be provided which will be fixed on a concrete gantry structure at intake tower deck as per the drawing and will be used for handling of hydraulic steel structures of intake tower. The hoisting capacity shall be confirmed by the Contractor to meet the operation requirements and shall be 20% more than all the forces opposing the raising of a single stoplog panel.

The hoists shall be designed and manufactured to conform to the requirements of FEM (European Federation of Materials Handling) , CMAA (Crane Manufacturers Association of America) or other equivalent International Standards. The hoists shall be installed on the monorails supported on hoist structure as shown in the appended drawings.

Mono-rail Hoist will consist of two electric motors (one for hoisting and the other for traversing mechanism), two independent electro-magnetic/thruster brakes, gear reduction units for both the motors (working independently), rope-drum, ropes, pendant switch, limit switches, main hoisting controls, PVC insulated cable for power supply and its mounting structure, other accessories etc. Electric interlocking shall also be provided to ensure that either raising / lowering operation or traverse motion is operative at a time. The hoists shall be suitable for outdoor service. Amber indicating lamp shall be provided on the pendant itself to indicate that the electric supply is “ON”.

5. **DESIGN DRAWING:**

The contractor shall submit drawings, data and perform all other work as specified hereinafter.

a) **DRAWINGS FURNISHED BY THE ENGINEER REPRESENTATIVE**

The general arrangement of the Equipment shall conform to the Tender Drawings. The Tender Drawings are not intended to define the detailed design of the Equipment to be furnished and installed but are merely illustrative to show the general layout of the Equipment except where limiting or mandatory dimensions, elevations, tolerances and similar features are indicated. Alternative details and arrangements will be considered if, in the judgment of the Engineer/Engineer representative, those are not inferior to the details and arrangement shown on the Tender Drawings.

b) **CONTRACTOR'S DRAWINGS AND DATA**

The Contractor shall submit drawings and instructions as outlined hereunder. The sequence of submission to the Engineer/Engineer representative, for review shall be such that information is available for review of each drawing when it is received Contractor’s drawings and design data, submitted formally shall have certification by an authorized representative of the Contractor to the effect that information shown thereon has been checked by the contractor and is correct for use in the project expect for drawings of preliminary nature furnished for information which shall be clearly identified as such. Before submitting any drawings for review, the Contractor shall submit a list of proposed drawings, showing sequence and dates of submittal to meet the requirements of the Tender Documents.

The application parts of the requirements of all paragraphs with reference to the drawings shall apply equally to design data, calculations, catalog pages, illustrations, descriptions, printed specifications, draft reports or any other similar data submitted for review.

(i) **OUTLINE DRAWINGS**

The Contractor shall submit outline drawings of the Equipment together with data, to permit final design of the structures into which the Equipment is to be incorporated. Outline drawings and/or data shall be submitted in accordance with a schedule mutually agreed upon between the Engineer/Engineer representative and the Contractor.

(ii) **DETAILED DRAWINGS AND DATA**

Before proceeding with manufacture of the Equipment, the Contractor shall submit general assembly drawings, sub- assembly drawings, detail drawings, calculations, design criteria, design data, catalog leaflets, specifications and similar Engineering documents required to demonstrate fully that all parts will conform to the provisions and intent of the Tender Documents. These drawings shall show all necessary dimensions and fabrication details, including the design of welded and bolted joint connections, tolerances on fits and clearances, and all field joints and sub-assemblies in which the Contractor proposes to transport the Equipment.

The detail drawings shall include but not limited to the following wherever applicable:

- **General arrangement drawings of embedded parts:** These drawings shall show all final dimensions, tolerances, and details of field connections.
- **General arrangement drawings of gates, stop-logs & trash-racks:** These drawings shall show all final dimensions and tolerances, surface finishes, details of field connections and final weights.
- **General arrangement drawings of the hoists:** These drawings shall show all final dimensions and tolerances, details of field connections, final weights and loads on foundation bolts.
- Slot and sill beam details showing seal contact with the embedded sealing faces.
- Typical seal details.
- Seal splice and seal corner details.
- Structural detail drawings of each gate, stop-log & trash-rack.
- Hoist platform, grating and access ladder details.
- Details of the hoist gearbox, hoist drum, drive shafts and couplings.
- Assembly match mark sheets.
- Paint material specifications and painting schedules.
- Other drawings and data, not specifically listed but required to develop the detailed drawings.

(iii) **STRUCTURAL DESIGN DATA.**

The design data and computations shall include the following:

- Structural analysis for Slide gates, Stop-logs, Trash-racks hoisting arrangement, dogging devices, embedded metal parts and other major structural parts.
- Weight and center of gravity, calculations

(iv) **MECHANICAL DESIGN DATA**

The Design data and calculations shall include the following:

- Required hoisting/operating force calculations.
- Speed reduction and gear box calculations.

(v) **REVIEW OF DRAWINGS**

- Three (3) copies on durable paper with dark lines on a white background and one durable paper type reproducible shall be furnished of each drawing submitted. All drawings submitted shall in so far as practicable, be of one standard size, measuring approximately 33 in. x 23.5 in. Printed catalogs and data shall be submitted in five (5) copies. Drawing should preferably be drawn on AutoCAD.
- One copy will be returned to the Contractor marked “Approved”, “Approved Except as Noted”, or “Not Approved”. Engineer’s / Engineer’s representative Review will not relieve the Contractor of responsibility for conformity with specified requirements and correct detail and fit of parts when installed. No revision affecting the design shall be made after a drawing has been “Approved” without resubmitting the drawing.
- When copies of drawings have been marked "Approved Except as Noted", or "Revise and Resubmit", or "Not Approved", the Contractor shall make the necessary corrections and resubmit three (3) copies and one reproducible. Every revision shall be shown by number and date.
- Should an error be found in a Contractor's drawing during the installation or field testing of equipment, the correction, including any field changes found necessary, shall be noted on the drawing, and it shall be resubmitted for review and record.

(vi) **AS-BUILT DRAWINGS**

Prior to completion of the work under the Contract, the Contractor shall furnish one complete set of full size permanent reproducible plastic film copies of approved quality and type of all Contractor's drawings of equipment as finally built, including any field changes and Stamped “As Built Drawings” to the Engineer/Engineer representative.

PS 11.3 MATERIAL SPECIFICATION

PS 11.3.1 GENERAL

Materials shall be new and of first-class quality, suitable for the purpose, free from defects and imperfections, and of the grades, classes and types listed herein, or their equivalents.

Structural Steel for Skin plate, main components of gate leaf.	ASTM A36, "Specification for structure steel”

Structural Steel for embedded meal parts (except seal and track plates and side guide plate which will be of CRES) and supports etc.	ASTM A36, "Specification for structure steel"
Corrosion-Resisting or Corrosion Resistant steel for bars, bolts, nuts, and washers, etc. (symbol "CRESS")	ASTM A-276. "Specification for stainless steel and heat resisting steel bars, and shapes. "Type 316L"
Stainless Steel (plate sheet and strip).	ASTM A240, "Specification for Heat Resisting Chromium and Chromium Nickel Stainless Steel Plate, Sheet, and Strip for Fusion Welded Unfired Pressure Vessels."
Corrosion Resisting Steel Castings	ASTM A 743, "Specification for Corrosion Resistant Iron Chromium, Iron Chromium Nickel and Nickel Base Alloy Casting for General Application".
Carbon Steel Axles	ASTM A21, "Specification for Carbon Steel Axles, on Heat Treated and Heat Treated for Railway use
Steel Shafting	ASTM A29, "Specification for Steel Bars, Carbon and Alloy, Hot Wrought and Cold Finished".
Steel Bolts and Nuts	ASTM A307, "Specification for Carbon Steel Externally Threaded Standard Fasteners," and ASTM A325, "Specification for High Strength Bolts for Structural Steel Joints."
Lock Washers Spring	SAE proportions, regular series.
Forged Steel	ASTM A668, "Specification for Steel Forgings, Carbon and Alloy for General Industrial Use."
Cast Steel	ASTM A27, "Specification for Mild to Medium Strength Carbon Steel Castings for General Application," Grade 65 35
Round Wire Rope	ASTM A492 "Specification for Stainless and Heat Resisting Steel Rope Wire" and U.S. Fed. Spec. RR W 410b. "Wire Rope and Strand,"
Wire Rope Fittings	Contractor's standard fittings for the type of rope used.
Permanent self-lubricating bearings and washers with rated coefficient of friction less than 0.15.	"Lubrite" A cast bronze alloy (ASTM-B22, "Specification for bronze casting for bridges and turntables." Alloy E) with self-lubricating inserts
Lubricating Fittings	According to manufacturer's published data.

Bronze Bushings, Sleeve type Bearings and other Lubricated Wearing Parts	SAE (Society of Automotive Engineers) Standard Specification No.64 for Phosphor Bronze.
Anti-Friction Bearings	According to manufacturer's published data
Steel Pipe	Refer to relevant section of “MS Delivery pipe and Appurtenances”.
Steel Pipe Flanges and Flanged Fittings	
Expansion Anchors	According to manufacturer's published data.
Gear & Speed Reducers	AGAMA (American Gear Manufacturers Association) Standards.
Rubber Seal	The Rubber Seal Shall be molded and the material shall be compounded of natural rubber or copolymer of butadiene and styrene of blend of both. The compounded shall be contain not less than 70% by volume of the basic polymer and the remainder shall consist of reinforcing carbon, black zinc oxide, accelerators, anti-oxidants, vulcanizing agents and plasticizers.
Fluoro-Carbon Clad Rubber Seals	Rubber Seals shall be as specified above, A fluoro-carbon sheath shall be bounded to the rubber on the sealing surface. The sheath shall be abrasion resistant. The outside surface of the flouro-carbon shall be free of adhering or bounded rubber

PS 11.3.2 SELECTION OF MATERIAL

The type of materials to be used for each specific part shall be selected as designated in these specifications and drawing.

The type of materials to be used for part in specific locations or having specific working requirement shall be selected according to the criteria listed below. The following abbreviation are used in this listing:

“CRES”	Corrosion-resistant steel
“CRES-clad”	Corrosion-resistant clad steel plate
“GP-CRES”	General purpose corrosion-resistant steel
“Mach-CRES”	Corrosion –resistant steel for machinery use
“BRNZ”	Any non-ferrous metal having corrosion-resistance properties, such as bronze or brass.

Where no designation is given and no applicable criterion is listed, the Contractor shall make the selection on the basis of functional requirement and good design practice, and as approved by the Engineer / Engineer representative.

1.**EMBEDDED PARTS**

Guide bars of guide rails shall be GP-CRES All other exposed surfaces of embedded parts, whether working surfaces, shall be either GP – CRES or CRES – clad.

2.**WELDED STRUCTURES AND PARTS**

Welded structure and parts shall comply with the relevant provisions of ASTM Specification for welded steel structure shapes.

Where a material is subjected to welding, only material of wieldable quality, which is compatible with the selected welding rod and welding procedure, shall be used.

Welding rods shall be used CRES wherever CRES or CRES-clad is welded to CRES, When CRES or CRES-clad is to be welded structural steel, rod may be non-CRES if otherwise compatible with both materials and if no corrosion-resistant properties are needed on the area of the CRES which is affected by the welding. This shall also apply to the clad portion of CRES-clad, so that the integrity CRES-cladding shall be maintained.

3.**SEAL MOUNTING**

All seal clamp bolts shall be Mach-CRES with bronze nut, or shall be of bronze with a Mach-CRES nut. Each seal clamp bolts shall have one seal washer and one CRES washer. Where a screw is used for clamping a seal, it shall be Mach-CRES.

4. **BEARINGS AND ARTICULATIONS**

Bearings and articulation shall include all pivots, linkages and other similar connection, which provide for either rotation or self-alignment.

All bearing and articulation provide for rotation, (such as sheave bearings, guide roller bearing, hinges, dogging device pivots etc.) which are subject to submersion, shall have Oil-Impregnated Sintered Bronze (OISB) bushing rotating on CRES pins. The axial loading parts shall be axially supported by an OISB surface (flange of the OISB washer) sliding on CRES washer. In the absence of axial loading, the axial support may be given by bronze washers.
Bearings and articulation which are not subject to submersion, or those which are intended for submergence but do not require rotation (only self-alignment or other small movement) shall have bronze bushings, and shall have bronze washer or bronze flange for axial support.

5. ROLLER BEARINGS

Roller bearings which may become submerged shall be entirely of Mach-CRES, including all load carrying parts such as roller (or balls, inner races outer races, except roller spacers, which shall be either CRES or BRNZ. Alternatively, roller bearing subject to immersion may be of the TDC (Thin Dense Chromium) plated type. The pin and bore area where such roller bearings area seated shall be chrome-plated or CRES.

6. GUIDE ROLLERS

Guide roller rims be shall either CRES or shall be provided with a weld CRES overlay of minimum 4 mm thickness after finish machining.

7. CHAINS AND WIRE ROPES

Permanently or occasionally submerged wire ropes shall be CRES. All parts of roller chains shall be CRES or BRNZ.

8. BOLTING

Bolting submerged or exposed to weather, which is to be tightened or disconnected for operation or normal maintenance purposes, shall be CRES bolts with BRNZ nuts, or conversely BRNZ bolts with Mach-CRES nuts. Such bolts include semi-permanent connection items. Where screws are used for such application, these shall be of Mach –CRES or, for light loading condition, of BRNZ.

Where submerged or weather exposed connection provide for self-alignment or small adjustment movement, a spherical BRNZ washer shall be the first choice over the spherical CRES washer; one of these washers may be substituted by a spherical surface machined on the bronze or CRES nut or bolts head of the connection.

Wire, cotter pins or locking plates used for securing bolts, nuts or screw, which may be submerged, shall be of CRES OR BRNZ.

9. PIPING

Piping that may be submerged shall be of CRES or BRNZ, including fitting and flange.

10. LUBRICATION SYSTEM

All piping’s for lubrication purposes, which are to be submerged or exposed to weather shall be of copper.

All lubrication nipple, including springs, which may be submerged shall be entirely of CRES or BRNZ.

11. **AXLE SEAL AND PACKAGES**

Axle seal and packing submerged or exposed to weather shall have no parts or components that can be adversely affected by corrosion. Spring mountings, exposed metal and similar parts shall be Mach-CRES or BRNZ.

12. **DIALS AND NAMEPLATES**

All dials, nameplates, instrument housing and similar parts, which are submerged or exposed to weather, shall be GP-CRES or BRNZ.

PS 11.3.3 MATERIAL TESTING

1. **GENERAL**

All materials or parts used in the Intake Tower Gate equipment shall be tested, in conformity with applicable methods prescribed by the ASTM, or equivalent as may be specified in these documents and in general, accordance with the best commercial methods. When requested, tests shall be made in the presence of the Engineer/ Engineer representative. Stocked material may be used, provided evidence is furnished to the Engineer/Engineer representative to show that such material meets the requirements specified herein, in which case tests on stocked materials may be waived or as directed by the Engineer/Engineer representative otherwise.

2. **TEST CERTIFICATES**

Certified material test reports shall be furnished in triplicate to the Engineer/Engineer representative as soon as possible after the test are made. The test certificate shall identify the component for which the material is to be used and shall contain all information necessary to verify compliance with the specifications.

3. **RUBBER SEALS**

a) All rubber seal shall be tested for and shall have the following physical properties.

S.No:	PHYSICAL PROPERTIES	TESTS

S.No:	PHYSICAL PROPERTIES	TESTS
1.	Tensile strength min. 210 Kg/cm^2 (3000 lbs/sq.in)	ASTM-D412, Test for rubber properties tension.”
2.	Elongation at break min	ASTM-D 412
3.	300% Modulus, min. 60 Kg/cm^2 (850 lbf/sq.in)	ASTM-D 412
4.	Shore Durometer (type A) 60 to 70	ASTM-D2240, Test for Rubber property-Durometer Hardness
5.	Specific Gravity	1.15 ± 0.03
6.	Absorption of water by Weight, max.5%	ASTM-D471 “Test for Rubber property-effect of liquids.”
7.	Compression set (constant deflection). Or original Deflection max.30%	ASTM-D395 (Method B) “Test for Rubber property-compression
8.	Tensile strength after Oxygen Bomb Aging for 48 hr., at 70°C and pressure of 21 Kg/cm^2 (48 hr., 158°F 300 lb./sq.in); Percentage of tensile Strength before aging min. 80.	ASTM-D572 “Test for Rubber deterioration by heat and oxygen.”

b) One rubber seal with fluoro-carbon cladding, the rubber shall be tested as specified above. The fluoro-carbon shall be tested for and shall possess the following physical properties.

Tensile strength	2000 psi (min.)
Elongation	250 %(min)

c) The fluoro-carbon cladding on rubber seals shall be tested for adhesion in accordance with ASTM – D413, “Test for Rubber property adhesion to flexible substrate”, using either the machine method or the dead –weight method.

d) Except where tolerances for rubber seals are specified on the drawing, seal dimensions or nominal and slight variations will be acceptable.

PS 11.4 DESIGN & STRESS LEVELS - HYDRAULIC STEEL STRUCTURES

PS 11.4.1 GENERAL

The Contractor's scope of work for this section includes design, manufacture, supply, install, test and commission of all required hydraulic steel structures (HSS) i.e., gate, stop-logs, trash-racks for the Project.

The section covers the technical requirements to manufacture and deliver the HSS complete with lifting / handling and cleaning devices, embedded parts and any other parts as necessary for safe operation of each hydraulic steel structure.

PS 11.4.2 GATE

1. Various components of the gate and embedded parts shall be designed in accordance with the provisions ASTM, DIN, BS or US Corps manual or equivalent International Standards. The horizontal girders and wheels shall be so spaced that they carry equal load (approximately).

2. Loads to be considered for design:

    a) The gate shall be designed for the hydrostatic head corresponding to upstream maximum surge levels.

    b) The design of gate shall be checked for the combination of above design head and earthquake effect in accordance with ASTM, DIN, BS or US Corps manual or other equivalent International Standards Criteria for Earthquake Resistant and the Building Code of Pakistan for Design of Structures.

    c) The friction forces considered in design shall be based on the application coefficients of friction taken from the following table.

	Maximum	Minimum
Rubber on seal	1.0	0.3
Rubber on corrosion-resisting Steel	0.8	0.2
Fluoro-carbon on corrosion-resisting steel	0.15	0.05
Corrosion-resisting steel	0.5	0.1
On carbon steel, lubrication	0.18	0.08
Bronze on corrosion-resisting Steel, non-lubricated	0.5	0.15
Bronze on corrosion-resisting Steel, lubricated	0.2	0.07
“Lubricated" on corrosion- Resisting steel	0.2	0.06

d) Horizontal wind load of 30 lbs/sq.ft acting in any direction on the projected area of affected components, shall be considered in the design.

e) All components of gate shall be designed to withstand safely the seismic force computed by using the following seismic coefficient and design factor.

- OBE: An operating basis earthquake (OBE) equivalent to a horizontal ground acceleration equal to 0.1 g acting simultaneously with a vertical acceleration equal to 1/3 of horizontal acceleration.
- Seismic force to be considered for the design of gate leaf shall be the sum of inertia and hydrodynamic forces, equal to the product of the mass and the effective acceleration of the gate leaf assembly. The hydrodynamic forces shall be assumed equal to the product of added mass of water acting on the skin-plate and the affective acceleration of the skin-plate. The seismic forces on all other components of the gates and hoists shall be taken equal to the product of their mass and affective acceleration.

f) The thermal forces shall be considered in the design of the components when temperature flocculation relative to an assumed erection temperature exceeded by 10˚C, the following temperature variations shall be assumed:

For components located above Water or periodically Exposed and submerged.	+70°C - 0°C
For components partly Submerged or protected from direct sun	+50°C – 0°C
For components permanently submerged in water	+20°C – 0°C

PS 11.4.3 STOP-LOGS

1. The stop-logs for intake tower shall be designed for the hydrostatic head corresponding to upstream maximum flood levels.
2. Various components of stop-log and embedded parts shall be designed in accordance with the provisions of ASTM, DIN, BS or US Corps manual or other equivalent International Standards.
3. The design of stop-log shall be checked for the combination of above hydrostatic head and earthquake effect in accordance with DIN, BS or US Corps manual or other equivalent International Standards Criteria for

Earthquake Resistant and the Building Code of Pakistan for Design of Structures.

PS 11.4.4 TRASH-RACKS

1. The trash racks shall be designed for a differential head of 1.5 m.
2. Various components of trash racks shall be designed in accordance with the provisions of ASTM, DIN, BS or US Corps manual.

PS 11.4.5 STEM ROD HOISTS

Various components of stem rod hoist such as gears, pinions, worm gear reducer, shafts, keys, bearings and coupling etc. and their design shall meet the requirements of ASTM, DIN, BS or US Corps manual or other equivalent International Standards.

The worm gear reducer shall be a standard superior quality product of established/reputed manufacturer of such equipment. The openings in the housing of the reducer etc. shall be provided with dust proof seals/packing.

All gears/pinions shall be enclosed in fabricated steel cases having air tight covers with windows at the top for inspection. The openings in the gear cases for shafts shall be provided with dust proof seals.

Bolts, nuts and screws used shall conform to relevant ASTM standards. Bolts and screws in rotating parts shall be locked. Bolts in tension shall be avoided as far as possible. Wherever necessary, net section of such bolts at the root shall be increased by 15%.

PS 11.4.6 MONO-RAIL HOISTS (FOR STOP-LOGS AND TRASH-RACK)

Various components of these equipment shall be designed in accordance with provisions of ASTM, DIN, BS or US Corps manual or other equivalent International Standards. Capacities of these shall be 125 percent of all the forces opposing the hoisting with loads intended to be handled.

PS 11.4.7 LIFTING BEAMS

The lifting beam for stop-log gate shall be designed in accordance with provisions ASTM, DIN or US Corps manual or other equivalent International Standards.

PS 11.5 PERMISSIBLE STRESSES

PS 11.5.1 GATE

The permissible stresses shall be taken those corresponding to wet inaccessible conditions as per ASTM, DIN, BS or US Corps manual or other equivalent International Standards and are given as under:

Material and Type of Stress		Permissible Stress
Structural Steel – Wet & Accessible conditions		
a)	Direct Compression/Tension	0.45 Y.P.
b)	Compression/Tension in bending	0.45 Y.P.
c)	Shear	0.35 Y.P.
d)	Combined	0.55 Y.P.
e)	Bearing	0.45 Y.P.

PS 11.5.2 STOP-LOGS

As this shall be stored above water level and shall be occasionally used, permissible stresses shall be taken corresponding to Dry-accessible conditions as per ASTM, DIN, BS or US Corps manual or other equivalent International Standards and are given as under

Material and Type of Stress		Permissible Stress
Structural Steel – Dry & Accessible conditions		
a)	Direct Compression/Tension	0.55 Y.P.
b)	Compression/Tension in bending	0.55 Y.P.
c)	Shear	0.40 Y.P.
d)	Combined	0.75 Y.P.
e)	Bearing	0.75 Y.P.
f)	Bearing Stress – Bronze on Steel	0.04 U.T.S.

PS 11.5.3 DESIGN CRITERIA FOR GATE HOIST:

1. **Loads:** the loads used in hoist operating system design shall include the following.

- Suspended weight of gate including weight of hoist rope, fittings, applicable hydrostatic and frictional loads.
- Load due to operating motor maximum torque. Maximum motor torque used for design purposes shall be the maximum torque which the motor can develop over its percent of its rated voltage.

2. **Efficiencies:** Efficiencies of operating machinery components shall be assumed as no greater than the following:

• Speed reducer with worm gear	90 percent
• Speed reducer (Triple reduction)	90 percent
• Gear and pinion	95 percent
• Bearing's	96 percent

3. **Operating speed:** The hoisting speed for all fixed wheel gates shall not be less than 1/16 in. per revolution for hand operated hoisting system and 1.5 ft and 1 ft per for motorized operated system of fixed wheel and slide gate respectively.

4. **Shafting:** A shock or fatigue factor of 1.25 shall be used for shafting, except for speed reducers, which shall conform to applicable AGMA standards

5. **Anti-friction Bearing:** Anti-friction bearing shall be of standard design most suitable for the applicable and shall have both inner and outer racers. The bearing manufacture's published rating shall be used in determining the bearing capacity. They shall have a B-10 life of 5000 hours, which is the number of hours (at a given constant speed and load) that 90 percent of group of tested bearings will exceed before the first evidence of fatigue develops.

6. **Gears:** Gear design shall be in accordance with applicable AGMA standards.

7. **Steel Wire Ropes:** The ropes shall be of steel wire. The rope shall be capable of supporting maximum loads during worst maneuvering position. The minimum breaking strength of the rope shall be not less than six (6) times the respective maximum load. The ropes shall be impregnated with grease to resist wear.

   Eye splices, shock, thimbles and rope anchorage shall be galvanized and capable of with ninety percent (90%) of the guaranteed breaking strength of the rope to which they are attached. The wire rope makers shall provide sufficient length of wire rope in the hoisting rope and any sling for a test piece to be cut for breaking tests.

   The minimum breaking strength the lifting chain shall not be less than four (4) times the respective maximum loads.

8. **Drum:** The minimum diameter of the drum for winding the rope shall be not less than 20 (twenty) time nominal rope diameter. The outside diameter of the drum flanges or spacers shall not be less than the outside diameter of the rope

wrapped on the drum. With gate resting on the sill, there shall be at least two complete wraps on each drum.

9. **Walkways and catwalks:** Walkway flooring shall be design for a uniformly distribute live load of 105 lb. /sq. ft. plus a superimposed concentrated load of the heaviest pieces of hoisting equipment or sub-assembly. Stair treads and their fastenings shall be designed for a concentrated live load of 1000 lbs. The catwalk shall be 3 ft. clear width and shall be designed for a uniform live load of 50 lb. per sq ft a single movable concentrated load of 1000 lb. The catwalk structure shall be sufficiently rigid to deflect no more than 0.25 in. under above maximum live load condition.

10. **Hoisting Platform:** The platforms shall be designed to suite the proposed equipment layout. All mechanical components will be supported directly on the structure members of the platform. The platform grating shall be all welded construction and shall be fastened to the steel supports by clip or fasteners subject to the approval of the engineer. Platforms will be tied down to concrete pier by means of anchor bolts designed to resist all possible loading cases. Platforms shall be designed to carry the specified live loads. Dead loads, machinery loads. Catwalk and normal hoisting/operating loads at the specified basic stress. The platform shall also be designed to resist the load resulting from stall torque of the operating motors together with dead and machinery loads. Deformation of the platform shall be limited to that permitted by AGMA standard.

PS 11.6 GATE EQUIPMENT DETAILS

PS 11.6.1 SKIN PLATE STRUCTURE

The fixed wheel gate shall be of welded construction and consist of downstream skin plate strengthened by horizontal and vertical stiffener plates all of ASTM A36. Wheel axles shall be attached to end vertical stiffener plates by means of locking plates. Wheels shall move on downstream stainless steel/CRES rails. Special care shall be exercised in the fabrication of all parts affecting the strength, rigidity and water tightness of the gate. Unless otherwise specified herein or shown on the Drawings, all connections shall be welded.

Each gate leaf shall be completely assembled in the shop and be free of twists, bends and open joints. Pockets or depressions that may hold water, shall be provided with effective drains. Connections between structural members for the gate leaf shall have continuous welds designed to develop full strength of the members. Sections of skin plate shall be connected by continuous welding all around.

1. **WHEELS AND AXLES**

Each gate shall be provided with fixed wheels of material conforming to ASTM A743. The wheel rims shall be heat treated to a minimum BHN (*Brinell Hardness Number kg/mm^2)* of 225. Wheel axles shall conform to the material of ASTM A276.

Holes for the wheel axles shall be bored and counter bored in pairs to a common axis after the gate's leaf is fully fabricated. The accuracy of locating and boring holes shall be such that the axis of the completed holes will be perpendicular to the vertical centerline of the gate and lie in a common plane which shall be parallel to the skin plate surface of the gate within a tolerance of plus or minus 0.060 in. Wheels on the same side of the gate shall be in a common plane through the midpoint of the wheel treads within a tolerance of + or 0.006 in. and such plane shall be parallel to the corresponding plane through the wheels on the other side of the gate.

The bushings of the gate wheels shall be self-lubricating/lubrite bushings, suitable for use in drain water.

2. **SEALS:**

J type side and top rubber seals with fluoro carbon cladding shall be attached to gate skin plate on downstream side with CRES holding plates and CRES bolts, nuts and washers. Sill seal shall be compression type attached to bottom of gate with CRES holding plates and CRES bolts, nuts and washers. Side and sill seals shall bear against stainless steel/CRES bearing surfaces. Sill beam steel strip and side and top seal bearing plates shall have hardness not less than 150 BHN. Joints in rubber seal shall be minimum in number. Holes in seals and gate skin plates will be drilled in workshop. After match marking, the seals will be attached to gates in field. Complete leak proof seal corner blocks shall be provided.

3. **EMBEDDED PARTS**

The Fixed Wheel Gate shall be provided with one set of embedded parts which shall include sill beam, stainless steel/CRES seal bearing plates, guide rails, welding pads embedded in first stage concrete and alignment studs with nuts and washers. The guide rail material shall conform to ASTM A 240 and will have hardness not less than 275 BHN. The guide rails shall extend from sill beam to top of the piers and side seal bearing plates shall extend from sill beam to 1 ft. above the top of fixed wheel gate. The top edge of guide rails and side seal bearing plates shall be tapered.

Fixed wheel gate side slots shall act as guides for the gate. The width of the slots shall be such that it will provide ample clearance for gate movement and at the same time it will not allow the wheel collars to come out of rails. The rails shall also act as guides for gate wheels and will restrict the lateral movement of the gate.

4. **GATE HOIST**

An electrically operated wire rope and drum type hoist with provision of manual operation, shall be provided for the gate operation. Each gate shall have an independent local control panel. The hoisting arrangement shown on the Drawings is indicative only. The Contractor shall design the system and shall start fabrication after approval of the Engineer/Engineer representative. The hoist shall consist of the following equipment:

a) **WORM GEAR REDUCERS:**

The worm gear reducers shall be standard, high grade reduction units suitable for the service intended, and the proportioning of all parts therein shall be in accordance with the best engineering practice. Either cylindrical or double envelope type worm gear reducers will be acceptable.

The reducers shall be standard, regularly produced commercial units, manufactured in accordance with standard practice for heavy duty worm gear speed reducers. The worm gear shaft shall extend through the housing on one end for the attachment of flexible coupling and on other end for fixing of motor assembly and also handle for manual operation of the gate. Keyways shall be cut to suit all flexible couplings. Worm shaft and gear shaft openings shall be provided with seals or packing glands.

The gear reduction ratio shall be selected such that one-man effort will be required to lift the gate manually. The minimum output torque rating shall be not less than the torque required to lift the gate at a speed of 0.060 in. per revolution of handle.

b) **DRUMS AND ROPES:**

Drums shall be of fabricated construction or cast steel. Drum diameter shall not be less than 20 times the rope diameter. When assembled, the shafts and drums shall have a common horizontal axis. Each drum shall be supported by grease lubricated, self-aligning, roller bearings and pillow blocks mounted on a common base plate. Drums shall be accurately machined and keyed properly to the shafts. Drums shall have sufficient grooves to provide two dead wraps of the rope on them when the gate is fully closed. Drums shall be equipped with integral cable clamps. Rope shall be standard hoisting wire rope made of plow steel, galvanized, non-preformed and regular lay. Rope size shall be selected according to the loading given in design criteria. Provision for adjusting the length of one of the two ropes in each hoist shall be made. The ends of the wire rope shall be fitted with wire rope fittings for connection to the gate. Dust covers shall be constructed of 16-gauge sheets steel. One intermediate shaft support containing a split babbitted bearing shall be provided between each drum and gear reduction unit.

c) **DRIVE SHAFTS:**

The lengths of the drive shafts will depend upon the length of the worm gear output shaft and shall be such that when the hoist is completely assembled with proper clearances between the faces of the halves of the flexible couplings, the distance between the drums will be approximately as shown on the Drawings.

d) **FLEXIBLE COUPLINGS:**

The flexible couplings shall be fully enclosed, dustproof, geared type, and shall be bored for tight fits on the shafts and shall be fitted accurately on the shafts, shall be of the size rated for the shafts they connect and shall have torque ratings suitable for the load transmitted. The flexible couplings shall be designed for oil or grease lubrication, and shall be all metallic except that oil or grease seals may be of suitable nonmetallic material.

e) **LUBRICATING FITTINGS:**

Lubricating fittings shall be provided for parts needing lubrication.

f) **BEARINGS AND BEARING BLOCKS:**

Bearings and bearing blocks shall be of standard well known manufacturer like SKF or other equivalent known make.

g) **SHAFTING:**

Shafting shall have provision for longitudinal movement. Lateral shaft deflections shall not be more than 0.01 in. per foot length of shaft and angular shaft deflection shall not exceed 0.08 deg. per foot.

5. **HOISTING/OPERATING DECK:**

Hoisting/operating deck shall be furnished for the gate to support the gate and all hoist loads. The hoisting deck shall consist of structural steel framework and chequered plate flooring. Before being laid out, all structural steel components shall be straight and free from kinks and bends. All working surfaces shall be finished neatly. Connections between adjoining members shall be welded or bolted. Holes for bolts shall be accurately located and drilled 0.060 in. larger than the nominal size of the bolts. When placed in structure, the length of bolt shall extend at least 0.25 in. beyond the nuts.

Washers shall be used with all bolts. Beveled washers shall be used on sloping member.

6. **HAND RAILING:**

Hand railing of 2-inch dia. Schedule 40 posts and 1.5-inch Dia schedule 40 pipe railing galvanized and painted steel pipe shall be provided along the opening side of all the hoisting deck, catwalks, walkways, piers and steps. Bends and turns shall be smooth and accurately formed. Railing and parts shall be shop assembled in convenient sections. Welded sections may be used provided that all welds are ground smooth.

7. **GATE POSITION INDICATOR AND GATE LOCKING ARRANGEMENT:**

A gate position indicator shall be provided and installed with the gate so that operator while working on the hoist can easily see and read the position of the gate. Gate position shall be indicated by a pointer on a 12 in. diameter circular graduated scale. The Contractor shall design and provide required mechanism of speed reduction so that total travel of the gate can be calibrated on the scale. The Contractor shall also be required to provide a device to lock the gate at any position.

PS 11.6.2 SEALING SYSTEM

Each Gate Unit shall be provided with a sealing system consisting of seals mounted on the gate and seal plates embedded in the concrete structures. Seals shall not be mounted on embedded parts.

The sealing system for fixed wheel gates shall consist of side, bottom and top seals. The sealing system shall be continuous providing a tight closed sealing line without gaps when the gate is closed.

a) **SEAL PLATES:** The sealing surface of the seal plates shall be arranged as shown on the Drawings.

Seal plates shall be of an adequate width to ensure the seals remain on seal plates under all possible working conditions. These working conditions shall consider the most unfavorable combinations of all factors causing relative position change, including the following:

- The contact width of the expanded rubber seal when compressed by maximum load.
- The extreme lateral positions of the gate as limited by actual clearances.
- The most unfavorable manufacturing and erection tolerances.
- Deformation or deflection of structures.
- Thermal expansion effects

b) **SEAL PROFILES:** Seals shall be of the following profiles, as specified:

(i) **WEDGE TYPE SEALS:** Wedge type seals shall be without cladding and shall have a rectangular profile with chamfers as required.

(ii) **J-TYPE SEALS:** J-type (music note type) seals shall be with fluoro-carbon cladding as shown on the Tender Drawings.

(iii) **GASKETS:** Gaskets shall be flat or of some other profile suitable for their function.

c)**SEAL ARRANGEMENT AND MOUNTING:**

(i) **J-TYPE SEALS:**

J-type seals shall be arranged to have a positive initial recompression when the gate is closed. Mountings shall provide adequate freedom of movement for seal deflection.

- Seals shall be seated on seal seating bars and held in place by clamp bars bolted to the gate.
- Seal seating bars shall be continuous within each section.
- Clamp bars shall be arranged in sections ending at corners.
- Clamp bars shall be fastened with CRES bolts, nuts and washers.
- The splices of clamp bars shall overlap all seal splices by at least 4 in.

(ii) **WEDGE TYPE SEALS:**

Wedge type seals shall seal by expansion of the edge of their profile when the seal is compressed due to the gate weight or water load.

Wedge type seals shall be seated on the gate skin plates or seal seating bars, and clamped as specified for J-type seals.

(iii) **SEAL CORNERS**

Corners where seals of same type of profile are connected shall be molded in one piece.

Corners where wedge type seals are connected to J-type seals shall be overlapped and cemented.

d) **SEAL SPLICES**

(i) **SEAL LENGTHS:**

Seals shall be furnished in sections as long as feasible. Each section shall have minimum 6 in. of excess length for field splices and for trimming the seal end in the field.

(ii) **SHOP SPLICES:**

All splices other than those specified herein as field splices shall be connected in Contractor's shop.

(iii) **FIELD SPLICES:**

Connections between a lower corner block and either a side seal or a bottom seal, shall be field spliced.

PS 11.7 SHOP ASSEMBLY & TESTING

All equipment fabrications and structures covered by the specifications shall be fully assembled in Manufacturer's shop for inspection by Engineer to the extent necessary to demonstrate matching of structural components. All necessary adjustments shall be made in the shop to achieve the specified tolerances.

Before assembly all bearing surfaces, journals, and grease and oil grooves shall be carefully cleaned and lubricated with an approved oil or grease. After assembly, each lubricating system shall be filled with and approved lubricant. “Lubrite” bearings shall not be greased and shall be assembly dry according to the manufacturer’s instructions.

Prior to dismantling for shipment, each assembly shall be permanently and clearly match marked in the shop to facilitate site erection. Dismantling shall be done only to the point required for shipping.

Engineer/ Engineer representative will inspect all equipment during fabrication and before shipment and witness the shop tests after final assembly.

PS 11.7.1 GATE AND STOP-LOG

Each component of gate and stop-log shall be assembled in the shop to the extent necessary for inspection and to ensure that all parts fit properly and that dimensions. Clearances and tolerances required in the specifications and drawing has been achieved. Holes for field connections shall be carefully drilled or reamed. Connections which have to be disassembled for shipment shall be made by the use of erection pins, one size less in diameter than the designed size or temporary machine bolts.

Proper functioning / operation of filling in valve and lifting beam, automatic engaging / disengaging shall be checked during shop assembly.

PS 11.7.2 HOISTS

All mechanical components shall be tested in accordance with the appropriate applicable standards at either the Maker’s or equipment manufacturer’s works or tests certificate provided.

The hoist shall be assembled in the shop to the extent necessary 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, riveting or welding is commenced. Drifting done during assembly shall be only that is necessary to bring the parts into position and not so much as to enlarge the holes or distort the member, if any, hole must be enlarged to admit fastening, it shall be reamed. 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 works in accordance with relevant Standards. The manufacturer shall supply all material equipment and labor required for shop assembly and tests and cost thereof shall be included in the bid price.

All shop tests shall be made in the presence of the Engineer / Engineer representative. The hoist shall be prepared for shipment in as large units as practicable. One print of a diagram of match marks shall be enclosed with the shipment and four prints shall be forwarded to the Engineer / Engineer representative.

PS 11.7.3 PLACE OF MANUFACTURE AND INSPECTION

The contractor shall intimate the place of manufacturer, testing and inspection of the various portions of the work. Engineer / Engineer representative may be present at the time of any or all tests and the Manufacturer shall provide all necessary facilities for the same. Engineer/Engineer representative shall also be entitled to access to Manufacturer's sub-contractors work at any time during the working hours for the purpose of inspecting the manufacture of equipment and materials.

PS 11.7.4 INSPECTION

All materials furnished shall be of tested quality and all work performed shall be subject to rigid inspection and no articles or materials or supplies shall be dispatched until all tests, analysis and shop inspection have been completed or certified copies of reports or results of tests and analysis shall have been accepted. Duplicate copies of manufacturers test certificate shall be submitted to the Engineer / Engineer representative as soon as the tests are completed. In case tests certificate are not available for any of the materials, the same may be got tested and only those materials which fulfill the requirements of the specifications shall be used.

From any part/item, it should be possible to locate its manufacturer Batch/Lot mark, which shall be achieved by transferring the batch mark before parting the materials.

All supplies (which include without limitation raw materials. components. intermediate assemblies and assemblies and end products) shall be subject to inspection and test by the Engineer / Engineer representative to the extent practicable at all times and places. If any inspection or test is made by the Engineer / Engineer representative in the premises of the Manufacturer or subcontractor, the Manufacturer without additional charge shall provide all reasonable facilities and assistance and the safety and convenience of inspectors in the performance of their duties.

PS 11.8 SITE TESTING & COMMISSIONING

PS 11.8.1 OPERATIONAL TESTS

1. The Manufacturer shall carry out in the presence of Engineer / Engineer representative such tests on the equipment to determine that the same will fulfill the functions for which they have been designed. The tests shall be carried out in accordance with applicable standards. Tests shall be repeated, if necessary, until successfully carried out to the satisfaction of the Engineer / Engineer

representative. Leakage tests and operational tests shall be carried out after completion of other portions of the work at upstream maximum water level.

2. For hoists the following tests shall be carried at site after erection.

a) **INSULATION TESTS**

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 DC voltage not less than twice the rated voltage.

b) **TEST FOR OPERATION**

After the supply has been connected and before the complete hoist installation is put to commercial service, tests shall be carried out to prove the following:

(i) 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.

(ii) The correctness of all circuits and interlocks and sequences of operation.

(iii) Satisfactory operation of all protective devices.

(iv) The satisfactory operation of each motion of the hoist.

(v) The compliance of the hoist with the specified performance requirements.

(vi) Tolerances on specified speed on full load shall be within ± 10%.

c) **DEFLECTION TESTS**

The deflection test shall be carried out with the safe working load at rest. The measurement shall not be taken on the first application of the load.

d) **OVERLOAD TESTS**

After the above tests but before the hoist is put into service, it shall, with overload relay appropriately set, be tested to lift and sustain a minimum test load of 125 percent of the working load.

PS 11.8.2 DRY TEST

Operational tests in dry shall be carried out as soon as possible after completion of erection and shall include at-least two complete traverses from the maximum raised position to the full sealing position. All adjustments, clearances, brakes etc. shall be checked for proper and smooth operation.

PS 11.8.3 WET TEST

These tests should simulate the actual operating conditions as closely as possible. At-least two complete traverses will be made from the fully closed position to the fully raised position as follows:

a) When gate is closed, raise gate to its fully open position in steps and observe the performance including vibration.

b) Lower the gate to the full closed position in steps and observe the performance of the gate vibration.

PS 11.8.4 LEAKAGE TESTS

Leakage tests shall be carried out with the gate resting on to the sill. Before measuring the leakage the gate shall be raised and lowered several times by about 20 to 40% or so in order to dislodge any debris that may have lodged in the side seal seat. The leakage shall then be measured and recorded. The maximum leakage past the seals shall not be more than 1.24 liters per min. per meter length of seal under maximum head conditions.

PS 11.8.5 FINAL ACCEPTANCE

Final acceptance of the equipment shall be based on the following:

a) Quality and workmanship of the equipment including dimensional accuracy.

b) Satisfactory operation of the equipment after erection as required under these specifications.

c) Acceptance of various tests or test certificates by the Client.

All tests may be witnessed by the Manufacturer or his authorized representative. On successful completion of all tests the equipment shall be accepted but all the responsibilities shall remain with the Manufacturer within the defect liability period.

The labor and material for the field tests shall be provided by the Contractor. The test load and necessary lifting tackles shall be provided by Contractor.

PS 11.9 WELDING PROCEDURE

PS 11.9.1 GENERAL

The edges of plates and shapes to be joined by welding shall be properly formed to suit the type of welding selected. Where plates and shapes have been sheared edges to be joined by welding shall be machined or chipped to sound metal. Plates and shapes to be field welded shall have their edges prepared in the shop for the type of weld selected.

Where bending or forming of plates or shapes is required, the plates or shapes shall be bent by cold forming. Heating and hammering to correct bends will not be permitted.

PS 11.9.2 WELDING

1. 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 planned, if necessary, to accomplish this result. Members to be welded together shall be in sufficiently 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.

2. The surfaces of plates to be welded shall be free from rust, grease and scale for a distance of 12 mm back 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 edges 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.

3. **Welding Technique:** Care shall be taken in designs that the welds when being made are well accessible. Overhead welding shall be avoided, if possible and flat position welding shall be strived for. Drawings should clearly indicate the joint position, or field welding, kind of welding, method of welding, welding sizes and other required information/data. Symbols to be shown on the drawing would conform to relevant Standards. All welding shall be done by the electric arc method by a process which will exclude the atmosphere from the molten metal, except where otherwise specifically permitted. All welding electrodes required shall be furnished by the Contractor. Correct selection of electrodes shall be done taking due care of welding method and base metals of components to be welded. The welding electrodes shall be of heavily coated type designed for all position welding. The make, type and size of all welding electrodes shall be subjected to the approval of the Engineer /Engineer representative. In assembling and during welding the component parts of built-up members shall be held in place by sufficient clamps or other adequate means to keep all parts in proper alignment and position.

   Radiographic tests shall be carried out for all critical full strength butt welds.

a) **BUTT JOINTS**

In principle, butt joints shall be made with back-run. Backing strap should be placed and welding should be so made that the molten metal fully penetrates and a full penetration is achieved. Dye-penetrant test shall be carried out after each pass of the weld. Radiographic testing of butt welds shall be carried out to the extent required by the Engineer/Engineer representative.

b) **FILLET JOINTS**

All fillet welds shall be continuous. For the main member, no fillet welding should be made on members whose thickness differs substantially. Fillet weld at T Joints should be made, as a rule, on each side of the joint unless it is otherwise agreed due to some practical reasons. Radiographic test is not normally required for fillet welds. All the fillet welds shall be checked by Dye Penetrant Test by the Manufacturer in the shop. However, 20% to 30% of fillet welds shall be checked by dye-penetrant test in presence of Engineer/Engineer representative to check soundness of weld.

At Welded butt joints, where the weld material is required to be deposited on both sides of the joints, the weld shall be chipped or melted to obtain a clean surface prior the application of the first head of the welding on the opposite side of the joint. Where fillet welds are used, the lapsed sections shall fit closely and shall be held together during the welding operation. 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 minimize stresses due to expansion or contraction either by peening the welds while hot, or by other satisfactory methods and also by using the proper sequence in welding. 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.

4. WELDING PROCESS

All specification of the welding process that is proposed to be used shall be established and recorded and if required, a copy of such specification together with a certified copy of report for results of tests made in accordance with the process and specifications shall be furnished. The qualification of the welding process shall be at least equal to that required by “Standard Qualification Procedure” of the ASME Standards and the minimum requirement of the tests shall be at-least as stated in the said “Standard Qualification Procedure”.

5. **QUALIFICATION OF WELDERS**

The Manufacturer shall be responsible for the quality of the work performed by his welding staff. All welders assigned to the work shall have passed qualification tests for welders. If at any time the work of any welder appears questionable, welder shall be required to pass additional qualification tests to determine his ability to perform the type of work on which he is engaged.

PS 11.9.3 EXAMINATION OF WELDS

a) **MAIN WELDS:**

All butt welds on main components & other shall be given complete non-destructive examination by ultrasonic, dye Penetrate, or magnetic particle methods, supplemented by radiographic examination. Supplemental radiographic examinations shall include examination of areas where the Interpretations by other methods is unclear or where integrity of the weld is doubtful.

b) **SECONDARY WELDS:**

The Engineer / Engineer representative shall have the right to request random spot-check examination of welds, including radiographic examination, as part of the Equipment inspection.

c) **TECHNIQUE & ACCEPTANCE STANDARD:**

Examination of welds shall be in accordance with the technique and acceptance standards of "AWS Code D-1.1 Structural Welding Code for Steel”.

PS 11.10 SURFACE PREPARATION & PAINTING

PS 11.10.1 GENERAL

a) The Manufacturer shall provide as part of his 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 up to and including the finish painting. Unless otherwise specified the coating and painting shall be carried out in accordance with provisions of DIN, BS, ASTM and ASME Standards. All paints, painting material and accessories for painting shall be included in the price bid. All finished and unfinished surfaces of metal work (other than of aluminum brass, bronze or stainless steel)- except screw threads, mating surfaces, sliding surfaces, rolling surfaces shall be cleaned and protective coatings applied as specified in the above-mentioned Standard.

b) All paints and painting material shall satisfactorily fulfill 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.

c) The paints and shades of the finished coatings proposed by the Manufacturer must be got approved by the Engineer / Engineer representative before application of the same. The analysis in respect of paint properties, paint composition and performance requirements of the paints shall be submitted by the Manufacturer for check and approval. All painting material shall conform to relevant Standards.

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.

d) The Manufacturer shall supply full details regarding the extent to which sand-blasting, priming and painting will be carried out in his workshops (or his sub-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 organization, experienced and skilled in the preparation and application of protective coatings at the conditions prevailing at the site.

PS 11.10.2 SURFACE PREPARATION

After the equipment has been fabricated, it is essential that before any primer and coat of paint is applied, the surface is properly prepared. Such preparation shall include through cleaning, smoothing, drying and similar operation that may be required to ensure that the primer and/or paint is applied on suitable surfaces. Clean cloths and clean fluids shall be used to avoid greasy film or greasy residue on the surfaces being cleaned. The procedure for surface preparation shall be as follows:

a) Weld spatters or any other surface irregularities shall be removed by any suitable means before cleaning.

b) All oil grease and dirt shall be removed from the surface by the use of clean mineral spirits, white gasoline (lead free) and clean wiping materials.

c) Following the solvent cleaning, the surfaces, to be painted shall be cleaned of all rust, mill scale, and other tightly adhering objectionable substances by sand blasting or grit blasting to uniform bright base metal. Average surface roughness for sand blasted area shall not exceed 40 microns. Any grit or dust remaining after the cleaning operation shall be completely removed from the surface by wire brushing; air blowing, suction or other effective means before the surface is painted.

d) Surfaces of stainless steel, nickel, bronze and machined surface adjacent to metal work being cleaned or painted shall be protected by masking tape or by other suitable means during the cleaning and painting operations.

e) Primers shall be applied as soon as the surface preparation is complete and prior to be development of surface rusting. In case there is considerable time gap, the surface shall be re-cleaned prior to priming.

PS 11.10.3 SHOP PAINTING

a) Stainless steel and bronze surfaces shall only be cleaned but not painted.

b) All surfaces of the gate, stop-logs and their embedded parts shall be protected from corrosion in accordance with the following Painting Schedule.

PAINT SCHEDULE

S. NO:	ITEM / PART	SURFACE PREPARATION	PAINT SYSTEM	TOTAL DRY FILM THICKNESS (µm)
Hydraulic Steel Structures at Intake Tower				
1.	Trash-racks and Top grating.	Thorough cleaning and degreasing as specified by the standards for hot-dip galvanizing	Hot-dip galvanizing	approx. 70

S. NO:	ITEM / PART	SURFACE PREPARATION	PAINT SYSTEM	TOTAL DRY FILM THICKNESS (µm)
2.	Stop-logs, Hydraulic Gate and hoists; Exterior surfaces of valves, cranes, electric motors and all other steel structures which are exposed to UV-rays	Sa 2.5 **(Very thorough blast cleaning**: Near white metal 85% clean.)	**Prime coat:** 1x zinc-rich epoxy primer	Min: 60 Max: 120
			Intermediate coat: 2x epoxy micaceous iron oxide paint	2x80 = **160**
			Finish coat: 1x epoxy micaceous iron oxide paint of different color	**80** **Total Min: 300µm**
3.	Indoor steel structures like Exterior surfaces of valves, cranes and electric motors etc.	Sa 2.5 **(Very thorough blast cleaning**: Near white metal 85% clean.)	**Prime coat:** 1x zinc-rich epoxy primer	Min: 60 Max: 120
			Intermediate coat: 1x epoxy micaceous iron oxide paint	**80**
			Finish coat: 1x 2-pack polyurethane or epoxy paint	**80** **Total Min: 220 µm**

PS 11.10.4 MEASURES DURING PAINTING

a) Any bare spots or holidays shall be recoated with additional application of primer.

b) All runs, sags, floods, or dips shall be removed by scrapping and cleaning, the cleaned area shall be retouched or all such defects shall be remedied by re-blasting or re-priming.

c) Special attention shall be given to obtaining good coverage on rivets, welds and sharp edges and corners.

d) Suitable measures shall be taken to protect applied primer from contact with rain, fog, mist, dust or other foreign matter until completely hardened and next coat applied.

e) The air temperature at the time of application must not be below 10°C and relative humidity must not be above 60%.

PS 11.10.5 APPLICATION PROCEDURE

All paints and coating materials shall be in a through mixed condition at the time of application and shall not be thinned except as hereinafter specifically provided. Any warming of the paint shall be performed by means of hot water bath. On all surfaces, to which paint shall be applied immediately after cleaning, and except otherwise specifically provided, shall be applied by either brushing or by spraying.

When paint is applied by spraying, a mechanical agitator type of paint pot shall be used. Means shall be proved for removing all free oil and Posture from the air supply lines of spraying equipment. Each coat of paint shall be free from runs, sags, pin holes and holidays.

Each coat of paint shall be allowed to dry or harden thoroughly before the succeeding coat is applied.

The paints shall be applied by skilled workmen in a workmanlike manner. Paint shall not be applied during damp weather and on surfaces that are not entirely free from moisture. Rust preventive compound shall be applied by any convenient method to ensure complete coverage of heavy coating. After the final application the paint film shall be allowed to cure at least for 7 days.

PS 11.10.6 FIELD PAINTING

The painted metal work shall be handled with care so as to preserve the shop coats. The area of the shop paint which has been damaged during transport shall be cleaned to base metal and repainted. Paint applied to such areas shall be of the same type as used originally in shop painting. All unfinished surfaces of embedded parts and gates that are exposed to atmosphere or submerged in water shall be given a finishing paint of Aluminium-Epoxy paint to as to obtain shining surface of pleasing color. This finishing coat should be able to reflect light and limit the heat absorption when exposed to sun.

PS 11.11 INSTALLATION, OPERATION & MAINTENANCE MANUALS

For guidance during the installation of the work and subsequently for guidance of the plant operating and maintenance staff, Manufacturer shall prepare requisite manuals.

The manuals shall include a separate and complete section describing the normal and emergency operating procedures for the gates and control equipment and shall include easily read diagrammatic drawings of the equipment to facilitate understanding of the descriptive information.

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.

Manuals shall also describe and illustrate procedures for installation, storage, handling, unloading, reloading, unpacking and upkeep of each component and of the system.

Three (3) copies of the manuals shall be submitted in English in draft form for approval of Engineer three months prior to the time the information is at site. Six (6) suitably bound copies shall be provided to Engineer not later than 07 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 six (6) copies of the revised sections.

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 and source of their procurement.

Manufacturer shall ensure that his Erection, Installation Supervisor has a copy of all approved drawings and the manuals in his site office.

PS 11.12 ERECTION TOLERANCES

The Erection Tolerances shall be as per DIN, BS or ASTM Standards or other equivalent corresponding International Standards. However, the following is given as a general guidance.

PS 11.12.1 GATE

S.No:	EMBEDDED PARTS	TOLERANCE LIMIT (mm)
1.0	**Track Plates**	
1.1	Alignment in plane parallel to flow	± 1.0

1.2	Distance between center line of opening and track	± 1.5
1.3	Coplanerness	± 1.0
2.0	**Guides**	
2.1	Alignment in plane parallel to flow	± 1.0
2.2	Distance between center line of opening and face of guide	± 1.0
3.0	**Side Seal Seats**	
3.1	Alignment in plane parallel to flow	± 2.0
3.2	Distance between center line of opening and side seal seat	± 1.5
3.3	Coplanerness	± 1.0
4.0	**Top Seal Seat**	
4.1	Alignment	± 2.0
4.2	Height above sill	± 3.0
4.3	Coplanerness with side seal seat	± 1.5
5.0	**Critical Dimensions**	
5.1	Centre to center distance between track plates	± 3.0
5.2	Centre to center & distance between side seal seats	± 3.0
5.3	Face to face & distance between guides	± 2.0
5.4	Face of track to face of side seal seat	± 0.0
5.5	Face of track to center fine of guide	± 2.5
6.0	**Side and Top Seal Base**	
6.1	Alignment	± 1.0
6.2	Coplanerness	± 1.0
7.0	**Critical Dimensions**	
7.1	Centre to center distance between seal bases	± 2.0

PS 11.12.2 STOP-LOGS

S.No:	EMBEDDED PARTS	TOLERANCE LIMIT (mm)
1.0	**Side Seal Seat**	
1.1	Alignment in plane parallel to flow	± 0.5
1.2	Distance between center line of opening and seal seat	± 1.5
1.3	Coplanerness	± 1.5
2.0	**Side Guide Track**	
2.1	Alignment in plane normal to flow	± 1.00
2.2	Distance between center line of opening and guide track	± 1.00
2.3	Alignment in plane parallel to flow	± 1.00
3.0	**Bottom Seal Seat**	
3.1	Alignment in horizontal plane	± 0.25

PS 11.13 MEASUREMENT AND PAYMENT

PS 11.13.1 MEASUREMENT

a) Measurement for the payment for furnishing and installing gate shall be according to the number of gate units inclusive of all fittings, operating gear, built-in parts and appurtenances installed in accordance with the Engineer's / Engineer's representative instructions. Double-leaf gate shall be measured as a single gate unit.

b) Stop-logs & trash-racks shall be measured separately as a single leaf unit.

c) Concrete gantry structure / Lifting beam for handling of stop-logs & trash-racks shall be measured as a separate item.

d) Electrically operated, under running single girder gantry crane of 5-ton capacity shall be measured separately

e) The amount tendered by the Contractor shall be full amount for completion of the work specified herein and elsewhere in these specifications and on the drawings including all costs for manufacturing, loading, transportation, unloading storing and handling at the site for installation.

PS 11.13.2 PAYMENT

a) Payment for gate, stop-logs, trash-racks, gantry crane etc., measured above shall be made at the Contract Rate for the respective item and shall be inclusive of fabricating, delivering at site, painting, transporting, handling, storing, remedying defects, provision of installation and maintenance tools, winding gear and the specified spare parts, assembling and installation at site, all costs incurred in design and submission of shop drawings/as-built drawings, testing, and successful commissioning.

PS 11.14 STEEL ACCESS BRIDGE

PS 11.14.1 PURPOSE AND SCOPE

This specification covers materials, fabrication, welding, bolting including bearing devices, anchor bolts, bridge deck, pedestrian railings and erection of structural steel bridge works at the Intake tower.

1. **CODES AND STANDARDS**

All labor, materials and equipment shall be governed by the latest edition of the codes and standards as mentioned below:

a) Clause 16.6.9.2 – Material Requirements; sub-clause 16.6.9.2.1 – Description; Table # 70, *Material Requirements of “Technical Specifications for Workmanship, MRS – 2019”;*
b) Clause 25.2 – References; sub-clause’s 25.2.1 – ASTM (American Society for Testing and Materials), 25.2.2 – BS (British Standards) & 25.2.3 – AWS(American Welding Society) *of “Technical Specifications for Workmanship, MRS – 2019”.*

2. **REFERENCES**

The related work specified in other sections of the Contract Documents as references shall be as follows: -

a) Chapter – 16 Road and Bridges; Section: 16.6.9 – Steel Structures, of *“Technical Specifications for Workmanship, MRS – 2019”.*
b) Chapter – 25 Iron Works, of *“Technical Specifications for Workmanship, MRS – 2019”.*

PS 11.14.2 SUBMITTALS

1. **SHOP DRAWINGS**

The Contractor shall submit detailed shop drawings for the steel truss span, bearing devices, bridge deck, deck joints, bridge railings, and accessibility handrails. Three -3 complete copies of the shop drawings for review and approval of the Engineer / Engineer representative shall be submitted at least 06 weeks prior the start of the fabrication works. The Engineer / Engineer representative shall review and approve or return the shop drawings with observations etc., within 07 calendar days of shop drawing submittals. The Contractor shall be responsible for correcting any errors / miscalculations etc., detected by the Engineer / Engineer representative as resulted from shop drawings review and resubmit the revised drawings within week time for approval of the Engineer / Engineer representative.

The Engineer / Engineer representative review will not relieve the contractor from responsibility for errors or omissions on shop drawings. The contractor shall bear the costs of any substitutions to the shop drawings, as approved by the Engineer / Engineer representative.

The Contractor shall ensure that shop drawings conform to the approved Construction drawings and provide additional details, dimensions, computations, and other information necessary for completely fabricating and erecting the works. Information to be provided by shop drawings shall include, but not limited to, the followings:

(i) Unique identification of each member and fabricated subassembly.
(ii) Position and dimensions of each member in the structure.
(iii) Details of fittings, e.g., gusset plates, base plates etc.
(iv) Joint and connection details with clear differentiation between shop and field connections, welds and bolts.
(v) Weld details including location, type and size.
(vi) Location, type and size of bolts and holes and referenced bolt list.
(vii) Layout and details of required ladders, stairs, walkways etc.
(viii) Material specifications.
(ix) Shop coatings specifications.
(x) Details of handling and transportation provisions including packing, lifting, and support and lashing points and lifting spread requirements.

2. **ASSEMBLY DRAWINGS**

Assembly drawings shall include, but not be limited to, the following information required for erection work on site.

(i) All information contained on the shop drawings as may be required for erection, testing and inspection purposes.
(ii) Framing elevation at each reference line and where intermediate framing is provided.
(iii) Framing plan at each elevation.
(iv) Required erection order and methods (including handling).

3. **ERECTION PLANS**

The Contractor shall submit Erection Plans and Erection Procedures to the Engineer / Engineer representative for bridge structural unit identified on the drawings and specifications. The Contractor shall also submit Erection Engineering Calculations to the Engineer / Engineer representative for bridge structural unit identified on the drawings and specifications.

The Erection Plans and Procedures shall be prepared by a Professional Engineer qualified in steel erection. The Erection Plans and Procedures submittal shall address all requirements for erection of the structural steel into the final designed configuration. Any and all written review comments provided by the Engineer / Engineer representative shall be addressed to the Engineer's satisfaction prior to the start of erection.

PS 11.14.3 EXECUTION SPECIFICATION

The Contractor should note that the Materials and Construction / Fabrication Requirements for truss structure, bearing devices, and other permanent metal components, as provided in the tender drawings for a fully engineered clear span bridge of steel construction, shall be in accordance with the following sections of General Specification.

a) Chapter – 16 Road and Bridges; Section: 16.6.9 – Steel Structures, of *“Technical Specifications for Workmanship, MRS – 2019”.*

b) Chapter – 25 Iron Works, of *“Technical Specifications for Workmanship, MRS – 2019”.*

The Contractor must remember that the Contract Documents are mutually explanatory and these Technical Specifications are taken to be correct, but complete accuracy is not guaranteed. Any error or ambiguity must be reported to the Engineer / Engineer representative before starting the work affected. In the event of any dispute arising as to the true intended meaning of Technical Specifications, the Engineer / Engineer representative shall interpret the same and his interpretation shall be accepted as final and binding upon all parties concerned.

PS 11.14.4 MEASUREMENT AND PAYMENT

1. **Clause 25.4.18 – Measurement and Payment;** Chapter – 25 Iron Works, of *“Technical Specifications for Workmanship, MRS – 2019”.*

   Completely delete the subject clause.

2. **Clause 16.6.9.4 – Measurement and Payment; sub-clause 16.6.9.4.2 – Payment,** Chapter – 16 Road and Bridges, of *“Technical Specifications for Workmanship, MRS – 2019”.*

   a) In the fifth line, delete “excluding the weights ……. protective coatings” and replace with the followings:

      excluding the weight of protective coatings, galvanization, or weight of welds, fillets but including the weight of heads, nuts, single washers, and threaded stick-through of high-strength bolts and heads, based on the weights given in the table below.

   b) Completely delete the ***Table 78, Mass of Fillet Welds*** and the relevant text.

CHAPTER NO. 12

SPECIFICATION FOR DAM CUTOFF WALL

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ITEM PS – 12: SPECIFICATION FOR DAM CUTOFF WALL

PS 12.1 DESCRIPTION

The work covered in this item shall consist of furnishing all plant, equipment, materials and labour in performing all operations in connection with constructing Cast in-situ Dam Cut-off Wall of specified width by Hydraulic Trench Cutters and Hydraulic / Mechanical Grabs in riverbed (overburden and rock) of all kinds with its top end embedded in the clay core of the Earth Core Rockfill Dam (ECRD) and the bottom end embedded into underlying hard rock, all in conformity with the lines, grades and dimensions shown on the drawings or as established by the Engineer / Engineer representative, including construction of working platform with guide wall from EGL to required depth, trench stabilization by circulation of bentonite slurry with desanding operation etc., and satisfactory disposal of surplus spoils with all lead and lifts.

Cut-off wall shall be constructed of cement bentonite slurry / plastic concrete, using slurry panel construction method and shall have sufficient strength to withstand both static and seismic stresses beneath the new embankment, and yet is flexible enough to undergo seismic deformations, without cracking, with the surrounding soils.

The work shall include cost of all materials, machinery, labour, sub-contractors, site preparatory works, geotechnical investigations of the river bed along the cut-off wall central axis, preparation of cement bentonite slurry / plastic concrete mix design, cleaning, batching, mixing, transporting, placing C-B slurry / plastic concrete in final position using tremie system, curing, conducting requisite quality control tests, dismantling, site clearing, any other incidental works etc., strictly in accordance with these specifications, the drawings, and or as required by the Engineer / Engineer representative.

The construction of the C-B slurry / plastic concrete cut-off wall shall include the trial laboratory and field testings program to confirm design wall stiffness, strength, and hydraulic conductivity requirements and the QA/QC testings conducted during construction.

The work shall also include supply, installation, maintenance, measurement and recording of monitoring devices for cutoff walls performance during the operation stage.

The contractor shall provide an outline of his proposed method for constructing the Cut-off wall trench when submitting his tender; the proposed method of excavation being stated.

The requirements specified herein are minimum. Strict compliance with these requirements will not relieve the Contractor of the responsibility for adopting whatever additional provisions may be necessary to ensure the successful completion of the works.

PS-12.2 SUBMITTALS

PS-12.2.1 Method Statement

Not less than 56 days before the contractor proposes to commence the trenching operation, detailed proposal for the cut-off wall construction shall be delivered to the Engineer / Engineer representative. These proposals shall include full details of materials, plant, equipment and operations he intends to adopt for construction of the cutoff wall. It shall include details of:

a) a program for works including details of manpower and proposed plants / equipment to be used including hydraulic trench cutters, hydraulic / mechanical grabs & chisels, cranes, drills, bailing buckets, final cleaning equipment, desanding equipment, slurry pumps, sampling equipment, tremies or concrete pumps, temporary casing etc. that he intends to employ.

b) trench stability calculation

c) details of trench excavation methods, including sequence of construction of the primary & secondary wall panels.

d) the sequence of trench excavation and plastic concrete pouring of panels, with minimum and maximum time interval between completion of primary panel and the commencement of the adjacent secondary panel.

e) the formation of the joints between the primary & secondary panels, including sealing the joints.

f) dimension and details of guide wall.

g) C-B slurry and plastic concrete mix design.

h) details of the method proposed to mix, circulate and desand bentonite slurry.

i) the type, source, chemical and physical properties of the bentonite to be used.

j) the cleaning and re-use of bentonite slurry.

k) calculations to show that the density of the bentonite and lowest head of slurry are sufficient to maintain the stability of the trench to its entire length.

l) the methods of monitoring and checking the stability of the cutoff wall trench, to be substantiated with relevant calculations.

m) the methods of monitoring and checking the tolerances associated with the cutoff wall panels.

n) details of methods to clean the trench excavation and disposal of contaminated bentonite slurry.

o) the method of installation of monitoring devices prior to pouring the cutoff wall.

p) all temporary works at each stage of construction, including proposals for the guide wall trenches and necessary sub-surface grouting.

q) plant to be used and precautions proposed with respect to emergency backfilling should a rapid loss of bentonite slurry occur.

r) layout, setting out, dimensions and special reinforcement cage details for the cutoff wall instrumentations and guide walls, including sections and elevations.

s) sizes, details, levels and locations of monitoring devices, inserts, vertical uPVC tubes, tremie pipes, etc.

t) Other information shown on the plans or requested by the Engineer / Engineer representative

Construction of cutoff wall shall not commence until the Contractor's method statement has been accepted in writing by the Engineer / Engineer representative.

The construction of panels shall be continuous once excavation has commenced, unless otherwise accepted by the Engineer / Engineer representative. Excavated panels or part panels shall not be left open at night or during weekends.

The construction shall be carried out in a sequence and to a program agreed with the Engineer / Engineer representative.

PS-12.2.2 Daily Progress Report

During the execution of cut-off wall excavation and pouring works, the Contractor shall keep record for each panel completed and such records shall be made available for inspection by the Engineer / Engineer representative.

Moreover, a daily progress report of the cut-off wall activities shall be submitted to the Engineer / Engineer representative for review & approval, encompassing at least the following information's:

a) Geotechnical investigation details (log of field borings, lab test results and water table etc.,) of the subsoil conditions along the Cut-off Wall / Dam central axis, including confirmatory boreholes of 150mm diameter in soil and NX size drilling into underlying bed rock at locations indicated by the Engineer / Engineer representative

b) Panel number (Primary & secondary)

c) Top & Bottom of guide wall level

d) Top level of Cutoff wall as cast in relation to top of guide wall

e) Depth of base of panel (rock socketing) from top of guide wall

f) Date and time of start of panel excavation

g) Date and time of finish of panel excavation

h) Date and time of start and completion of panel concreting

i) C-B slurry / plastic concrete cylinders taken, markings, date and results obtained on testings

j) A graph showing actual volume of C-B slurry / plastic concrete used as against theoretical volume and method of calculating the volume

k) Quantity of slurry and spoiled removed from the site recorded by date

l) Placement of special reinforcement cage for monitoring devices including support and centralization methods into respective panels

m) Date and time of completion of cage placement

n) Details of any obstructions encountered and time spent in dealing with obstructions

o) Trench verticality record / scanning graph

p) Details of any trench collapse incident encountered.

The details of the construction record sheet shall be discussed and agreed with the Engineer / Engineer Representative prior to proceeding for construction.

PS-12.2.3 Codes of Practice

The design and construction where relevant, shall be carried out in accordance with standard engineering practices and shall comply with the latest applicable United States Bureau of Reclamation (USBR), ASTM, API, British-European and other International Standards including Trench Cutter manufacturers technical data:

USBR Design Standards No. 13 - Embankment Dams, DS-13(16) -14	:	Cutoff Walls
BS EN 1538:2010+A1:2015	:	Execution of special geotechnical works, diaphragm walls as either retaining walls or cut-off walls
BS 8004:2015+A1:2020	**:**	**Code of practice for foundations**
ASTM Publication Code Number 04-011290- 38, STP 1129	:	Slurry Walls: Design, Construction, and Quality Control.
ASTM STP 1142	:	Hydraulic conductivity of vertical cutoff walls. Hydraulic Conductivity and Waste Contaminant Transport in Soils.
IS 14344:1996 (Reaffirmed 2016)	:	Design and Construction of Diaphragm for under seepage control
IS 9556: 1980 (Reaffirmed 2018)	:	Code of Practice for Design and Construction of Diaphragms Walls
API 90-30, 1992	:	Specification Parameters Determination Drilling Fluid Materials.
API Spec 13A	:	Specification for Drilling - Fluid Materials,16th Edition, Feb 01, 2004
BAUER Maschinen GmbH	:	Trench Cutter Systems for Diaphragm and Cut-off Walls

Javed, F., Nasim, M.A. (2005). “Construction of Seepage Measurement System at Jatiluhur Dam, Indonesia.” Electronic Journal of Geotechnical Engineering, 2005.

ICOLD (1985). “Filling Materials for Watertight Cut-Off Walls,” International Committee of Large Dams, Paris, Bulletin N. 51.

State-of-the-Art Report “Plastic Concrete for Cut-Off Walls” by Karlsruhe Institute of Technology (KIT) June 2018.

If no codes or standards exist for a given activity, the Contractor shall perform the work according to an internationally recognized practices, as approved by the Engineer/Engineer representative.

PS-12.2.4 Contractor’s Responsibilities

The Contractor shall be responsible for satisfactory construction of all permanent works in the approved construction drawings. In addition, the Contractor shall satisfactorily design and construct of all temporary works, and any specified permanent work details as agreed with the Engineer/Engineer representative. The Contractor shall also ensure that the proposed temporary work has no adverse effect on the permanent work (both in short term and long term), subject to the agreement of the Engineer/Engineer representative.

The Contractor shall make allowance in his tender for compliance with all the specifications and other requirements necessary for the proper execution and completion of the works to the satisfaction of the Engineer/Engineer representative inclusive of the necessary soil treatment such as grouting etc.

The Contractor's attention is drawn to the presence of alluvial formation in the central riverbed reaches which may require stabilization by bentonite. The rates for the wall panels shall include all costs necessary for the satisfactory completion of these works.

The Contractor shall be deemed to have inspected the site and geotechnical and geological conditions applicable to his work. The work shall be carried out on the basis of ground as found and no additional cost will be paid for handling hard materials or other obstructions encountered during the installation of the cutoff wall.

The rates for cutoff wall shall include the provision of ultrasonic 'KODEN' testing or equivalent technique, as agreed by the Engineer/Engineer representative to determine the accuracy of the excavated trench prior to C-B slurry / plastic concrete pouring. If the wall is constructed beyond the specified tolerances, hacking the protrusions and any other remedial works required by the Engineer/Engineer representative shall be carried out at the expense of the Contractor carrying out the works for cutoff wall. The Contractor shall allow for 30% of the panels to be tested as directed by the Engineer/Engineer representative.

The panels of the cutoff walls shall be properly interlocked & socketed deep into bedrock to provide a watertight barrier. Any seepage of water shall be promptly reported to the Engineer/Engineer representative and shall proceed with the rectification works as directed by the Engineer/Engineer representative at the Contractor's expense.

All the site activities of the Contractor shall comply with the requirements of the relevant local and statutory authorities especially with respect to the pollution control requirements governing the discharge of the bentonite and disposal of construction wastes.

Defective works shall be all works that, in the opinion of the Engineer / Engineer representative, do not fully comply with specifications and /or the drawings. The Contractor shall make good or carry out such additional works as may be necessary at this own expense to the Engineer / Engineer representative’s satisfaction.

PS-12.2.5 As-Built Drawings

The Contractor shall make accurate records of the actual works constructed. For those parts of the works that will become hidden by further progress, such records shall be checked and verified by the Engineer / Engineer representative while those parts of the works are open for inspection.

All drawings submitted by the Contractor shall be in CAD format and shall have relevant particulars at the bottom right-hand corner including the project title, Contractor's name, title of drawing, scale, date, drawing number and notes identifying revisions made thereto.

The Contractor shall submit within two weeks of completion of Cutoff wall a reproducible copy and 6 numbers of prints of as-built drawings together with one set of drawings in CAD files to the Engineer / Engineer representative showing the following: -

a) Verticality of Cutoff walls at the face and ends of panels.

b) Position of Cutoff walls installed horizontally in relation to grid line or center of wall.

c) Length and depth of each panel of wall.

d) Complete details of Cutoff wall including instrumentations, special reinforcement cages and other relevant details.

PS-12.3 CONSTRUCTION REQUIREMENTS

PS-12.3.1 Working Drawings

The Contractor shall submit working drawings, quite ahead of the commencement of works to permit sufficient time for review by the Engineer / Engineer representative and modifications to be made by the Contractor as deemed necessary by the Engineer / Engineer representative so that any undue delay to the delivery or installation of the works could be avoided.

The modified drawings shall be resubmitted for further review. The Contractor shall provide the Engineer / Engineer Representative with three copies of each approved working drawings and design calculations within 2 weeks of receipt of approval from the Engineer / Engineer Representative.

For each submission of working drawings, a minimum initial time period of 2 weeks shall be allowed for the first review thereof by the Engineer / Engineer representative. Delays caused by late submission of such drawings or modifications thereto arising from repeated errors, unacceptable details, unclear or insufficient information will under no circumstances be construed as reasons for a request to an extension of time and claim for additional cost thereof.

The Engineer / Engineer representative's review of such drawings or approval accorded thereto shall not exonerate the Contractor from any of his primary responsibilities and obligations under the Contract. The Contractor shall be responsible for all financial and time consequences arising out of errors, omissions or non-clarity in such drawings or delays in the submission thereof.

PS-12.3.2 Site Conditions

The Contractor prior to the submission of the bid is required and deemed to have inspected the site and satisfied himself with regard to access, site conditions, existing topographical & geological features.

The Contractor shall satisfy himself regarding subsoil conditions and the underground water table. No claims for extra cost or time shall be entertained on these grounds.

Limited data of geological and geotechnical site investigations, carried out during feasibility & detailed design stages, are available with the Procuring Entity. The Contractor is advised to conduct at his own cost, in-depth geotechnical investigations of the site prior to execution of works and with the written approval of the Engineer / Engineer representative.

The Contractor's subsurface investigation shall consist of an appropriate combination of percussion boring/straight rotary drilling, field instrumentation (such as piezometers or inclinometers), geophysical surveys and in situ testing and collection of disturbed/undisturbed samples from the project site. The selected samples of soil and water shall be tested in the approved laboratory for their physical, chemical and engineering properties. Borehole / drillhole numbers, locations and depth will be finalized by the Engineer / Engineer representative in the field.

PS-12.3.3 Cut-off wall Excavation

(i) General

Cut-off wall shall be constructed by the two-phase process involving excavation of the soil & rock materials for primary / secondary panels under bentonite slurry. The support fluid shall be subsequently cleaned and then replaced in a second phase by the actual barrier material (plastic concrete, cement-bentonite mixture etc.,) to be placed in the trench by the tremie pipe process.

The construction of the two-phase cut-off wall shall comprise of the following minimum components:

- Installation of working platforms at different elevations with cross drainage strong enough to withstand heavy rainfall flooding during the time of wall installation.
- Installation of ramps to reach the different platform elevations.
- Installation of guide walls.
- Pre-treatment of bedrock and over burden soil
- Pre-excavation and final excavation of the individual panels under slurry support.
- Continuous quality control during execution of the panels including cleaning and preparation for concreting.
- Tremie-concreting.

(ii) Setting Out

The setting out of cutoff wall shall be carried out jointly by the Qualified Land Surveyors of the Engineer's representative and the Contractor. The Contractor shall ensure that all lines and levels are in accordance to the working drawings.

(iii) Working platforms and ramps

The construction of a high-quality, all-weather working platform is a prerequisite for successful installation of the plastic concrete cut-off wall, enabling unhindered working of heavy equipment placed along the axis of the barrier wall.

The working platform with proper cross-drainage facilities shall be designed and built on different levels including ramp connections, as the contractor considers necessary, in order to move safely the crawler mounted digging equipment of capacity up-to 250 tons and transit mixers. The platforms shall be leveled firmly and maintained all the time to ensure a safe operation. Ramp inclination shall be kept at maximum 10% and temporary slopes at an inclination of 1:1.5 without stabilization and 1:1 with stabilization (boulders etc.,).

Particular care with extensive measuring and controlling shall be taken to assure the continuity of the cut-off wall at the joints of elements executed from different elevations.

In addition, regular maintenance of the platform shall be the contractor's responsibility for safety & stability of the permanent and temporary works system during all conditions of river current, which may occur during the period of construction.

iv). Guidve Walls

Reinforced concrete guide walls shall be constructed prior to the cutoff wall construction in order to provide:

- Guidance to ensure the correct alignment of the Cutoff wall.
- Protection against instability of the top soil zone of the trench caused by fluctuating bentonite levels and agitation of the slurry during excavation.
- Support for the trench stability at the top zone, affected by the vertical surcharge weight of the trench cutter and other heavy jobsite machineries adjacent to the trench.

The design and construction of the guide walls shall be the responsibility of the Contractor and shall take into account the actual site and ground conditions and the equipment's to be used on the site. Approval of the Engineer / Engineer representative for design / drawings shall be obtained prior to proceeding for installation of guide walls.

Guide walls shall be constructed of sufficient size, height and shape to suit the excavation plant used and the site conditions. They shall be high enough to maintain the required head of bentonite slurry, yet lower than the working platform level to limit bentonite or concrete spill during operation and deep enough to prevent erosion of the soil by disturbance of bentonite and provide lateral stability to working platform.

During panel excavation / cutting with trench cutters, the level of slurry shall be maintained at not lower than 0.3 m below top of guide walls, while during grabbing or concrete casting operations it shall be maintained at not lower than 1.2 m below top of guide walls or at such level as the Contractor considers necessary. Similarly, depending on the actual river level/ groundwater situation, level of bentonite slurry be kept at least 1.5m above the level of external ground water level.

After completion of the works the guide walls shall be removed by the Contractor.

v) Tolerances

Cutoff wall excavation shall be carried out in accordance with the following normal tolerances: -

(a) The minimum clear distance between the faces of guide walls shall be the specified Cutoff wall thickness plus 25mm and the maximum distance shall be the Cutoff wall thickness plus 50mm. The guide walls shall be propped, as necessary, to maintain these tolerances during the course of construction of the Works. The face of the guide wall towards the trench nearest to the subsequent excavation shall be vertical and shall represent the reference line. This reference line shall not vary from a straight line or specified profile by more than ± 6mm in any 5 meters wall length and it shall be so maintained that there is no abrupt change.

(b) The plane of the Cutoff wall face to be exposed shall be vertical to within a tolerance of 1 in 200. For the purpose of measuring the verticality of the wall at a particular location, the reference point shall be at the top of the wall on the exposed face at that location.

vi). Wall Panels Layout and Lengths

The Contractor shall have to propose the layout of the primary & secondary panels to be used in the Works subject to the constraints and construction sequence described by the Engineer / Engineer representative. The sequence of panel construction shall be arranged to avoid damage to panels which have already been cast. Adjacent primary and secondary panels shall not be excavated or constructed concurrently.

The Contractor shall specify in his method statement the lengths of all panels to be filled with C-B slurry or plastic concreted taking into account of the ground conditions at the site and the need to maintain stability of the trench and limit movements in the adjacent ground. The Contractor shall demonstrate trial panel excavation / pouring methodology, if Engineer / Engineer representative so specify prior to actual construction, without any additional cost to the Procuring Entity.

The Contractor shall not alter his accepted layout and lengths of the panels without the prior written approval of the Engineer / Engineer representative.

vii). Levels of Cutoff Walls

All Cutoff wall panels shall be poured with C-B slurry or plastic concrete to the following top level:

a) to the top of the guide wall; or

b) to the levels shown in the drawings.

A tolerance of +0.3m deeper / - 0m shallower shall be allowed for in respect of the levels for case (b). C-B slurry or plastic concrete shall be cast to such level that only sound plastic concrete remains below the specified levels. The minimum overcast shall be 300mm and/or as directed otherwise by the Engineer / Engineer representative.

viii). Pre-treatment

The contractor shall take all such measures and provide such strengthening and stabilization of soil along the dam axis and mitigation of water paths within the vicinity of the cutoff wall as are necessary to enable a safe and continuous cutoff wall excavation operation. All such pre-treatment methods of modifying the natural state of the soil and reducing abrupt losses of the bentonite slurry from cutoff panels or at a steady and continuous rate indicating a network of well interconnected fractures forming a preferential fluid path, shall be approved by the Engineer / Engineer representative.

Pre-treatment may involve conventional (bulk infill) grouting at low pressures or under gravity, TAM grouting by pressure injection etc., to avoid significant losses of slurry material and time consumption, particularly over weekends when work is not being undertaken, by filling the voids and macro cracks in the bed rock and in the overlain fill, alluvium and colluvium deposits

ix). Bentonite Mud Management

The general bentonite mud management procedure, as proposed by the Contractor and approved by the Engineer / Engineer representative, shall be as follows:

- Prior to the commencement of cutoff wall construction, the bentonite plant shall be set-up on a designated secured location for the purpose of mixing bentonite, supply and storage of bentonite slurry as well as treatment of used bentonite slurry.

- The bentonite shall be mixed in a high turbulence mixer and pumped directly into silos or pond for storage and hydration. The slurry used shall consist of bentonite powder dispersed in water with the proportions of about 3-8% by weight. The mud quality shall be maintained by circulation or agitation.

- Bentonite mud shall be circulated around the site through 4” Steel / PVC pipes. Mud returning from the trench after excavation shall first pass through a desanding unit to remove impurities. Mud which is contaminated beyond use shall be stored temporarily in pits and then disposed of the site to designated dumping yards.

- In the vicinity of any trench cutter, a collection of desander and pools or liquid storage tanks, as well as new drilling mud production equipment shall be installed.

- Desanders shall composed of centrifugal vibrating screens, to separate the drilling mud from excavated gravel, sand and silt. This complex shall be connected to storage ponds and trench cutter through a network of pipes.

x). Panel excavation and pouring

The equipment used for panel cutoff wall excavation shall be adequate to ensure that each panel segment penetrates to the required founding level.

Cutoff wall panel excavations through the overburden soils and bedrock shall be accomplished by using a combination of conventional / hydraulic trench cutters and grabs. Trench excavating machineries & tools shall be pitched at the exact locations as given on the drawings to ensure that the panels when excavated to rock socketing level are within the specified tolerances. Trench cutters shall be used for better excavation control to the designed final depth and the over-cutting of adjacent (primary) panels. Crawler mounted cranes for chiseling operation may be adopted, when obstacles like boulders and hard strata have to be shattered & removed. The entire cutoff wall shall be constructed along the dam central axis by excavating & pouring pre-determined number of panels in alternating sequence of primary and secondary panels. The combined excavated length, number of excavation bites and single bite length etc., of primary and secondary panels shall be compatible with frame width of trench cutters, grab buckets and as shown on the drawings or as approved by the Engineer / Engineer representative.

During excavation, the sides of the trench shall be maintained with bentonite slurry against lateral movement and formation pressure. The soil and debris from inside the panels shall be removed by trench cutters, grabs/ clamshell buckets and circulating bentonite slurry. Methods of excavation, which in the opinion of the Engineer/ Engineer representative may damage the panel walls, shall not be employed.

The level and properties of the bentonite slurry (viscosity, density, shear strength and pH value) within the excavated trench shall be continuously monitored and tested to ensure the slurry does not become excessively diluted or contaminated by soil particles.

Cutoff wall excavation shall be carried out as rapidly as possible in order to reduce to a minimum the time in which any strata are exposed to the atmosphere, bentonite slurry or water. In any case, a panel shall not remain unfilled with C-B slurry / plastic concrete for period exceeding twelve (12) hours after completion of excavation.

The cement bentonite slurry or plastic concrete shall be poured into the trenches with tremie pipe, once excavation for panels completed. The excess bentonite, as rises during C-B slurry / plastic concrete placement in the trenches shall be pumped back to the desanding unit for cleaning & re-use.

After construction of planned number of primary panels, the intermediate secondary panels shall be excavated by cutting in between two adjacent primary panels with 20 to 40 cm overlapping with side panels or as provided on the drawings and agreed by the Engineer / Engineer representative. Cutting into the plastic concrete of the two adjacent primary panels through the trench cutters or hydraulic / mechanical grab buckets shall result in a rough grooved surface in the casted primary panel to ensure higher quality joint between the primary and secondary panels.

The overcutting shall be carried out not before the minimum plastic concrete strength of at least 0.5 MPa attained. The required curing period for the approved mix design shall be verified on site in trial mixes carried out prior to execution. Generally, a curing period of 3 days shall be observed before proceeding for secondary panels excavation between the primary panels.

The Contractor shall ensure that an adequate supply of plastic concrete and cement bentonite slurry to the tremie is available at all times so that placement is continuous. Plastic Concrete and C-B slurry shall be placed continuously by one or more tremie pipes, as agreed by the Engineer / Engineer representative and care shall be taken during placing to avoid contamination of the plastic concrete & C-B slurry. Where two or more pipes are used in the same panel simultaneously, care shall be taken to ensure that the plastic concrete & C-B slurry level at each pipe position is maintained nearly equal.

During pouring, the displaced bentonite slurry shall be continuously pumped from the trench to the de-sanding unit from where the de-sanded bentonite may be either pumped back to the silos for reuse or disposed of, if contaminated. A continuous supply of plastic concrete & C-B slurry shall be ensured, as interruptions in the pouring process may result in cold joints.

The tremie pipe shall be clean, watertight and with a minimum internal diameter of 150 to 300 mm to allow the free flow of plastic concrete.

When initially charging the tremie, a wad of empty cement bags or a foam rubber plug shall be stuffed into the bottom end of pipe to keep the flow under control while the first batch of plastic concrete or C-B slurry forces the plug down the pipe and displaces the water or contaminated bentonite slurry. The temporary plug will float out and rise to the surface. The discharge opening of the tremie must be kept well immersed in the placed concrete, allowing flow from within the placement. A 1.5 meter of embedment should be maintained as a minimum to maintain the plastic concrete or C-B slurry quality and homogeneity. As the pour progresses, the discharge opening shall be raised gradually so that the head in the pipe can maintain continuous flow.

When it is required to move the tremie laterally, it shall be lifted out vertically, plug it and start a new pour at the new position rather to drag it sideways through freshly placed slurry or concrete. If the area of the pour is too large to manage from a single point, then several tremies in parallel shall be used instead of shifting a single tremie around. A spacing of 3.5 and 5 m between tremies shall be maintained. The risk of segregation and uneven setting can be minimized by providing a continuous flow of slurry or concrete through all the tremies to maintain a moderately even surface.

The casting tolerance of cutoff wall profile shall be a minimum of 150mm and a maximum of 300mm above the specified wall level, as shown on the drawings.

Any adjustments to the final cutoff levels, as directed by the Engineer / Engineer representative shall be ensured by the Contractor without any delay.

The method / procedure used in execution of cutoff wall panels and other operations shall not be such as to cause vibrations resulting in damage to completed or partially completed panels or to adjacent structures, services or other property.

The procedure shall not be such as to cause harmful loosening or softening of overburden soil outside the panel widths that has to be filled with cement-bentonite slurry or plastic concrete, as directed by the Engineer / Engineer representative.

The materials from cutoff wall excavation shall be disposed so that the same does not interfere with any part of the permanent works of the project, in neat and workmanlike manner.

xi). Verticality and integrity of wall

The Contractor shall ensure that cutoff wall as constructed is continuous and properly aligned with designed thicknesses. Any slackness's during construction operations leading to misalignment of panels will cause defects in the wall thus allowing piping or leakage to occur. Hence careful control regarding the alignment and verticality of each panel shall be exercised.

All cutoff wall excavating equipment are subject to the Engineer's / Engineer's representative approval. The plant and equipment furnished by the Contractor shall have sufficient capacity to excavate the cutoff wall panels down to the required depth, true alignment and verticality.

In-built electronic inclinometer (B-Tronic) of modern trench cutters and grabs, measures the deviation in two directions. Any such deviation is displayed on the computer monitor installed in the operator's cabin and accordingly the cutters/ grabs are steered during excavation to compensate any drift in verticality. Also, the trench verticality in both directions shall be checked at every 5-7m interval by the Ultrasonic measuring device like "KODEN" brand, to avoid undercut or overcut of the cutoff wall excavation.

xii). Confirmation of socketing length of panels

The Contractor's method and equipment for panel excavations shall be such that no seepage path is left beneath the cutoff wall. The Contractor shall have to ensure that all the panels of wall are sufficiently embedded in the bedrock, as shown in the drawings.

In order to assess the quality of bedrock samples, the Contractor shall make special arrangements at de-sander plant to collect the rock samples of that depth, like placing the excavator bucket beneath the discharge point for collecting larger cuttings from the assumed depth. The decision of minimum and maximum socketing length of respective panels into the bedrock shall be based on joint assessment and recommendations of the Engineer's representative and Contractor's geologist.

(iv) Inspection

After the individual panel has reached its final stipulated position, as provided in the drawings or as required by the Engineer / Engineer representative, and the cutoff wall panel has been completely cleaned of all loose matter and otherwise made ready to receive the special reinforcement cage and thereafter the plastic concrete and C-B slurry, the Contractor shall so inform the Engineer / Engineer representative.

The Engineer / Engineer representative shall inspect the excavated spoils, check the elevation of the bottom of the panel, the amount and direction, if any, by which the specific panel is out of position, or out-of-plumb having satisfied himself on these and on any other points which he may consider relevant shall sign permission authorizing the Contractor to proceed with the placing of the special reinforcement cage and / or plastic concrete and C-B slurry. The Contractor shall under no circumstances proceed with the placing of special reinforcement cage or with the subsequent plastic concreting and C-B slurry without having first obtained the authority signed separately for each and every panel by the Engineer / Engineer representative.

(v) Special Reinforcement Cages

The reinforcement cages shall be assembled and securely tied by means of binding wire and by welded reinforcement rings or stirrups (four-legged), of twenty-five (25) mm diameter bar as shown on the drawings, in such a manner as to form a rigid cage.
The reinforcement cages for monitoring devices shall be maintained, in position and at locations of cutoff wall during pouring, by a method approved by the Engineer / Engineer representative. The shop drawings prepared by the Contractor should show all the steel reinforcement necessary including that required for lifting stiffening and splicing.

The reinforcement cage shall be of sufficient strength to resist damages during handling and placement into the panel, with no displacement in the course of the pouring operation.

Should the Contractor prefer to lower the reinforcement cage assembly into the panel in sections, he may do so provided the same lapping requirements as for assembly on the ground are followed, namely, the longitudinal reinforcement shall be lapped as shown on the drawings and the spiral or stirrups shall be doubled over the lap zones.

(vi) Transit Mixing

Plant mixed plastic concrete & C-B slurry shall be agitated continuously by rotation the mixer drum during transit and while awaiting discharge. In the case of truck mixed plastic concrete & C-B slurry, the water may be added either at the plant or under the Contractor's supervision after arrival at site, but shall not be added during transit. Any additional water added must be recorded.

(vii) Records

The Contractor shall maintain full records of all supplies of plant mixed plastic concrete & C-B slurry placed in the works, including: -

a) Delivery notes giving details of quality, mix proportions and time of adding cement & bentonite to the aggregates.

b) Position in the works where the plastic concrete & C-B slurry is placed.

(viii) Sampling and Testing

Works test cylinders and other samplings of plastic concrete & C-B slurry mixes shall be conducted on site by the Contractor in accordance with the schedule for QA / QC sampling and testings of these specifications and as provided in the drawings or as directed by the Engineer / Engineer representative.

PS-12.4 MATERIAL REQUIREMENTS

PS-12.4.1 General

This section specifies materials and workmanship required for cutoff wall construction. The materials and workmanship specified in other sections of project specifications shall apply, except where modified, amended or excluded herewith. The construction of the cutoff wall, all as indicated in the drawings and as specified, shall be carried out to the satisfaction of the Engineer / Engineer representative.

PS-12.4.2 Plastic Concrete

Plastic Concrete for use in cutoff wall shall have unconfined compressive strength of 500 to 1000 KPa at 28 days as prescribed in the drawings, except if otherwise directed by the Engineer / Engineer representative and shall contain ordinary portland cement complying with ASTM C150 Type -1 or sulphate resisting cement complying with ASTM C150 Type - 2 if required. Fine aggregates (0-5 mm), coarse aggregates (6-10 mm) and clean water, free from acids and other impurities, shall comply with relevant AASHTO, ASTM & BS Standards as mentioned in the Cement - Concrete section of General Specifications of the project.

The slump of the plastic concrete mix shall be in accordance with the following standard:

a) Slump: 150 – 200 mm (+/- 30 mm)

b) The plastic concrete mix shall flow easily in the tremie pipe and shall be designed to give a dense plastic concrete when placed by the tremie method.

The maximum size of aggregate shall be limited to 10 mm (3/8"). The shape of grading curve should flow evenly graded to prevent segregation.

The chloride ion content of the aggregate shall be such that the chloride ion content of the mixed plastic concrete shall not exceed 1.2 percent.

Unless otherwise approved by the Engineer / Engineer representative, a minimum cement content of 80 kg/m^3 shall have to be employed in making plastic concrete which is to be placed by tremie methods under a bentonite slurry.

The plastic concrete mix shall flow easily in the tremie pipe and shall be designed to give a dense plastic concrete when placed by the tremie method.

Suitable retarder, plasticizer may be added as approved by the Engineer / Engineer representative.

The Contractor shall submit the detailed proposed additive for approval which shall be approved after laboratory trial mix results. The dosing of retarders shall ensure initial setting time of not less than five (5) hours corresponding to the ambient temperature at which the concreting is proposed to be carried out.

Notwithstanding any such inspection and/or approval by the Engineer / Engineer representative, the Contractor shall take responsibility that plastic concrete complies with all the requirements as stated in the drawings and these specifications.

PS-12.4.3 Plastic Concrete Properties

The Contractor shall have to design and recommend for the approval by the Engineer / Engineer representative, appropriate plastic concrete mixes for the cut-off wall, meeting the following requirements for fresh and hardened plastic concrete.

a) Fresh plastic concrete properties

- Sufficient flow ability in terms of slump (in the range of 200 +/- 30 mm).
- Water/ Cement ratio **> 3.0**
- Adequate stability with respect to bleeding, segregation and water losses by filtration.
- Ample duration of workability considering the time frame needed for the casting of subsequent plastic concrete batches.

b) Hardened plastic concrete properties after 28 days

- Unconfined compressive strength: **0.5 to 1 MPa**.
- Permeability: **(< 01 Lugeon** or < **1x10^{-7} m/s)**
- Deformation modulus: **100 to 150 MPa**
- Ductile stress-strain properties to accommodate differential stresses and deformation without cracking.

PS-12.4.4 Plastic Concrete Mix Designs

Based on the aforesaid requirements, the Contractor shall have to conduct sufficient number of suitability trials on site and shall establish two to three preliminary mix designs and properly validate the same by laboratory testings, in advance. typical mix design as given below was chosen for construction of plastic concrete cutoff wall, after several trial mixes.

However, the Contractor should be cautioned to simplify the mix design procedures at the batching plant on site, in order to limit the mix design variations to a minimum i.e., on proportions of available constituents only.

In addition, the minimum allowable strain at failure measured by triaxial tests during mix design tests shall be between 2% to 3%.

PS-12.4.5 Cement Bentonite Slurry Mix Designs

Cement Bentonite slurry mix design shall be determined on site with actual material to be used and with the same mix design approach as described hereinabove for plastic concrete. Following are the required properties for the C-B slurry mix to form an impervious barrier against subsurface seepage.

a) Fresh cement bentonite slurry properties

- Sufficient flow ability in terms of slump
- Marsh Funnel Viscosity **≥ 40 seconds**
- Adequate stability with respect to bleeding, segregation and water losses by filtration.
- Ample duration of workability considering the time frame needed for the casting of subsequent C-B slurry batches.

b) Hardened cement bentonite slurry properties

- Unconfined compressive strength: **≥ 0.2 MPa** after 07 days
- Unconfined compressive strength: **≥ 0.4 MPa** after 28 days
- Permeability: **(< 01 Lugeon or < 1x10^{-7} m/s)**

PS-12.4.6 Proportioning of plastic concrete & cement bentonite slurry mix

All the plastic concrete and C-B slurry mix shall be proportioned by weighing, except as directed by the Engineer / Engineer representative otherwise. The proportions by weight of cement, bentonite, fine aggregates, coarse aggregates and water necessary to produce plastic concrete and C-B slurry mix of the required strength and consistency shall be approved by the Engineer / Engineer representative. Such approval may be withdrawn at any time, and changes in the proportions may be required for the purpose of required workability, density, impermeability, durability and strength.

Based on the approved mix proportions, the Contractor shall prepare lists showing the number of kilograms of the various material to be used in the batch size adopted. The required consistency shall also be shown. Such lists are subject to approval by the Engineer / Engineer representative, and shall be posted at the plant mixer. The amount of water in the mix shall be the total amount of free water, including the free water held by the aggregates.

No plastic concrete and C-B slurry mix shall be placed in the works until the results of the twenty-eight (28) days test indicate that the design proportions are satisfactory as per requirements of unconfined compressive strength and permeability:

Adjustment of the proportions shall be subject to the following provisions:

a) **Adjustment for variation in workability**: If it is found impossible to obtain plastic concrete and C-B slurry mix of the desired workability with the proportions originally approved, the Engineer / Engineer representative shall make such changes as are necessary.

b) **Adjustment for new materials**: No change in the source or character of the material shall be made without due notice to the Engineer / Engineer representative and no new materials shall be used until the Engineer / Engineer representative has accepted such materials and has approved new proportions based on trial mixes.

The Contractor's attention is drawn to the time required to prepare and test trial batches and the Contractor shall be responsible for production of trial batches at a sufficiently early date so that the progress of the work is not delayed.

PS-12.4.7 Laboratory and Field Trial Mix Design Demonstration

The Contractor shall conduct a laboratory trial program under the supervision of Engineer representatives with selected material sources to design plastic concrete and cement-bentonite mixtures that meets the design requirements, following the testing standards and requirements as specified below.

Tests	Standards
Slump	ASTM C143
Unit weight	ASTM C138 / C138M
Hydraulic Conductivity with hydraulic gradient of 20 at 7 and 28 Days	ASTM D5084
Unconfined Compressive Test with initial tangent modulus measurements at 7, 14, and 28 Days	ASTM C39/C39M
Consolidated Undrained Triaxial Test (initial tangent modulus, ductility and strength) at 7 and 28 Days	ASTM D4767
Gradation and Specific Gravity on selected aggregates	ASTM C136, ASTM C127, ASTM C128
Compressive strengths shall be tested on 150 mm diameter by 300 mm long cylindrical specimens or as otherwise directed by the Engineer / Engineer representative.	

After the plastic concrete and cement-bentonite design mixtures have been determined in the laboratory and prior to actual production of plastic concrete and cement-bentonite mix, the Contractor shall perform trial demonstration of a minimum 10 m^3 each of plastic concrete and cement-bentonite mix at site in accordance with the Contractor's design mix using the materials, mixer and procedures to be actually employed for the production.

Laboratory testings for the specified properties shall be conducted on each 5 m^3 batch of plastic concrete and cement-bentonite mixture. The field trial mix and tests shall be repeated until the test results shows the plastic concrete and cement-bentonite mixture properties meet the design requirements.

The Contractor shall not start the production / placement of plastic concrete and cement-bentonite mix in the cutoff wall panels until the results of trial demonstrations have been approved by the Engineer / Engineer representative. Such approval will not relieve the Contractor of responsibility for use of these results or any of his other responsibilities under the contract

PS-12.4.8 Bentonite

Bentonite, as supplied to the site and prior to mixing, shall be in accordance with ANSI / API SPEC 13A – Drilling Fluids Materials, *Nineteenth Edition, Includes Addendum 1 (2020)* and Specification No. DFCP. 4 of the Oil Companies Materials Association, London.

The contractor's proposals for excavation and pouring of cutoff as described hereinabove shall include the following details of the slurry.

a) The source of the bentonite.

b) The constitution of the slurry.

c) Specific gravity, viscosity, shear strength, gel strength and PH value of slurry.

d) The methods of mixing, storing, placing, removal and recirculating the slurry, and

e) The provision of stand-by equipment.

Tests shall be carried out to ensure that the proposed constitution of the slurry suit the particular conditions expected. Proposals for the constitution and physical properties of the slurry shall include average, minimum and maximum values. The contractor shall use additives where necessary to ensure the satisfactory functioning of the slurry.

A manufacturer's certificate showing the properties of the bentonite powder shall be delivered to the Engineer / Engineer representative for each consignment delivered to site. Independent tests shall be carried out at laboratory approved by the Engineer / Engineer representative on samples of bentonite frequently.

Control tests under the supervision of the Engineer / Engineer representative shall be carried out on the bentonite slurry using suitable apparatus, to determine the following parameters.

1. Freshly Mixed Bentonite Slurry and Storage

The bentonite/water ratio (B/W) shall be adopted according to the quality of bentonite & water and the soil type. The industry practice is to keep B/W ratio within 2% and 8% ranges. During cutoff wall excavation & pouring works, the properties of fresh and contaminated mud shall be maintained and tested at frequencies, as provided on the drawings or as agreed by the Engineer / Engineer representative.

Bentonite slurry shall be prepared by mixing the bentonite powder to the fresh & clean water at the mixing plant.

High turbulence mixers shall be used to ensure complete wetting of the bentonite particles and avoid lumps. A mud hopper mixer can also be installed.

In the mud hopper, the required amount of bentonite powder flows at constant rate (out of the special funnel), falling on a pre-determined flow rate of water. Both, water and bentonite are consequently in right proportion and are mixed by a Venturi tube; the mix is circulated a few times through a centrifugal pump in the mud hopper tank.

The mix is then pumped into the slurry ponds for hydration, where a constant circulation of the mud is provided. Care is to be taken to avoid the use of bentonite slurry before the appropriate hydration (at least 12 hours and preferably ≥18 hours shall be adopted). Full bentonite hydration is actually achieved after 24 hours.

The following tests shall be applied to the bentonite slurry, supplied to the trench for cutoff wall excavation, once per day for each panel and the results shall generally be within the ranges stated in the table below:

Items to be Measured	Required Values		Test Method
	As supplied at 20°C	Before Backfill	
Density (g/ml)	1.01 – 1.1	1.01 – 1.20	Mud Density Balance
Viscosity (seconds)	30 – 50	< 90	Marsh Cone Method
Shear Strength (10 min gel strength)	1.4 to 10 N/mm^2		Shearometer
Alkalinity	7 - 11	7-11	Electric pH meter; pH indicator strips
Sand content (%)	< 0.5	< 2	Wet sieving though # 200 ASTM mesh

Tests to determine density, viscosity, shear strength, gel strength, sand content and pH value shall be carried out initially until a consistent working pattern has been established, taking into account the mixing process, any blending of freshly mixed bentonite slurry and previously used bentonite slurry and any process which may be employed to remove impurities from previously used bentonite slurry.

ii). Bentonite Slurry Supplied to Trench Excavation

When the results show consistent behavior, the tests for shear strength, gel strength and pH value may be discontinued and tests to determine density and viscosity only shall be carried out as agreed with the Engineer / Engineer representative. In the event of a change in the established working pattern, the additional tests for shear strength and pH value shall be reintroduced for a period if required by the Engineer / Engineer representative.

iii). Bentonite Slurry in Trench Prior to Placing Plastic Concrete & C-B Slurry

Prior to placing plastic concrete & C-B slurry in any panel, the Contractor shall ensure that heavily contaminated bentonite slurry, which could impair the free flow of plastic concrete & C-B slurry from the tremie pipe, has not accumulated in the bottom of the trench. Samples have to be taken from the bottom of the trench for testing.

One method of identifying contaminated bentonite slurry is to take a sample of the slurry from near the bottom of the trench excavation (about 0.2m above the base of trench) and to carry out a density test on this using a Mud Balance. Where this method is employed, the density determined should not be greater than 1.2 g/ml to enable satisfactory plastic concrete & C-B slurry placing.

The proposed method for checking this item shall be agreed with the Engineer / Engineer representative prior to the commencement of the works. If the bentonite slurry is found to exhibit properties outside the agreed appropriate range, then it shall be modified or replaced until the required agreed condition is achieved.

During construction, the level of the bentonite slurry in the trench shall be maintained within the depth of the guide walls and at a level not less than 1.5m above the level of external standing ground water.

In the event of a sudden loss of bentonite slurry, the trench shall be backfilled without delay and proceeded further after due consultation with the Engineer / Engineer representative.

Where saline or chemically contaminated ground water occurs, special measures shall be taken as required by the Engineer / Engineer representative to modify the bentonite slurry. The modification required depends on the nature of the contamination. In saline conditions, it is frequently necessary to ensure that the bentonite is fully hydrated in fresh water before supplying into the trench.

All reasonable steps shall be taken to prevent spillage of bentonite slurry in the immediate vicinity of the cutoff wall. Discarded bentonite slurry which has been pumped from the trench shall be removed promptly from the site.

PS-12.5 QA/QC PROGRAM

(i) Trench Bentonite Slurry

The Contractor's quality control program shall consist of testing the slurry for density, pH, viscosity, sand content, gel strength, water loss in the filter press and filter cake. Testing shall be made twice daily during excavation with samples taken at approximately 5 m depth spacing or each change of soil type.

A full range of tests shall be taken when additional wall support materials are added to the slurry.

The pattern of relationship between gel strength, viscosity, and density shall be established on site so that:

a) The gel strength / viscosity relationship does not produce excessive combined values likely to produce slurry entrapment;
b) No flocculation of the bentonite occurs;
c) No settlement of the solids within the slurry occurs;
d) The range of values for slurry properties shall conform to these specifications and BS EN1538, unless otherwise acceptable to the Engineer / Engineer representative.

Just prior to backfill placement, the slurry shall be tested to ensure it is sufficiently thin for thorough displacement during tremie placement of plastic concrete and C-B slurry mix.

(ii) In-panel Hydraulic Conductivity Measurements

Hydraulic conductivity tests shall be performed on plastic concrete & C-B slurry mix cylinders, for ascertaining the permeability coefficient (i.e., less than $1x10^{-7}$ m/s).

In order to estimate the in-situ hydraulic conductivity of the plastic concrete & C-B slurry mix cutoff wall, test holes shall be formed in selected panels by presetting a length of NW casing as agreed by the Engineer / Engineer representative , with an oversized 250 mm diameter casing to centralize the smaller casing in the panel (with removable close-end plug at the bottom) in the panel prior to the pour and then removing the casing after the plastic concrete or C-B slurry mix has cured for 48 to 72 hours and grouting the bottom length of the hole with cement-bentonite. The casings shall be periodically rotated 2 to 3 times daily during the curing period inside the panel.

NW series drill casing is made from steel tubing and is flush inside and outside with no internal coupling, and has a specified outside diameter of 89 mm (3.5 inches). In-situ testings for hydraulic conducti shall consists of a series of falling head tests in open holes and selected response zones isolated by pneumatic packers in the test holes. After tests, the test holes shall be grouted with cement-bentonite. Permeability coefficients of in-situ Vs laboratory plastic concrete or C-B slurry mix cylinders, shall be determined and reported to the Engineer / Engineer representative for verification and confirmation that the field hydraulic conductivity meet the design intent of the seepage cutoff wall.

(iii) Hardened plastic concrete & C-B slurry testing and quality control

The hardened plastic concrete and C-B slurry properties shall be tested at 7,28, 90 days and verified by the Contractor under the supervision of Engineer representative in the project site laboratory. The Contractor shall provide the requisite quantity of testing equipment like water permeability testing cell and triaxial cell for confined compression strength (CCS) and deformation modulus testing.

The Contractor shall be aware that different testing conditions such as various confining pressure, back pressure, saturation time or deformation speed and the different methods of CCS testing (consolidated, unconsolidated, drained or undrained) have significant influence on the confined compressive strength and deformation modulus of testing samples. The exact testing procedure for the specified and required plastic concrete and C-B slurry properties will be established, once the Contractor's Geotechnical investigation details are completed and approved by the Engineer / Engineer representative.

Triaxial compressive strength tests shall be carried out on plastic concrete, cement – bentonite slurry mixes to determine stress-strain characteristics, modulus of elasticity and shear parameters. Tests shall be carried out at 7, 28 and 90 days in consolidated undrained conditions.

PS-12.6 CONSTRUCTION CONTROL

(i) Safety Precaution and Emergency Procedures

Safety precaution shall be taken throughout the construction of Cutoff walls in accordance with the relevant statutory requirements and suggestions given in BS EN 1538:2010+A1:2015 Execution of special geotechnical works - Diaphragm walls and B.S. 8004: Code of Practice for Foundation.

The Contractor shall take all necessary precautions to ensure stability of his excavations and guide walls and shall take all necessary precautions and be responsible for safety of personnel in the area of operation.

The Contractor shall maintain and make available for immediate use, a sufficient quantity of slurry to allow for any sudden loss. Should the loss continue despite the addition of the slurry and the stability of the trench be placed at risk, the Contractor shall promptly advise the Engineer / Engineer representative and take such remedial actions as are necessary to preserve the stability of the trench.

(ii) Watertightness

The Contractor is responsible for providing a watertight cutoff wall. Should the wall be not watertight, the Contractor shall with the approval of the Engineer / Engineer representative and, at his own expense carry out all remedial measures, as required to render the wall watertight.

(iii) Blasting

Blasting operations in the vicinity of cutoff wall construction for allied project activities shall not be permitted without the written approval of the Engineer / Engineer representative. The Contractor shall comply with all regulations of the relevant statuary authorities and take all precautions necessary to avoid damages to permanent and temporary works. Should any damage be caused this shall immediately be made good at the Contractor's own expense.

Details of all proposed blasting operations for allied Works shall be submitted to the Engineer / Engineer representative with as much advance notice as possible and at least 72 hours prior to blasting. These shall include charge calculations and expected ground vibration levels.

(iv) Disposal of Spoil

Spoil removed from the cutoff wall excavations shall be separated from the slurry employed in the excavation process. It shall be disposed of in accordance with the current statutory requirements and as quickly as possible to an approved dump site and in such a manner, as agreed by the Engineer / Engineer representative, that spillage and annoyance at construction site or haul roads are minimized.

Used bentonite or contaminated slurry, not suitable for re-use shall be disposed of by mixing it with sufficient granular soil or similar approved material in such properties as will neutralize its characteristic properties and produce a material that is, in the opinion of the Engineer / Engineer representative and local authorities, suitable for placing in public dumps to form usable areas of reclaimed land.

PS-12.7 MEASUREMENT AND PAYMENT

PS-12.7.1 Measurement

Dam cutoff wall will be measured by the square meters of cutoff wall completed as shown on the Drawings or directed in writing by the Engineer / Engineer representative, excavated and concreted to the specified or directed elevations, completely tested in-situ and accepted.

PS-12.7.2 Payment

Payment of dam cutoff wall as determined under measurement shall be made at the contract unit price per square meter for the pay item shown in the Bill of Quantities. Such prices and payment shall be considered full compensation for furnishing labor, materials, and equipment necessary to satisfactorily complete the work including the cost of following items:

a) Site clearance before starting the work and after completion of work including survey work.

b) Satisfactory disposal of excavated earth & construction wastes, with all lead and lift, obtained from dismantling of working platform, the upper part of the dam clay-core and upper part of the cutoff wall etc., to designated dumping sites, outside the project area.

c) Preconstruction geotechnical investigations / testings and pretreatment of ground along the cutoff wall.

d) Construction of all season working platform above the water level upto the guide wall level, with approach ramps.

e) Construction of RCC guide wall, including earthwork in excavation and /or backfilling. Demolishing and stacking of unused material of concrete guide wall after completion of the cutoff wall as directed by the Engineer representative. Cost of reinforcement for concrete guide wall is included and shall not be separately payable.

f) Trenching & grabbing of cutoff wall by adopting approved method with trench cutter's and hydraulic / mechanical grabs plus chiseling equipment upto desired depth in all sorts of soil/ sand/ gravel/ boulder and rocks upto specified socketing depth.

g) Furnishing bentonite mixing and pumping system including mixer, desander tank, slurry tank, centrifugal pumps, bentonite silo / hydration tank and ring mains etc.,

h) Furnishing / mixing / testing bentonite - water slurry with / without admixtures. Furnishing the necessary lab and field-testing equipment, clean-up including disposal of slurry and excavated material, and providing required protection.

i) Providing and laying in position plastic concrete and cement – bentonite mixed slurry manufactured separately, in fully automatic batch mixed plant of specified / required capacity on site for cutoff wall work as per approved design mix, at all places and heights/ depths of cutoff wall including transporting by transit mixer for any lead to site having continuous agitated mixer, laying of plastic concrete and cement – bentonite mixed slurry by any means like pumping, tower crane or boom placer etc., vibrating, finishing and curing etc. and including cost of all materials & wastages, labour, tools, plants, equipment and admixtures in recommended proportions, to improve workability without impairing strength, hydraulic conductivity and durability as per direction of Engineer / Engineer representative.

j) All QA / QC testings in the project & independent laboratory’s and in-situ testings of cutoff wall, including such other tests as directed by the Engineer representative.

k) The cost of trench dewatering will not be paid separately and the quoted rates for cutoff wall are deemed to be inclusive of this component.

l) The cost of special reinforcement cage for instrumentation and its lowering into the cutoff wall will not be paid separately and the quoted rates for cutoff wall are deemed to be inclusive of this component.

m) All other incidental expenses including fuel, welding etc. necessary to complete the item as directed by the Engineer / Engineer representative.

n) No extra payment will be made for mobilization and demobilization of the Contractor's forces and equipment necessary for performing the work including loading, unloading, handling, lead, lift, stacking, storage, security etc., The quoted rates for cutoff wall are deemed to be inclusive of all these components.

SUPPLEMENTARY SPECIFICATIONS

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Chapter 3 Earth Work 1

Chapter 6 Cement Concrete 46

Chapter 18 Piles -- 127

CHAPTER – 3 EARTHWORK

S #	STANDARD NAME	DESCRIPTION
ASTM		
1.	**ASTM C136/C136M** -19	Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
2.	**ASTM D2487**-17	Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
3.	**ASTM D6913/D6913M** -17	Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis
4.	**ASTM D422** -14	Standard Test Method for Particle-Size Analysis of Soils
5.	**ASTM D1140** -17	Standard Test Methods for Determining the Amount of Material Finer than 75-μm (No. 200) Sieve in Soils by Washing
6.	**ASTM D4318** -18	Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
7.	**ASTM C33/C33M** -18	Standard Specification for Concrete Aggregates
8.	**ASTM D698** -15	Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (*12,400 ft-lbf/cu. ft - 600 kN-m/cu.m*)
9.	**ASTM D1557** -15	Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (*56,000 ft-lbf/cu. ft -* 2700 *kN-m/cu.m*)
10.	**ASTM D1556/D1556M** -16	Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method.
11.	**ASTM D2167** -15	Standard Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method
12.	**ASTM D6938** -17a	Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
13.	**ASTM D4253** - 16e1	Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table
14.	**ASTM D4254** - 16	Standard Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density
15.	**ASTM D4914/D4914M** -16	Standard Test Methods for Density of Soil and Rock in Place by the Sand Replacement Method in a Test Pit
16.	**ASTM D5030/D5030M** - 21	Standard Test Methods for Density of In-Place Soil and Rock Materials by the Water Replacement Method in a Test Pit
17.	**ASTM D4643** -17	Standard Test Method for Determination of Water Content of Soil and Rock by Microwave Oven Heating

S #	STANDARD NAME	DESCRIPTION
ASTM		
18.	**ASTM D2216** -19	Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
19.	**ASTM D4718/D4718M** -15	Standard Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles
20.	**ASTM D2166/D2166M** -16	Standard Test Method for Unconfined Compressive Strength of Cohesive Soil
21.	**ASTM D2850** -15	Standard Test Method for Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils
22.	**ASTM D4767**-11	Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils
23.	**ASTM D5084** -16a	Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter
24.	**ASTM D2434** -22	Standard Test Methods for Measurement of Hydraulic Conductivity of Coarse-Grained Soils
25.	**ASTM D5856** -15	Standard Test Method for Measurement of Hydraulic Conductivity of Porous Material Using a Rigid-Wall, Compaction-Mold Permeameter
26.	**ASTM D5126/D5126M** -16	Standard Guide for Comparison of Field Methods for Determining Hydraulic Conductivity in Vadose Zone
27.	**ASTM D3385** -18	Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer
28.	**ASTM-D5093** -15e1	Standard Test Method for Field Measurement of Infiltration Rate Using Double-Ring Infiltrometer with Sealed-Inner Ring
29.	**ASTM D4221**-18	Standard Test Method for Dispersive Characteristics of Clay Soil by Double Hydrometer
BS		
30.	**BS 1377-2:2022**	Methods of test for soils for civil engineering purposes - Classification tests and determination of geotechnical properties
USBR		
31.	**USBR 3900**	Standard Definitions of Terms and Symbols Relating to Soil Mechanics
32.	**USBR 5005**	Determining Unified Soil Classification (Visual Method)
33.	**USBR 7300**-89	Procedure for performing field permeability testing by the well permeameter method
34.	**USBR 7305**-89	Procedure for field permeability test (shallow-well permeameter method)
35.	**USBR 7010**	Performing Disturbed Soil Sampling Using Auger Boring Method

SS-01 Replace the word "Engineer-in-charge" with "Engineer / Engineer Representative" wherever appears in these "Technical Specifications for Workmanship - MRS 2022".

SS-02 Clause 3.1 General (Technical Specifications for Workmanship Page **-** 5)
Delete the whole paragraph and replace with the following:

Earthwork covers any or all works involved in dam area preparation including clearing and scrapping of working area required to prepare the existing embankment to the design elevations and limits indicated on the Drawings and specified herein , cutting or digging in soil or rock of various classifications for cutoff trench, and foundations of spillway and relevant hydraulic structures; dressing the excavated pit to the specific grades and dimensions; sorting, transporting and re-handling of excavated material; stacking, filling or refilling, compacting and dressing the top and side slopes of the resultant's embankment or spoil bank to the required grades and dimensions, along with all other related operations.

It shall include furnishing of all labor, materials, plant, tools, equipment, instruments, energy and services for the followings, in accordance with these specifications and in conformity with the lines, grades, sections, and dimensions shown on the drawings or as directed by the Engineer.

The Contractor shall provide all labor, materials, and equipment necessary to maintain vehicular and pedestrian traffic throughout the project. The Contractor shall be responsible for obtaining all permits and approvals required from local, country, and state regulatory agencies to cross local Roads with earthmoving equipment. Signs, lights, barricades, and manpower shall be provided wherever necessary to protect the traveling public from hazardous conditions in accordance with local, country, and administrative transportation requirements.

SS-03 Clause 3.1.2 Classification of Soil (Technical Specifications for Workmanship Page - 10)

Add the following at the end:

Definition of Earthwork Materials

Suitable material shall comprise all that material which is obtained from excavations within the site or which is approved by the Engineer as acceptable for use in the Works for Embankment fill or backfill.

Unsuitable material shall mean other than suitable material and shall comprise:

- material from swamps, marshes and bogs;
- logs, stumps and perishable materials;
- material susceptible to spontaneous combustion;
- clay of liquid limit exceeding 90 and/or plasticity index exceeding 65;
- any other material declared as "Unsuitable material" by the Engineer.

SS-04 Clause 3.2 Excavations (Technical Specifications for Workmanship Page - 14)

Delete the text "The method ……..in writing" in the last line and Add the following as second paragraph:

Contractor shall submit to the Engineer for review and comment a plan indicating the contractor's proposed equipment and methods for completing the excavation suitable materials for embankment fill and unsuitable materials for disposal. This plan shall include anticipated production rates, locations of proposed access into the excavation area, and estimated timeframes for completing 25%, 50%, 75% and all of the excavation to the lines, grades, and elevations shown on the Drawings. Note that, quantities of excavation and grading may have changed from the time that plans were prepared. This may reduce quantities of excavation required on the project.

An estimate of the volume of excavated material that is suitable for use as structural fill and temporary stockpile locations shall also be included. The plan shall be submitted at least two (2) weeks prior to the start of excavation.

SS-05 Clause 3.2.1.2 Borrow-pit Excavation (Technical Specifications for Workmanship Page - 15)

After the sub-clause 6), Add the following paragraph:

Borrow fill used for earthwork construction shall meet the following requirements:

- Material shall be environmentally clean and free of refuse, debris, organic matter, frozen material, and miscellaneous or deleterious materials.
- Material shall classify as CL, ML, CL-ML, SC, SM, or SW according to the Unified Soil Classification System (USCS).
- Material shall have a liquid limit not exceeding 45 and a plasticity index not exceeding 30.

The Contractor shall submit for Engineer prior approval, representative samples from each proposed borrow source for the required laboratory tests as specified in these specifications at no additional cost to the Procuring Entity. Acceptance of material from any particular borrow location shall not be construed as approval of the entire location but only insofar as the material continues to meet the specification requirements.

In making his bid, the Contractor shall inspect the site and prepare his estimate of the haulage cost on the basis of his own survey of the possible nature and locations of the borrow pits. Their distance from the work sites shall not be grounds for extra payment or revision of the contract price.

The consent of the landowner or tenant for excavating the borrow material and hauling along private access roads shall be secured by the Contractor who shall, if required, pay for such concession. Borrow pits shall be left in a condition acceptable to the landowner and/or tenant and the Engineer.

SS-06 Clause 3.2.4 Excavated Material (Technical Specifications for Workmanship Page - 17)

Before the sentence “As far as practicable….. ” in the fourth line, Add the following paragraph:

However, when the excavation from approved borrow sources or required structural excavations progresses at a faster rate than placement / compaction in the embankment fill is being accomplished, then stockpile the excavated materials at approved locations adjacent to the work until its use is authorized by the Engineer. No payment will be made for such stockpiling nor for the reloading and hauling of this material to its final position in the embankment.

SS-07 Clause 3.2.4.1 Classification of Excavated Material (Technical Specifications for Workmanship Page - 19)

In sub-clause 7, replace "No. (vi)" with "No.6" in first line.

SS-08 Delete the following clauses of "Technical Specifications for Workmanship"

a) Clause 3.2.5 Filling around Foundations, Footings, Pipes etc. (Page - 19).

b) Clause 3.2.6 Dealing with Bad Soil etc. (Page - 19).

c) Clause 3.2.7 Tolerances (Page - 19).

d) Sub-clauses 3.2.8.1 General and 3.2.8.2 Materials of Clause 3.2.8 Trenching/ Open cut Excavation (Page 19 to 21)

SS-09 Clause 3.2.8.3 Construction Requirements (Technical Specifications for Workmanship Page - 21)

Add the following before this clause.

3.2.5 Execution

3.2.5.1 Site Clearing

a) Clearing & Grubbing

All areas which require clearing, as determined by the Engineer, shall be cleared of all trees less than 150mm girth, complete roots, stumps, bushes, vegetation, rubbish and other objectionable matter and such materials shall be removed from the site of work or otherwise disposed-off as approved by the Engineer. Any damage to the Works and public or private property caused by the Contractor's operations shall be made good through repair or replacement at the sole expense of the Contractor.

b) Trees owned by the Forest Department

All plantations and trees greater than 150mm girth will normally be removed by the Forest Department. For the removal of trees and stumps, as may be required by the Contract or directed by the Engineer, the Procuring Entity shall make all arrangements, carry out negotiation and resolve with Forest Department. Removal of trees shall be in accordance with the requirements prescribed by the Forest Department and shall be under the general direction of the Engineer. It shall be the Contractor's responsibility to ensure timely notification to the Engineer for removal of trees.

c) Trees owned by General Public

For the removal of trees and stumps, as may be required by the Contract or by the Engineer, the Contractor shall make all necessary arrangements, carry out negotiations and resolve with the owners. It shall be the Contractor’s responsibility to ensure timely removal of trees.
For the removal of those trees and stumps which are not owned by the Forest Department, the Contractor shall negotiate with the owners thereof and remove the trees and stumps as directed by the Engineer

d) Disposal of trees/stumps

The materials obtained from clearing & grubbing shall be removed from the site of work or otherwise disposed of as follows:

- If it is a private property then it shall be under the general direction of the Procuring Entity.
- If ownership cannot be established or is disclaimed the Contractor shall handover the material to the Procuring Entity.

e) Dismantling

If clearance involves dismantling of existing structures such as walls, fences, foundations, ruins and other permanent or temporary structures, these shall be dismantled with care without causing any damage to the Works or adjacent property. Components of dismantled construction materials or debris shall be stacked or disposed off as approved by the Engineer.

3.2.5.2 Survey and Leveling Prior to Commencement of Earthwork

The Contractor shall be responsible for the setting out of the work immediately after the Contractor has completed the job of clearing and grubbing, including removal of top 150 mm surface soil to the required or possible depth, cutting and removal of unwanted trees up to 150mm girth, stumps and roots of trees.

Notwithstanding that project drawings would have been issued to the Contractor, the Contractor shall be responsible for conducting joint survey on the proposed alignment of the Dam, spillway, cofferdam etc, submitting three copies of the plotted cross-sections and longitudinal profile to the Engineer and obtaining the approval of the Engineer to such survey data before any work in connection with earthwork is commenced. These cross-sections and longitudinal profile shall be in the form and manner as instructed in writing by the Engineer.

The layout and level readings and measurements shall be taken, agreed to and recorded jointly by the Contractor with the Engineer's Representative, which shall constitute the basis for measurement and payment.

The Contractor shall also take and record such other dimensions as are necessary during the progress of the excavation to allow for accurate measurement of the excavated quantities.

SS-10 Clause 3.2.8.3 Construction Requirements (Technical Specifications for Workmanship Page - 21)

Delete the whole Clause and replace with the followings:

. **3.2.6 Construction Requirements**

3.2.6.1 Soil and Rock information

Any engineering data concerning the properties of the soil, rock or subsurface and other geotechnical information shown on the drawings or other documents forming part of the contract are for information only. The contractor is obliged to make his own assessment of site conditions prevailing.

No claim for extra cost or time extension will be entertained based on the information indicated in the Drawings or in any other Contract Documents or the materials obtained from boring or trial holes.

The Contractor shall be deemed to have visited the site prior to making his bid and shall ascertain the nature of the earth and rock, its quantity, locations and suitability to meet the specified requirements, and he shall base his bid estimates solely on his own soil/sub-surface investigation. After the award of the contract no claim for a revision of bid prices depending on the sources of soil / rock information will be entertained.

3.2.6.2 Method Statement

The Contractor shall submit method statements for excavation in soil, rock (all classes), for all activities including structural and trench excavation in conformity with lines, grades, sections and dimensions shown on the Drawings for approval of the Engineer prior to proceeding for works.

3.2.6.3 Excavation in Soil, Rock and Overburden.

a) Not Requiring Blasting in Dry, including Disposal of Material, and Dressing of Slopes.

The Contractor shall carry out excavation in soil /rock (all classes) not requiring blasting to a depth where further excavation is not possible and blasting will be required. The Engineer's Representative will verify and record this depth. disposal of excavated material to any lead/lift shall be made to designated spoil tips as directed by the Engineer. The side slopes and benches shall be made and dressed as shown on Drawings.

b) Not Requiring Blasting in Wet, including Disposal of Material, and Dewatering for Lowering and Control of Water Table and Dressing of Slopes.

The Contractor shall carry out excavation in wet soil /rock (all classes), not requiring blasting, below water table conditions. The depth at which water table is encountered shall be recorded and verified by the Engineers Representative, and excavation below this level shall be considered as excavation in wet conditions. To maintain and stabilize the slopes, dewatering for lowering and control of water table shall be carried out during construction stage by the Contractor. Any slips/slides shall be controlled and cleared by the Contractor and he shall not be entitled to any additional payment or claim in this regard.

The rate is deemed to be inclusive of measures taken for control of water and additional expenses incurred to excavate in wet conditions.

c) Excavation in Rock Requiring Blasting in Dry, including Disposal of Material, and Dressing of Slopes.

When further excavation cannot be carried out with the use of Dozers/Tractors of 150 BHP capacity with blade or ripper, then blasting operations shall be carried out to excavate all classes of rock to the required line, slopes, berm levels, dimensions and grades as shown on the Drawings. The depth at which blasting is required shall be recorded and verified by the Engineer's Representative.

The pay line or Clearance line shall be to the outer line of initial concrete lining in Tunnel / underground excavations and 0.5 m beyond the concrete outline in other structures. The Contractor is deemed to have included the over break quantities in his unit rates of the respective BOQ items. Under breaks shall not be allowed and have to be removed by the Contractor to the satisfaction of the Engineer.

All safety precautions shall be taken to ensure that due to blasting operations, general public, the workmen, the structures and the properties located in the vicinity are not damaged. Any claim for damage arising out of blasting of rock shall be the responsibility of the Contractor. He shall take care that vibrations created by blasting and flying splinters remain within safe limits.

In selected locations, side slopes may have to be stabilized by shotcreting of 50 mm thickness and occasional rock bolting, as and where directed by the Engineer, as the excavation work proceeds.

The rate is deemed to be inclusive of precautionary measures taken for maintaining stability of excavated slopes.

d) Excavation in Rock Requiring Blasting in Wet, including Disposal of Material, and Dewatering for Lowering and Control of Water Table and Dressing of Slopes.

The Contractor shall carry out excavation in rock requiring blasting in excavations below water table condition. The depth at which water table is encountered shall be verified and recorded by the Engineers Representative, and excavation below this level shall be considered as excavation in wet conditions. To maintain and stabilize the slopes, dewatering for lowering and control of water table shall be carried out during construction stage by the Contractor. Any slips/slides, caving, silting shall be controlled and cleared by the

Contractor and he shall not be entitled to any additional payment or claim in this regard.

The rate is deemed to be inclusive of all measures taken for control of water and any additional expenses incurred to excavate in wet conditions.

3.2.6.4 Explosives for Rock Excavation

Where explosives are used the Contractor shall provide suitable buildings or warehouses in approved locations for the storage of explosives, in accordance with statutory regulations and shall be stored in the manner and quantity approved by the Engineer/Engineer representative. Such storage places shall be accessible only to authorized personnel. They shall be properly marked. All doors or accesses thereto shall be constructed of materials as directed by the Engineer/Engineer representative and provided with secure locks and all necessary means for preventing access by unauthorized persons.

The contractor shall give facilities to appropriate authorities for any inspection from time to time they may require to make.

The Contractor shall be responsible for the prevention of any unauthorized issue or improper use of any explosives. The handling of explosives shall be entrusted only to experienced and responsible men, to the satisfaction of the Engineer/Engineer representative, and in conformity with the statutory regulations.

The Contractor shall not use any explosive without the written permission of the Engineer, who shall require that the Contractor has complied in full with the regulations in force in Pakistan and in the province regarding the use of explosives. The Engineer's/Engineer's representative refusal to permit the use of explosives shall not constitute any ground for claims.

No blasting operations shall be carried out except under the direction of an experienced operator holding a valid blasting-license.

Proper record of all explosives used, showing locations and amounts, shall be kept by the Contractor for checking by the Engineer/Engineer representative.

All drilling and blasting shall be done in such a manner as to bring the excavation as close as possible to the required cross sections, and to disturb as little as possible the material to be left in place. Blasting by means of drill holes, pilot tunnelling, or any other method shall be performed at the entire risk and responsibility of the Contractor who shall have no claim to payment for extra work occasioned by breakage outside the approved cross-sections or dimensions.

The greatest care shall be taken by the Contractor during all blasting operations to ensure that no injury be done to persons or damage to property or to the finished work. Shots shall be properly loaded and capped, and only a moderate charge shall be used in each hole. A record of all explosives used, showing locations and amounts, shall be kept by the Contractor for checking by the Engineer/Engineer representative.

Where directed by the Engineer/Engineer representative, the Contractor shall provide heavy mesh blasting mat for protection of persons, property and the work. If necessary, blasting shall be restricted to time prescribed by the Engineer.

The Engineer/Engineer representative may prohibit blasting and order the rock to be excavated by other means, if, in his opinion, it would be dangerous to persons or adjacent structures, or is being carried out in a reckless manner. If traffic / pedestrian movement on the local roads have to be interrupted, the Contractor shall obtain approval of his schedule for such interruption from the local authorities and shall satisfy the Engineer/Engineer representative that he has obtained it. No extra payment shall be admissible for such arrangements as described herein above.

The cost of licenses, provision of stores, employment of watchmen, explosives, labor, appliances and all other matter and things used by the Contractor shall be at the Contractor's expense and the Contractor at his own expense shall make good, under the direction and to the satisfaction of the Engineer/Engineer representative, any injury or damage arising from or occasioned by his blasting operations.

The Contractor shall indemnify, save harmless and keep indemnified the Procuring Entity and his officers and the Engineer and his representatives from and against all actions, claims or any expenses whatsoever, arising out of or incidental to blasting operations.

3.2.6.5 Excavation of Core Trench

Beneath the foundation of the dam within limits as shown on the Drawings necessary earth materials shall be excavated, bed rock surface prepared and impervious fill material placed as required for the control of under-seepage.

Excavation shall be carried to a specified depth in the river bed and to reasonably sound strata at the abutments. Contractor shall be responsible for the maintenance of stable slops during the excavation and backfill of the core trench. The slopes shown on the drawings are indicative only and may be varied or supplemented with berms, if required, subject to the approval of the Engineer/Engineer representative.

The suitable material excavated from the core trench will be allowed to be placed in main embankment as directed by the Engineer/Engineer representative and the Contractor may stockpile such suitable material for further use.

a) Exposed Surfaces

The work shall be carried out in a careful manner to ensure that the exposed surfaces are as sound as the nature of the material permits and that no point shall protrude inside the lines shown on the Drawings except as otherwise specified or agreed by the Engineer/Engineer representative. In soft excavation, which is to remain open permanently, exposed faces shall be formed accurately to the required slopes and profiles. For excavations in rock, which remain open permanently, the faces shall be so trimmed that no point protrudes within the required profile.

The Contractor shall examine all excavated faces regularly and shall remove all insecure material or materials resulting from any falls or slides.

b) Trimming Excavations

When excavating to specified levels for the foundation of any structure or to specified limits for the face of any structures required to abut undisturbed ground, the Contractor shall not finally complete the excavation until immediately before commencing the constructional work, except where the Engineer/Engineer representative shall permit otherwise.

Before commencement of any constructional work all shattered and loose material shall be removed from the excavations so as to ensure that the work rests on a sound and clean foundation or where appropriate, abuts against undisturbed ground.

3.2.6.6 Stockpiling of Suitable Material

Excavated material suitable for use as filling material shall be temporarily stockpiled, if required, at locations designated by the Engineer/Engineer representative. These stockpiles shall be in an orderly manner separately from unsuitable material to avoid any contamination / degradation and at a sufficient distance from the edge of the excavated cutoff trench on the dam foundation lines to prevent material from sloughing or sliding back into the trench.

All excavated material suitable for use shall be transported back to locations requiring embankment fill or backfill.

3.2.6.7 Excavation of Unsuitable Materials

Excavation of unsuitable materials (spillway foundation, cutoff trench), as defined in these specifications, shall be completed to the limits indicated on the Drawings or until suitable bearing soils are encountered as determined in the field by the Engineer/Engineer representative. Contractor shall conduct his own subsurface explorations, as necessary, to base his bid. The Contractor shall transport and dispose of excavated materials at the "spoil areas" indicated on the drawings or as specified and approved by the Engineer/Engineer representative.

No additional payment will be made for excavation, transportation and disposal of unsuitable material, as the same is deemed to be included by the contractor in his bid rates for excavation/placement of earth fill material.

3.2.6.8 Excess Excavation

The Contractor shall not be entitled to payment in respect of excavation to any greater extent, whether horizontally or vertically, than is necessary to receive any structure for which the excavation is intended, except where a separate item is provided for additional excavation for working space, timbering, or other temporary work.

Excavation to a greater depth or width than directed shall be made good with suitable materials to the satisfaction of the Engineer/Engineer representative and at the Contractor’s cost.

3.2.6.9 Water in Excavations

All excavations shall be kept free from water, from whatever source, at all times during construction of works until in the opinion of the Engineer/Engineer representative, any concrete or other works therein are sufficiently set. The Contractor's rates are deemed to cover compliance with this requirement.

The Contractor shall provide all plant, labor and materials required for such work and all costs incurred shall be deemed to be included in his rates for excavation/placing earth fill material.

3.2.6.10 Groundwater/ Storm water Control

Contractor should anticipate encountering groundwater, storm water, or perched water during earthwork activities. Removal of water below excavation grade to a depth necessary to allow compaction in accordance with the Contract documents should be anticipated by the Contractor.

No payment will be made for dewatering. The Contractor shall provide necessary measures to sufficiently and properly control, convey, and remove from the work area, storm water, groundwater and/or perched water for the duration of earthwork activities, as required in these specifications. These measures shall allow for uninterrupted continuance of the work and shall not result in damage to or otherwise diminish the integrity of work already completed, unless approved by the Engineer/Engineer representative.

3.2.6.11 Rates of Excavation

Where required, the Contractor shall control the rates of excavation and draw-down of water so as not to endanger the stability of earthworks or adjoining structures. The Contractor shall protect and maintain the beds and foundations of structures by providing proper drainage system. Any damage resulting from operations of the Contractor shall be repaired as directed by the Engineer/Engineer representative at the sole expense of the Contractor.

SS-11 Clause 3.2.8.4 Measurement and Payment (Technical Specifications for Workmanship Page - 24)

Delete the whole clause and replace with the followings:

3.2.7 Measurements and Payment

The quantities of the various classes of excavation or embankment to be measured for payment under the contract shall be limited to the lines and level as taken under sub-clause SS-3.2.5.2 hereinabove. However, if the levels so taken differ appreciably from design levels the matter shall be referred to the Procuring Entity.

Excavation and filling / backfilling beyond the lines and level shown on the drawings, approved profiles and cross-sections will not be paid for. The Engineer/Engineer Representative will decide the angle of the slope of cuts and fills as the work proceeds on the basis of evaluation of the soil and rock characteristics. The actual lines of the cuts and fills as made will be duly measured and recorded by the Contractor. The Engineer / Engineer Representative will check these records and will approve the measurements, if correct, as a basis of payment. Excess of excavation shall be backfilled, as directed by the Engineer/Engineer Representative, with similar materials without extra payment to the Contractor. Excess of fill shall be removed as required by the Engineer/Engineer Representative.

The quantities of excavation, backfill and earthwork to be paid under relevant pay items shall be the number of cubic meters of material measured by the average end-area method, except where the Engineer/Engineer Representative authorizes the use of more accurate method. However, the Contractor shall request such authority before he submits his quantities for approval. Quantities measured on the average end-area basis, once they have been submitted and approved, shall not be subject to review for the purpose of applying a more accurate method.

3.2.7.1 General Requirements

Except where otherwise provided herein or elsewhere in the Contract, no measurement and payment shall be made for the under-mentioned works related to excavation / rock excavation / embankment fill / backfill; the cost thereof being deemed to have been included in the Contract unit rates of the respective items of the Bill of Quantities:

(i) Over breaks, beyond the pay line or Clearance line as shown on the drawings.

(ii) De-watering for lowering and control of water table, where not separately provided, to keep the foundations dry during construction.

(iii) Removal of additional material resulting from slides, slips, caving's, silting or filling whether due to the action of the natural elements or to carelessness of the Contractor.

(iv) Removal and disposal of trees less than 150mm girth, bushes, roots, stumps and other such items or organic matter or deteriorated soil.

(v) No separate payment shall be made for removal of trees, any work/time consumed for negotiations with owners or making necessary arrangements by any supervisory staff for supervising or expediting the work.

(vi) Timber shoring, planking, strutting for upholding the sides of excavations, and excavation beyond the vertical lines joining the surface to the widest part of the foundations shown on the Drawings.

(vii) Any fill with approved material necessitated by over excavation due to fault of or for the convenience of the Contractor.

(viii) Separation into different types and stockpiling of the excavated material at approved locations including spreading and leveling.

(ix) Excavation involved in providing more than 50 centimeters of working space around sides of structures, footings or foundations for Structural Excavation.

(x) Approved quality embankment fill/backfill material obtained from excavation, and used anywhere on the project, shall not be separately paid and shall be deemed to be included in the excavation items relating to the parts of the work where the material is used. Only dressing and compaction will be paid for, if approved.

(xi) Allowance for bulking, shrinkage and waste.

(xii) Temporary overfilling in order to achieve full compaction to the finished embankment profile.

(xiii) All laboratory and field tests stipulated in these specifications.

(xiv) Disposal of rejected, unsuitable and surplus excavated material, including haulage over any lead and lift.

(xv) Loading, dumping in designated areas and dressing of the dump areas.

(xvi) Temporary relocation/diversion of pipelines, watercourses, channels etc., and maintaining flows during construction, and rehabilitation thereof on completion of work, unless specifically provided for.

(xvii) All work necessary to maintain the excavation in good order during construction including moistening and proof rolling the surface for structures foundations.

3.2.7.2 Measurements

a) Site Clearing and Disposal of Unsuitable Material

Removal and disposal of all woody and other herbaceous vegetation, rubbish, unsuitable soils, and other objectionable materials from the construction site shall include excavation, hauling offsite and disposal at an approved disposal site to the satisfaction of Engineer / Engineer Representative. The unit price for this bid item shall also include the cost of temporary erosion and sedimentation control measures and will be measured for payment and the cost thereof will be considered as cost of this contract as per the bill of quantity.

Site clearing will be measured on the basis of square meter of area satisfactorily cleared as determined by joint survey and computed by an approved earthwork program.

b) Excavation for Structures

The volume of earth or rock to be measured for structural excavation shall consist of a prismoid bounded by the following planes:

(i) The vertical limits for computing pay quantities will be vertical planes 50 centimeters outside of the neat lines of footings or foundations as shown on the Drawings or as directed by the Engineer, except where the concrete abuts against the excavated rock surface.

(ii) The upper limit for payment of structural excavation shall be the ground surface as it existed prior to the start of construction operations, except where structural excavation is performed within roadway excavation or ditch excavation areas, in which case the upper limit shall be the planes of the bottom and side slopes of said excavation areas.

(iii) The lower limits for computing pay quantities of structural excavation or structure backfill shall be a plan at the bottom of the completed footings, foundation or structures.

(iv) The depth of the footings shown on the Drawings is approximate only and any variation found to be necessary for removal of unsuitable material during construction shall be paid for at the Contract unit price in the BOQ.

c) Excavation in Soil /Rock Not Requiring Blasting, in Dry Conditions

Before the start of work, the Contractor shall take joint cross sections with the Engineer's Representative of the natural surface levels, at not more than 10 meters intervals. The number of observations and the width of strip will depend on the topography, which shall be decided by the Engineer's staff at site and levels verified, agreed and recorded. The transverse and longitudinal profiles shall be plotted using AutoCAD Release 21 or later. The final section or the progress section/completed work for measurement shall also be plotted on the same section and will be checked by the Engineer's staff at site.

Excavation of materials shall be measured in cubic meters of the in-situ volume excavated to a depth (level) where further excavation by means of Dozers/Tractors of up to 150 BHP is not possible. Levels shall be taken at this depth and transmitted on cross-sections with the original agreed N.S.L.

Excavation for Spillway, Dam foundation trench, Intake structure etc shall be measured within the pay lines of the structures / trench prism, excavated to the satisfaction of the Engineer/Engineer Representative, and as shown on the Drawings.

d) Excavation in Soil /Rock Not Requiring Blasting, in Wet Conditions

Excavation in soil /rock not requiring blasting, in wet conditions, shall be measured in cubic meters from the depth at which water table is encountered to the finished grades, levels, dimensions as shown on the Drawings. The level at which water table is encountered shall be jointly taken, recorded and plotted. Variations in water table level will not be considered as grounds for additional compensation to the Contractor.

Excavation of materials shall be measured in cubic meters of the in-situ volume excavated from the water table depth to the finished grade and levels as shown on Drawings, or as directed by the Engineer/Engineer Representative.

e) Excavation in Rock (All Classes) Requiring Blasting, in Dry Conditions

The quantities for rock excavation to be measured for payment under the Contract will be limited to the lines shown on the Drawings. Excavation beyond the lines shown on approved profiles and cross-section will not be measured for payment. The Engineer/Engineer Representative will decide the angle of the slope of cuts as the work proceeds on the basis of his evaluation of the rock characteristics and, if necessary, revised Drawings shall be issued. However, any increase or decrease in quantities due to this revision shall not be made as a basis for claims or additional payment.

Excavation in rock (all classes) requiring blasting shall be measured in cubic meters from the depth at which further excavation with Dozers/Tractors of upto 150 BHP is not possible, to the finished grades, levels and dimensions as shown on the Drawings.

f) Excavation in Rock (All Classes) Requiring Blasting, in Wet Conditions

Excavation in rock (all classes) requiring blasting, in wet conditions, in tunnel structures and other locations shall be measured in cubic meters from the depth at which water table is encountered, to the finished grades, levels and dimensions as shown on the Drawings.

The level at which water table is encountered shall be jointly taken, recorded and plotted. Variations in water table level will not be considered as grounds for additional compensation to the Contractor.

The quantities in cubic meters of materials in-situ shall be computed by the end area method from the cross sections checked & verified by the Engineer/Engineer Representative to his satisfaction for all BOQ items mentioned hereinabove.

3.2.7.2 Payments

Payment against all sort of above-mentioned excavations shall be made for the number of cubic meters as measured above at the contract unit rate for the relevant items in the bill of quantities. The amount provided shall be full payment for the proper completion of the work and shall constitute full compensation for all the works to maintain the excavation in good order during construction and as described herein or shown on the drawings, including all costs of loading and disposal to any lead/lift, dressing of slopes, dewatering for control of water table, all as directed by the Engineer/Engineer Representative.

The extra costs for control of seepage water, dewatering and maintaining the stability of slopes shall be deemed to be included in the contract unit rates.

SS-12 **(a)** Clause 3.3.2 Construction of Embankments (Technical Specifications for Workmanship Page - 27)

Delete the clause completely.

(b) Clause 3.3.3 Compaction of Embankment (Technical Specifications for Workmanship Page - 28); Sub-clauses 3.3.3.1 and 3.3.3.1.1(Page-29)

Delete the main clause and sub-clauses completely, and replace with the followings:

3.3.2.1 Description

This work shall consist of construction of embankment, including furnishing of all tools, plant, labor, materials required, stripping of the borrow areas, excavating the material from the borrow areas, hauling and placing and/or the structural excavated materials from Cut-off trench, Spillway and Intake structure foundations etc. and/or materials obtained from excavation of diversion tunnel. This also includes preparation of area for placement of materials in specified layers including watering and mixing (or drying as the case may be), and mechanical compaction to specified density and moisture contents and all ancillary items required to prepare the embankment to the design elevations and limits, in accordance with the specifications and in conformity with the lines, grades, thickness and typical cross-section shown on the drawings or established by the Engineer/Engineer Representative.

In these specifications, the following terms and definitions are used: -

- **Embankment** is defined as the earth and rock fill portion of the dam structure and includes all types of earth and rock fill, filter / drain materials for the dam and cut-off trench, and all other specified or directed earth and rock fills within the limits of the dam, excepting those stone and filter materials used for slope protection.
- **Compacted Fill** includes all **Common fill**, ***except backfill and rock fill***, deposited in layers and compacted by rolling or tamping. This type of compacted earth fill includes all eolian, alluvial and residual materials like gravel, shale, volcanic ash, loess, dunes and, loams, sands and clays or any combination of these materials:

a. Impervious fill for the impervious section of the embankment like cut-off trench, horizontal and inclined impervious blankets;

b. Random fill where indicated on the plans;

c. Pervious fill forming the upstream and downstream sections of the embankment or where indicated on the plans, and

d. Filter drainage layers forming the horizontal, vertical or inclined pervious drainage blankets.

- **Uncompacted Fill** All fill, deposited in layers but not compacted except by the controlled movement of hauling and spreading equipment.

- **Backfill**, as used in these specifications, is defined as that **excavation refill** which cannot be placed around or adjacent to a structure until the structure is completed and reached a specified concrete strength, requires special compaction efforts, and is defined by limits indicated on the plans and specifications.

- **Filter Materials**, are defined as material used as drainage or transition zones between various types of earth fill including impervious, pervious, random, rock fill etc. and backfill.

- **Rock Fill**, are those portions of the embankment where rock is used as embankment fill.

- **Zone** is that part of dam embankment, the material for which has specified characteristics such as particle size, moisture contents, density and method of placing. Only that zone will be applicable which is mentioned in the drawing and BOQ of the project.

- **Unsatisfactory Materials**, those earth and earth mixtures that are unsatisfactory for use as earth fill and backfill. All topsoil, organics, roots and other organic matter, biodegradable materials, debris, trash, rubble and contaminated soil are unsatisfactory for use as embankment, backfill or engineered fills.

- **Unsatisfactory vs Satisfactory** The use of these terms in this section is in reference to the Contractual requirements. Satisfactory materials or processes are in full compliance with these specifications and unsatisfactory materials or processes are not in compliance with these specifications.

3.3.2.2 Material Requirements

Material for dam embankment shall consist of suitable material excavated from borrow, tunnel excavation or structural excavation and shall include all lead and lift. Borrow material will be used only when material obtained from tunnel or structural excavation is not suitable or is deficient for embankment formation and shall include all lead and lift.

Classification of soils shall be in accordance with **ASTM D2487-17** *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)*

Earth fill material for construction of the dam embankment shall be taken from the zones designated "proposed borrow areas", as shown on plan or as declared “suitable” by the Engineer’s representative following the requisite laboratory testing’s.

Materials containing brush, roots, sod, organics or other perishable materials will not be considered suitable. The suitability of the materials and their disposition in the embankment shall be as per direction of the Engineer / Engineer representative.

Contractor shall excavate in the borrow areas at the locations determined by the Engineer / Engineer representative, whenever such control is necessary to obtain the type of material required for the embankment.

Impervious Fill: Material for compacted impervious fill shall consist of clays (CH and CL), silts (ML), clayey sands or gravels (SC or GC), and silty clays (CL-ML) classified as cohesive materials, in accordance with ASTM D4318, ASTM C136/C136M and ASTM D1140 and shall be obtained from the designated borrow areas as approved by the Engineer / Engineer representative.

Increasing the fines content of a soil increases its imperviousness. In general, materials can be considered impervious if they have at least 15 to 25 percent passing the standard No. 200 sieve.

Random Fill: Provide material for compacted random fill consisting of any or all types of satisfactory material which are suitable for use in the dam embankment.

Pervious Fill: Material for compacted pervious fill shall consist of free draining silty sands or gravels (SM or GM) or other approved inert materials with similar characteristics, or a combination thereof, having clean, hard, strong, sound, durable, uncoated grains free from injurious amount of dust, lumps, soft or flaky particles, shale alkali, organic matter, or other deleterious substances.

Sands with borderline gradations classifying as SW-SM, SW-SC, SP-SM, or SP-SC, having as high as 12 percent passing the No. 200 sieve, generally have the characteristics of semipervious material, but may be used in embankment zones designated as pervious fill.

05 percent passing the No. 200 sieve is the usual upper limit for a material to be classified as pervious.

Filter Drainage Layers: Filter materials must meet the quality requirements of ASTM C33/C33M concrete aggregate derived from river deposits or equivalent crushed rock material source.

Filter materials must consist of sand, gravel, or crushed stone composed of tough, durable, angular particles; must be free from thin, flat and elongated pieces, and must contain no organic matter or soft, friable particles. The material must be washed with clean water such that the final product has no visible soil, soil slurry, or objectionable coatings.

Gradation of the material must be determined in accordance with ASTM D2487, ASTM D422, ASTM D1140, and ASTM D4318. All points on individual grading curves obtained from representative samples of filter material must lie between the boundary limits as defined by smooth curves drawn through the tabulated grading limits plotted on a mechanical analysis diagram. The individual grading curves within these limits must not exhibit abrupt changes in slope denoting skip grading, scalping of certain sizes or other irregularities which would be detrimental to the proper functioning of the filter.

The material shall not be gap graded, nor shall the ratio of its D_{60} size to its D_{10} be less than 4. Filter material shall, after compaction, have less than 5% passing the No.200 sieve and such a portion shall be non-cohesive.

Filter materials, after compaction, shall conform to the following grading limits.

Grading Limits mm	Percent by weight passing			
	Filter 1 F1	Filter 2 F2	Filter 3 F3	Filter 4 F4
400	-	-	-	100
150	-	-	-	40-75
100	-	-	85-100	20-50
70	-	-	95-72	5-25
30	-	100	45-70	0
10	-	71-95	6-30	-
5	100	56-80	0-11	-
2	85-100	30-54	-	-
1.18	76-100	11-35	-	-
0.600	60-84	0-15	-	-
0.425	47-70	-	-	-
0.300	34-58	-	-	-
0.150	6-30	-	-	-

Rock: Stone classed as "rock" must be sound; well graded and free draining. Material for rockfill embankment can be obtained from required tunnel and spillway excavations and from designated quarries, as approved by the Engineer/Engineer representative.

Gradation of rock for embankments is dependent on the rock quality, quarrying and handling procedures. The maximum lift thickness usually controls the maximum permissible size of the material.

Rock, which does not readily break down during handling, transportation, and compaction, results in a pervious to very pervious fill, depending on the amount of fines present. Such sound rock is desirable for rockfill dams.

Less desirable rocks break down in varying degrees during excavation, handling, compaction, and even in-situ. These unsound rocks may break down because of their lack of induration; their primary structure, such as thin bedding; their degree of fracturing; their weathering; and other physical and chemical properties. Unsound rocks like shales, mudstones, siltstones, clay stones, chalk, earthy limestones, decomposed granite's and poorly cemented, highly weathered and fractured sedimentary rocks are unsuitable for use as rock fill because of their susceptibility to break down and shall be wasted in designated spoil areas.

The most frequent problem occurs when the quarried material from tunnel and spillway excavations are blasted in a reckless manner leading to either more generation of quarry fines and dust, or more oversized material, than anticipated in the design. The Engineer/Engineer representative may make such major design changes because of different rock behavior or breakdown than that anticipated by the designers. The contractor's method statement for Engineer/Engineer representative approval of proposed drilling and blasting technique shall include trial for test excavation blasting to demonstrate that specified rockfill size's will be produced.

3.3.2.3 Construction Requirements

a) Preparation of Foundation / Surface of Earthwork Previously Laid

(i) Surface preparation of the dam foundation is a crucial prerequisite for making the surface suitable for placement of the overlying embankment and ensure satisfactory performance. Such preparation includes excavation, stripping to remove vegetation and other unsuitable material, cleanup, filling surface irregularities with slush grout or dental concrete and shaping the foundation surface with dental concrete or shotcrete on a limited basis and special earth fill compaction of the first several layers of earth fill placed at the foundation contact.

(ii) No earth and rock fill material shall be placed in any section of the dam until the foundation for that section has been dewatered and suitably prepared, treated and has been approved by the Engineer/Engineer representative.

(iii) All portion of excavation made for test pits and all other existing cavities found within the area to be covered by earth and rock fill, which extend below the established lines of excavation for dam embankment foundation, shall be filled with properly moistened compacted earth fill materials as specified herein according to the embankment zoning in which section such cavities and pits are located.

(iv) Earth abutment surfaces shall be free of loose, un-compacted earth in excess of 2 inches in depth normal to the slope and shall be at such a moisture content that the earth fill can be compacted against them to produce a good bond between the fill and the abutments.

(v) Rock foundation and abutment surfaces shall be cleared of all loose material by hand or other effective means and shall be free of standing water when fill is placed upon them.

(vi) Rock outcrops in earth foundations of dams and hydraulic structures designed to restrain the movement of water, shall require special treatment to avoid interference with the compaction of the foundation and initial layers of the earth fill or the bond between the foundation and the fill.

(vii) Large depressions or humps in rocky foundations caused by abrupt changes in levels shall be evened out to 1:5 slope. For better bondage with earth fill material the surface shall be roughened by shallow longitudinal trenches or corrugations cut in the rock. The rock surface including all pockets and depressions shall be carefully cleaned of soil and rock fragments before placing of the first layer. Dykes and seams of soft material shall be opened out, cleaned to the depth as directed and filled selected impervious material or as directed by the Engineer/Engineer representative. The Foundation surface shall be moistened but no standing water shall be permitted when the first layer is placed. The rock surface after moistening shall be given a soil slurry wash just immediately ahead of the placement of first layer of embankment.

(viii) Before placing embankment against rock abutments or sides of rock cutting, the same shall be trimmed to 0.5:1 slope, preferably 1:1 slope and be thoroughly washed with mud slurry and selected moist soil is placed against the same before being drying out. The moist soil laid against the rock surface shall be compacted in layers not exceeding twenty (20) cm in thickness to 97 percent of Max. dry density as per

ASTM D698 with moisture content ± 2 % of O.M.C by mechanical tampers, plate compactors or hand guided rollers.

(ix) The cost of operations involved in preparation of foundation surface shall be deemed to have been included in the rates of formation of dam embankment.

(x) Surface of Embankment fill previously laid in specified thickness, moistened and compacted shall be constantly observed for deterioration, rutting or wetting etc. before fresh layer is laid upon it. Over compacted portions of embankment formed due to constant construction traffic movement which are likely to separate from the layers below shall be entirely removed without any extra cost.

(xi) When smooth drum rollers are used for compaction, the surface of previously compacted layer shall be scarified or roughened before fresh layer is laid on it. When sheep foot rollers are used for compaction, fresh layer may be directly laid on the previously compacted layer unless the material in the surface is sufficiently wet due to overnight rain etc. The surface in that case shall be allowed to dry out till reached to O.M.C and then rolled again.

(xii) If in the opinion of Engineer/Engineer representative, the top or contact surfaces of the previously compacted section, exclusive of filter material and rock fill, become too dry to permit suitable bond with the succeeding lift, the Contractor shall be required to moisture condition the materials on the fill. The Contractor shall loosen the dried materials by scarifying or disking to such depths as may be directed by the Engineer/Engineer representative, dampen the loosened material to an acceptable moisture content, and compact to the density specified herein without any additional cost to the Procuring Entity.

(xiii) In order to prevent seepage transport of the impervious core and sand filter into the abutment rock, the rock surface should be covered with geo-membrane.

b) Selection of Borrow Material

To meet the requirements and conditions of the particular zone of embankment materials for incorporation in work, proper borrow areas shall be selected. Borrow material shall be obtained from the borrow areas, shown on drawings or selected by the contractor and approved by the Engineer/Engineer representative for material compliance with specification requirements.

Unless otherwise provided in the contract, the contractor is responsible for obtaining the right to procure material, pay royalties and other charges involved, and bear the expense of developing the sources, including rights-of-way for hauling from the owners.

Unless specifically provided, borrow within the limits of the project site shall not be acquired without prior written approval of the Engineer/Engineer representative. The Contractor shall be responsible for necessary clearing, grubbing, and satisfactory drainage of borrow pits and the disposal of debris thereon related operations to the borrow excavation.

No borrow-pits shall be excavated on or close to rail or road ways, village tracks, canals, level crossings or existing embankment and within 1 meter of the railway boundary. Borrow-pits shall not be located near residential and commercial areas but in case it is not avoidable their depth shall be limited and, where possible, arrangements shall be made to drain them. The sides of all such borrow-pits shall have a slope of 3:1. Any borrow-pit which does not confirm to these specifications shall be properly filled in with earth obtained from approved pits and consolidated and dressed correct as specified at the contractor’s expense.

c). Reference Pillar

Before commencing the placement of embankment materials, all lines marking the extremities of zones of shoulders, semi-impervious, impervious / core, filters drainage etc. of the embankment shall be marked with reference to “reference pillars”. The reference pillars shall be of concrete or masonry and the information indicating chainages, levels etc. shall be properly inscribed or written on them as directed by the Engineer/Engineer representative. The Contractor shall construct and maintain all reference pillars at no extra cost to the Procuring Entity.

d) Formation of Embankment with Common Material

(i) Laying and Spreading

Approved material free from clods, lumps, larger than 50mm size etc. shall be conveyed directly from the source of excavation or from temporary stock piles or approved borrows and laid in appropriate zones of embankment, as directed by the Engineer/Engineer representative, on the surface of foundation or previously laid earth work prepared as specified herein above.

The material shall then be spread on the embankment in uniform and continuous layers approximately horizontal and in conformity with the lines, grades, sections and dimensions shown on the drawings or as required by the Engineer/Engineer representative.

Except as otherwise directed by the Engineer/Engineer representative and as a result of trial sections prepared, demonstrated and approved, prior to commencement of embankment construction, the maximum loose thickness for materials of different zones shall be as follows:

Rock fill Material	60 cm to 90 cm (24~36 Inches)
Shells Material	30 cm (12-Inches)
Impervious Clay Core Material	15 cm (6-inches)
Coarse Filter Material	20 cm to 30 cm (8 ~12 inches)
Fine Filter Material	20 cm to 30 cm (8 ~12 inches)

Dump successive loads of material at locations on the fill as directed or approved.

Do not place fill material on any part of the embankment foundation until such areas have been inspected and approved by the Engineer/Engineer representative in writing. The gradation and distribution of materials throughout the compacted earth fill section of the dam must be such that the embankment will be free from lenses, pockets, streaks, and layers of material differing substantially in texture or gradation from surrounding material of the same classification.

Do not place fill material upon a frozen surface, nor shall snow, ice, or frozen earth be incorporated in the embankment. Fill shall not be placed on or against any dry surface, but against a surface that is moist or damp.

Remove all material that freezes or has been subjected to freeze-thaw action during the construction work, or during periods of temporary shutdowns, such as, but not limited to, nights, holidays, weekends, or winter shutdowns or earthwork operations, to a depth that is acceptable to the Engineer/Engineer representative and replace with new material.

Alternatively, the material must be thawed, dried, reworked, and re-compacted to the specified criteria before additional material is placed. The Engineer/Engineer representative is the sole authority to determine when will placement of fill must cease due to cold weather.

As soon as practicable after commencement of construction of any section of the embankment, raise or crown the central portion thereof with grades not to exceed 03 percent so that the surface of the fill will drain freely and maintain the cross-slope throughout the construction.

Filter material placement should lead the placement of adjacent materials to avoid contamination of the filter material.

Segregation controls of filter/drain material during the construction process have a significant bearing on the ultimate performance of the embankment dam.

Adoption of proper construction practices for storing, hauling, dumping, spreading, and compacting filter/drain materials can significantly reduce the amount of segregation

At all times during the dumping and spreading processes, a force of men should be maintained to remove all roots, debris and oversize stones from all embankment materials and dispose of in an approved manner. Maintain the entire surface of any section of the embankment under construction in such condition that construction equipment can travel on any part of any one section.

If, during or after placement, material in any zone has become contaminated with material from another zone or with topsoil or other objectionable 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 cost for construction of or placing and compaction of materials in the zone by reason of this requirement.

(ii) Moisture Content and Compaction

Impervious Clay Core & Pervious Shell Material

The material placed in layers and that scarified to the designated depth for formation of embankment shall be watered, brought to within **0% to + 2.0%** of their optimum moisture content and compacted to the **97 Percent of Maximum Dry Density (average density) as determined by ASTM D698 (**AASHTO T- 99**;** Method 'A' or 'C' whichever is applicable).

In-place density determinations of the compacted layers shall be made in accordance with ASTM D1556/D1556M (AASHTO T-191) or other standard methods as mentioned in these specifications and/or as approved by the Engineer/Engineer representative. For all soils, with the exception of rock fill materials, containing more than 10% oversize particles (retained on 3/4 inch/ 19 mm sieve), the in-place density thus obtained shall be adjusted to account for such oversize particles or as directed by the Engineer/Engineer representative. Subsequent layers shall not be placed and compacted unless the previous layer has been properly compacted and accepted by the Engineer/Engineer representative.

Test fill of 30.5 m (100 ft) minimum length shall be constructed for respective embankment zones for trial as directed by the Engineer/Engineer representative. The minimum compacted width shall be at least three rollers width and for two specified fill thicknesses. No separate payment will be made for these test fills, and if approved, will form part of permanent works.

Material for embankment at locations inaccessible to normal compacting equipment shall be placed in horizontal layers of loose material not more than 15 centimeters thick and compacted to the densities specified above by the use of mechanical tempers, or other appropriate equipment.

Embankment material that does not contain sufficient moisture to obtain the required compaction shall be given additional moisture by means of approved sprinklers and mixing. Material containing more than the optimum moisture may not, without written approval of the Engineer/Engineer representative, be incorporated in the embankment until it has been sufficiently dried out. The drying of wet material may be expedited by scarification, disking or other approved methods. The Contractor shall ensure that water being applied to adjust the moisture contents of material in any one zone does not drain off the surface on to another zone.

The work in various zones including the riprap and blanket shall as far as possible be raised simultaneously. If, however any zone or its part is permitted by the Engineer/Engineer representative to be raised higher than the part adjacent to it, the loose uncompacted material at the junction shall be removed or watered, brought to **0 to + 2.0%** of O.M.C and compacted to 97% of MDD (max) as described herein above, without extra cost to the Procuring Entity. A minimum slope of 1:2 should be provided at such junctions and the differential height between the two zones shall be no greater than 300 mm.

(iii) Moisture Content and Compaction

Filter and Transition Drainage Layers

Filter and drainage material placed in layers and scarified to the designated depth for formation of embankment shall be watered, and compacted to the relative densities of no less than 70 percent and no greater than 85 percent for fine filters.

Similarly, for Coarse filters and transition drainage layers other than rock materials shall be compacted to relative densities of 65% (minimum) & 80% (maximum) as determined by ASTM D4253 (Max Index Density) and D4254 (Min Index Density) or BS-1377. The ASTM D4253 and D4254 shall be used only for free-draining soils that contain less than 15 percent by weight passing the No. 200 sieve.

In-place density determinations of the compacted layers shall be made in accordance with ASTM D4914 or ASTM D5030 or as approved otherwise by the Engineer/Engineer representative.

If the pervious material is gravel, no water content control is necessary, and the material is compacted in its as-received condition. If the material is sand or contains a significant quantity of sand sizes, the material is maintained in a condition as saturated as possible during rolling by using water trucks with pressure spray bars, or other approved methods.

Pervious material containing appreciable quantity of fines (more than 5 to 10 percent passing the No. 200 sieve), may require the use of water content control to ensure that the water content is within a range that will permit desired compacted densities to be obtained.

Moistened sand tends to segregate significantly less during handling than dry sand. If the sand is completely dry in the stockpile, it shall be wetted prior to handling and placement.

Previously compacted filter lifts, should never be allowed to dry out in the sun. If a lift has dried, it must be rewetted and rolled again.

During construction of embankment, placement of filter or drainage materials should always be kept higher than adjacent fill containing fines (impervious & semi-impervious) to prevent spillage of fine-grained soil onto the pervious material and to reduce the possibility of washing fine-grained soils into the filter material by surface runoff.

A good indicator of excessive fines content (material passing the No. 200 sieve) is when the hauling and compacting equipment sink into the filter or drainage fill and cause ruts in the fill surface. This usually indicates that water applied during compaction is not draining through the material due to reduced permeability caused by excess fines content.

Filters/drains and transition zones shall never be compacted to an excessively high density. Very densely compacted sand with several passes of a heavy vibratory roller results in particle breakage of filter material thereby generate a thin layer of excessive fines at the lift surface. This has the effect of reducing vertical permeability, while at the same time reducing self-healing properties of the material.

The minimum relative density of 70 percent in filter drainage zones has been specified to reduce the potential for liquefaction during earthquake loading.

Contacts between the filter/drain and the adjacent impervious core materials shall be adequately compacted, to avoid an area of low shear strength and high compressibility along the contact surfaces.

Proper compaction of the contacts is accomplished by overlapping the smooth-drum vibratory roller (meant for compacting the filter / drain material) onto the adjacent impervious core for about 30 cm, rather than overlapping the tamping (sheep-foot) roller (meant for compacting the impervious core material) onto the filter/drain.

To facilitate compaction of contacts, all grade stakes used to mark zonal contacts prior to compaction shall be removed so that operators do not drive around the stakes.

Density testing shall be conducted at or near zonal boundaries to verify that adequate compaction is being achieved in these critical areas.

To avoid contamination of filter/drain zones with excess fines from flanking impervious fill zones during construction, the filter/drain zone should be maintained higher than the surrounding fill surface, and the surrounding impervious fill should be so placed to maintain drainage of surface water (and sediments) away from the filter/drain zones. This prevents the flow of muddy water into the filter or drain.

Traffic should be well controlled, with crossings limited to haul routes that will be removed entirely prior to placing of additional filter/drain materials. Crossings should be staggered to remove any possibility of vertical permeability of the filter/drain zone being reduced.

The sand filter and gravel drain material should be covered either with a geo-textile or steel plates to protect them from contamination during the crossing-over of the haul truck’s / compaction equipments etc. or placement of a “sacrificial pad” of drain material at each crossing. This sacrificial pad should be wide enough to accommodate equipment being used and should have a minimum thickness of 18 inches. When the crossing is no longer needed, the pad and drain material below the crossing are excavated, and the filter/drain are brought back to desired grade with clean, well-compacted filter/drain material.

Equipment for placement and compaction of filter/drain zones should be maintained clean and restricted to operation only on the filter/drain zones; additional equipment should be cleaned before moving onto the filter to avoid unnecessary cross contamination.

When the construction activities suspended due to adverse weather or other unforeseen events, the surface of the compacted filter/drain zones should be covered (in addition to surface drainage requirements) and removed completely before resuming placement activities.

Contamination of filter/drain materials occurs both in the stockpile and the loading, hauling, placing, and compaction processes. Improper control of material handling sometimes causes the gradation to be out of specification requirements.

Stockpiled materials can become contaminated by airborne dust and drainage runoff, resulting in an increased amount of fines in the material that can further reduce the filter permeability. Dust abatement procedures should be used to prevent contamination by fines into the stockpiled material.

Positive drainage should be maintained so that suspended sediment is not carried into the stockpile. A stockpile pad of concrete, geo-membrane should also be used to minimize contamination between the stockpile and ground surface.

c) Formation of Embankment with Rock Material

(i) Laying and Spreading

Materials that are hard, durable, well-resistant to weathering, wetting, excessive breakdown during excavations, loading, hauling, and placing operations shall be dumped and bulldozed in the upstream and downstream sections of the dam embankment.

Placement in lifts shall not be greater than 900 mm and to the lines and grades shown, or as staked in the field, and in such manner as to produce a reasonably well graded mass with no objectionable pockets of small stones or clusters of larger stones.

For central earth-core rock fill dams, the larger and stronger rock should be placed in the outer rock fill zones and grade from fine rock next to the filter to coarse rock near the outer slope.

When rock is dumped on the fill surface and pushed into place by a bulldozer, the fines are moved into the upper part of the lift, thereby creating a smoother working surface for the compacting equipment. If, however, a layer of fines is produced that is thick enough to choke the upper part of the lift and prevent distribution of the fines throughout the lift, then upon approval of the Engineer/Engineer representative the rock shall be dumped directly in place.

Prior to compaction, all oversized rock must be removed. This is usually done with bulldozers, crawler tractors fitted with special "rock rakes," or cranes. Oversized rocks shall be pushed into a specified zone in the outer slopes.

Excessively large rocks shall be removed from site or broken down with hydraulic chisels / breakers or explosives and used in the rock fill or riprap zone.

The rock material dumped and graded at site should not contain an excessive quantity of fines. An excessive quantity of fines will not produce free draining rock fill where it is desired and can cause excessive post construction settlements when the reservoir is filled.

QA / QC staff must be alert for material variations that could result in undesirable changes in gradation of the rock material being hauled to the embankment. If this occurs, the contractor should be notified, so that a change can be made in quarrying techniques.

A tolerance of plus 300 mm and minus 150 mm from the slope lines and grades shown will be allowed in the finished surfaces of the rock fills, except that the extreme minus tolerance must not be continuous over an area greater than 20 square meters.

All bridging in rock fills shall be broken as well as all slabs and slabby rock. Stone having a length to thickness ratio greater than 3:1 are considered flat, elongated, or flat and elongated and shall be rejected.

Special care shall be exercised in placing rock fill in all areas within one meter of structures to avoid damage to such structures.

Test fills and compression tests shall be demonstrated for approval of the Engineer/Engineer representative, to determine the desired lift thickness and compaction efforts for a specific maximum rock size, rollers type, tolerable settlements and seismic concerns etc.

(ii) Moisture Content and Compaction

Embankment with rock materials shall be compacted to relative densities of 70% (minimum) & 85% (maximum) as determined by ASTM D4253 (Max Index Density) and D4254 (Min Index Density) or BS-1377.

In-place density determinations of the compacted layers shall be made in accordance with ASTM D4914 or ASTM D5030 or as approved otherwise by the Engineer/Engineer representative.

No moisture control will be necessary on rock fills. However, the moisture content of the rock fill must be reasonably uniform throughout each layer of material placed prior to and during compaction. Add water in an amount equal to 15 percent of the volume of the fill to the material on the embankment prior to compaction by uniform spraying from a water truck. The required water amount may be modified based on the results of trial sections demonstration, as approved by the Engineer/Engineer representative.

Good compaction of rock fill materials not only minimizes total settlement but also minimizes differential settlements between zones that have significantly different consolidation characteristics.

The lift thickness specified is dependent on the size and type of rock and the type of compaction equipment to be used, and it is usually determined from results obtained during construction of a test fill section and approval of the Engineer/Engineer representative. The lift thickness specified herein shall be 60 cm, unless test fills show that adequate compaction can be obtained using thicker lifts.

Test trenches should be excavated through the completed test fill for visual observation of compacted lift thicknesses and distribution of fines, and to determine distribution of density. Test fill operations, including inspection of test trenches, should be thoroughly documented with measurements, photographs, and written results of visual observations.

The material shall be carefully placed in layers with maximum-sized rock should not exceed 67 percent of the lift thickness, all larger stones shall be well distributed and voids completely filled with smaller stones, clean small spells, shale, earth, sand, gravel, to form a solid mass. After placing rock material, surface shall be covered with a layer of fine material having thickness less than twenty (20) centimeters. Such fine material shall be reserved from tunnel and spillway excavation by the Contractor. Should such material be available but not reserved, Contractor will supply and place borrow material for forming smooth grade without extra payment.

Each layer shall be bladed or leveled with motor grader, bulldozer or similar equipment capable of shifting and forming the layer into a neat and orderly condition. No rock larger than eight (8) centimeters in any dimension shall be placed in the top fifteen (15) centimeters of embankment unless otherwise allowed by the Engineer/Engineer representative.

Material for each layer should be consolidated with heavy weight vibratory roller until settlement as checked between two consecutive passes of roller is less than one (1) percent of the layer thickness. In evaluation of settlement, survey points should be established and rolling continued until difference of levels as checked after two consecutive passes is less than one (1) percent of the total layer thickness. More-over initial rolling of overlaid fine material shall be done without watering to ensure their intrusion in voids of rock layer beneath. Watering shall be done when voids are properly filled.

If densification of a layer is determined from settlement readings, caution must be exercised to ensure that the settlement measured is, in fact, that of the layer in question and does not include settlement of the foundation or underlying layers. Survey equipment is required for this activity. Settlement in the foundation and within lifts can be determined from settlement plates.

Filed Compaction tests shall be conducted according to the specified testing frequencies and whenever the Engineer/Engineer representative determines they are feasible and necessary. Each layer must be approved by the Engineer/Engineer representative before the next layer is placed.

When rock to be incorporated in fill is composed largely of weak or friable material, the rock shall be reduced to a maximum size not exceeding fifty (50) percent of the thickness of the layer being placed. Unsound rocks can be efficiently incorporated in rock fill by first rolling the loose lift with a heavy tamping roller equipped with long spike or chisel-type teeth (shale breaker), and then compacting of the lift with conventional tamping or rubber-tired rollers.

Scarification of previously compacted lift surfaces is not necessary and should not be allowed because it disturbs the compacted mass.

In order to have unrestrained edges of the designed section of dam embankment be properly compacted, the section shall be widened by 50 cm on each side of U/s and D/s and extra material shall be deposited for this purpose at the section. The whole section shall then be compacted and then dressed / trimmed and brought to the required slope. Necessary extra quantity required to be handled for this purpose shall not be paid for and is deemed to be included in the rate of relevant item.

To avoid interference with the construction of spillway structure or instrument installation in different zones of embankment, the Contractor shall at points determined by the Engineer/Engineer representative, suspend work on embankments specific section without the risk of interference or damage to the spillway works or instruments. The cost of such suspension of work shall be included in the contract unit prices for dam embankment formation. Contractor shall make special arrangements to ensure proper compaction in restricted spaces and around structures and locations of instruments. No compensation shall be made to the Contractor for working in narrow or otherwise restricted areas.

The Contractor shall be responsible for the stability of dam embankment and shall replace any portions that in the opinion of the Engineer/Engineer representative have been damaged or displaced due to carelessness or neglect on the part of the Contractor. Dam embankment material which may be lost or displaced as a result of natural causes such as storms, cloud-burst or as a result of unavoidable movement or settlement of the ground or foundation upon which the embankment is constructed shall be replaced by the Contractor with acceptable material from excavation or borrow. No additional compensation will be allowed for this replacement.

SS-13 Clause 3.3.6.4 Borrow-Pits (Technical Specifications for Workmanship Page - 38)

Delete the whole clause.

SS-14 Clause 3.3.7 Measurements (Technical Specifications for Workmanship Page - 38), and Clause 3.3.8 Payments (Technical Specifications for Workmanship Page - 38).

Delete both clauses and replace with the followings:

3.3.7 Measurements

The quantities to be paid for shall be the number of cubic meters calculated on theoretical designed lines, grades, slopes and the ground levels, including the cut-off trench and accomplishment of foundation preparation, as established under “Surveying and Setting out” works of these specifications, compacted in place, accepted by the Engineer/Engineer representative, formed with materials resulting from excavations in tunnel, spillway, plunge pool etc and/or approved borrow sources.

3.3.8 Payments

a) Formation of Dam Embankment from Borrow Excavation.

The quantity to be paid for shall be the number of cubic meters placed in the dam embankment, measured as provided above for materials obtained from borrow excavations and such a payment shall be deemed to include full compensation for the cost of searching for and finding borrow pits, for acquiring the right to occupy the sites and extract the material, for the cost of any negotiations in connection with borrow pits, for the cost of obtaining right of access, for the cost of establishing and maintaining access, for clearing, grubbing, sloping, draining, and cleaning up of borrow pits, cost of excavation, payment of royalty, levies and taxes of local, provincial and federal government, cost of hauling including all lead and lift, spreading, watering, rolling, labor, equipment, tools, removing objectionable materials and all other incidental work required for the construction, protection, and maintenance of the dam embankment.

b) Formation of Dam Embankment from Tunnel, Spillway, Plunge pool etc. Excavation.

The quantity to be paid for shall be the number of cubic meters placed in embankment and measured as provided above for materials obtained from tunnel, spillway, plunge pool excavations etc and such payment shall be deemed to include cost of hauling, dumping, spreading, watering, rolling, labor, equipment, tools removing objectionable materials and all other incidental work required for the construction, protection, and maintenance of the dam embankment.

CHAPTER – 6 CEMENT CONCRETE

SS-15 Clause 6.1 General; sub-Clause 6.1.1 Description (Technical Specifications for Workmanship Page – 10 of 192).

Add the following paragraphs to this sub-clause:

Where the soil in contact with the concrete has sulphate content more than 0.1% or if the ground water has a sulphate content of more than 1500ppm, or if so indicated on the drawing or directed by the Engineer/Engineer representative, sulphate resisting cement shall be used.

The maximum chloride ion concentration (as a percentage of the weight of cement) arising from all sources including aggregates shall not exceed 0.1 for pre-stressed concrete,0.2 for any concrete using sulphate resisting cement and 0.35 for all other concrete containing metal reinforcement.

SS-16 Clause 6.1.3 Classes of Concrete; sub-Clause 6.1.3.1 Normal Weight Concrete (Technical Specifications for Workmanship Page – 164 of 192).

This sub-clause along-with Table # 1 - Classes of Concrete and their strength (Chapter 6) shall be read in conjunction with sub-para 16.5.1.1.1 – Classes of Concrete and Table # 57 - Portland Cement Concrete Requirements (Chapter 6).

SS-17 Clause 6.1.4 Materials; sub-clause 6.1.4.1 Cement (Technical Specifications for Workmanship Page – 65 of 192).

Add the following paragraphs to this sub-clause:

Cement shall be delivered in sufficient quantities to ensure that there is no suspension of the work of concreting at any time. Different brands of different types of cement from the same mill, or the same brand or type from different mills shall not be mixed or used alternately in the same time of construction unless authorized by the Engineer.

Ordinary Portland cement shall confirm to the requirements of the Standard Specification for Portland cement, ASTM Designation C-150 or Equivalent British-Adopted European Standard.

The type of cement to be used, unless otherwise shown on the drawings, shall be type-1.

Sulphate resisting cement shall be sulphate resisting cement type "A" fully confirming to Pakistan Standard Specification PS No.612 1989 and satisfying to requirements for fineness, chemical composition, strength, setting time, soundness etc. The average compressive strength of three concrete cubes, prepared, stored and tested as described in Appendix-G of PS: 232/1983(R) shall not be less than 2000 lbs / sq.in. (14 N / sq-mm) at seven days. The initial setting time shall not be less than 45 minutes and final setting time not more than 10 hours.

SS-18.1 Sub-Clause 6.1.4.3 Aggregates; para (iv) Grading (Technical Specifications for Workmanship Page – 66 of 192).

Delete the word " id " in the seventh line of this para and replace with " is ".

SS-18.2 Sub-Clause 6.1.4.3 Aggregates; para (v) Durability (Technical Specifications for Workmanship Page – 66 of 192).

Delete the word "grading" in the first line of this para and replace with "grinding".

SS-19 Sub-Clause 6.1.4.3 Aggregates; para (2) Test Requirements for Fine Aggregate (Technical Specifications for Workmanship Page – 67 of 192).

Delete the sentence "Test for Organic Impurities, AASHTO Than standard T-21" in the twenty-fifth line of this para and replace with "Test for Organic Impurities, AASHTO T-21".

SS-20 Sub-Clause 6.1.4.3 Aggregates; para (3) Test Requirements for Coarse Aggregates (Technical Specifications for Workmanship Page – 68 of 192).

- Delete the word "Table-2" in the seventh line of this para and replace with "Table-4".

- Add the following paragraph at the end of this para at Page - 69 of 192:

  No aggregate for testing during the production of concrete shall be sampled at the discharge gates of the bins feeding the weight hopper. The Contractor, at his expense, shall provide safe and suitable facilities for obtaining the samples. No concreting work on the project will be permitted until the Engineer/Engineer representative signifies in writing his approval, following the performance of the necessary tests, on all the materials involved in making concrete.

- Change the numbering of para “(4) Tests & Approval” to “ (i) Tests & Approval” at Page - 69 of 192:
- Change the numbering of para “(i) Combined Aggregate” to “ (ii) Combined Aggregate” at Page - 71 of 192:
- Shift the para “(ii) Combined Aggregate” at Page – 71 of 192, before the para “(4) Water**”.**
- Delete the whole sub-para’s (a) Potential Reactivity Tests; (b) Shrinkage; and (c) Reactivity; at Page – 72 of 192.

SS-21 Sub-Clause 6.1.4.3 Aggregates; para (4) Water (Technical Specifications for Workmanship Page – 71 of 192).

Table 6 – Water requirements (Chapter 6)

Delete the figure “1000” under the heading: Sulphates (Parts per million) both for Conventionally Reinforced and Pre-stressed Concrete and replace with “600”.

SS-22 Sub-Clause 6.1.4.5 Air-Entraining and Chemical Admixtures; para (3) (Technical Specifications for Workmanship Page – 73 of 192).

Delete the sentence “Admixtures in excess of 0.1% shall not be used” in the second line and replace with “Admixtures containing chloride ion (Cl) in excess of 0.1% by weight of the admixture shall not be used”.

SS-23 Sub-Clause 6.1.4.6 Mineral Admixtures (Technical Specifications for Workmanship Page – 73 of 192).

Add the following paragraph at the end of this sub-clause:

With prior approval of the Engineer/Engineer representative, the Contractor will be permitted to replace up to 20% of the required Portland cement with a mineral admixture, if the quantity of mineral admixture not specified. The weight of the mineral admixture used shall be equal to or greater than the weight of the Portland cement replaced. In calculating the water/cement ratio of the mix, the weight of the cement shall be considered to be the sum of the weights of the Portland cement and the mineral admixture.

SS-24 Sub-Clause’s 6.1.4.7 Steel and 6.1.4.8 Dry Ramming of Brick or Stone Ballast (Technical Specifications for Workmanship Page – 73 & 74 of 192).

Delete both the sub-clauses.

SS-25 Clause 6.2 Proportioning of Concrete; sub-clause 6.2.1.1 Mix Design - Responsibility and Criteria (Technical Specifications for Workmanship Page – 75 of 192).

Delete the word “finish able” in the third line of this sub-clause and replace with “finishable”.

SS-26 Clause 6.2 Proportioning of Concrete; sub-clause 6.2.1.3 Approval (Technical Specifications for Workmanship Page – 75 of 192).

Delete the text of this sub-clause and replace with the following:

The proportions by weight or volume of cement, fine aggregates, coarse aggregates and water necessary to produce concrete of the required strength and consistency shall be approved by the Engineer/Engineer representative. Mix design data provided to the Engineer/Engineer representative for each class of concrete required shall include the name, source, type, and brand of each of the materials proposed for use and the quantity to be used per cubic meter of concrete. Such approval may be withdrawn at any time, and changes in the proportions may be required for the purpose of required workability, density, impermeability, durability and strength.

Based on the approved mix proportions, the Contractor shall prepare lists showing the number of kilograms or cubic meters of the various materials to be used in the batch size adopted. The required consistency shall also be shown. Such lists are subject to approval by the Engineer/Engineer representative, and shall be posted at the mixer. The amount of water in the mix is the total amount of free water, including the free water held by the aggregates.

No concrete shall be placed in the works until the results of the twenty eight (28) days test indicate that the design proportions are satisfactory as per requirements under sub-clause 16.5.1.3.9 - Testing and Sampling; para-2 "Testing of Compressive Strength". Adjustment of the proportions shall be subject to the following provisions:

a) Adjustment for variation in workability - If it is found impossible to obtain concrete of the desired workability with the proportions originally approved, the Engineer/Engineer representative shall make such changes as are necessary.

b) Adjustment for new materials - No change in the source or character of the material shall be made without due notice to the Engineer/Engineer representative and no new materials shall be used until the Engineer/Engineer representative has accepted such materials and has approved new proportions based on trial mixes.

The Contractor's should be conscientious towards the time-line required to prepare and test trial batches and the Contractor shall be responsible for production of trial batches at a sufficiently early date so that the progress of the work is not delayed.

SS-27 Clause 6.2 Proportioning of Concrete; sub-clause’s 6.2.1.6 Mineral Admixture and 6.2.1.7 Air-Entering and Chemical Admixtures (Technical Specifications for Workmanship Page – 76 & 77 of 192).

Delete both the sub-clauses.

SS-28 Clause 6.2 Proportioning of Concrete; sub-clause 6.2.2 Water Cement Ratio Law (Technical Specifications for Workmanship Page – 77 of 192).

Delete this sub-clause completely, including the para's (i) Selection of Water-Cement Ratio; (ii) Consistency of Concrete; (iii) Unit Water Content.

SS-29 Clause 6.2 Proportioning of Concrete; sub-clause 6.2.3 Volumetric Proportions (Cement: Sand: Aggregate) (Technical Specifications for Workmanship Page – 78 & 79 of 192).

Delete this sub-clause completely.

SS-30 Clause 6.3 Manufacture of Concrete; sub-clause 6.3.4.2.1 Hand Mixing; Table 9, Approximate yield of concrete per bag of cement and volume of loose materials (Technical Specifications for Workmanship Page – 82 of 192).

Add the word "Cu.ft**."** after "Minimum size of mixer for 1- bag batch" in the header-row, column # 05.

SS-31 Clause 6.4 Protection of Concrete from Environmental Conditions; sub-clause 6.4.3 Hot and Weather Protection (Technical Specifications for Workmanship Page – 97 of 192).

- Delete the word "and" from the heading "Hot and Weather Protection".
- Delete the text of this sub-clause and replace with the following:

The temperature of concrete shall not exceed thirty-two (32) degree C at the time of laying, unless the Contractor incorporates in the mix a plasticizer, of a make and in proportion which he has shown by laboratory tests and full-scale trial to be satisfactory, to eliminate detrimental effects of high temperature without introducing any other detrimental effect on quality.

The following may be used to keep the temperature of concrete below the above limitations:

a) Chilling of concrete water by heat exchange coils or by addition of broken ice, provided that the water shall be free from ice at the time of entry into the mixer.

b) Cooling of coarse aggregate by watering, provided that the water content of the aggregate so cooled shall be uniform.

c) Reclaiming of aggregate from stock piles by the tunnel method to avoid using the surface layer of the stockpile with shade and wind protection of conveyor elevating to batching plant.

d) Night work concreting, provided that (a), (b) and (c) during day-times are proved inadequate or unsatisfactory in their results and providing also that the Engineer has no other reason for refusing permission for night work.

e) Painting the mixer drum white and spraying it with cool water or shading the mixer from direct sunrays.

f) Maintaining the mixing time and delivery time to the minimum acceptable.

g) Sprinkling of forms sub-grade and reinforcement with cool water prior to placement of concrete.

The Engineer/Engineer representative shall have power to order the suspension of concrete production in case of not taking precautionary measures by the Contractor as mentioned above. Under no circumstances will the Contractor be entitled to receive any additional payment for complying with the requirements of this clause.

SS-32 Clause 6.5 Form Work; sub-clause 6.5.2 Formwork Design; para 6.5.2.1 Choose a Formwork System (Technical Specifications for Workmanship Page – 103 & 104 of 192).

Delete the text from “For example .... construction cycle” in the first paragraph of this para and replace with the following:

1) Horizontal Formwork Systems

Horizontal formwork systems are used to temporarily support horizontal concrete work such as concrete slabs and beams. There are seven horizontal forming systems that can be used to support different slab types. They are:

a) conventional wood system (stick form),

b) conventional metal (aluminum) system (improved stick form),

c) flying formwork system,

d) column-mounted shoring system,

e) tunnel forming system,

f) joist-slab forming system, and

g) dome forming system.

Joist-slab and dome forms are steel or fiberglass pans usually placed above the plywood sheathing and thus can be used with any of the first five horizontal formwork systems.

Formwork systems for horizontal concrete work can be also classified into two main categories: hand-set systems and crane- set systems. Conventional wood systems and conventional metal systems are classified as hand-set systems. In hand-set systems, different formwork elements can be handled by one or two laborers. Flying formwork systems, column-mounted shoring systems, and tunnel formwork are classified under crane-set systems. In crane-set systems, adequate crane services must be available to handle formwork components.

Loading of horizontal formwork

Horizontal formwork is used for ceilings and beams. Horizontal formwork is subjects to vertical loads which are to be carried off to solid subsoils through formwork bearers and main bearers as well as columns.

Vertical loads are produced by

- the concrete mix weight in the specified height,
- reinforcements,
- concrete cones on the concrete pouring spot,
- concrete pouring impact on the formwork,
- persons and working tools, and
- dead load of the formwork.

In addition to vertical loads, there are also horizontal loads which are produced by:

- wind effects
- inclined position of columns,

The horizontal forces are taken up by auxiliary structures, such as braces and struts, or rigid connection to existing structural components, such as walls and columns.

2) Vertical Formwork Systems

Vertical formwork systems are those used to form the vertical supporting elements of the structure like strip foundations, concrete walls, columns, core walls, and shear walls. The functions of the vertical supporting systems are to transfer the floor loads to the foundation and to resist the lateral wind and earthquake loads. Consequently, the construction of vertical structural elements precedes flat horizontal work. Typical vertical formwork systems utilized in construction include conventional formwork, ganged forms, jump forms, slipforms, and self-raising forms.

Formwork systems for vertical concrete work can be classified into two main categories, namely, crane-dependent systems and crane-independent systems. Gang formwork and jump form are classified under crane-dependent systems. On the other hand, slipform and self-raising formwork are classified as crane independent systems in which formwork panels are moved vertically by other vertical transportation mechanisms.

The conventional wall system is the only hand-set system. The other four formwork systems are made of prefabricated modular panels before they can be transported by cranes or any other vertical transportation system.

Loading of vertical formwork

Immediately after placement in the formwork until achievement of its inherent stability, the concrete mix, under the effect of its own load and of compaction by vibration, exerts lateral pressure on the formwork which is called lateral pressure of the concrete mix.

The lateral pressure of the concrete mix depends on the following factors:

- Composition and properties of the concrete mix (density, type of cement, quality of concrete),
- concrete placing technology (concreting speed, compaction, vibration depth, total height of the concrete mix)
- ambient conditions (temperature, air humidity).

Tie wires (tie rods) are used to take up the lateral pressure of the concrete mix. They are to be included in the formwork project.

The maximum lateral load with external vibration occurs at the foot of the formwork and with internal vibration above the foot.

In addition to the lateral pressure of the concrete mix, the concrete mix also produces buoyant forces which may cause lifting of the formwork. This can be the case particularly with foundation formwork. To avoid this, the formwork is to be anchored in the subsoil.

SS-33 Clause 6.5 Form Work; sub-clause 6.5.7 Measurement and Payment (Technical Specifications for Workmanship Page – 107 of 192).

Delete the text of this sub-clause and replace with the following:

Unless otherwise specified, no separate measurement or payment shall be made for provision, erection and removal of “Formwork” as specified herein, as all costs thereof including false works, ties, cleaning, oiling, tools, equipment, replacement of defective/rejected forms, cost of material, energy and labor, being deemed to be included in the Contract unit rates for the various concrete items requiring formwork except formwork for mass concrete which shall be paid separately.

SS-35 Clause 6.6 Handling and Placing Concrete; sub-clause 6.6.2.3 Arches (Technical Specifications for Workmanship Page – 109 of 192).

Delete the text of this sub-clause and replace with the following:

The concrete in arch rings shall be placed in such a manner as to load the centering uniformly and symmetrically. Arch rings, shall be cast in transverse sections of such size that each section can be cast in a continuous operation. The arrangement of the sections and the sequence of placing shall be as approved by the Engineer and shall be such as to avoid the creation of initial stress in the reinforcement. The sections shall be bonded together by suitable keys or dowels. Arch barrels for culverts and unless prohibited by the special provisions, other arches rings may be cast in a single continuous operation.

SS-36 Clause 6.6 Handling and Placing Concrete; sub-clause 6.6.2.4 Precast Elements (Technical Specifications for Workmanship Page – 109 of 192).

Delete the word “Present” in the heading of this sub-clause and replace with “Precast”.

SS-37 Clause 6.6 Handling and Placing Concrete; sub-clause 6.6.4 Consolidation (Technical Specifications for Workmanship Page – 110 of 192).

Add the following para’s at the end of this sub-clause:

7. Concrete in walls, beams, columns, etc. shall be placed in horizontal layers not more than thirty (30) centimeters thick except as hereinafter provided. When less than a complete layer is placed in one operation, it shall be terminated in a vertical bulkhead.

8. Each layer shall be placed and compacted before the preceding layer has taken initial set to prevent injury to the green concrete and avoid surfaces of separation between the layers.

9. Each layer shall be compacted so as to avoid the formation of a construction joint with a preceding layer, which has not taken an initial set.

SS-38 Clause 6.6 Handling and Placing Concrete; sub-clause 6.6.5 Placing Concrete Underwater; (Technical Specifications for Workmanship Page – 110 to 112 of 192).

Delete the para's # 6.6.5.1 General, 6.6.5.2 Equipment & 6.6.5.3 Cleanup and replace with the followings:

Placing Concrete Underwater

Concrete shall not be placed under water except where inevitable in which case approval must be sought from the Engineer/Engineer representative and the work carried out under his immediate supervision. In this case the method of placing shall be as hereinafter specified.

Concrete deposited under water shall be class A concrete with a minimum cement content of three hundred fifty (350) Kg per cubic meter of concrete.

The slump of concrete shall be maintained between ten (10) and fifteen (15) cm. To prevent segregation, it shall be carefully placed in a compact mass, in its final position, by means of a tremie, a bottom-dump bucket, or other approved means, and it shall not be disturbed after being placed. Water must not be allowed to flow past the fresh concrete surface.

A tremie shall consist of a tube having a diameter of not less than 25 cm constructed in sections having flanged couplings fitted with gaskets with a hopper at the top. The tremie shall be supported so as to permit free movement of the discharge end over the entire top surface of the work and so as to permit rapid lowering when necessary to retard or stop the flow of concrete. The discharge end shall be closed at the start of work so as to prevent water entering the tube and shall be completely submerged in concrete at all times; the tremie tube shall be kept full to the bottom of the hopper. When a batch is dumped into the hopper, the flow of concrete shall be induced by slightly raising the discharge end, but always keeping it in the placed concrete. The flow shall be continuous until the work is completed.

When the concrete is placed with a bottom-dump bucket, the top of the bucket shall be open. The bottom doors shall open freely downward and outward when tripped. The bucket shall be completely filled and slowly lowered to avoid backwash. It shall not be dumped until it rests on the surface upon which the concrete is to be deposited and when discharged shall be withdrawn slowly until well above the concrete.

In order to dewater the cofferdam, the bottom must be stable and able to resist hydrostatic uplift. Placement of an underwater concrete seal course is the fastest and most common method.
Underwater concrete seal course shall be placed prior to dewatering in order to seal off the water, resist its pressure, and also to act as a slab to brace against the inward movement of the cofferdam walls / sheet piles in order to mobilize their resistance to uplift under the hydrostatic pressure.

Dewatering of cofferdam may proceed after test specimens, cured under similar conditions, indicate that the concrete has sufficient strength to resist the expected loads. All laitance or other unsatisfactory materials shall be removed from the exposed surface by scraping, chipping, or other means which will not injure the surface of the concrete before placing foundation concrete. When cofferdam struts prevent lateral movement of tremies, one tremie shall be used in each bay.

Concrete pumps used to place concrete under water shall include a device at the end of the discharge tube to seal out water while the tube is first being filled with concrete. Once the flow of concrete is started, the end of the discharge tube shall be kept full of concrete and below the surface of the deposited concrete until placement is completed.

SS-39 Clause 6.6 Handling and Placing Concrete; sub-clause 6.6.8 Compaction; para's # 6.6.8.1 Hand Compaction, 6.6.8.2 Compaction by Vibration & 6.6.8.2.1 Vibratory Equipment (Technical Specifications for Workmanship Page – 112 to 114 of 192).

Delete the sub-clause and para's completely.

SS-40 Clause 6.8 Construction Joints; sub-clause 6.8.3 Bonding and Doweling to Existing Structures (Technical Specifications for Workmanship Page – 115,116 of 192).

Delete the word "Hen" at the beginning of second paragraph in fourteenth line and replace with "When".

SS-41 Clause 6.9 Contraction & Expansion Joints; sub-clause 6.9.2 Material; para 6.9.2.4 Pourable Joint Sealants; sub-para (3) (Technical Specifications for Workmanship Page – 117 of 192).

Delete the word "which one will be mentioned in BOQ" in the first line of the sub-para.

SS-42 Clause 6.9 Contraction & Expansion Joints; sub-clause 6.9.2 Material; para 6.9.2.5 Metal Armor (Technical Specifications for Workmanship Page – 117 of 192).

Delete the sentence "Chapter of Structure Steel" in the second line of the para and replace with the following:

AASHTO M-160 and shall be hot zinc sprayed (galvanized) with the exception of the nuts and washers which shall be in stainless steel.

SS-43 Clause 6.9 Contraction & Expansion Joints; sub-clause 6.9.2 Material; para 6.9.2.6 Water stops (Technical Specifications for Workmanship Page – 118 of 192).

Add the following paragraph's at the end of this para.

Water-stops shall be furnished and installed in accordance with the details shown on the Drawings or where required by the Engineer/Engineer representative and in accordance with the provisions in these specifications.

Water-stops shall be furnished in full length for each straight portion of the joint, without field splices. Manufacturer's shop splices shall be fully vulcanized.

Reinforcing bars provided to support the water-stops shown on the Drawings or as required by the Engineer/Engineer representative shall be securely held in position by the use of spacers, supporting wires, or other approved devices. Such reinforcing bars shall be considered, for payment purposes, as a part of the water-stop. If, after placing concrete, water-stops are materially out of position or shape, the surrounding concrete shall be removed, the water-stop reset, and the concrete replaced, all at the Contractor's expense.

Field splices for neoprene water-stops shall be either vulcanized, or mechanical, using stainless steel parts, or made with a splicing union of the same stock as the water-stop, at the option of the Contractor. All finished splices shall have a full-size tensile strength of eighteen (18) kg per cm of width.

Field splices for polyvinyl chloride water-stops shall be performed by heat sealing the adjacent surfaces in accordance with the manufacturer's recommendations. A thermostatically controlled electric source of heat shall be used to make all splices. The heat shall be sufficient to melt but not char the plastic.

Water-stops when being installed shall be cut and spliced at changes in direction as may be necessary to avoid buckling or distortion of the web or flange.

SS-44 Clause 6.10 Curing Concrete (Technical Specifications for Workmanship Page – 120 of 192).

Delete the text of this clause and replace with the following:
All newly placed concrete shall be cured so as to prevent loss of water by use of one or more of the methods specified herein. Curing shall commence immediately after the free water has left the surface and finishing operations are completed. If the surface of the concrete begins to dry before the selected cure method can be applied, the surface of the concrete shall be kept moist by a fog spray applied so as not to damage the surface.

Curing plays an important role on strength development and durability of concrete. Curing involves maintenance of desired moisture and temperature conditions, both at depth and near the surface, for extended periods of time. Properly cured concrete has an adequate amount of moisture for continued hydration and development of strength, volume stability, resistance to freezing and thawing, and abrasion and scaling resistance.

The length of adequate curing time is dependent on the following factors:

- Mixture proportions
- Specified strength
- Size and shape of concrete member
- Ambient weather conditions
- Future exposure conditions

Slabs on ground (e.g., pavements, sidewalks, parking lots, driveways, floors, canal linings) and structural concrete (e.g., bridge decks, piers, columns, beams, slabs, small footings, cast-in-place walls, retaining walls) require a minimum curing period of seven days for ambient temperatures above 40 degrees Fahrenheit

SS-45 Clause 6.10 Curing Concrete; sub-clause 6.10.2 Period of Curing (Technical Specifications for Workmanship Page – 120 of 192).

Delete the text of this sub-clause and replace with the following:

American Concrete Institute (ACI) Committee 301 recommends a minimum curing period corresponding to concrete attaining 70 percent of the specified compressive strength. The often specified seven-day curing commonly corresponds to approximately 70 percent of the specified compressive strengths. The 70 percent strength level can be reached sooner when concrete cures at higher temperatures or when certain cement/admixture combinations are used. Higher curing temperatures promote an early strength gain in concrete but may decrease its 28-day strength. Similarly, longer time may be needed for different material combinations and/or lower curing temperatures. For this reason, ACI Committee 308 recommends the following minimum curing periods:

- ASTM C 150 Type I cement seven days
- ASTM C 150 Type II cement ten days
- ASTM C 150 Type III cement three days
- ASTM C 150 Type IV or V cement 14 days
- ASTM C 595, C 845, C 1157 cements variable

SS-46 Clause 6.10 Curing Concrete; sub-clause 6.10.6 Wet Coverings (Technical Specifications for Workmanship Page – 121 of 192).

Add the following sub-clauses after the sub-clause 6.10.6 Wet Coverings.

6.10.7 Curing Compound Method

Surfaces exposed to the air may be cured by the application of an impervious membrane if approved by the Engineer/Engineer representative.

The membrane-forming compound used shall consist of a practically colorless liquid. The use of any membrane forming compound that will alter the natural color of the concrete or impart a slippery surface to any wearing surface shall be prohibited. The compound shall be applied with a pressure spray in such a manner as to cover the entire concrete surface with a uniform film, and shall be of such character that it will harden within 30 minutes after application. The amount of compound applied shall be ample to seal the surface of the concrete thoroughly. Power operated spraying equipment shall be equipped with an operational pressure gauge and means of controlling the pressure.

The curing compound shall be applied to the concrete following the surface finishing operation immediately after the moisture sheen begins to disappear from the surface, but before any drying shrinkage or craze cracks begin to appear. In the event of any delay in the application of curing compound, which results in any drying or cracking of the surface, application of water with an atomizing nozzle as specified above shall be started immediately and shall be continued until application of the compound which shall not be applied over any free-standing water surface. Should the film of compound be damaged from any cause before the expiration of seven (7) days after the concrete is placed in the case of structures, the damaged portion shall be repaired immediately with additional compound.

Curing compounds shall not hard settle in storage. They shall not be diluted or altered in any manner after manufacture. At the time of use, the compound shall be in a thoroughly mixed condition. If the compound has not been used within one hundred twenty (120) days after the date of manufacture, the Engineer/Engineer representative may require additional testing before use to determine compliance to requirements.

An anti-settling agent or combination of anti-settling agents shall be incorporated in the curing compound to prevent caking.

The curing compound shall be packaged in clean barrels or steel containers or shall be supplied from a suitable storage tank located at the job-site. On-site storage tanks shall have a permanent system designed to completely re-disperse any settled material without introducing air or any other foreign substance. Containers shall be well sealed with ring seals and lug type crimp lids. The linings of the containers shall be of a character that will resist the solvent of the curing compound. Each container shall be labeled with the manufacturer's name, specification number, batch number, number of gallons, and date of manufacture, and shall have a label warning concerning flammability. The label shall also warn that the curing compound shall be well stirred before use. When the curing compound is shipped in tanks or tank trucks, a shipping invoice shall accompany each load. The invoice shall contain the same information as that required herein for container labels.

Curing compound may be sampled by the Engineer/Engineer representative at the source of supply and at the job-site.

The compound shall be completely compatible with adhesives, joint sealants and cement grout.

6.10.8 Reinforced Waterproof Paper Method

The exposed finished surfaces of concrete shall be sprayed with water, using a nozzle that so atomizes the flow that a mist and not a spray is formed, until the concrete has set, after which the waterproof paper shall be placed. The paper shall remain in place for a period of not less than 72 hours.

Reinforced waterproof paper shall comply with ASTM C 171 specifications. It shall be composed of two sheets of Kraft paper cemented together with a bituminous adhesive and reinforced with fiber. The waterproof paper shall be formed into sheets of such width as to provide a complete cover of entire concrete surface.

All joints in the sheets shall be securely cemented together in such a manner as to provide a waterproof joint. The joint seams shall have minimum lap of ten (10) cm.

The sheets shall be securely weighted down by placing a bank of earth on the edges of the sheets or by other means satisfactory to the Engineer/Engineer representative.

Should any portion of the sheets be broken or damaged within seventy-two (72) hours after being placed, the broken or damaged portions shall be immediately repaired with new sheets properly cemented into place.

Sections of sheets, which have lost their waterproof qualities or have been damaged to such an extent as to render them unfit for curing the concrete, shall not be used.

6.10.9 Forms-in-Place Method

Formed surfaces of concrete may be cured by retaining the forms-in-place. The forms shall remain in place for a minimum period of seven (7) days after the concrete has been placed, except that for members over five (5) cm's in least dimension, the forms shall be in place for a minimum period of five (5) days. Wooden forms shall be kept wet by watering during the curing period.

6.10.10 Steam Method

After placing and vibrating, the concrete shall be allowed to attain its initial set before steam is applied. During the placing of concrete and application of steam, provision shall be made to prevent surface drying by means of a coating of approved material.

Live steam at atmospheric pressure and high-pressure steam in autoclaves are the two methods of steam curing. Steam temperature for live steam at atmospheric pressure should be kept at about 140 degrees Fahrenheit or less until the desired concrete strength is achieved.

6.10.11 Heating Coils

Heating coils are usually used as embedded elements near the surface of concrete elements. Their purpose is to protect concrete from freezing during cold weather concreting.

In cold weather, some of the procedures include heated enclosures, evaporation reducers, curing compounds, and insulating blankets. The temperature of fresh concrete shall be above 50 degrees Fahrenheit (10° C). The curing period for cold weather concrete is longer than the standard period due to reduced rate of strength gain. Compressive strength of concrete cured and maintained at 50 degrees Fahrenheit (10° C) normally gain strength half as quickly as concrete cured at 73 degrees Fahrenheit (23° C).

6.10.12 Polyethylene Sheeting Method

The wet surface of fresh concrete shall be covered with white polyethylene sheeting as soon as possible without marring the surface and should cover all exposed surfaces of the concrete. The edges of the sheeting shall be weighted securely with a continuous windrow of earth or any other means satisfactory to the Engineer/Engineer representative to provide an air-tight cover. Adjoining sheets shall overlap not less than thirty (30) cms. and the laps shall be securely weighted with earth, or any other means satisfactory to the Engineer/Engineer representative to provide an air-tight cover.

SS-47 Clause 6.11 Finishing Concrete Surfaces (Technical Specifications for Workmanship Page – 122 of 192).

Amend the title of this clause, from "Finishing Concrete Surfaces", to read "**Finishing Plastic Concrete**".

SS-48 Clause 6.11 **Finishing Plastic Concrete;** sub-clause 6.11.1 General; para's (1) To (4) (Technical Specifications for Workmanship Page – 122 of 192).

Delete all the four para's.

SS-49 Clause 6.11 **Finishing Plastic Concrete;** sub-clause 6.11.2.1 Straight Edging (Technical Specifications for Workmanship Page – 122 of 192).

Amend the title of this sub-clause, from “Straight Edging”, to read “**Striking off, Floating and Straight-edging**”.

SS-50 Clause 6.11 **Finishing Plastic Concrete;** sub-clause 6.11.2.1 **Striking off, Floating and Straight-edging**; para (1) (Technical Specifications for Workmanship Page – 122 of 192).

Delete the text “Heading 6.7” in the first line and replace with “Clause 6.6 Handling and Placing Concrete”.

SS-51 Clause 6.11 **Finishing Plastic Concrete;** sub-clause 6.11.4 Finishing Formed Concrete Surfaces (Technical Specifications for Workmanship Page – 124 of 192).

Add the following paragraph before para 6.11.4.1 “Class -1 Ordinary Surface Finish”.

Surface finishes for formed concrete surfaces shall be classified as follows: -

Class 1 Ordinary Surface Finish
Class 2 Rubbed Finish
Class 3 Tooled Finish
Class 4 Sandblast Finish
Class 5 Wire Brush, or Scrubbed Finish

All concrete shall be given a class 1, Ordinary Surface Finish, and in addition if further finishing is required, such other type of finish as is specified.

If not otherwise specified, exposed surfaces except the soffits of superstructures and the interior faces and bottoms of concrete girders shall also be given a class 2, Rubbed Finish.

Class 3, 4, or 5 type surface finishes shall be applied only where shown on the plans or specified.

SS-52 Clause 6.11 **Finishing Plastic Concrete;** sub-clause 6.11.4 Finishing Formed Concrete Surfaces; para 6.11.4.1 Class -1 Ordinary Surface Finish; sub-para (3) (Technical Specifications for Workmanship Page – 124 of 192).

Delete the text “as specified under Heading 6.11.4” in the Eighth line of this sub-para and replace with “as specified herein”.

SS-53 Clause 6.13 Molded Cement Concrete Article**;** sub-clause’s 6.13.6 Measurement and Payment and 6.13.7 Rate (Technical Specifications for Workmanship Page – 131 & 132 of 192).

Delete both the sub-clause’s and refer to succeeding clause “6.16 Measurement and Rate”.

SS-54 Clause 6.14 Mortar and Grout**;** sub-clause 6.14.2 Materials and Mixing (Technical Specifications for Workmanship Page – 133 of 192).

- Delete the word’s “Article 20.3” in the first line of para (1) and replace with “Clause 6.1.4 Materials”.
- Delete the word “expensive” in the second line of para (4) and replace with “expansive”.

SS-55 Clause 6.14 Mortar and Grout**;** sub-clause 6.14.3 Placing and Curing (Technical Specifications for Workmanship Page – 133 of 192).

- Delete the word “and” between the word’s “bond” and “the concrete surfaces” in the second line of para (1) and replace with the word “with”.

- Delete the word’s “Heading 6.12” in the fourth line of para (2) and replace with “Clause 6.10 Curing Concrete”.

SS-56 Clause 6.15 Application of Loads**;** sub-clause 6.15.3 Construction Loads (Technical Specifications for Workmanship Page – 134 of 192).

Delete the symbol “(**f’**)”in the fourth line of para (3) and replace with the symbol “(**f_c’**)”.

SS-57 Clause 6.16 Measurement and Rate (Technical Specifications for Workmanship Page – 135 of 192).

Amend the title of this clause and replace the word “Rate” with “**Payment**”.

SS-58 Clause 6.16 **Measurement and Payment;** sub-clause 6.16.1 Measurement (Technical Specifications for Workmanship Page – 135 of 192).

Delete the text of para (3) of this sub-clause and replace with the following:

Deductions from the theoretical volume of concrete shall be made for the volumes of draining holes, weep holes, pipes and conduits, etc., in case where their cross-sectional areas exceed 232 square centimeters.

The measurement shall not include any concrete used in the construction of falsework.

The volume involved in fillets, scorings, or chamfers ten square centimeters in cross-sectional area or less shall be disregarded when measuring the quantity of concrete to be paid for.

Deductions for other embedded materials including reinforcing, structural and prestressing steel, expansion joint filler material, water stops and deck drains shall not be made.

SS-59 Clause 6.16 **Measurement and Payment;** sub-clause 6.16.2 Rate (Technical Specifications for Workmanship Page – 135 of 192).

Amend the title of this clause and replace the word “Rate” with “**Payment**”.

SS-60 Clause 6.16 **Measurement and Payment;** sub-clause 6.16.2 **Payment** (Technical Specifications for Workmanship Page – 135 of 192).

Delete the text of this sub-clause and replace with the following:

Payment

The accepted quantity measured as provided above shall be paid for at the contract unit price respectively for the pay items listed in the Bill of Quantities which prices and payment shall be full compensation for such works, as the cost of cement, sand, aggregate, water, mixing, placing, vibrating, curing, preparing, surface finishing and/or rendering as required, formation of construction joints , assembling and removing form, testing of concrete and all other operations, procedures and incidentals necessary to finish the concrete in accordance with these specifications.

For all concrete structures or portions, thereof, no separate measurement or payment shall be made for false work, centering, formwork or any other temporary work to complete the concrete structure or portion thereof, payment for all such temporary works shall be deemed to be included in the contract price paid under various items of concrete work.

SS-61 Clause 6.17 Reinforced and Pre-stressed Cement Concrete**;** sub-clause 6.17.2 Construction Requirements; para 6.17.2.1 General (Technical Specifications for Workmanship Page – 138 of 192).

Delete the text of this para and replace with the following:

Unless otherwise ordered by the Engineer/Engineer representative, the Contractor shall certify for approval of the Engineer/Engineer representative, to sublet the pre-stressing / post-tensioning work to an approved specialized firm.

The firm experience certificates for similar projects including list of qualified technicians for completion of pre-stressing operations, equipment's for jacking, calibration certificates for equipment's to be used and methodology to be adopted, for early completion of the work etc. shall be submitted for prior approval of the Engineer/Engineer representative.

The tensioning process shall be conducted so that the tension being supplied and the elongation may be measured at all times.

During the prestressing operations, standing behind or under jack will not be allowed in order to ensure that no one is injured by the flying spindle, tendon or the jack in the event of a break occurring.

SS-62 Clause 6.17 Reinforced and Pre-stressed Cement Concrete**;** sub-clause 6.17.2 Construction Requirements; para's 6.17.2.2 Size of Aggregates & 6.17.2.3 Reinforcement; sub-para 6.17.2.3.1 Placing Reinforcement (Technical Specifications for Workmanship Page – 138 to 140 of 192).

Delete the para's 6.17.2.2 & 6.17.2.3 and sub-para 6.17.2.3.1 completely, as the same have been addressed in the relevant sections of succeeding **Clause 6.19 - Reinforcement.**

SS-63 Clause 6.17 Reinforced and Pre-stressed Cement Concrete**;** sub-clause 6.17.2 Construction Requirements; para 6.17.2.8 Depositing Concrete in Forms (Technical Specifications for Workmanship Page – 142 of 192).

Delete the text of this para and replace with the following:

Concrete shall be controlled, mixed, and handled as specified in other articles of this section unless otherwise specified herein.

Concrete shall not be poured in the forms until the Engineer/Engineer representative has inspected the placing of the reinforcement, conduits, anchorages, and prestressing steel and has given his approval thereof.

The concrete shall be vibrated internally or externally, or both, as ordered by the Engineer/Engineer representative. The vibrating shall be done with care in such a manner as to avoid displacement of reinforcement, conduits, or wires.

SS-64 Clause 6.17 Reinforced and Pre-stressed Cement Concrete**;** sub-clause 6.17.2 Construction Requirements; para 6.17.2.10 Post Tensioning (Technical Specifications for Workmanship Page – 143 of 192).

Delete the friction loss formula and replace with the following:

$$F_t = 2(F_1 - \underline{a\ c\ E})$$

d

Where

F_t = total friction loss

F_1 = Observed tension at the jack

a = cross-sectional area of the prestressing element.

c = observed elongation of the element when the force at the jack is F_1.

E = secant modules of elasticity of the element for the stress F_1 as determined from the stress-strain diagram of the element.

d = distance from the jack to the point of lowest tension in the element. Where jacking is done from both ends of the members, the point of minimum tension is the center of the member. Where jacking is done from one end only, d is the distance to the other end of the member.

SS-65 Clause 6.17 Reinforced and Pre-stressed Cement Concrete**;** sub-clause 6.17.2 Construction Requirements; para 6.17.2.10 Post Tensioning (Technical Specifications for Workmanship Page – 143 of 192).

Delete the last sentence "After cutting .... (4000 Psi)" of the para and replace with the following:

"After cutting surplus length of cables, recess will be filled by concrete type- Y, as specified in Table 1, Classes of Concrete and their strength (Chapter 6)".

SS-66 Clause 6.17 Reinforced and Pre-stressed Cement Concrete**;** sub-clause 6.17.2 Construction Requirements; para 6.17.2.11 Grouting of Bonded Steel; sub-para (6) Grouting Operation (Technical Specifications for Workmanship Page – 145 of 192).

Delete the figures “10.6 & 10.9 “in the first line and replace with “10.9 & 10.11”.

SS-67 Clause 6.17 Reinforced and Pre-stressed Cement Concrete**;** sub-clause 6.17.3 Measurement and Payment; para’s 6.17.3.1 Composite Rates and 6.17.3.2 Labor rates (Technical Specifications for Workmanship Page – 147 of 192).

Delete the title and text of both para’s and replace with the following:

6.17.3.1 Measurement

Measurement and payments for the various items of prestressing precast concrete members shall be made in accordance with appropriate items of relevant sections, as depicted in the drawings, specified BOQ items supplemented by **MRS-2022 Schedule of rates** and shall constitute full compensation, for procurement, transportation, performance in all respects and completion of work as specified including the site clearance as approved by the Engineer.

6.17.3.2 Payment

Precast Prestressed Concrete Member

The quantity to be paid for shall be the number of prestressed concrete structural members of the several types and sizes, constructed and installed in place, as per drawings completed and accepted. Each member shall include the concrete, reinforcement and prestressing steel, enclosures for prestressing steel, anchorage, plates, nuts, formwork, shuttering and centering if required, and other such material contained within or attached to the unit.

Cast-in-Place Prestressed Concrete

The work to be paid for under this item will be only the prestressing work and shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals, and for doing all work involved in supply , installation of prestressing steel, spacers, enclosures, anchorages plates, nuts, incidental parts deemed necessary to complete the work and tensioning of the prestressing steel in cast-in-place concrete structures, as shown on the plans, as specified in these Specifications and as directed by the Engineer/Engineer representative.

Concrete and steel reinforcement including falsework, and formwork will be measured and paid for according to specified BOQ item of Section **6.0 – Cement Concrete and 6.19 – Reinforcement** respectively.

Full compensation for furnishing and placing of any additional concrete and deformed bar reinforcing steel required by the particular system used and for furnishing samples for testing, working drawings, and for pressure grouting ducts shall be considered as included in the contract price for furnishing precast prestressed members, and no additional compensation will be allowed therefore.

SS-68 Clause 6.19 Reinforcement**;** sub-clause 6.19.2 Materials, Table 22 (Technical Specifications for Workmanship Page – 150 & 151 of 192).

- Delete the Last Row of Table 22, intended for Bar Designation No 20 [64].
- Add the following footnotes to Table 22.
  - ✓ [A] The nominal dimensions of a deformed bar are equivalent to those of a plain round bar having the same weight [mass] per foot [meter] as the deformed bar.
  - ✓ Deformations means transverse protrusions on a deformed bar.
  - ✓ Rib means longitudinal protrusions on a deformed bar.

SS-69 Clause 6.19 Reinforcement**;** sub-clause 6.19.5 Handling, Storage, Surface Condition and testing of Reinforcement; para 6.19.5.1 Deformation Requirement (Technical Specifications for Workmanship Page – 152 of 192).

Delete the word “table – 17” in the first line and replace with “table – 22”.

SS-70 Clause 6.19 Reinforcement**;** sub-clause 6.19.5 Handling, Storage, Surface Condition and testing of Reinforcement; para 6.19.5.2 Tensile Requirement (Technical Specifications for Workmanship Page – 152 of 192).

Delete the word “Table – 18” wherever appears in the sub-para’s and replace with “Table – 23”.

SS-71 Clause 6.19 Reinforcement**;** sub-clause 6.19.5 Handling, Storage, Surface Condition and testing of Reinforcement; para 6.19.5.3 Bending Requirement (Technical Specifications for Workmanship Page – 153 of 192).

- Delete the word “Table –” in the third line of sub-para (1) and replace with “Table – 24”.
- Delete the text “prescribed in 6.19.5.3(2)” in the last line of sub-para (6) and replace with “prescribed in sub-para’s (2) to (5) above”.

SS-72 Clause 6.19 Reinforcement**;** sub-clause 6.19.6 Placing and Fasting; para 6.19.6.1 General (Technical Specifications for Workmanship Page – 154 of 192).

Delete the text of this para and replace with the following:

The number, size, length, form and position of all bars, links, stirrups, distance pieces and other member of the steel reinforcement shall be in exact accordance with the working drawings. The contractor shall take particular care that the reinforcement is laid out correctly in every respect and temporarily suspended by annealed wire or supported on small tapered concrete blocks in the forms to prevent displacement before or during the placing and consolidation of concrete.

Pieces of steel or wood shall not be used on the bottom boards or against the sides of molds for this purpose. Stirrups and distance pieces shall be kept tight to the bars they embrace or support. Stirrups shall be kept away from the face of the concrete at the distance shown on the working drawings.

Binding wire for steel reinforcement shall be soft annealed wire of No. 16 gauge and lashings. It shall be considered enough to secure the bars in position.

After reinforcement has been placed and fixed in the correct position, no concreting shall be done unless the Engineer has inspected and approved it.

SS-73 Clause 6.19 Reinforcement**;** sub-clause 6.19.6 Placing and Fasting; para 6.19.6.3 Pre-Cast Concrete Blocks (Technical Specifications for Workmanship Page – 154 of 192).

- Delete the word “blocs” in the fourth line of the para and replace with “blocks”.
- Delete the letter “a” in the last line of the para after the word “blocks” and replace with the word “in”.
- Add the following paragraph at the end of this para.

Unless otherwise specified the following minimum thickness of concrete cover, exclusive of plaster or other decorating finish, shall be provided in all cases.

	Minimum cover, in inches
Concrete exposed to earth or weather:	
a. No.6 through No.18 bars	2
b. Nn.5 bar, W31 or D31 wire, and smaller	1-½
Concrete not exposed to weather or in contact with ground:	
Slabs. walls joist:	
a. No. 14 and No.18 bars	1-½
b. No. 11 bar and smaller	¼
Beams, Columns:	
Primary reinforcement, ties, stirrups, spirals	1
Shell, folded plate member:	
a. No. 6 bar and larger	¾
b. No. 5 bar, W31 or D31 wire and smaller	1-½

SS-74 Clause 6.19 Reinforcement**;** sub-clause 6.19.7 Splicing of Bars (Technical Specifications for Workmanship Page – 154 of 192).

Amend the title of this sub-clause and replace with "**Laps Splices and Development length**".

SS-75 Clause 6.19 Reinforcement**;** sub-clause 6.19.7 **Laps Splices and Development length;** para 6.19.7.1 General (Technical Specifications for Workmanship Page – 154 of 192).

Delete the word "slices" in the second line of the para and replace with "splices".

SS-76 Clause 6.19 Reinforcement**;** sub-clause 6.19.7 **Laps Splices and Development length;** para 6.19.7.2 Lap Splicing (Technical Specifications for Workmanship Page – 154 & 155 of 192).

Add the following paragraphs at the end of this para.

Splices shall be staggered as far as possible and with a minimum separation of not less than forty (40) times bar diameters. Not more than one third (1/3) of the bars may be spliced in the same cross-section, except where shown on the drawings.

Unless otherwise shown on the Drawings, bars shall be lapped with a minimum overlap of forty (40) times the bar diameter. In lapped splices, the bars shall be placed in contact and wired together. Lapped splices will not be permitted at locations where the concrete section is insufficient to provide a minimum clear distance of one bar diameter or one and one third (1-1/3) the maximum size of coarse aggregate between the splice and the nearest adjacent bar.

The length of lap splice shall be calculated as hereunder specified.

a) **Lap Splices in Tension.**

Splices for No. 11 bars and smaller are usually made simply by lapping the bars in a sufficient distance to transfer stress by bond from one bar to the other. The lapped bars are usually placed in contact and lightly wired so that they stay in position as the concrete is poured.

Required lap l_s for tension splices is stated in terms of the development length l_d with application of modification factors according to ACI 12.14.

Two classes of lap splices are specified by the ACI Code. The minimum length l_s not less than 12 inches is:

Class A: $l_s = 1.0\ l_d$

Class B: $l_s = 1.3\ l_d$

Lap splices, in general, must be class B splices, according In ACI Code 12.15.2, except that class A splices are allowed when the area of reinforcement provided is at least twice that required by analysis over the entire length of the splice and when one-half or less of the total reinforcement is spliced within the required lap length.

b) **Compression Splices**

Reinforcing bars in compression are spliced mainly in columns, where bars are normally terminated just above each floor or every other floor. This is done partly for construction convenience, to avoid handling and supporting very long column bars, but it is also done to permit column steel area to be reduced in steps, as loads become lighter at higher floors.

Compression bars may be spliced by lapping, by direct end bearing, or by welding or mechanical devise that provide positive connection.

The lap length l_s should be equal to at least the development length in compression and the modifiers. l_s should also satisfy the following, but not less than 12 inches according to ACI Code 12.16:

if $f'_c > 3{,}000$ psi then

$f_y \leq 60{,}000$ psi $\qquad l_s \geq 0.0005\ f_y d_b$

$f_y >$ 60, 000 psi $l_s \geq (0.0009\, f_y - 24)\, d_b$

if $f'_c <$ 3,000 psi then

$f_y \leq$ 60, 000 psi $l_s \geq 1.333 \times 0.0005\, f_y d_b$

$f_y >$ 60, 000 psi $l_s \geq 1.333 \times (0.0009\, f_y - 24)\, d_b$

When bars of different sizes are lap-spliced in compression, the lap splice length l_s must be the larger of the compression development length of the larger bar or the compression lap splice length of the smaller bar.

Lap splices of #14 and #18 bars should not be used, except in compression only to #11 and smaller bars. Lap splices of bundled bars should be based on the lap splice length recommended for individual bars of the same size, and individual splices within the bundle should not overlap each other. The length of lap should be increased 20% for a three-bar bundle and 33% for a four-bar bundle.

Spiral reinforcement shall be spliced by lapping at least one and one half (1-1/2) turns or by butt welding unless otherwise shown on the Drawings.

Sheet of mesh or bar-mat reinforcement shall overlap each other sufficiently to maintain a uniform strength and shall be securely fastened at the ends and edges. The overlap shall not be less than one mesh in width.

SS-77 Clause 6.19.9 Measurements and Rates; sub-clause 6.19.9.2 Rates (Technical Specifications for Workmanship Page – 155 of 192).

Amend the titles of both clause & sub-clause and replace the word “Rates” with “**Payment**”.

SS-78 Clause 6.20.1 Cement Concrete D.P.C.; sub-clause 6.20.1.2 Materials (Technical Specifications for Workmanship Page – 156 of 192).

- Delete the text “chapter 3 of Book – 1 (Specification for Engineering Material)” of para (a) and replace with “6.1.4.3 Aggregates”.

- Delete the text "chapter 3 of Book – 1 (Specification for Engineering Material)" of para (b) and replace with "6.1.4.3 Aggregates".
- Delete the text "chapter 3" of para (e) and replace with "chapter 12 – Bitumen and Tar".

SS-79 Clause 6.24 Shotcrete; sub-clause 6.24.1 Description (Technical Specifications for Workmanship Page – 183 of 192).

Delete the text of this sub-clause and replace with the following:

The work shall consist of furnishing, mixing, applying and curing shotcrete. Shotcrete for the purpose of this work shall only be wet mix shotcrete unless otherwise directed by the Engineer.
This Section specifies basic and minimum materials and construction standards for coarse-aggregate shotcrete (both wet & dry type) for use as structural support for underground works and for application on excavated slopes.

Standards Shotcrete materials, production methods or application, testing and admixtures shall conform to the following International Standards. In case of conflict between the following standards and the specifications given herein, the Engineer decision shall take precedence.

American Concrete Institute (ACI)
ACI 506.2-13 "Specification for Shotcrete"

ACI 506R-16 "Guide to Shotcrete"

ACI 506.1R-08 "Guide to Fiber-Reinforced Shotcrete"

ACI 506.2-13 "Specification for Shotcrete"

ACI 506.5R-09 "Guide to Specifying Underground Shotcrete"

ACI 506.6T-17 "Visual Shotcrete Core Quality Evaluation Technote"

American Society for Testing Materials (ASTM)

ASTM C1140/C1140M-11, "Practice for Preparing and Testing Specimens from Shotcrete Test Panels"

ASTM C1141/C1141M-08, “Specification for Admixtures for Shotcrete”

ASTM C1385/C1385M-10, “Practice for Sampling Materials for Shotcrete”

ASTM C1436 -08, “Specification for Materials for Shotcrete”

ASTM C1480/C1480M-07, “Specification for Packaged, Pre-Blended, Dry, Combined Materials for Use in Wet or Dry Shotcrete Application”

ASTM C1604/C1604M-05, “Standard Test Method for Obtaining and Testing Drilled Cores of Shotcrete”

ASTM C1550-12a, “Test Method for Flexural toughness of Fiber-Reinforced Concrete (Using Centrally Loaded Round Panel)”

ASTM C1583/C1583M-20, “Standard Test Method for Tensile Strength of Concrete Surfaces and the Bond Strength or Tensile Strength of Concrete Repair and Overlay Materials by Direct Tension (Pull-off Method)”

ASTM C1609/C1609M-12, “Standard Test Method for Flexural Performance of Fiber Reinforced Concrete Using Beam with Third Point Loading”

ASTM C143 / C143M-12, “Standard Test Method for Slump of Hydraulic-Cement Concrete”: Wet-mix shotcrete only.

ASTM C231/C231M-10, “Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method”: At pump and as shot.

Hardened Shotcrete Properties

ASTM C1604/C1604M-05(2012), “Standard Test Method for Obtaining and Testing Drilled Cores of Shotcrete”: Compressive strength at 7 and 28 Days.

ASTM C642-13, “Standard Test Method for Density, Absorption, and Voids in Hardened Concrete”: Boiled absorption and volume of permeable voids at 28 days.

ASTM C1202-12, “Standard Test Method for Electrical Indication of Concrete’s Ability to Resist Chloride Ion Penetration”: Rapid chloride penetrability testing.

ASTM C1556-11a, “Standard Test Method for Determining the Apparent Chloride Diffusion Coefficient of Cementitious Mixtures by Bulk Diffusion”: Apparent chloride diffusion (chloride ponding) testing.

ASTM C1585-13, “Standard Test Method for Measurement of Rate of Absorption of Water by Hydraulic-Cement Concretes”: Rate of water absorption testing.

European Standards

BS EN 14487-1-2005 (Sprayed concrete - Definitions, specifications, and conformity) and

EFNARC -1996 (European specification for sprayed concrete).

Austrian Society for Concrete and Construction Technology

Austrian Guideline for Shotcrete, Österreichischer Betonverein (ÖBV), Oct. 1998

6.24.2 Definitions

a) Shotcrete has been generally referred as sprayed concrete, spraycrete, gunite, pneumatically applied mortar or concrete, air-blown mortar or concrete and gunned concrete. American standards term this concrete as shotcrete, whereas European standards use the term sprayed concrete.

b) Shotcrete is defined by ACI 506R as “mortar or concrete (conveyed through a hose) and pneumatically projected at high velocity onto a surface”.

c) As per BS EN 14487 (European Standards), sprayed concrete is defined as “concrete produced with basic mix and projected pneumatically from nozzle into place to produce a dense homogeneous mass by its own momentum”.

d) EFNARC (European Federation of National Associations Representing for Concrete) states that “sprayed concrete is a mixture of cement, aggregate and water projected pneumatically from a nozzle into place to produce a dense homogeneous mass”.

e) Dry shotcrete method is a mixture of cement and aggregate weight or volume batched, thoroughly mixed dry and fed into a purpose-made machine wherein the mixture is pressurized, metered into a dry air stream and conveyed through hoses or pipes to the nozzle before which water as a spray is introduced to hydrate the mix which is projected without interruption into place.

f) Wet shotcrete method is mixture of cement and aggregate weigh batched and mixed with water at site or in mixer trucks prior to being conveyed through a pipeline to a nozzle where air is injected and the mix projected without interruption into place.

g) Nozzle is an attachment at the end of the shotcrete material hose from which material is jetted.

h) Rebound is the part of the shotcrete that does not adhere to the surface during application**,** causing some material to bounce off.

i) Shotcrete developing an early compressive strength of approximately 1 MPa (145 psi) within first 3 hrs of shooting are accepted to be self-supporting and allow safe re-entry of workers and machinery for emplacement of the remaining support elements that require drilling of the shotcrete layer without degradation.

j) Final strength of shotcrete is the strength at an age of 28 days.

k) Reference shotcrete is made of the same mix as in-situ shotcrete, but not containing accelerator. Reference shotcrete shall be sprayed into panels by means of the same shotcrete equipment and sampled, cured and tested in the same conditions as shotcrete.

l) Accelerator is an admixture to produce a fast setting and early strength development of the shotcrete.

m) When spraying on an irregular surface, in awkward geometries (such as sharp corners) or around obstructions (such as reinforcing bars), there is a danger of forming **voids** if the angle of the jet of concrete is wrong.

n) **Shadowing** are voids formed behind reinforcement bars, exposing the steel to a greater risk of corrosion and reducing the effectiveness of the reinforcement.

o) **Sloughing** are sections of sprayed concrete fall off under their own weight, either because the bond is too weak or because the layer that has been applied is too thick.

p) When the sprayed concrete consists of layers (**laminations**) due to poor bond between the layers rather than being a homogeneous mass, this may be due to inadequate surface preparation between applications of sprayed concrete or variations in compaction during spraying.

6.24.3 Submissions

1. Prior to the commencement of any works covered by these specifications, the Contractor shall submit to the Engineer/Engineer representative for approval a comprehensive program for material testing and quality control covering all elements of the tunnel support.

2. Manufacturer's certificates of compliance shall be submitted certifying that the materials used meet specification requirements.

3. The method of installation of each type of support element including description, specification and pertinent manufacturer's literature for drilling, rock bolting etc. shall be submitted by the Contractor to the Engineer/Engineer representative.

4. The Engineer/Engineer representative shall be provided with all submissions in sufficient time ahead of the construction works, or at such dates as mutually agreed upon.

SS-80 Clause 6.24 Shotcrete; sub-clause 6.24.3 Material Requirement; Para 6.24.3.1 Cement (Technical Specifications for Workmanship Page – 183 of 192).

Delete the text of the Para and replace with following:

Material Requirements of Shotcrete as specified herein, shall be read in conjunction with the various items of concrete work in **Chapter – 6 Cement Concrete**, of these specifications. In case of ambiguity, the Engineer decision shall be final and binding.

Portland cement shall conform to the requirements of ASTM Specification C 150 for the specific types of cement. When Type I Portland cement is specified, Type B Portland blast-furnace slag cement or Type IP Portland-pozzolan cement conforming to the requirements of ASTM Specification C 595 can be used unless prohibited by the specifications.

When air-entraining cement is required, the Contractor shall furnish the manufacturers written statement providing the source, amount and brand name of the air-entraining component.

SS-81 Clause 6.24 Shotcrete; sub-clause 6.24.3 Material Requirement; Para 6.24.3.2 Aggregate (Technical Specifications for Workmanship Page – 183 of 192).

Delete the text of the Para and replace with following:

Aggregate shall conform to the requirements of ASTM Specification C 33 for the specified sizes. Aggregates that fail to meet any requirement may be accepted only when:

a) the specified alternate conditions of acceptance can be proven prior to the use of the aggregates on the job and within a period of time such that no work under the contract will be delayed by the requirements of such proof; or,

b) the specification for concrete expressly contains a provision of special mix requirements to compensate for the effects of the deficiencies.

1. Fine aggregate

The use of finer sand will generally result in greater drying shrinkage and coarser sand in more rebound. Sand for shotcrete shall grade evenly from fine to coarse. The fine aggregate grading limits specified by ACI 506R shall be adopted.

2. Coarse aggregate

ACI 506R suggests the combined aggregates (fine and coarse) conform to either grading #1 or grading #2 with maximum aggregate size of 4.75 or 10 mm respectively.

It has been observed that a coarse aggregate with maximum size of 10mm promotes an in-place shotcrete composition as close as possible to that of cast-in-place concrete. ACI therefore limited maximum aggregate size for Shotcrete to 10mm and omitted 12.5mm and 20mm maximum aggregate sizes.

The maximum size of the aggregates shall not exceed 12 mm for wet process or 16 mm for dry process. The proportion of aggregate larger than 8mm in size should not exceed 15% for the wet process in order to minimize rebound.

All fine and coarse aggregates to be used shall be supplied from approved sources, which shall not be changed without permission in writing from the Engineer/Engineer representative.

The aggregates shall be clean, strong and durable, suitably graded and shall not contain detrimental amounts of dust, mud, clay or organic impurities.

Water-soluble chloride ion content in a shotcrete mixture shall be maximum of 0.06% by weight of cement and as measured by ASTM C1218.

It is the responsibility of the Contractor to choose the most suitable grading for the process and materials available.

Frozen aggregates shall not be used. Minimum temperature of the aggregates shall be 5°C.

During rainy and cold weather periods, the aggregates for the dry process shall be stored undercover for at least 48 hours before being used and kept sufficiently dry.

Aggregates of each class and size shall be stored and handled by methods that prevent segregation of particle sizes or contamination by intermixing with other materials.

3. Reactivity with Alkalis

The potential reactivity of aggregates with the alkalis in cement shall be evaluated by petrographic examination and where applicable, the chemical method of aggregate testing by ASTM Designation C 289, or by the results of previous tests or service records of concrete made from similar aggregates from the same source. The standards for evaluating potential reactivity shall be as described in ASTM Specification C 33, Appendix A1.

Aggregates indicated by any of the above to be potentially reactive shall not be used, except under one of the following conditions:

a) Applicable test results of mortar bar tests, made according to ASTM Method C 227, are available which indicate an expansion of less than 0.10 percent at six (6) months in mortar bars made with cement containing not less than 0.8 percent alkalis expressed as sodium oxide; or

b) Concrete made from similar aggregates from the same source has been demonstrated to be sound after three (3) years or more of service under conditions of exposure to moisture and weather similar to those anticipated for the shotcrete under these specifications.

Aggregates indicated to be potentially reactive, but within acceptable limits as determined by mortar bar test results or service records, shall be used only with "low alkali" cement, containing less than 0.60 percent alkalis expressed as sodium oxide.

4. Water Cementitious Ratio

The water cementitious (w/c) ratio should be as low as possible to achieve high strength and durable shotcrete.

ACI 506.5R specifies maximum w/c of 0.45. Similarly, ACI 506R suggests a typical range for w/c as 0.4 to 0.5 without admixture and also lower w/c is possible with the use of water- reducing admixtures.

EFNARC specifies maximum w/c as 0.55. EN refers to EN 206 for maximum w/c. EN 206 recommends maximum water cement ratio as 0.55.

5. Pozzolana

Pozzolana in shotcrete enhances the strength and durability properties through either purely physical effects or physicochemical effects, which results in pore-size and grain-size reduction phenomena.

ACI 506.5R suggests a typical range from 7 to 10% (Max 15%) for the replacement of cement by silica fume as per industry guidelines, the addition of fly ash and slag should be accepted only if all shotcrete performance requirements can be demonstrated during preconstruction testing and approved by the Engineer/Engineer representative.

EFNARC has given max percentage of silica fume as 15% of Portland cement. It has also given that max percentage of fly ash and GGBS (ground granulated blast-furnace slag) each as 30% of Portland cement as per the design requirement of the project.

Although slag, fly ash and silica fume are used for durability requirement and cost effectiveness, codes and literatures generally specify silica fume with shotcrete instead of fly ash and slag. This may be due to the fact that silica fume increases early compressive and flexural strength of shotcrete considerably than fly ash and slag. ACI recommends the usage of fly ash and slag only after preconstruction testing.

SS-82 Clause 6.24 Shotcrete; sub-clause 6.24.3 Material Requirement; Para 6.24.3.4 Admixture and Short fiber (Technical Specifications for Workmanship Page – 184 of 192).

Delete the second and third paragraph of the Para and replace with following:

Admixtures for the improvement of performance, workability, etc. of the Shotcrete may be added, with the approval of the Engineer/Engineer representative.

Technical criteria, approved documentation, test reports and test certificates shall be furnished to the Engineer/Engineer representative for approval.

Admixtures shall be stored under the conditions specified and recommended by the manufacturers. The related storage Specifications and recommendations shall be presented to the Engineer/Engineer representative before approval of such admixtures. The manufacturer’s safety instructions shall be observed.

Plasticizers and super-plasticizers can be used to achieve pumpable concrete with minimum water content. Plasticizers shall be checked regularly, or as required by the Engineer/Engineer representative, for setting time, water reduction and development of strength as compared with the base concrete.

Compatibility of plasticizers with cements, latent hydraulic binders and accelerators shall be verified by observation in the field suitability tests.

The effects and optimum dosages of plasticizers and super-plasticizers shall be determined by the field suitability test to achieve the shotcrete properties as required in these specifications.

Shotcrete’s using fine limestone powder as well as those using admixtures have been determined to improve the ease of construction and work and reduce the dust concentration and rebound.

Fine limestone powder is sometimes used with other types of admixtures. When using fine limestone powder, it should be verified in advance by conducting testing that the designated quality requirements are met for the concrete.

Accelerators are used to produce a fast set and to get sufficient early strength development. Accelerating admixtures shall be compatible with the cement used.

The compatibility of the accelerator with the cement used, dosage rate etc. shall be tested in the laboratory by the Manufacturer and verified by the Engineer in field suitability tests to achieve the required properties for early and final strength as specified herein-below in these specifications.

Only alkali-free accelerators shall be used. The alkali content shall be less than 1% mass (Na_2O-equivalent, EN 480-12).

An addition to the dosage rate determined by the field suitability tests shall not exceed 2% of the cement content of the mix design by weight.

The dosage of accelerator shall be kept to the minimum required for spraying in situ.

Automatic devices shall be used to add the accelerator.

SS-83 Clause 6.24 Shotcrete; sub-clause 6.24.3 Material Requirement; Para 6.24.3.5 Curing Material (Technical Specifications for Workmanship Page – 184 of 192).

Add the following at the end of the Para.

The curing compound as approved by the Engineer/Engineer representative shall be delivered to the site of the work in the original container bearing the name of the manufacturer and the brand name. The compound shall be stored in a manner that prevents damage to the container and protects water-emulsion types from freezing.

SS-84 Clause 6.24 Shotcrete; sub-clause 6.24.4 Construction Requirements; para 6.24.4.1 Batching and Mixing (Technical Specifications for Workmanship Page – 184 of 192).

- Amend the title of this para and replace with "Proportioning of Shotcrete, Batching and Mixing".

- Construction procedure as relevant to this para and specified in **Clause 6.2 – Proportioning of Concrete** of these specifications shall be applicable.

- Delete the text of the para and replace with the following sub-para's.

1. Proportioning of Shotcrete

a) Mix Design

The mix for shotcrete shall be designed by the Contractor under supervision of the Engineer/Engineer representative in the field laboratory to meet the requirements of these specifications.

- The shotcrete mixes shall be designed to provide 28 days cylinder strength and slump value at the pump when tested, as specified on drawing.
- Thirty days minimum prior to shotcrete placement the Contractor shall submit for Engineer/Engineer representative acceptance a proposed mix design for the shotcrete with the tolerances of any variable components identified.
- The design shall include a complete list of materials and copies of test reports showing that the mix has been successfully tested to produce shotcrete with the properties specified.
- The proportions of ingredients selected on the basis of trial mixes and field trials shall be used in the actual application of shotcrete.
- The Contractor shall submit test results on Preconstruction test panels for each mix design being considered following the testing guidelines as specified herein-below in these specifications.
- The combined aggregate shall be a blend of sizes as required to produce a combined grading within the limits of ACI 506R-16, Table 1.1.1 with Grading Number as specified on drawing.

b) Cement Content

- For the dry shotcrete process the quantity of cement shall not be less than 350 kg/m³ dry mix**.**

- For the wet shotcrete process the minimum cement content shall be 400 kg/m³ of batched shotcrete.

c) Preconstruction Tests

- Tests at the execution site should be carried out on regular basis on cores or other samples taken from shotcrete applied in the works. Tests may be repeated if the source or qualities of any of the materials or the mix proportions are likely to be changed during the course of the works.

- The frequency of carrying out each test for mix control shall be in accordance with the **Table for Sampling and Testing Frequency**.

(i) **Fresh concrete:**

- Water demand, workability, pumpability
- Sprayability/rebound
- Slump, density
- Accelerator dosage and compatibility with type.

(ii) **Hardened concrete**:

- Compressive strength and density at 7 days and 28 days
- Flexural strength
- Residual strength
- Bond
- Permeability

2. Batching and Mixing

Mix proportions shall be controlled by weight batching in accordance with ASTM C94 or by volume batching meeting the requirements of ASTM C685. Volume batching shall be verified once a week by a weight batching check.

Use batching and mixing equipment capable of proportioning and mixing the required materials at a rate to maintain continuous placement capability and assure uniformity of product

If new batch procedures for shotcrete are required, they shall be submitted to the Engineer/Engineer representative for approval.

Batched Shotcrete delivered to the tunnel portal for subsequent transport to a subsurface delivery point shall meet all the requirements of ASTM C94, Sections 11 and 12.

Equipment's used for transport of the batched shotcrete shall be approved by the Engineer/Engineer representative.

Transit mixers to be used for the transportation of shotcrete underground must be fitted with approved exhaust filters.

A method of measurement for adding water and admixtures underground, if used, shall be approved by the Engineer/Engineer representative and in compliance with ASTM C94.

a) Dry Shotcrete Process

- Cement and aggregates shall be batched in the proportions specified and designed. Measurement shall be done by weight. At the time of batching all aggregates shall have been dried or drained sufficiently to result in a stable surface moisture content, which shall not exceed 7 %.
- Mixing of cement and aggregates shall be performed mechanically with a pan type mixer. Shotcrete shall not be used unless placing can be completed within a period of 90 minutes from the time of mixing unless a hydration control admixture is used that is suitable to inhibit setting and retain consistence for the time span required until placing the shotcrete. The hydration control admixture must be approved by the Engineer/Engineer representative.
- The mixing time shall be in accordance with ACI 211.1-91; Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete (Reapproved 2009)
- A system of delivery notes shall be maintained to record the date, the time of mixing, mix design number, quantity, delivery point, time of delivery and completion of placing. The delivery notes shall be available to the Engineer/Engineer representative for inspection.
- For the dry process, powder or liquid type accelerating admixtures shall be added to the dry-mix. The powder type accelerator shall be

proportioned and added just before the dry mix enters the shotcrete machine through a mechanical device (dispenser). Periodic calibration checks shall be performed in accordance with the manufacturer's recommendation. Liquid type accelerator shall be delivered by a special dosage pump and added to the dry-mix at or near the nozzle. Dosage pump and the hoses to the nozzle shall be kept in good order.

- Dry-Mix delivered to the shotcrete machine shall have a minimum temperature of 5°C and a maximum temperature of 32°C.
- During hot weather periods the water content of the aggregates for the dry process shall be kept above 4%, in order to avoid cement loss at the rotor of the shotcrete machine.
- During transportation the dry mix shall be effectively protected against the influence of weather.

b) Wet Shotcrete Process

- Only liquid types of accelerators apply to the wet process; these shall be added at or near the nozzle. The delivery from the accelerator pump must be controlled to be proportional to the output of the concrete pump. Accelerator pump calibration shall be periodically checked in accordance with the manufacturer's recommendations. The nozzle must be such as to ensure a homogeneous mixture of the accelerator with the wet-mix.
- Shotcrete shall not be used unless placing can be completed within a period of 120 minutes from the time of mixing unless a hydration control admixture is used that is suitable to inhibit setting and retain consistence for the time span required until placing the shotcrete. At high temperatures hydration control admixtures shall be used at all times to ensure fresh concrete and sufficient open time.
- Concrete delivered to the shotcrete machine shall have a minimum temperature of 15°C and a maximum temperature of 32°C.
- A system of delivery notes shall be maintained to record the date, the time of mixing, mix design number, quantity, delivery point, time of delivery and completion of placing. The delivery notes shall be available to the Engineer/Engineer representative for inspection.

SS-85 Clause 6.24 Shotcrete; sub-clause 6.24.4 Construction Requirements; para 6.24.4.2 Production; sub-para 1 General (Technical Specifications for Workmanship Page – 185 of 192).

Add the following at the end of this sub-para.

Construction procedure as relevant to the sub-para and specified in **Clause 6.3 – Manufacture of Concrete** of these specifications shall be applicable.

SS-86 Clause 6.24 Shotcrete; sub-clause 6.24.4 Construction Requirements; para 6.24.4.4 Applications; sub-para 1 Placement techniques (Technical Specifications for Workmanship Page – 186 of 192).

Delete the text of this sub-para and replace with the following:

1. Thirty days prior to the start of shotcrete placement, the Contractor shall submit a placement plan for acceptance of the Engineer describing the preconstruction-testing of mix design, control of thickness, dust control, surface preparation, curing of in-place shotcrete, curing and handling of test panels including provisions for chain of custody, precautions taken to avoid and/or control spills of cementitious materials and methods for prompt removal of rebound.
2. Rock surfaces against which shotcrete are to be placed shall be scaled to remove loose, semi-detached rock fragment. However, there may be situations where complete removal of fragments may be hazardous or inadvisable, including where early support is required and where the in-place rock is fractured. Rock surface shall be washed with water and the surface shall attain surface saturated dry condition prior to shotcrete application.
3. Previously applied shotcrete surfaces to be shotcreted shall be carefully cleaned of all loose material, scale and other contaminations. It may be necessary to use compressed air and a water jet.
4. Provide a platform that permits nozzleman unobstructed access to the receiving surface.
5. The optimum distance between nozzle and surface of application should be 1.0 to 1.5 meter. The nozzle should be positioned at right angles to the surface of application.

6. Place shotcrete first in corners, recesses, and other areas where rebound or overspray cannot escape easily. In corners, direct nozzle at approximately 45 deg angle or bisect the corner angle.
7. Apply shotcrete in a manner that sagging or sloughing do not occur.
8. Shotcrete shall be applied to the required thickness tolerances at the locations shown on the drawings or as necessary for worker's safety. The coverage of any welded wire fabric shall be in accordance with ACI 506.2, Parts 3.3.3 and 3.3.4.
9. If the design thickness must be applied in more than one layer, then the previous layer must have developed sufficient strength to support the additional layer(s).
10. Remove laitance from shotcrete surfaces to receive additional shotcrete layers.
11. Lattice girders, roof ties, wire mesh and other reinforcement shall be embedded in shotcrete as shown on the drawings. The minimum cover of wire mesh and re-bars applied at the inner side of a tunnel lining shall be 2 cm or as shown on the drawings.
12. If more than one layer of reinforcement is used, the second layer shall not be positioned before the first one is embedded and covered with shotcrete. Exemptions are to be approved by the Engineer.
13. In sound, competent rock the shotcrete shall follow the rock surface with proper rounding of notches and corners. At projections of sound and hard rock edges, the actual shotcrete thickness may be locally reduced to two thirds of the specified thickness. This shall apply only to rock with Unconfined Compressive Strength UCS > 50 MPa.
14. Rebound and overspray shall be removed immediately after finishing of each shotcrete application. In particular at horizontal shotcrete connections due to separate excavation sequences and at all construction joints the rebound shall be removed, if necessary, by pneumatic hammers, prior to further application of shotcrete.
15. Under no circumstances rebound material shall be worked back into the construction. The work shall be continuously kept free of rebound material.
16. Measures to establish the thickness of shotcrete shall be set up by the Contractor and approved by the Engineer/Engineer representative. These may include visual guides installed prior to shotcreting, holes drilled after completion of shotcreting or a full control by laser scanning.
17. If deemed necessary by the Engineer/Engineer representative, curing of the shotcrete shall be performed by water spraying or other appropriate measures subject to the approval of the Engineer/Engineer representative in the first 48 hours after application.

18. Major ground water seepages shall be drained off prior to spraying or after application of a first sealing layer.
19. Nozzle men shall be trained in the correct application of shotcrete.
20. The static compressed air capacity measured at the shotcrete pump shall be according to the manufacturer's recommendations and generally as per EFNARC guidelines G 8.3.2 for wet process and G8.3.3 for dry process.
21. Full personal protection equipment to protect the nozzle man from eye and skin contact and inhalation of shotcrete and/or admixtures shall be provided. The admixture manufacturer's precautions and actions for accidental contact shall be provided and adhered to.
22. When bonding is required for tunnel portals and other exterior surface shotcreting, remove all deteriorated, loose unsound material or contaminants that may inhibit bonding. Chip areas to be repaired to remove offsets causing abrupt changes in thickness.
23. No square shoulders shall be left at the perimeter of a cavity. All edges shall be tapered.
24. Unless construction joint configurations are otherwise shown on the drawings, the edge of the placed shotcrete shall be tapered to facilitate a smooth transition between adjacent application areas. The shotcrete thickness to tapered length ratio shall not be less than 1:4.
25. Do not apply curing compounds and bond breaking materials to surfaces that will be covered by an additional layer of shotcrete.
26. For vertical and near vertical surfaces of a tunnel lining, commence application of shotcrete at the bottom of the surface with the full thickness applied before applying any shotcrete to overhead surfaces.
27. Surface shall be saturated surface dry immediately prior to shooting.
28. Do not apply shotcrete on surfaces with standing water or running water.

SS-87 Clause 6.24 Shotcrete; sub-clause 6.24.4 Construction Requirements; para 6.24.4.6 Curing (Technical Specifications for Workmanship Page – 188 of 192).

At the end of this para, add the following supplementary para's.

6.24.4.7 Trial Testing of Shotcrete

The Engineer/Engineer representative and Contractor shall agree a program of Quality Control (QC) and Quality Assurance (QA) for achievement of quality shotcrete at least 30 days in advance of the shotcrete mix design and placement proposal. The objectives of QA / QC measures must ensure that the performance of the shotcrete in-place meets minimum design requirements and performance standards. This will usually start with mix design, testing and approval of constituent materials and placing equipment, and selection of suitably qualified personnel, and proceed to on-going performance testing of the in-place shotcrete. Pre-construction trials shall be used as part of benchmarking for quality control of shotcreting operation.

6.24.4.7.1 Preconstruction and Production Test Panels for Shotcrete

For each type of accelerating admixture and mix design a trial mix shall be sprayed onto test panels (3 No's. per trial mix) under site conditions to determine early and final strength of shotcrete. At least 3 different dosages of the accelerating admixture shall be tested following the recommendation of the accelerator manufacturer. The ambient temperature for the test shall be in accordance with the actual conditions in the tunnel**.**

21 days prior to placement of Shotcrete in the underground and surface works, the Contractor shall submit complete methodology of Preconstruction and Production Test Panels for approval of the Engineer/Engineer representative. In spite of the approval of Engineer/Engineer representative for trial section, contractor shall be responsible for the quality of work. Contractor will provide minimum of following information's in the methodology.

- Equipment to be used.
- Panel size to be adopted.
- Shotcrete thickness adopted.
- Productivity.
- Results of tests.

Test panels and samples moulds should be made of steel or other non-water-absorbing rigid material and fabricated in accordance with ASTM C1140 or, as directed by the Engineer/Engineer representative at locations specified on drawings or agreed by the Engineer/Engineer representative and Contractor.

a) **Preconstruction test panels** shall be used to qualify three different aspects of the shotcrete:
   - the material being shot;
   - the equipment used for shooting; and
   - the nozzleman doing the shooting.

- The preconstruction panel should represent the most difficult-to-shoot part of the tunnel or portal section. The test panels should be a replica of sections with the most congested reinforcing, large or irregular shaped block-outs or embeds, or a complicated geometry.
- The minimum plan dimensions of 600 x 600 mm for hand spraying and 1000 x 1000 mm for robot spraying shall be adopted for trial section demonstration of shotcrete application, curing and testing.
- The thickness should be appropriate to the size of test specimens to be cut from the panel, but should not be less than 150 mm. A minimum 150 mm diameter core is best for evaluation of the shotcrete in congested test panels. This size core will help prevent the core from breaking during the coring operation and will also have more surface area for evaluation.
- Appropriate measures should be taken to avoid entrapment of rebound in the mould (such as using chamfered or slotted sides).
- The test panels shall be positioned vertically and sprayed with the same operator, equipment, technique, layer thickness per pass, spraying distance, etc. as the actual work. The panels should be protected immediately against moisture loss using the same method to be used in construction. The samples shall be marked for later identification (Mix, location, date, operator). The panel should not be moved within 18 hrs of being sprayed.
- The orientation of the panels (horizontal, vertical, or overhead) should also match the orientation of the work on the project.
- Curing should continue thereafter for 7 days or until samples are to be extracted.
- Typical preconstruction panels shall have three cores taken for evaluation of encasement and consolidation, while three additional cores shall be taken for evaluation of compressive strength.

b) **Production test panels** are constructed once the preconstruction test panels are demonstrated, shotcrete finally approved for placement and the procedure accepted by the Engineer/Engineer representative.

- Production test panels shall be treated as equivalent to concrete cylinders used to evaluate compressive strength of the shotcrete material. Cores taken from the panel are then tested at the appropriate age to establish the strength of the shotcreted concrete. These panels should not contain any reinforcing.

- Test panels shall be shotcreted, cured and tested in compliance with ASTM C1140, “Standard Practice for Preparing and Testing Specimens from Shotcrete Test Panels,”
- Care must be taken in the handling and storing of production panels. Don’t move the panels and disturb the concrete before they gain adequate strength. Also, don’t expose the panels to environments that are significantly different than the exposed project’s sections (much hotter, colder, or drier).
- A minimum shotcrete production panel shall be 600 x 600 mm by 160 mm deep. This is 70 mm deeper than the ASTM C1140 minimum panel size of 600 x 600 mm by 90 mm. The added plan dimensions leave enough room to stay well off the edge and other cores for a non-disturbed sample, and the added length allows for squaring-up the end before testing.
- The panels shall be handled and stored with care; otherwise, low strength results could result despite the fact that the concrete in-place is perfectly good.

6.24.4.7.2 Field Quality Control

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1. Quality Assurance (QA) of Contractor’s Documentation

The Contractor shall be responsible for recording shotcrete placement location, installation witnessing and test documentation in accordance with the Engineer/Engineer representative instructions. The Contractor’s documentation shall include as a minimum:

- Documentation of shotcrete application area which is sufficiently accurate to permit subsequent identification of the application area at any time following installation.
- Document date and time of shotcrete installation, batch number(s).
- Document installation thickness as attaining the specified thickness within the tolerance given on the applicable drawing.

Visual Inspection

The in-place shotcrete shall be visually monitored by the QA & QC inspectors between coats and immediately following final application for laitance's, loose material, cracking, sloughing, and sagging. Visual inspection of all completed shotcrete work must ensure the conformity to compaction and finish requirements.

Tolerances

The maximum variation in alignment, grade, and thickness of the shotcrete from the established alignment, grade and dimensions shall be as shown on the drawings, unless otherwise agreed by the Engineer/Engineer representative.

2. In-situ Compressive Strength

The Contractor shall make 600 mm x 600 mm nominal size steel test panels, or as directed by the Engineer/Engineer representative and agreed by the Contractor, placed in the vertical position for every 25 m^3 of shotcrete placed but at least one panel per shift.

The shotcrete shall be applied perpendicular to the receiving surface and a minimum of 150 mm thick.

The Contractor's regular nozzle operator shall place the panels during the regular course of the work.

The panels shall be cured initially for a minimum 48 hours in the same or similar conditions as the work, including humidity, temperature, and shielding from direct sunlight. The test panels shall be covered with wet burlap and plastic immediately before removal from the tunnel or portal excavation area.

The panel, when removed from the tunnel or portal excavation area, shall be immediately transported to the testing laboratory for coring and curing. A chain of custody shall be established from the time the test panels are placed to where they are stored during initial field curing through transporting to the test facility. The contractor shall assure that the panels are handled, transported and treated properly.

The Contractor shall extract a minimum of eight cores or as agreed by the Engineer/Engineer representative, of a nominal 75 mm diameter and a length meeting an L/D ratio of between 1.94 and 2.10 from each panel.

Time tolerances may be relaxed, if agreed by the Engineer/Engineer representative and cores placed in moisture conditioning in accordance with ASTM C42 until removed for testing.

Two cores each shall be tested at three days, seven days, and twenty-eight days in accordance with ASTM C42.

The remaining two cores will be held for 90 days for further testing if needed. They may be discarded after 90 days if the 28-day breaks exceeded the specified strength.

For the three and seven day tests the laboratory test breaks may be scheduled to normal business days/hours and the results pro-rated for the three and seven day breaks. However, the 28-day compressive strength test shall meet the standard time tolerances since it is considered as the acceptance criteria.

Strength shall be evaluated following the recommended practice for evaluation of strength in ACI 214.

Test results shall be reported to the Engineer/Engineer representative as they become available or as requested by the Engineer/Engineer representative.

The shotcrete shall meet the specified strength and shall not contain defects like lacking uniformity, exhibiting segregation, honeycombing or lamination; or containing any dry patches, slug, voids or sand pockets.

Shotcrete test panel cores that fails to meet the specified requirements, additional samples shall be taken and tested in accordance with procedure stated herein above. These samples shall be taken from the in-place shotcrete from the area of work represented by the test panel.

The test results from the additional samples shall be provided as part of the non-conformance disposition. These core samples shall be a nominal 75 mm diameter and full thickness of the in-place shotcrete. For in-place core samples with an L/D ratio less than 1.94, the results shall be corrected in accordance with ASTM C42.

a) In-situ Early Compressive Strength.

In tunnel construction, thick layers of shotcrete have to be placed overhead or to vertical walls as a primary / initial support element. For shotcrete to achieve a fast setting and high early strength development properties within first few minutes of shooting, special binders or typical binder (e.g., cement) in combination with accelerators shall be used.

Safety requirements demand a sufficiently accurate knowledge of the actual shotcrete strength. The strength development also has to be proven during construction.

The development of strength during the first two minutes (0.1 – 0.2 MPa) also has a major influence on the extent of dust formation and rebound.

Shotcrete early strength evaluation as defined in EN 14487-1 and the Austrian Society for Concrete and Construction Technology guideline “Sprayed Concrete”, Edition 12/2009 shall only be conducted in the highly fractured and incompetent rock formations and/or as directed by the Engineer/Engineer representative as a supplementary to production testing.

b) In-situ Final Compressive Strength.

Compressive strength for three, seven and twenty-eight days of the shotcrete shall be evaluated in accordance with ACI 214.The average of the test results of the two samples as specified hereinabove shall be considered the acceptable value.
The Contractor, with approval of the Engineer/Engineer representative, may sample additional cores from the same test panel and include them in determining the average 28-day strength of a panel.

If a specimen shows evidence, other than low strength, of improper sampling, handling, curing or testing, it shall be discarded and the strength of the remaining core shall then be considered the test result.

ACI 506R recommends the strength of wet mix shotcrete between 30 to 50 MPa. ACI 506.5R specifies the minimum compressive strength as 30 MPa whereas for some special application such as permanent tunnel lining, compressive strength of 40 MPa or more is specified.

EFNARC states that compressive strength classes of sprayed concrete vary from C24/30 to C48/60 *(Compressive strength of Concrete in MPa when tested with Cylinder / Cube.)* The minimum compressive strength of C24/30 and

C48/60 are 20.5 MPa and 41 MPa respectively as per the in-situ strength requirement.

EN refers to EN 206-1 for the compressive strength classes of sprayed concrete. EN 206-1 lists compressive strength class from C8/10 to C 100/115.

Compressive strength of shotcrete increases with improving density of the material, maximizing hydration of cement and minimizing porosity. Industry's modern specifications typically require compressive strengths of 20 MPa (for temporary sprayed concrete) to 40 MPa or higher (for permanent sprayed concrete) at 28 days.

3. Slump & Temperature Testing

Slump of the fresh batched shotcrete shall be tested in accordance with ASTM C143 to the tolerances of the approved mix design. Temperature of the fresh batch shotcrete shall be tested in accordance with ASTM C1064.

Temperature of freshly placed shotcrete shall be taken with a concrete thermometer in accordance with ASTM C1064.

4. Shotcrete Thickness Testing

The Engineer/Engineer representative may call for confirmatory shotcrete thickness testing of the in-situ tunnel lining. The basic test shall consist of drilling 4 No's holes on a $1m^2$ pattern. The average thickness of the 4 holes shall exceed the specified design thickness. If not, the Engineer/Engineer representative shall propose remedial measures and/or further drill testing.

5. Additional Testing for Design Purpose

The Engineer/Engineer representative may call for permeability & porosity tests to evaluate durability properties of shotcrete as required for design purposes. Permeability tests shall be on in-situ cores taken from the tunnel. One set of cores shall be taken from the top heading and/or bench and/or invert, away from the construction joints, in order to give information on the permeability of intact shotcrete. Another set of cores shall be taken at the top heading-bench joint and/or the bench-invert joint in order to give information of the permeability of construction joints.

The Engineer/Engineer representative may call for additional compressive strength tests on cores taken from test panels in the direction perpendicular to the spray.

6. Compressive Strength Failures

The Engineer/Engineer representative shall take the following course of action in the event of cores not meeting the strength requirements as specified on drawings or these specifications.

Failure of 1, 3 or 7 day compressive strength tests:

a. Inform the Engineer/Engineer representative.
b. Immediate examination of tunnel lining in suspect area.
c. Immediate examination of elements concerned in making, transporting and placing of shotcrete.
d. Assess the results of the geotechnical monitoring program.
e. Prepare to take further tests, including in-situ cores.
f. Take further compression tests as soon as possible.
g. The Engineer/Engineer representative may order measures for strengthening of the area.

Failure of Final Strength tests:

a. Inform the Engineer/Engineer representative.
b. Further cores shall be taken from the tunnel lining in the vicinity of the failed specimen to establish the area of non-conformance.
c. Assess the results of the geotechnical monitoring program.
d. The Engineer/Engineer representative may order measures for strengthening of the area

7. Shotcrete strength & durability properties

(i) Flexural strength Test

Flexural strength is usually specified for fiber reinforced shotcrete. Dosage of fiber also influences flexural strength of shotcrete. Flexural strength also increases in accordance with compressive strength.

Load deflection curve obtained by testing a simply supported beam under third-point loading is used for the evaluation of flexural strength.

Minimum Flexural Strength as per ACI 506.5 ranges b/w 4.0 MPa to 4.5 MPa & EFNARC recommends 3.4 MPa for C 24/30; 4.2 MPa for C 36/45; and 4.6 MPa for C 44/55 concrete class.

ACI refers ASTM C1609 for the testing of flexural strength of shotcrete. The code recommends Third-point loading test with deflection-controlled machine. This test method utilizes two preferred specimen sizes of 100 x 100 x 350mm tested on a 300 mm span (or) 150 x 150 x 500 mm tested on a 450mm span. ACI suggests an increase in rate of deflection as illustrated below:

Beam Size (mm)	**Rate of Increase in Deflection**	
	Deflection up-to L/900	Deflection beyond L/900
100 x 100 x 350	0.025 to 0.075 mm/min	0.05 to 0.2 mm/min
150 x 150 x 500	0.035 to 0.1 mm/min	0.05 to 0.3 mm/min

NARC and EN 14488-3 also recommend Third-point loading with deflection-controlled machine. Both specify the test specimen of size 125 x 75 x 600mm tested on a span of 450mm. The code mentions the deformation rate of the midspan of the beam shall be 0.25 ± 0.05mm per minute until a deflection of 0.5mm. After this point the rate of deflection can be increased to 1 mm/min.

As per EN and EFNARC, the test shall be finished when the mid span deformation exceeds 4mm or the specimen fractures. But ACI does not specify the upper limit of deflection to finish the test.

(ii) **Bond strength test**

Strength developed between the substrate and shotcrete layer can be termed as bond strength. Inference from both ASTM and EN are; if the failure occurs in the bond zone, then it is reported as bond strength between the two materials whereas if the failure occurs in any individual material, then it is reported as tensile strength of that material.

ACI 506.1 & 506.5 recommended bond strength between shotcrete and rock varies b/w 0.2 MPa (Min:) ~ 3.7 MPa (Max:) and 1.0 MPa (Min:) ~ 1.5 MPa (Max:) respectively, whereas in ACI 506, the mentioned 0.7 MPa (Min:) ~ 1.0 MPa bond strength range is not clearly established as whether b/w the shotcrete and rock or else.

Minimum bond strength required as per EFNARC varies b/w 0.0 MPa (Min:) ~ 0.1 MPa (Max:) for shotcrete bonding with concrete and 0.0 MPa (Min:) ~ 0.5 MPa (Max:) for shotcrete bonding with rock.

ACI refers ASTM C1583 for the testing of bond strength of shotcrete and rock/concrete. The code suggests Direct tension (Pull-off method) test with tensile loading machine. In this test method, a test site of 1m x 1m is prepared and core of 50mm is drilled to at least 10mm below the concrete-overlay interface and tested without extracting the core. It specifies a rate of loading of 0.035 ± 0.015 MPa per second.

EFNARC and EN 14488-4 also suggest Direct tension test for the testing of bond strength of shotcrete and rock/concrete. The core is drilled out and extracted from sprayed concrete layer together with a portion of the substrate rock/concrete and then tested.

EFNARC specifies a specimen with core diameter of 50 to 60 mm. The code suggests the rate of loading shall be 1 to 3 MPa per minute. EN specifies a specimen with core diameter of 50 to 100mm and length not less than 2d. The code suggests the rate of loading shall be 0.05 ± 0.01 MPa per second.

(iii) **Toughness / Energy absorption test**

As per ACI 506.1R toughness energy is quoted as "ability of the shotcrete specimen to absorb energy before and after cracking", as per ACI & EFNARC~~.~~

The energy absorption of the shotcrete panel depends on centrally loaded round panel or square panel test method. Minimum energy absorption value of 280 joule (Upto 40 mm deflection as per ACI) and 500 joules (Upto 25 mm deflection as per EFNARC & EN) are recommended for round panel and square panel test respectively.

ACI refers ASTM C1550 for the testing of energy absorption or toughness of shotcrete. The code recommends centrally loaded round panel test with a deflection-controlled testing machine. It specifies a specimen with diameter of 800 ± 10 mm and thickness of 75 -5/+15 mm. The code suggests that the loading shall be applied so that the piston advances at a constant rate of 4.0 ± 1.0 mm/min up to a central displacement of at least 45mm and the fixture supporting the panel during testing shall include three symmetrically arranged pivot points on a pitch circle diameter of 750mm. Further it states that the energy absorption capacity in joules is reported as the area under the load-deflection curve between 0 and 40 mm deflection.

EFNARC and EN 14488-5 suggest centrally loaded square plate test with a deflection-controlled testing machine for the testing of energy absorption or toughness of shotcrete. Both specify a specimen of size 600 x 600 x 100 mm. Further these codes state that the specimen shall be supported on its 4 edges and a center point load is applied through a contact surface of 100 x 100mm.

EFNARC suggests that the rate of deformation of the midpoint shall be 1.5mm per minute and the test shall continue until a deflection of 25mm is achieved at the center point of the slab.

EN 14488-5 suggests that the loading shall be at a constant rate of 1 ± 0.1 mm/min at the center of slab and the load-deflection shall be continuously recorded with the data logger until a deflection of at least 30mm is obtained. It specifies the energy absorption capacity in joules is reported as the area under the load-deflection curve between 0 and 25 mm deflection.

(iv) **Durability Properties**

Permeability and porosity are the two important factors for a durable shotcrete and they in turn affect the other parameters such as strength and ability to resist deterioration mechanism.

a) Absorption and volume of permeable voids

Boiled Water Absorption (BWA) and Maximum Volume of Permeable voids (VPV) tests measure the porosity due to capillary action in the sample, but express differently. BWA represents mass ratio whereas the VPV represents the volumetric ratio of water absorbed.

ACI 506R recommends acceptable values of permeable void volume in the range of 14 to 17% and typical boiled absorption values in the range 6 to 9%.

Similarly, ACI 506.5R specifies maximum volume of permeable voids at 7 days as 17% and maximum boiled absorption at 7 days as 8%. ASTM C642 test method is recommended to find BWA and VPV.

b) Permeability

EFNARC suggests a maximum value of water penetration in accordance with EN 7031 as 50mm and the mean average value shall be less than 20mm. Also, it states that sprayed concrete is considered water-tight when the coefficient of water permeability is less than 10-12 m/s. Similarly, EN suggests resistance to water penetration in accordance with EN 12390-8 as 50mm.

c) Air content

Air content (%) and spacing factor are related to the freezing and thawing resistance of shotcrete. The term "spacing factor" refers to the distance between air bubbles in hardened shotcrete.

ACI 506R recommends an entrained air-void system with in-place air content in the range of 4 to 6% with a maximum air void spacing factor of 0.3mm to resist freezing and thawing cycles. Further it recommends total air content in concrete before shooting as 6 to 10%.

ACI 506.5R suggests air content as shot: 4 ± 1% and air content immediately before the pump as 7 to 10%. Further it states a maximum spacing factor of 0.3mm for as shot. A minimum air content of 7 ± 1% before shooting and 4 ± 1% as shot is recommended where freezing and thawing resistance is of interest.

EFNARC and EN haven't discussed the concept of air content. EN has noted that data of the current available test methods for the measurement of air content lacks reliability for fresh sprayed concrete.

SS-88 Clause 6.24 Shotcrete; sub-clause 6.24.5 Measurement and Payment (Technical Specifications for Workmanship Page – 188 of 192).

Delete the text of this sub-clause and replace with the following:

1. Measurement

a) For surface works (slopes) the quantities of shotcrete to be paid for shall be measured by the unit of cubic meters to be computed from the actual area of shotcrete placed and the theoretical thickness as shown on the drawings and/or directed by the Engineer/Engineer representative hereinbefore described and accepted with all its additional requirements in accordance with the contract unit rate for shotcrete. No separate remuneration for filling of over-breaks and rebound will be made.

b) For the primary lining of the tunnel, the quantities of shotcrete to be paid for shall be measured by the unit of cubic meters to be computed from the actual area of shotcrete placed and the theoretical thickness as shown on the drawings and/or directed by the Engineer/Engineer representative hereinbefore described and accepted with all its additional requirements in accordance with the contract unit rate for shotcrete. No separate remuneration for filling of over-breaks and rebound will be made.

c) Where fore-poling is required, no separate remuneration for the additional shotcrete will be made, i.e., the costs for the additional shotcrete shall be deemed to be included in the primary shotcrete lining costs.

2. Payment

a) The accepted quantity measured as provided above shall be paid for at the unit rates shown in the Bill of Quantities which price and payment shall be full compensation for all labor, supervisors, materials, welded wire fabrics/mesh, the contractor's equipment, transportation, preparations, storage, cleaning of application surfaces, operating, removal of rebound, temporary protection, submittals, making and handling test panels, QA / QC testing's, curing and all costs required for production and application of shotcrete and for any other contingencies as well as the costs of obtaining shotcrete test cores and of testing holes backfill, but not including reinforcing steel for Lattice Girders which shall be measured and paid as provided under the relative items of work.

b) In case the measured quantity as given in **sub-clause 1 above** is more than theoretical quantity calculated as per approved drawings, payment shall be limited to the theoretical quantity only.

SS-89 Clause 6.24 Shotcrete; sub-clause 6.24.5 Measurement and Payment (Technical Specifications for Workmanship Page – 188 of 192).

At the end of this sub-clause, add the following supplementary sub-clauses.

6.24.6 Reinforcing Steel

6.24.6.1 General

For specifications of steel reinforcement in-situ shotcrete and concrete, refer to Clause – 6.19 Reinforcement of these specifications. This Section includes additional requirements for steel reinforcement of primary tunnel support.

6.24.6.2 Wire Mesh (*Welded Wire Reinforcement* -WWR)

Wire mesh is used where low cohesion between shotcrete and rock surface is causing fallouts of shotcrete. These circumstances often occur during shotcreting of very wet, heavily jointed or sedimentary rock surfaces. Local shear failures due to pull weight of the shotcrete is also common in rock types with low cohesion strength and are often supported with wire mesh before shotcreting.

Main advantages:

- Increases shear strength and ductility of a shotcrete lining.
- Reduced fallout of shotcrete during shotcreting.

6.24.6.2.1 Material

Welded wire reinforcement shall conform to the following requirements:

- Deformed Billet-Steel Bars (Grades 40 and 60) for Concrete Reinforcement-AASHTO M-31 (ASTM A-615).
- Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete - ASTM A1064/A1064M-16.
- Welded Steel Wire Fabric for Concrete Reinforcement-AASHTO M-55 (ASTM A-185).
- Welded Deformed Steel Wire Fabric for Concrete Reinforcement-AASHTO M-221 (ASTM A-497)

The dimensions of the steel wire mesh shall be as specified in the drawings. The steel wire mesh, as approved by the Engineer/Engineer representative, shall be delivered to the site in flat mats or pre-bent to the specified shape.

6.24.6.2.2 Installation

The steel wire mesh shall be installed such that it follows as closely as possible the irregularities of the excavation surface or previous layers of shotcrete. It shall be firmly fixed to prevent vibration and change of position during spraying of shotcrete. The steel wire mesh shall be installed in the longest practical length. The overlap of the steel wire meshes applied in the shotcrete lining shall be at least twice the pitch distance in circumferential and one pitch distance in longitudinal direction.

The shotcrete protection layer thickness of steel wire mesh shall not be less than 20mm, if not specified in drawings. When use double layers steel wire mesh, the distance of double layers steel wire mesh shall not less than 60mm, or as specified in drawings.

6.24.6.3 Roof Ties

6.24.6.3.1 Materials

For roof ties, deformed steel bars of grades 40 or 60 as per ASTM A-615 shall be used.

6.24.6.3.2 Installation

Roof ties shall be attached securely to the rock and in front of the previously placed wire mesh. The position of the roof ties shall correspond to the line of the rock bolts to be installed and so that the rock bolts will pass through the section of the roof tie.

6.24.7 Lattice Girders

6.24.7.1 General

This section applies to the supply and installation of the lattice girders required and used as support in underground excavations.

Lattice girders serve some of the same basic functions in tunneling as steel arch supports. They are part of the temporary lining which initially supports the excavation and, in some cases, are part of the finished lining. Lattice girder systems offer a very economical alternative to other support methods for a wide variety of ground conditions, when used with the New Austrian Tunneling Method (NATM) of shotcrete application.

The main advantage of the Lattice Girder is its ability in working with shotcrete. It provides a more efficient bond with the shotcrete strength. Because of the open nature of the lattice beam's construction, shotcrete passes through it readily reducing the possibility of unconsolidated shotcrete areas behind the beam. The shotcrete can be applied evenly producing the superior, integral lining.

6.24.7.2 References

a) American Society for Testing and Materials (ASTM): ASTM A36/A36M Standard Specification for Carbon Structural Steel.

b) American Welding Society (AWS) D1.4: Structural Welding Code - Reinforcing Steel

6.24.7.3 General Requirements

a) Lattice Girders shall be effective as primary support element immediately after excavation and shall subsequently act as reinforcement and load distributing members for the shotcrete lining.
b) The lattice girders shall be manufactured to meet the geometrical requirements for the excavation geometries for each rock class including the relevant tolerances as specified herein below.
c) When handling and shipping lattice girders, prevent bending, scraping or overstressing members.
d) Block projecting parts likely to be bent or damaged during handling with wood or other material.
e) Replace pieces bent or damaged unless repair is possible.

6.24.7.4 Submission

a) Sub-clause 6.24.3 of these specifications.
b) Shop Drawings for the fabrication of the lattice girders.
c) Prior to the beginning of the work, the following shall be submitted:
   (i) Complete fabrication details of the lattice girders
   (ii) Installation procedures and layout
   (iii) Details of joints, connections, spacers, geometry etc.
   (v) Certificates of compliance of the materials.

6.24.7.5 Design of Lattice Girder

(i) Lattice girders are three-dimensional, lightweight steel frames manufactured of round or deformed steel bars in compliance with the required excavation geometry of the tunnel.
(ii) Contrary to standard rolled steel sections and regardless of shape, the lattice system, in conjunction with shotcrete is totally surrounded by concrete forming a complete homogeneous composite structure with no unconsolidated areas, voids or fissures visible. This result in a tunnel

lining that significantly reduces ground settlement and prevents the ingress of water.

(iii) Lattice girders shall be either three-chord or four-chord. Three-chord lattice has triangular section with a larger bar (25-40mm) at the apex and two smaller diameter bars at the base corners. Sinusoidal bars (10-12mm) separate the apex and the main bars. Four chord lattices have four equally sized bars (20-40mm) at the corners of rectangular section. Sinusoidal side bars and cross bars (16mm) separates the main bars. The stiffening elements shall be designed so as to:

a) Facilitate shotcrete penetration into and behind the girder, thereby minimizing the creation of projection shadows.

b) Provide good quality bonding between the steel and shotcrete, to form a composite structure in the sense of a continuous reinforced shotcrete lining.

(iv) A minimum 5% of the total moment of inertia shall be provided by the stiffening elements. This percentage is calculated as an average value along repeatable lengths of the lattice girder.

(v) To ensure stability against buckling, the maximum spacing between stiffening elements shall be less than three times the cross-sectional height of the girder.

(vi) In case of fabrication on site, the Contractor shall submit a detailed method statement for approval to the Engineer/Engineer representative.

(vii) The Contractor shall submit related detailed drawings of the lattice girders, showing also the number of sections in the frame and details of the connection between the sections. The detail to be approved by the Engineer/Engineer representative.

6.24.7.6 Materials

(i) Each of the primary bars of a lattice girder segment shall be composed of only one piece of high strength steel having a yield strength of 60 Ksi or stronger.

(ii) The connection elements at the end of the grinder shall be constructed of structural angle or plate meeting the minimum properties of A36 or stronger, or of welded flat steel ensuring similar strength characteristics. Bolts and nuts shall meet the requirements of A325 unless otherwise noted on the drawings.

6.24.7.7 Manufacturing of Lattice Girders

6.24.7.7.1 Geometry

The lattice girders shall be fabricated to meet minimum clearances as shown in the drawings to tolerate any inaccuracy of placement during construction.

6.24.7.7.2 Welding of Lattice Girders

Testing of materials and workmanship shall be carried out in accordance with AWS D1.4; If the testing performance is of low quality, the Engineer/Engineer representative may direct the contractor to execute the job through a reputed testing agency.

(i) The manual metal-arc welding process shall be employed. The manufacturer shall be responsible for ensuring that the capacity of the welding plant and ancillary equipment is adequate for the welding procedure to be used and for maintaining all welding plant and ancillary equipment in good working order.
(ii) Covered electrodes complying with German Standard DIN 1913, or ANSI/AWS A5.1-91 E6013 and E702 shall be used. Electrodes shall be selected with regard to the particular application (welding position, joint design). Electrodes shall be stored in their original containers in a dry, preferably heated place adequately protected from the effects of the weather and in accordance with the manufacturer's specification.
(iii) Surfaces to be welded shall be dry. Fusion faces and the surrounding surfaces shall be free from heavy scale, moisture oil, paint or any other substance which might affect the quality of the weld. Slag shall be removed from each run of weld metal before a further run is superimposed. The most favorable welding position for each case shall be chosen.
(iv) For the cutting of the steel profiles the manual flame cutting process may be employed. Also, sawing is permitted.
(v) Further preparation of joint and fusion faces shall be done by grinding.
(vi) Parts to be welded shall be assembled such that the joints are easily accessible and visible to the operator.
(vii) Slag shall be removed from all welds in order to allow visual inspection.

(viii) Welding operations shall be supervised by a suitably trained supervisor who shall have particular production experience. The welding supervisor is responsible for the following duties listed hereunder:

a. employment of the welders or skilled operators and supervision of their work

b. selection, use and storage of suitable welding filler metals and auxiliary materials

c. selection and use of satisfactory welding apparatus, welding plant and welding fixtures

d. visual and dimensional checking of the weld seams as described **herein (xii) below**.

(ix) Welders shall pass the acceptance test as described **herein (xii) below**.

(x) Prior to commencement of each welding connection type three No's of joints shall be manufactured by each welder under conditions of the regular manufacturing process for inspection. These joints shall be inspected by the Engineer/Engineer representative.

(xi) Routine inspection of welded joints shall be done by spot checking of not less than 10 per cent of the welded joints in compliance with **sub-para (xii)** by the Engineer/Engineer representative.

(xii) **Acceptance Test** and Routine Inspection shall be done in accordance to the criteria as described hereinbelow. Visible defects exceeding the limits as shown shall be removed and replaced by adequate means.

Table: Acceptance Test

Undersize welds	0.1 (10 %)
Undercuts	Permitted to a limited extent
Visible pores	some, 10% by area
Visible slag inclusion	permitted to a limited extent not continuous
Open end craters	slight depressions permitted
Lack of fusion	permitted, but no large and no continuous areas
Cracks	Individual small local cracks permitted
Excessive asymmetry of welds	side ratio < 1.0: 0.6

6.24.7.8 Installation of Lattice Girders

a) Install to conform to the excavated shape. Consider inaccuracy of construction and tolerances of materials.

b) Lattice girders shall be erected to the lines and levels as indicated on the drawings. The exact excavation levels will however be determined by the Contractor to match best his equipment and construction method subject to the approval of the Engineer/Engineer representative.

c) Secure lattice girders by use of spacers as well as temporary wood blocking, mortar sacks or other appropriate means to maintain position during shotcreting.

d) Provide butt plates for steel girder segments and expansion unit in invert as required. Ensure tight connection of all elements such that the static efficiency of the cross section is maintained.

e) Lattice girders shall be embedded in shotcrete, in order to get contact between rock and lattice girder by a solid shotcrete packing which shall have a minimum cover to steel of 20 mm.

f) The lattice girders shall be erected perpendicular to the tunnel axis.

6.24.7.9 Measurement

a) The quantity to be paid for shall be the calculated theoretical number of metric tons of lattice girders as determined from the approved bar bending diagrams and incorporated in the shotcrete and accepted.

Measurements shall be based on length of the lattice girder along the center-line, multiplied by the weight per linear meter of the lattice girder.

The weight of plain or deformed bars, from which the lattice girders are fabricated, will be computed from the theoretical weight of plain round bars of the same nominal size as described herein in **Clause – 6.19 Reinforcement**, of these specifications.

b) Clips, ties separators, and other material used for positioning and fastening the lattice girder in place shall not be included in the weight calculated for payment under this item. If bars are substituted upon the Contractor's request and as a result more steel is used than specified, only the amount specified shall be measured for payment.

c) When laps are made for splices, other than those shown on the drawings or required by the Engineer/Engineer representative and for convenience of the Contractor, the extra steel shall not be measured nor paid for.

d) When continuous bars are shown on the drawings, without the splices being shown the necessary steel in the splices will be paid for on the basis of the individual bars not being shorter than twelve (12) meters.

e) Steel work used for temporary work will not be measured.

6.24.7.10 Payment

The accepted quantity measured as provided above shall be paid for at the contract unit price for the pay item shown in the Bill of Quantities which price and payment shall be full compensation for all labor, supervisors, materials, the contractor's equipment, installation, QA / QC testings and incidentals necessary to complete the item.

6.24.8 Forepoling

6.24.8.1 General

Forepoling is a pre-excavation temporary support element installed in longitudinal direction of the tunnel. The support element shall be applied in rock and soil conditions, to reduce the free span of the unsupported excavation surface which tend to produce over-break, collapses or material inflows immediately following excavation. Forepoling is only support aids for the excavation and have less function after installation of the initial lining (shotcrete, wire mesh, rock bolts). Steel forepoling pipes, forepoling rods and lagging sheets are mainly used. They can be driven into the ground or, for forepoling, installed in pre-drilled holes. If installed in pre-drilled holes, the space between forepoling pipes (or bars) and borehole surface should be fully cement grouted.

The forepoling is usually provided in the crown area, each round from the current top heading to provide safety for the following top heading excavation round. It shall be installed through the last lattice girder installed. Depending on the ground conditions encountered, forepoling shall be performed with one of the following types:

- In ground conditions where the borehole stability can be guaranteed steel bars of grade 60 / 75, diameter 32mm should be installed.

- In ground conditions where borehole instabilities are likely to occur self-drilling anchor of type R32N with a yield strength of minimum 230 kN should be installed.

Forepoling length shall be kept 4 m for all support classes and 6m during start sequence, and is to be installed every round, thus giving sufficient overlap between adjacent rounds.

In the Forepoling Umbrella System (FUS), steel pipes installed from the tunnel face to form a roof above the tunnel heading, thereby contributing to decreasing the deformations caused by tunneling and increasing the tunnel heading stability. One of the noticeable advantages of FUS is the immediate support after installation of the steel pipes (also termed as forepoles) that allows the excavation to be carried out with minimal waiting time.

6.24.8.2 Material

With stable boreholes:

1. Steel pipes with a minimum outer diameter of 76 mm shall be used. Wall thicknesses of steel pipes shall not be less than 4 mm. Grout mortar shall comply with Clauses 6.14 of these specifications.

2. Dowels (spiles) consisting of deformed high yield steel bars grade 60 with a minimum diameter of 32 mm may be used instead of steel pipes, if approved by the Engineer/Engineer representative. Grout mortar shall comply with sub-clauses **6.24.9.4.4 & 6.24.9.6.1** of these specifications.

With unstable boreholes:

1. Self-drilling bolts shall be used as forepoling elements where stability of the predrilled boreholes cannot be achieved, due to the encountered ground conditions. Self-drilling bolts shall be installed upon instruction of the Engineer/Engineer representative only and shall have a yield load of at least 230 kN. The grout used for self-drilling bolts shall be in accordance with the requirements of the bolt manufacturer. Where required by the Engineer/Engineer representative, grouting shall be carried out

simultaneously with drilling to achieve a better grouting effect along the bolt.

6.24.8.3 Installation

1. Forepoling shall be applied as shown on the drawings or as instructed by the Engineer/Engineer representative.

2. Forepoling elements at 300 to 500 mm centers shall be inserted into the predrilled holes (steel pipes or dowels) at the face or drilled into the face (self-drilling bolts) from the face of the drivage towards the unexcavated ground as shown on the drawings.

3. The length of forepoling elements shall be according to the drawings or at least 1.50 meter longer than the applied length of round, as instructed by the Engineer/Engineer representative.

4. Forepoling requires the installation of lattice girders.

5. Grouting of forepoling pipes and dowels with cement mortar, either before or after the insertion of the pipes, to be determined by the Engineer/Engineer representative.

6. Forepoling shall be properly supported by the lattice girder and the shotcrete above the lattice girder. Therefore, shotcreting of the gap between lattice girder and rock in the portions of forepoling shall be completed after the installation of forepoling.

7. Spacing between consecutive forepoling pipes or bars around the crown of the excavation profile must comply with the distance specified on the drawings, but shall be adopted by the Contractor with due regard to the prevailing geological conditions of the tunnel face.

6.24.8.4 Pipe Roof

A pipe roof is a special type of long forepoling (typically 9 – 15 m). The forepoling elements shall consist of steel pipes with a minimum outer diameter of 76 mm and a minimum yield load of 122 Tonne. The pipes shall be grouted with cement mortar.

6.24.8.5 Measurement

The quantities of forepoles to be paid for shall be the theoretical length of the steel pipes, dowels or self-drilling bolts hereinabove described and accepted with all its additional requirements included in the unit price. Measurements shall be based on the dimensions shown on drawings or as otherwise directed or authorized by the Engineer/Engineer representative.

6.24.8.6 Payment

The accepted quantity measured as provided above shall be paid for at the contract unit prices respectively for the pay items shown in the Bill of Quantities which price and payment shall be full compensation for all labor, supervisors, materials, the Contractor's equipment, drilling, installation and grouting, QA / QC testing or any other contingencies.

6.24.9 Rock Bolts

6.24.9.1 General

1. The provisions contained hereunder shall apply to all rock bolts installed either locally or in a systematic pattern in the roof, side walls, invert of the tunnels and portal structures. In underground excavations, rock bolting form part of the primary support system, with the purpose of activating the composite action between the surrounding rock and the shotcrete, contributing to the load bearing capacity of the primary tunnel lining, while in open cut excavations, the same are used for stabilizing rock cuts.

2. Rock bolts shall be installed according to the lengths and rock bolt patterns shown on the drawings for each relevant standard support system unless otherwise approved of the Engineer/Engineer representative.

6.24.9.2 References

American Society for Testing and Materials (ASTM):

a) ASTM A36/A36M - Standard Specification for Carbon Structural Steel
b) ASTM C150 - Standard Specification for Portland Cement
c) ASTM C494 - Standard Specification for Chemical Admixtures for Concrete
d) ASTM D4435 - Standard Test Method for Rock Bolt Anchor Pull Test

e) International Society for Rock Mechanics (ISRM) - Doc.2, Part-1 "Suggested Method (SM) for Rock bolt Testing".
f) SM for Determining the Strength of a Rock bolt Anchor (Pull Test) Part-2
g) SM of Determining Rock bolt Tension Using a Torque Wrench Part-3
h) SM for Monitoring Rock bolt Tension Using Load Cells
i) SM for Rock Anchorage Testing - 1985

6.24.9.3 Definitions

1. SN-Bolts are made of deformed steel bars and fully bonded with the surrounding rock by cement mortar. The hole is filled with grout before insertion of the bolt. The abbreviation SN descends from the mine "Store Norfors" in Sweden where it had been applied first.
2. Self-drilling bolts are a combined system of rock bolt and drill rod. During drilling, the bolt is used as the drill rod fixed with a drill bit. Rod and bit remain in the hole as a rock bolt, which is grouted through the flushing hole. In case of collapsing boreholes, this system still enables the installation of rock bolts. Special provisions also allow the grouting to be carried out simultaneously with the drilling operation to achieve a better grouting effect.
3. Swellex-type rock bolts (friction anchored rock bolts) are mechanically folded steel tubes. High water pressure inflates the tube and adapts its shape to the irregularities of the borehole.

6.24.9.4 Materials

6.24.9.4.1 SN-Bolts

(i) SN-Bolts shall consist of rebars with a minimum diameter of 25 mm and shall be of deformed steel grade 60.
(ii) The yield loads of the bolts shall also apply to the thread, nut, anchor plate and coupling, if any.
(iii) Rock bolts shall be made of deformed reinforcing steel with a corrugated surface. One end shall be fitted with a suitable thread which is to receive an anchor plate and fixing nut.

(iv) Anchor plates with a size of 200 x 200 mm and a thickness of 12 mm shall be used unless otherwise shown in the drawing or as approved by the Engineer/Engineer representative based on support necessities. The shape shall allow a uniform seat, even if the bolt is not installed exactly perpendicular to the surface below.

(v) Washers and nuts shall allow the secure transfer of the anchor force to the anchor plate.

6.24.9.4.2 Self drilling Bolts

(i) Self-drilling bolts installed in tunnels shall have a minimum yield load of 20 Tonne.

(ii) Self-drilling bolts installed at slopes shall have a minimum yield load of 23.5 Tonne.

(iii) Self-drilling bolts installed as micro piles shall have a minimum yield load of 46 Tonne.

(iv) Self-drilling bolts for pipe roofs shall have a minimum yield load of 122 Tonne.

(v) The yield load shall also apply to threads, nuts, anchor plates and couplings.

(vi) The steel rods shall have a corrugated surface.

6.24.9.4.3 Swellex-type Rock bolts

(i) Swellex-type Rock bolts for local or systematic rock bolt patterns shall have a minimum yield load of 15.3 Tonne.

(ii) Bolt face plates shall be such as to allow transfer of the anchor force at the head of the rock bolt to the shotcrete, steel girder or rock surface.

(iii) For inflation of bolts, equipment as recommended by the manufacturer of the bolts shall be used.

6.24.9.4.4 Cement - Mortar Grout

(i) The cement mortar grout shall consist of sand, cement and water or neat cement and water.

(ii) Ordinary Portland cement shall be used.

(iii) Sand for grouting purpose shall be clean mineral sand, uniform in quality and from an approved source. This material shall be approved by the Engineer.

(iv) Water shall be clean, free from oil, acid, alkaline, organic and other deleterious substances.

(v) Additives for the improvement of workability may be used.

(vi) The cement mortar grout shall be mechanically mixed to produce a uniform consistency.

(vii) The cement mortar grout shall correspond to concrete class A2 according to Table -1, clause 6.1.3 Classes of Concrete of these specifications.

6.24.9.5 Execution

The introduction of cement mortar grout to the borehole may be carried out by pump or compressed air displacement vessel. The installation procedure of specialized products shall be as per the suggested method by the manufacturer duly approved by the Engineer/Engineer representative.

6.24.9.5.1 SN–Bolts

(i) Boreholes for all rock bolts shall be drilled to the depths as required by the lengths of rock bolts specified for the respective rock class and at diameters, which ensure best workability for grouting, coupling and installation. The minimum diameter of the boreholes shall be 10 mm larger than the diameter of the rock bolts/couplings installed.

(ii) The boreholes shall be cleaned of all drill cuttings, sludge and debris.

(iii) Prior to the installation of the rock bolt, the entire borehole shall be filled with cement mortar by inserting the grout hose to the full depth of the hole and withdrawing as the grout is pumped in. The nozzle shall be kept buried in the grout as the pipe is withdrawn so that air is displaced as the hole is filled. The bolt is then pushed into the hole.

(iv) The nut of the grouted rock bolts shall be tightened not later than 12 hours after installation to achieve a force at the anchor plate of approx. 2 Tonne. This force shall be applied by a calibrated torque wrench.

(v) In case of confined working space and/or great length of rock bolts, coupling shall be permitted. The number of coupled parts shall be kept to a minimum. However, the load capacity of such coupled rock bolts shall not be less than that of a standard integral rock bolt. Special attention shall be paid to the grouting procedure in order to ensure full embedment of the bolt by grout.

(vi) In case of coupled rock bolts, partly collapsed boreholes, or major water flow from the borehole, grouting may be done after installation of the bolt (post grouting). The hole is then grouted by a special attachment which allows the mouth of the borehole to be sealed whilst the grout is pumped in. Air is displaced from the hole via a tube which is attached to the full length of the rock bolt as it is installed. Grout is then pumped in and the hole can be seen to be full, when grout escapes from the end of the tube.

6.24.9.5.2 Self-drilling Bolts

(i) Self-drilling bolts shall be used in ground conditions where the effective installation of other types of rock bolts is impossible.
(ii) Self-drilling bolts shall be placed by drilling the rod into the ground without withdrawing the rod.
(iii) Self-drilling bolts shall be grouted through the flushing hole immediately after completion of the drilling operation or simultaneously with the drilling, as required by the Engineer. For grouting process, the grouting pump recommended by the manufacturer and approved by the Engineer/Engineer representative shall be used.
(iv) The grout mix, grouting pressure and quantity shall be as advised by the supplier and be approved by the Engineer/Engineer representative.

6.24.9.5.3 Swellex-type Rock bolts

(i) Boreholes for the rock bolts shall be drilled to the depths as required. The boreholes shall be cleaned of all drill cuttings, sludge and debris.
(ii) The installation of rock bolts shall be done not later than two hours after drilling of the borehole.
(iii) Installation / inflation of the bolts shall follow the manufacturer's recommendations. Specific inflation plant shall be used. The rock bolt shall be drained after inflation.

6.24.9.6 Testing

6.24.9.6.1 Grout Mortar

1. Prior to acceptance tests of rock bolts, tests with available cements and sands shall be carried out to determine an appropriate mix design to achieve the specified strength and a proper workability in association with the grouting equipment used.
2. Additives may be used to improve workability. The influence of the additive to the strength development shall be followed by tests as described under this Clause.

3. The grout mortar shall be tested according to ASTM C 942 & ASTM C 109 on cubes 5x5x5 cm. The cubes shall be cured in water.
4. Five numbers of cubes shall be prepared for each compressive strength test. The resultant strength is the average evaluated from the three remaining values after elimination of the highest and the lowest.
5. During construction, cube sample shall be taken weekly at each five bolts drivage from the grouting hose at the nozzle. Preparation and evaluation shall follow the procedure as described above.

6.24.9.6.2 Pull Out Tests on Rock Bolts

Pull-out tests shall be performed on basis of ISRM Doc.2, Part 1 "Suggested Method for Rock bolt Testing".

1. Proof Tests

(i) A detailed test program set up on basis of above-mentioned document shall be approved by the Engineer/Engineer representative prior to all testing work.

(ii) Specifically, deviations from the ISRM suggested method shall be approved by the Engineer/Engineer representative.

(iii) A test report shall be issued immediately after completion of the tests. It shall be submitted for approval to the Engineer/Engineer representative.

(iv) For each type of rock bolt submitted information shall comprise:

- type of bolts
- testing equipment
- location and installation records
- applied testing loads and records of deformation
- otherwise, the evaluation of test results as specified in ISRM's document
- interpretation and suggested action for failed pull-out tests

(v) Proof tests shall be carried out for all types of bolts to be used for this project prior to the commencement of tunnelling to demonstrate the effect and the service capacity of the bolts in the field.

(vi) The tests shall be performed in similar geological ground conditions as expected during tunnel drivage. The location of the bolts to be tested shall be selected by the Engineer/Engineer representative.

(vii) A minimum of five bolts of each type shall be tested. Depending on the testing procedure and the test results the Engineer/Engineer representative may require further bolts to be tested.

(viii) Adequate testing equipment, as specified in the above mentioned ISRM document shall be provided to record bolt elongation, movement of the bolts and tension forces.

(ix) The maximum load to be applied shall be the bolt´s yield load or as otherwise approved by the Engineer/Engineer representative.

2. Testing during Tunnel Driving

The Engineer/Engineer representative will select rock bolts for testing of production bolts. For each type of rock bolts five bolts will be selected from the first 100 bolts placed in the tunnel. From the remaining bolts five per 500 bolts will be selected for testing purpose. The testing force to be applied shall be equal to 80% of the bolt´s yield load.

(i) Bolts which fail the tests or which are pulled out shall be replaced.

(ii) For each failure, the Engineer/Engineer representative shall require further bolts to be tested in the vicinity.

(iii) Otherwise proceed as per sub-para’s **(i) to (ix)** of para **(1)** above.

6.24.9.6.3 Installation Records

Comprehensive records about details of the installation of rock bolts during drivage, such as grout consistency, drilling depth, length and type of rock bolts, deviations from the theoretical position, type and time of grouting, time of tightening, special observations, etc. shall be kept for each round by the Contractor and countersigned by the Engineer’s supervisory personnel. Copies of these records shall be submitted to the Engineer/Engineer representative.

6.24.9.7 Measurement

The quantities of rock bolts to be paid for shall be the number of various types and lengths of rock bolts as shown on the drawings and/or directed by the Engineer/Engineer representative as hereinabove described and accepted with all its additional requirements.

6.24.9.8 Payment

The accepted quantity measured as provided above shall be paid for at the contract unit prices respectively for the pay items shown in the Bill of Quantities which price and payment shall be full compensation for all labor, supervisors, materials, the Contractor’s equipment, drilling, installation, grouting and QA / QC testing for rock bolts or any other contingencies. No payment shall be made for unqualified rock bolts.

6.24.10 Shotcrete for inner lining

6.24.10.1 General

Material and construction requirements for primary shotcrete lining (outer lining) as specified hereinabove vide Clause **6.24** of these specifications shall conformably apply to the inner shotcrete lining (secondary lining) unless otherwise specified in this section.

The early strength requirements for the primary shotcrete as specified herein above shall not apply for Secondary shotcreting.

The 3, 7 and 28 day’s strength criteria as specified hereinabove and the corresponding tests shall be carried out as specified vide sub-clause **6.24.4.7.2 - Field Quality Control.**

Additional requirements for the shotcrete of the Inner Lining shall be as specified below:

6.24.10.2 Material

(i) Shotcrete for the Inner Lining shall only be wet-mix shotcrete.
(ii) The shotcrete shall comply with the requirements of concrete grade as specified in the drawing.
(iii) The wet-mix for the shotcrete shall have a water/binder ratio of less than 0.5. The term “binder” shall comprise all cementitious material.
(iv) The maximum accelerator dosage for the shotcrete shall be 5% (of the cement weight).

6.24.10.3 Execution

(i) Before applying the shotcrete for the inner lining, the surface of the outer lining shall be cleaned by means of a high-pressure water jet.
(ii) Installation of wire mesh shall be carried out in a way that an overlap of four layers of mesh does not exist at any location.
(iii) In case of several shotcrete layers, construction joints shall be staggered.

SS-90 Clause 6.25 Mass Concrete (Technical Specifications for Workmanship Page – 189 of 192).

Amend the title of this clause and replace with “Mass and Plum Concrete”.

SS-91 Clause 6.25 **Mass and Plum Concrete;** sub-clause 6.25.1 Description (Technical Specifications for Workmanship Page – 189 of 192).

Add the following after the first paragraph.

Plum concrete, also known as Rubble or cyclopean concrete shall be a type of Mass Concrete consisting of Concrete Class 'B' 170 Kg /Cm^2 (2500 Psi) intermixed with large embedded stones up to 300mm size, with No stone dimension less than 150mm.The maximum size of stones shall be determined by the size of the structure.

SS-92 Clause 6.25 **Mass and Plum Concrete;** sub-clause 6.25.2 Material Requirements; (Technical Specifications for Workmanship Page – 190 of 192).

Add the following additional para after the “para 25.2.3 Water”.

6.25.2.4 Rubble

Rubble shall consist of tough, sound and durable rock. The stone shall be free from coatings, seams or flaws of any character. In general; the percentage of wear shall not exceed fifty percent when tested in accordance with the Standard Method of Testing for Abrasion of Coarse Aggregate by the use of the “Los Angeles Machine", ASTM C535.

The stones used for the plum material should be ideally made from the very same rock as aggregate particles of concrete. It shouldn’t be flaky or elongated and shouldn't have any dirt or clay in it. If there is any dirt on the top of the plum substance, it should be washed before using it.

SS-93 Clause 6.25 **Mass and Plum Concrete;** sub-clause 6.25.3 Construction Requirements; para 25.3.3 Placing (Technical Specifications for Workmanship Page – 189 of 192).

Add the following at the end of this para:

The stone for this class of work shall be placed carefully so as to avoid damage to the forms or to the partially set adjacent concrete. Stratified stone shall be placed upon its natural bed. Stone shall be washed and saturated with water before placing. The formwork used to pour the plum concrete shall be of steel plates and it should not be damaged or misplaced while placing/dumping of stones.

Plum concrete can be done in two ways. Either by inserting the plum to the concrete mix mostly during the mixing process or by scattering the plums over the regular concrete layer but instead distributing an additional layer of concrete.

The incorrect practice of initially spreading a layer of stones and then spreading a layer of concrete over the stone layers should be avoided. The correct practice of first placing a concrete layer of 150mm, followed by spreading the plum material 150mm apart carefully and then a concrete slab sprayed over it should be adopted. Only after concrete gradually fills in the gaps between the plum elements, an additional layer of plum substance must be applied to the concrete. This procedure is repeated several times until the design level is attained. Each stone should be covered by 150mm Class 'B' concrete all around and the spaces in between the larger stones should not be filled with smaller stone chippings except concrete.

When putting plum concrete, special care must be taken to avoid air traps, which can reduce the strength of the plum concrete. It is therefore essential to ensure that they will be put at once.

The total volume of the stone shall be between 30% to 50% of the total volume of the portion of the work in which it is placed. If the plum materials are positioned close together, the amount of concrete needed will be reduced, even below 50%.

For walls of piers greater than sixty (60) cms in thickness, stone of such size that one man can handle it, shall be used. Each stone shall be surrounded by at least fifteen (15) cms of concrete and no stone shall be closer than thirty (30) cms to any top surface nor any closer than fifteen (15) cms to any coping. For walls or piers greater than one (1) meter in thickness, larger stone (50 Kg or more) may be used. Each stone shall be surrounded by at least thirty (30) cms of concrete, and no stone shall be closer than sixty (60) cms to any top surface nor closer than twenty (20) cms to any coping.

After all of the layers of plum concrete have been carefully placed, they are neatly finished and left to cure for at least 14 days. Curing can be accomplished in a variety of ways. Water can be dumped on the plum concrete at regular intervals, or it can be covered with moist jute containers.

SS-94 Clause 6.25.3 Construction Requirements; sub-clause 6.25.3.3 Placing (Technical Specifications for Workmanship Page – 191 & 192 of 192).

Delete the word “laced” in the sixth line of 2nd paragraph and replace with “placed”.

SS-95 Clause 6.25.4 Measurement & Payment Technical Specifications for Workmanship Page – 192 of 192).

Delete the text of this clause and replace with the following: -

Unless otherwise specified explicitly in these specifications or elsewhere in the contract documents, the measurement and payment against the Concrete and steel reinforcement items of **“Mass and Plum Concrete”** including falsework, and formwork shall be according to specified BOQ items of **Section 6.0 – Cement Concrete** and **6.19 – Reinforcement** respectively.

CHAPTER - 18 PILES

SS-96 Sub-clause 18.1.3 Material Requirement; para 18.1.3.1 Types of Piles; sub-para 5 Pre-Cast Concrete Piles (Technical Specifications for Workmanship Page – 4 of 36).

Delete the word “Class-01” in the second line of 1st paragraph and replace with “Class-D1”.

SS-97 Sub-clause 18.1.4 Construction Requirements; para 18.1.4.1 Driven Piles (Displacement Method); sub-para 3 Pile Driving (Technical Specifications for Workmanship Page – 5 of 36).

Delete the word “Mien” in the second line of 2nd paragraph and replace with “Where”.

SS-98 Sub-clause 18.1.4 Construction Requirements; para 18.1.4.1 Driven Piles (Displacement Method); sub-para 4 Pile Driving Formula (Technical Specifications for Workmanship Page – 7 of 36).

- Delete the word “smaller” in the second line of formula for “Single-acting steam or air hammers and for Diesel hammers” and replace with “larger”.
- Delete the word “smaller” in the second line of formula for “Double-acting steam or air hammers and for Diesel hammers” and replace with “larger”.
- In the second line of the last paragraph, provide “full stop (.)” after the word “pile” and replace the word “other” with “Other”.

SS-99 Sub-clause 18.1.4 Construction Requirements; para 18.1.4.2 Cast in Place Piles; sub-para 18.1.4.2.1 Working Drawings (Technical Specifications for Workmanship Page – 7 & 8 of 36).

Delete the word “wring” in the second line of the sixth bullet-point and replace with “curing”.

SS-100 Sub-clause 18.1.4 Construction Requirements; para 18.1.4.2 Cast in Place Piles; sub-para 18.1.4.2.3 Piles Cast in Drill-Bore hole; sub-title 1 Boring Procedure (Technical Specifications for Workmanship Page – 8 & 9 of 36).

Delete the word “pie” in the fifth line of the third paragraph and replace with “pile”.

SS-101 Sub-clause 18.1.4 Construction Requirements; para 18.1.4.2 Cast in Place Piles; sub-para 18.1.4.2.3 Piles Cast in Drill-Bore hole; sub-title 2 Temporary Casing Method (Technical Specifications for Workmanship Page – 11 & 12 of 36).

- Amend the label of this sub-title and replace the label "Temporary Casing Method" with "Casing Method".
- Add the following captions in the sub-title 2 "**Casing Method**".

  (a) Temporary Casing Method.

  (b) Permanent Casing Method.

SS-102 Sub-clause 18.1.4 Construction Requirements; para 18.1.4.2 Cast in Place Piles; sub-para 18.1.4.2.3 Piles Cast in Drill-Bore hole; sub-title 3 Bentonite Slurry (Technical Specifications for Workmanship Page – 12 of 36).

Delete the word "(sub clause vi) hereof" in the second line of the 1st paragraph and replace with "this sub-para".

SS-103 Sub-clause 18.1.4 Construction Requirements; para 18.1.4.2 Cast in Place Piles; sub-para 18.1.4.2.3 Piles Cast in Drill-Bore hole; sub-title 3 Bentonite Slurry, (c) Precautions (Technical Specifications for Workmanship Page – 12 of 36).

Delete the text "The level of the slurry in the bentonite" in the first line of the second bullet-point and replace with "The level of the bentonite slurry in the borehole".

SS-104 Sub-clause 18.1.4 Construction Requirements; para 18.1.4.2 Cast in Place Piles; sub-para 18.1.4.2.3 Piles Cast in Drill-Bore hole; sub-title 4 Excavation from Boreholes (Technical Specifications for Workmanship Page – 12 of 36).

- Delete the word "toads" in the fifth line of the 1st paragraph and replace with "loads".

- Delete the word “this” in the last line of the 2nd paragraph and replace with “the”.

SS-105 Sub-clause 18.1.4 Construction Requirements; para 18.1.4.2 Cast in Place Piles; sub-para 18.1.4.2.3 Piles Cast in Drill-Bore hole; sub-title 7 Tolerances (Technical Specifications for Workmanship Page – 14 of 36).

- Delete the word “very” in the first line of the second bullet-point and replace with “vary”.
- Delete the word “plants” in the last line of the fourth bullet-point and replace with “plan”.
- Add “i.e.,1 in 16” after “3/4 inch per foot” in the seventh bullet-point.

SS-106 Sub-clause 18.1.4 Construction Requirements; para 18.1.4.3 Concreting of Piles (Technical Specifications for Workmanship Page – 15 of 36).

Add the text “Chapter 6.0 Cement Concrete” after the words “In general” in the first line of the para.

SS-107 Sub-clause 18.1.4 Construction Requirements; para 18.1.4.3 Concreting of Piles; sub-para 1 Materials (Technical Specifications for Workmanship Page – 15 of 36).

Delete the word “requirements” in the second line of the 1st bullet-point and replace with “Clause 6.1.3 Classes of Concrete; sub-clause 6.1.3.1 Normal Weight Concrete, of these specifications”.

SS-108 Sub-clause 18.1.4 Construction Requirements; para 18.1.4.3 Concreting of Piles; sub-para 3 Placing of Concrete (Technical Specifications for Workmanship Page – 16 & 17 of 36).

- Delete the word “upper” in the sixteenth line of the 1st paragraph and replace with “hopper”.

- Delete the text “tip of cut-off” in the first line of 3rd paragraph and replace with” tip to cut-off”.

SS-109 Sub-clause 18.1.4 Construction Requirements; para 18.1.4.4 Withdrawal of Temporary Casing (Technical Specifications for Workmanship Page – 17 of 36).

- Delete the word “hall” in the second line of the 1st paragraph and replace with “shall”.
- Delete the word “he” in the fourth line of the 1st paragraph and replace with “the”.
- Delete the sentence “the construction of the pile shall be abandoned, in which case the provision of the clause herein which refers to Defective Piles, shall apply” in the second & third line of 2nd paragraph and replace with “as directed by the Engineer/Engineer representative”.

SS-110 Sub-clause 18.1.4 Construction Requirements; para 18.1.4.5 Cutting of Piles (Technical Specifications for Workmanship Page – 17 of 36).

- Delete the word “according to requirements” in the last line of the 3rd paragraph.
- Delete the word “dean” in the second line of the 4th paragraph and replace with “clean”.

SS-111 Sub-clause 18.1.4 Construction Requirements; para 18.1.4.8 Pile Record (Technical Specifications for Workmanship Page – 19 of 36).

- Delete the word “8.S.C.P. 2001.” in the fourth row of the 2nd column and replace with “BS CP 2001”.
- Delete the word “pole” in the eleventh row of the 1st column and replace with “pile”.

SS-112 Sub-clause 18.1.4 Construction Requirements; para 18.1.4.9 Confirmatory Boring (Technical Specifications for Workmanship Page – 20 of 36).

Delete the word "day" in the seventh line and replace with "clay".

SS-113 Sub-clause 18.1.5 Measurement and Payment; para 18.1.5.1 Measurement (Technical Specifications for Workmanship Page – 20 of 36).

- Delete the word "My" in the seventh line and replace with "Any".
- Delete the word "Structures" in the second line of the 4th bullet-point and replace with "Chapter 6.0 - Cement Concrete".

SS-114 Sub-clause 18.1.5 Measurement and Payment; para 18.1.5.2 Payment (Technical Specifications for Workmanship Page – 21 of 36).

Add the text "clause 6.19 Reinforcement of these specifications" at the end of second bullet-point.

GENERAL SPECIFICATIONS

(TECHNICAL SPECIFICATION FOR WORKMANSHIP)
MRS-2019, COMMUNICATION AND WORKS DEPARTMENT, KPK