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FOR

DESIGN, PROCUREMENT AND CONSTRUCTION

OF

LOT-2 – DESIGN AND CONSTRUCTION OF PSKEM RCC DAM WITH BOTTOM AND SPILLWAY OUTLETS SYSTEM WITH SUPPLY, INSTALLATION, TESTING AND COMMISSIONING OF EQUIPMENT AND SPARE PARTS

SINGLE-STAGE: TWO ELECTRONIC FILES

BIDDING DOCUMENTS
SECTION 6 – EMPLOYER'S REQUIREMENTS
APPENDIX 1 – TECHNICAL SPECIFICATIONS

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SECTION 6 – EMPLOYER'S REQUIREMENTS

APPENDIX 1 – TECHNICAL SPECIFICATIONS

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GENERAL SPECIFICATIONS

Chapter 0110

1 INTRODUCTION

1.1 INTRODUCTION

1.1.1 General

The present document contains the "Specifications" of *Section 6 - Employer's Requirements* of the *Bidding Documents* for the Pskem Hydropower Project, Lot-2 Construction of Pskem RCC Dam With Bottom And Spillway Outlets System.

1.2 PROJECT LAYOUT AND SCOPE OF WORKS

1.2.1 Introduction

The present document defines the scope of the Works to be completed under the Lot 2 Contract. The principal elements of such scope are:

- Design, planning, and supervision of the Works in coordination with the Works performed by the Other Contractors as organized / managed by the Employer and his General Coordinator and taking into account the Employer's Works.
- Provision of Materials, Labour, Construction Plant (RCC Dam With Bottom And Spillway Outlets System) and Permanent Equipment.
- Provision of Services.
- Construction of Temporary Works.
- Construction of Permanent Works.
- Completion and commissioning of the Plant (RCC Dam With Bottom And Spillway Outlets System) and the Works
- Testing and Taking Over of the Works by the Employer.
- Remedy of defects during the Defects Notification Period.

The descriptions given in this document are outline descriptions only, based on previous design works elaborated by the Employer. Such descriptions do not include or give full descriptions of all equipment, materials, or other items to be supplied or all works and services to be executed by the Contractor in order to fulfill his obligations in accordance with the Contract.

The general layout and profile of the structures and Plant (RCC Dam With Bottom And Spillway Outlets System) to construct are shown, as information for the Contractor's consideration, on the drawings forming the Employer's Basic Design. Employer's studies are also provided, as information. Any locations and dimensions (length, depth, diameter, volume, width, etc.) provided here below are given as information and shall not be interpreted by the Contractor as requirements regarding final dimensions, except otherwise stated in the Contract.

1.2.2 Scope of Works

The Works to be performed by the Contractor shall include all works required under the Contract, including but not limited to: labor, tools, plants, materials, services, design, planning, construction, maintenance and operation during construction, manufacture, quality assurance, quality control, field testing, model testing, shop assembly, shop testing, delivery to site, site storage and preservation, installation, site inspection, commissioning, finishing works, remediation works, reporting periodically to the Employer, and handing over to Employer.

The Contractor shall, unless specifically excluded in the Contract, perform all such work and / or supply all such items and materials not specifically mentioned in the Contract but that can be reasonably inferred from the Contract as being required for attaining Completion of the Facilities as if such work and / or items and materials were expressly mentioned in the Contract.

The intended purpose for which the Works are required is the function of safely retaining and storing water at the Pskem site including all dam and related works, under a defined head sufficient to produce electricity and ensure water tightness with minimal and controlled water losses through the dam body and its foundation, and also the spillway system that will transfer the 10 000 years return period flood (Q_{10000}) safely downstream. all along the lifetime of the Project. Bottom outet will serve as a safety structure to control reservoir level and for emergency operations. Bottom outet will be used as filling of the reservoir, drawdown the reservoir and etc.

Accordingly, the detailed scope of Works to perform for the Pskem HPP Project under the Lot 2 Contract includes, but is not limited to:

1.2.2.1 Construction Works

125 m high Roller Compacted Concrete Dam (RCC) with bottom outlet and spillway construction and all necessary appurtenant works satisfaction of the Employer, and approved at Basic Design or Detailed Design stage.

- The Project Evaluation Document (PED) for RCC Dam Alternative (2025) attached to this Contract is given only for information purposes.
- Main Dam construction including all access works, excavation works, foundation treatment, roller compacted concrete, conventional concrete, water-tightening, material borrowing, transport and placing, monitoring, and all other necessities to fulfill the Employer's Requirements.
- On body surface spillway, energy dissipation structure, and auxiliary structures..
- Dimensions of the on body surface spillway and spillway tailwater canal will be designed so that, the 10 000 years return period flood (Q_{10000}) will safely spill downstream.

- Hydraulic model to show that the on body surface spillway system,energy dissipation structures and spillway tailwater canal are working as designed. While setting up the model, the effects of spillway structures and powerhouse elevation should be taken into account.
- Hydraulic steel structures of bottom outlet system. Such as gates (operation and maintenance), valve chamber gates (operation and maintenance) (if any), and steel lining (if any), etc.
- Survey, design and stabilization works of all fill or natural slopes, which failure would affect the performance of the permanent components of the Works, would endanger personnel or would affect the timely completion of the Works.
- Dam monitoring instruments supply, installation, calibration, and surveillance during the whole Time for Completion; and reservoir monitoring instrumentation.
- Rehabilitation / completion / construction of the necessary temporary access roads / bridges as deemed necessary by the Contractor for the timely and safe completion of the Works.
- Operation and maintenance of the temporary access roads / bridges as deemed necessary by the Contractor for the timely and safe completion of the Works.
- All landscaping and rehabilitation / remediation works necessary before the Taking-Over by the Employer, on those areas which were used and / or impacted by the Contractor during the Works.
- Design and construction of cable & pipe trenches, cable & pipe bridges, cable & pipe ways of any kind within the limits of supply.

1.2.2.2 Other Works and Services

- Coordination (for design, installation, erection, program implementation, construction works, and services) with the Other Contractors and with the Employer, as defined in the Contract.
- Preparation of all basic and detailed analyses and design calculations, technical data and specifications, detailed construction drawings and quality control and quality assurance procedures, Social Management Plan, and Environmental and Social Monitoring Plan necessary for the complete construction of the project together with O&M manuals and as-built record drawings.
- Planning of all activities (design, manufacture, procurement, construction, installation, etc.) required for the Works.
- Additional investigations, where necessary, to develop proper designs, including but not limited to topographical investigations, site geological / geotechnical investigations, material testing, and full reservoir area geological survey.

- Procurement of all materials, construction plants (RCC Dam With Bottom And Spillway Outlets System), consumables, equipment, etc. necessary for the Works.
- Provision and maintenance of services at Site (supplying of electricity, water, housing, offices, communication system as may be specified in the Contract).
- All field works consisting of receipt, storage, maintenance during storage, retrieval from storage, assembly, and installation of all equipment furnished under the Contract, and placing in the operation of all equipment furnished under the Contract.
- Training of Employer's operation and maintenance personnel, as set out in the Employer's Requirements.
- Tests on Completion / Tests after Completion as may be required under the Contract.
- Remedying of defects in the Works according to the Contract during the Defects Notification Period. Provision of guarantees and warranties for all the systems, materials, workmanship, equipment, and other aspects of the project according to the Contract.
- Any other design services or works that can be reasonably inferred from the Contract as being required for the Works being "fit for the purpose" and for attaining Completion of the Works even if not expressly mentioned in the Employer's Requirements or the present Contractor's.

Chapter 0120

2 STANDARDS, CODES AND GENERAL DESIGN REQUIREMENTS

2.1 GENERAL

The Permanent Works shall be designed and built according to:

- Each and every requirement in this Employer Requirements
- The latest relevant Republic of Uzbekistan Standards and Codes,
- The latest International Standards, Codes, and regulatory documents in its English version.

By definition, including but not limited to such standards comprise those latest issued versions of standarts by the organizations such as USACE, USBR, ICOLD, FERC, FEMA, ACI, Eurocode, ASTM, etc.:

[1] EUROCODES, including the EN (European Standard),

[2] ACI, The American Concrete Institute

[3] ICOLD, The International Commission on Large Dams

[4] USBR, U.S. Bureau of Reclamation

[5] ASTM, American Society for Testing and Materials

[6] ASCE, American Society of Civil Engineers

[7] FEM, European Materials Handling Federation

[8] USACE, U.S. Army Corps of Engineers (including Engineering Manuals).

[9] ISO (International Organization for Standardization), as far as quality management is concerned

[10] IEC (International Electrotechnical Commission)

or equivalent standards, subject to the Employer's review and approval.

The Contractor shall provide the requirements for bringing the developed projects into compliance with the standards of the Republic of Uzbekistan (Adaptation), as well as undergoing expertise in the prescribed manner based on the Resolution of the Cabinet of Ministers of the Republic of Uzbekistan No. 579, dated 17.09.2021; and also the requirements of No. 5963, dated 13.03.2020, regarding the additional measures to deepen reforms in the construction sector in the Republic of Uzbekistan.

In case of discrepancy with any requirement, codes, or standard stipulated in the Employers Requirements, the latest edition will prevail in order to meet prudent engineering and building standards and a safe and reliable design.

Except where otherwise specified or shown in other contract documents, the latest edition of the above-mentioned Standards shall govern. The latest edition of each standard and code shall mean the revised available edition as defined in GCC-Sub-Clause 5.4, including all amendments and additions current at the Base Date.

In the following phases of the project, the calculations to be performed and the constructive measures to be taken shall follow the following regulatory documents:

ACI 207.5R-11 Roller Compacted Mass Concrete (RCC)

ASCE / SEI 7-22 Minimum Design Loads and Associated Criteria for Buildings and Other Structures (2022)

ASCE Task Committee on Instrumentation and Dam Monitoring Performance, "Guidelines for Instrumentation and Measurements for Monitoring Dam Performance", ASCE American Society of Civil Engineers, Reston, Virginia, 2000.

DIN 19704 - Hydraulic Steel Structures

EN 13670 1:2007 – Execution of concrete structures. Common

EN 1993 Eurocode 3: Design of Steel Structures

EN 206 1:2007 – Concrete. Specification, performance, production and conformity

EN1991 Eurocode 1: Actions on structures;

EN1992 Eurocode 2: Design of concrete structures – Part 1-1: General – Common rules for building and civil engineering structures;

EN1997 Eurocode 7: Geotechnical Design, Ground investigation and testing

EN1998 Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings;

FEMA Federal Guidelines for Dam Safety – Earthquake Analyses and Design of Dams (2005);

FERC Federal Energy Regulatory Commission, Chapter 10, Other Dams (1997)

FERC Federal Energy Regulatory Commission, Chapter 13, Evaluation of Earthquake Ground Motions (2018)

FERC Gravity Dams

ICOLD Bulletin 120 Design Features of Dams to Resist Seismic Ground Motion

ICOLD Bulletin 126 Roller Compacted Mass Concrete (RCC)

ICOLD Bulletin 148 Selecting Seismic Parameters for Large Dams (Bulletin 72, 2010 revision)

USACE Earthquake Design and Evaluation for Civil Works Projects, ER 1110-2-1806

USACE Earthquake Design and Evaluation of Concrete Hydraulic Structures, EM-1110-2-6053 (2007)

USACE EM 1110-2-2100 - Stability Analysis of Concrete Structures

USACE EM 1110-2-2200 - Gravity Dam Design

USACE EM 1110-2-2502 - Retaining and Flood Walls

USACE EM 1110-2-6050 - Response Spectra and Seismic Analysis for Concrete Hydraulic Structures

USACE EM 1110-2-6051 - Time History Dynamic Analysis of Concrete Hydraulic Structures

USACE EM 1110-2-6053 - Earthquake Design and Evaluation of Concrete Hydraulic Structures

USACE EP-1110-2-12 - Seismic Design Provisions for Roller Compacted Concrete Dams

USACE ER 1110-2-1806 - Earthquake Design and Evaluation for Civil Works Projects

USACE Hydraulic Design of Reservoir Outlet Works, EM 1110-2-1602 (1980)

USACE Hydraulic Design of Spillways, EM 1110-2-1603 (1992)

USACE Permanent Seismically Induced Displacement of Rock-Founded Structures Computed by the Newmark Program ERDC TR-09-2 (2009)

USACE Response Spectra and Seismic Analysis for Concrete Hydraulic Structures, EM 1110-2-6050 (1999)

USACE Retaining and Flood Walls, EM 1110-2-2502 (1989)

USACE Rock Foundations, EM 1110-1-2908 (1994)

USACE Roller-Compacted Concrete, EM 1110-2-2006

USACE Seepage Analysis and Control for Dams, EM-1110-2-1901 (1993)

USACE Slope Stability, EM 1110-2-1902 (2003)

USACE Stability Analysis of Concrete Structures, EM 1110-2-2100 (2005);

USACE Standard Practice for Concrete for Civil Works Structures, EM 1110-2-2000 (1994)

USACE Strength Design for Reinforced Concrete Hydraulic Structures, EM 1110-2-2104 (1992)

USACE Time-History Dynamic Analysis of Concrete Hydraulic Structures, EM 1110-2-6051 (2003)

USBR Design of Gravity Dams

USBR Design of Small Dams (1987)

USBR Roller-Compacted Concrete, Design and Construction Considerations for Hydraulic Structures

2.1.1 Dam Design Requirements

2.1.1.1 General Methodology

The slope stability studies to be undertaken that shall lead to the final geometry should be based on two-dimensional (2D) and three-dimensional (3D) models with the following safety checks included:

- **2D Slope stability** analysis of the dam using the limit-equilibrium method.
- **Dam Stability Analysis** with Low-dip Shear Zone
- **Rigid Body Analysis and Static FEM Analysis**
- **Thermal Stress Analysis**
- **2D and 3D Seepage analysis** to define pore water pressures in the dam-foundation system.
- **2D and 3D Stress – deformation analysis** to check displacements and stresses for all load conditions (staged construction and operation with staged reservoir impounding up to full reservoir level)
- **2D Linear time-dependent dynamic analysis**, based on the results of seismological studies. 2D study with equivalent linear dynamic analysis. Permanent deformation analysis, Newmark sliding rigid block method and empirical methods (defined in ICOLD Bulletin 141) should be performed and compared.
- **3D Nonlinear time-dependent dynamic analysis** of the dam and its foundation are mandatory for the dynamic structural behavior assessment of the structural system.
- **2D and 3D Liquefaction analysis**, as a result of the geotechnical investigation, if required, liquefaction analyses on the foundation (dynamic settlement, lateral displacement, loss of shear strength) will be performed.
- **Design of concrete structures**, Roller Compacted Concrete, conventional concrete, etc.

For the dam body, the purpose of modeling is to verify if the structure complies with the various design criteria present in international regulations, including the ones from ICOLD.

The three-dimensional analysis must be performed through a dam-bedrock model (fluid may be added) with a finite element model using solid elements, or with other comparable numerical models.

For the definition of the seismic action and to define the time-history accelerograms to be used in seismic calculations of the dam, the existing Seismic Hazard Evaluation study should be complemented. This study shall also meet the requirements of the Resolution of the Cabinet of Ministers of the Republic of Uzbekistan No. 603, dated 15.10.2022

regarding the obtaining a positive conclusion on seismic resistance. And also, it shall meet the requirements of No. 579, dated 17.09.2021 regarding the measures to improve the procedures for the examination of urban planning documents.

It is necessary to choose at least three real motion records to be used for 2D linear dynamic analysis and at least five real records for 3D nonlinear dynamic analysis, from different earthquake events to include variability in the spectrum and pulse sequencing.

The 2D dynamic analysis shall be performed considering both Operating Basis Earthquake (OBE) and Safety Evaluation Earthquake (SEE) or Maximum Credible Earthquake (MCE). However, earthquake analysis at SEE (or MCE) level will be sufficient for 3D dynamic analysis.

If the stability performance under OBE level earthquake is not sufficient as a result of 2D static and dynamic analyses and then 3D dynamic stability analysis is required, the number of real records can be decreased to three for Normal Operation Water Level and one for End of Construction.

2.1.1.2 Basic Design Methodology

The design methodology to be followed for the **Basic Design** of the dam is as below:

- 2D Slope stability analysis of the dam by using the limit-equilibrium method for end of construction, operation, and earthquake load conditions. Earthquake load conditions to be considered seismic coefficients the following approach:

  $k_h = (0.40\sim0.60)a_{max}$ or $k_h = (a_{max}0.333) / 3$ in case of PGA > 0.20g, $k_v = (2 / 3)k_h$
- 2D Seepage analysis to define pore water pressures in the dam-foundation system.
- Determination of the valley shape factor (SF) of the dam body and the transverse rockfill modulus (Et) to be used at the impounding stage for the direction of movement under the reservoir load.
- 2D Stress & deformation analysis in order to determine displacements and stresses for all load conditions and compare foundation stress with bearing capacity.
- 2D Linear time-dependent dynamic analysis of dam body.
- Permanent deformations after an earthquake.
- Newmark sliding block analysis with equivalent linear dynamic analysis.
- Simplified empirical methods (Makdisi-Seed, Bureau, Swaisgood, and Pells & Fell) and to be compared results with other methods.
- Comparing all crest deformations with different methods.
- Stability and design of concrete face slab, parapet wall, and plinth.
- Determination of freeboard.

- 2D Evaluation of the liquefaction potential of the foundation, as a result of the geotechnical investigation, if required, liquefaction analyses on the foundation (dynamic settlement, lateral displacement, loss of shear strength) will be performed.

2.1.1.3 Detailed Design Methodology

The design methodology proposed for the **Detailed Design** of the dam is as follows:

Confirmation of the results of the analyses carried out in previous studies and the accomplishment of the following studies:

- 3D Seepage analysis to define pore water pressures in the dam-foundation system.
- 3D Stress – deformation analysis in order to determine displacements and stresses for all load conditions and compare foundation stress with bearing capacity.
- Nonlinear 3D time-dependent dynamic analyses of the dam and its foundation (the fluid may be added) are mandatory for the concrete face and embankment behaviors assessment of the structural system. The nonlinear dynamic analysis should be performed in the time domain considering a non-elastic behavior.
- Construction, operation, and earthquake stages must be performed in 3D nonlinear dynamic analysis.
- 3D Evaluation of the liquefaction potential of the foundation, as a result of the geotechnical investigation, if required, liquefaction analyses on the foundation (dynamic settlement, lateral displacement, loss of shear strength) will be performed.
- Crest deformations, concrete face deformations, the behavior of contraction and extension joints (including perimeter joints), and reinforcement design must be studied.

2.1.1.3.1 Dam Design Loads

The loads to be considered in the design of the dam and its appurtenant structures (spillway etc.) can be divided into two main categories: Dead Loads and Imposed Loads.

2.1.1.3.2 Dead Loads

The unit weight of roller compacted concrete (RCC) will be taken from the literatures. After the completion of the RCC field test at the site, the unit weight taken at the design stage will be checked.

The unit weight of the concrete structure has a value of 24 kN / m³.

2.1.1.3.3 Imposed Loads

a) Upstream hydrostatic pressure

The upstream hydrostatic pressure at one given point is a function of the unit weight of the water and the water depth at that point in relation to the reservoir surface level. The unit weight value of water is 10 kN / m³.

b) Downstream hydrostatic pressure

Similar to the upstream hydrostatic pressure, the downstream hydrostatic pressure at one given point is a function of the unit weight of the water. The unit weight value of water is 10 kN / m³.

c) Seismic Inertial Loads

Seismic Hazard Assessment Report shall be prepared by the Contractor, considering the detailed distribution of earthquakes around the project area and possible seismogenic structures considering ICOLD recommendations. This study shall also meet the requirements of the Resolution of the Cabinet of Ministers of the Republic of Uzbekistan No. 603, dated 15.10.2022 regarding the obtaining a positive conclusion on seismic resistance. And also, it shall meet the requirements of No. 579, dated 17.09.2021 regarding the measures to improve the procedures for the examination of urban planning documents. The report will be submitted to the Employer within 6 months after Commencement Date, with adequate reference magnitude for the Safety Evaluation Earthquake (SEE or Maximum Design Credible Earthquake, MCE) and the Operating Basis Earthquake (OBE), and related spectra and peak ground accelerations for design purposes.

According to the ICOLD guidelines, the Safety Evaluation Earthquake (SEE) shall be considered equal to the Maximum Credible Earthquake (MCE), evaluated through a deterministic procedure or probabilistic procedure. The Operating Basis Earthquake (OBE) shall be determined by a Probabilistic Seismic Hazard Analysis (PSHA) procedure, at least 144 years return period event.

Therefore, the seismic loads to be considered in the design will be defined on the basis of the peak ground acceleration and spectra for SEE (or MCE) and the OBE. These loading cases shall be taken into consideration and shall be applied as indicated in each case of the Technical Specifications, and according to these Employer's requirements.

d) Hydrodynamic Pressure

The effects of hydrodynamic pressure on the concrete face under seismic loads by performing dynamic analysis considering fluid-structure interactions.

2.1.1.4 Dam Design Scenarios

2.1.1.4.1 End of Construction Scenario

The End of Construction scenario represents the static load condition of the dam with an empty reservoir.

2.1.1.4.2 Normal Operation Scenario

The Normal Operation scenario represents the long-term static load condition of the dam with the reservoir water level at the normal operation level.

2.1.1.4.3 Maximum Flood Scenario

The Maximum Flood Operation scenario represents a static load condition of the dam with the reservoir water level at the Maximum Flood Level.

2.1.1.4.4 Operating Basis Earthquake Scenario

The Operating Basis Earthquake scenario (OBE) represents a short-term dynamic load condition of the dam, which consists in the occurrence of the Operating Basis Earthquake (OBE) during an end of construction (empty reservoir) and normal operation scenario, i.e. with the reservoir water level at the maximum operation level. According to ICOLD guidelines, "Operating Basis Earthquake (OBE) represents the level of ground motion at the dam site at which only minor damage is acceptable. The dam, appurtenant structures (parapet wall), and equipment should remain functional and damage easily repairable from the recurrence of the earthquake not exceeding the OBE".

2.1.1.4.5 Safety Evaluation Earthquake Scenario

The Safety Evaluation Earthquake scenario (SEE) represents the most severe short-term dynamic load condition of the dam, which consists in the occurrence of the Safety Evaluation Earthquake (SEE) during a normal operation scenario, i.e. with the reservoir water level at the maximum operation level. As per ICOLD guidelines (2016), "the Safety Evaluation Earthquake (SEE) will produce the maximum level of ground motion for which the dam should be designed or analyzed. For dams whose failure would present a great social hazard, the SEE will normally be characterized by a level of motion equal to that expected at the dam site from the occurrence of deterministically evaluated Maximum Credible Earthquake (MCE)." For this scenario, damage is acceptable, although no uncontrolled release of water when the dam is subjected to the seismic load imposed by the SEE is allowed.

2.1.1.4.6 Grout / Drainage Curtains Damage Scenario

The Grout / Drainage Curtains Damage scenario represents an unusual scenario, for which, with the reservoir water level at the maximum operation level, it is considered that the grout / drainage curtains are damaged and fully non-operational.

2.1.1.5 Design Considerations

2.1.1.5.1 Settlement and Compression

The deformation modulus is derived from measurements of vertical settlement during construction and the calculated vertical fill load above the settlement gage, as follows:

$E_v = H * \gamma_r * h / 1000*s$

Where:

Ev = Vertical deformation modulus, MPa

H = Vertical depth of rockfill above the settlement gage, m

γr = Unit weight of rockfill, kN / m³

h = Column of rockfill below the settlement gage, m

s = Settlement of the gage, m

2.1.1.5.2 Estimating Construction Settlement

Settlement during construction at any location within the embankment varies with the deformation modulus, the thickness of compressible material beneath the location of interest, and the load on the compressible material.

$S = (\gamma_r * H^2) / (100 * E_v)$

Where:

S = settlement in meters

γ_r = unit weight of rockfill, MN / m³

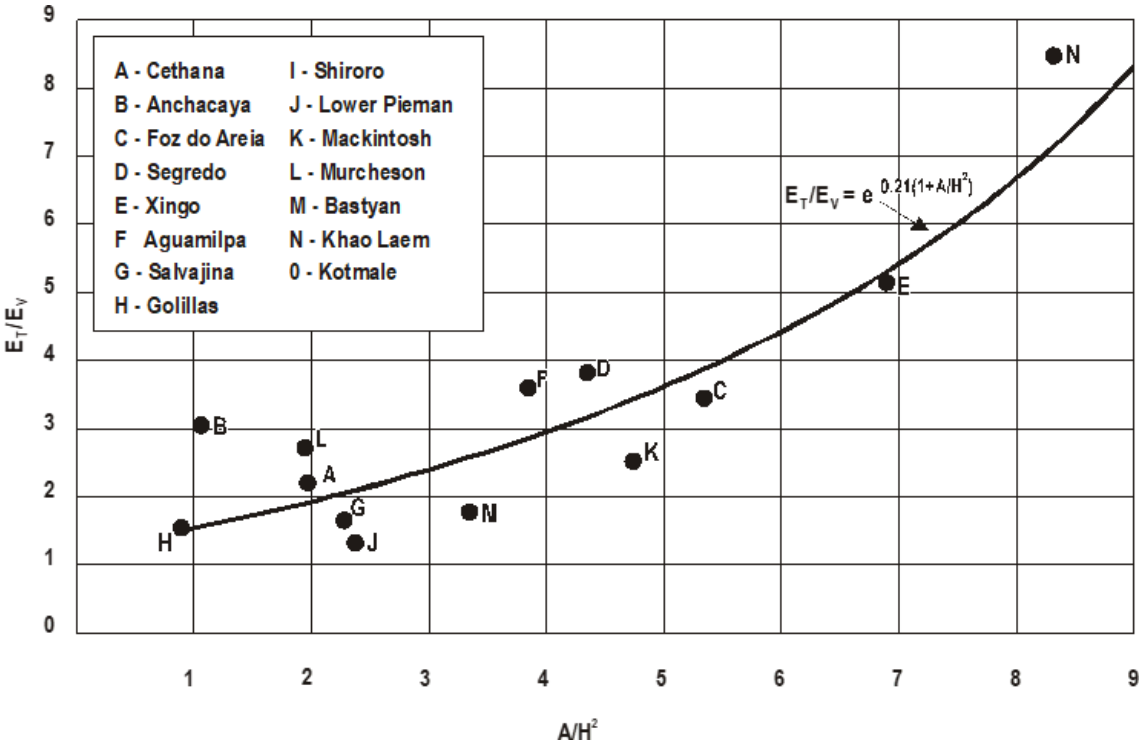
H = height of the column within the dam in meters

E_v = vertical deformation modulus, MPa

2.1.1.5.3 Valley Shape Factor

The valley shape factor, A / H^2, affects the construction deformation modulus, E_v. In narrow valleys, with lower values of the shape factor, the arching effects across the valley reduce the load within a vertical column of rockfill at the maximum height section, thus reducing the measured settlement. The smaller settlement results in a larger estimate of the vertical modulus of deformation, E_v. In this case, the indicated transverse modulus would only be slightly larger than the calculated E_v.

Relationships between valley shape, modulus of deformation during construction, and the maximum height of the dam can be used to estimate the performance of the dam during the first filling of the reservoir.



Ratio Transverse to Vertical Modulus as a Function of A / H2 (Pinto and Marques, 1998)

2.1.1.5.4 Crest Width

The Contractor will determine the width of the crest according to the results of the static and dynamic analyses, which should not be narrower than 7.0 m.

2.1.1.5.5 Embankment Zones and Properties

Embankment zones and filter design must be performed considering ICOLD Bulletin 95 and 141 given references Chapter 1.1.

2.1.1.5.6 Instrumentation

The quantity, type, and location of instruments depend on design and construction concerns, experience, and common sense; there are no specific guidelines. However, the available documents and guidelines published by the internationally accepted establishments regarding the Design of Dam Instrumentation and Monitoring System can be utilized. Generally, the following factors govern the design of the instrumentation system:

- Purpose or need for the instrument,

- Reliability, short term, and long term,
- Low maintenance requirements,
- Compatibility with construction,
- Low cost and ease of installation,
- Simplicity,Ruggedness.

The dam monitoring instruments and equipment to be placed and installed shall be the latest model and type at the date of placement and installation.

2.1.2 Design Requirements for Spillway System

As per the "Project Evaluation Document (PED), dated 2025"; Spillway System of the PSKEM HPP Project is consisting of Power Tunnels at the Right Bank (Construction of the Right Bank Spillway is continuing under the Lot-1 Contract) and Overflow Crest Spillway to be constructed on the Dam Body. The Spillway System of the PSKEM HPP Project has been designed to safely dischage the 10,000-year return period flood (Q10,000=1,003 m^3 / s) from the Dam Reservoir to downstream.

The Contractor shall design and construct the Overflow Crest Spillway on the Dam Body. The design discharge capacity of the Spillway System (Including the Right Bank Spillway / Power Tunnels in the scope of Lot 1 Contract) shall be equal to the 10 000 years return period flood (Q10000).

The type, number, and dimensions of the structures in the Spillway System, will be specified as result of the geological, structural, and hydraulic investigations and evaluations.

2.1.2.1 General

For the inlet and outlet structures to be considered stable, the following requirements should be satisfied:

- safety against sliding along any horizontal plane shall be guaranteed;
- safety against overturning about any point of the dam shall be guaranteed;
- allowable stresses in both the concrete and foundation shall not be exceeded.

2.1.2.2 Sliding Stability Analysis

The sliding stability analysis consists of the determination of the factor of safety against sliding ($FoS_{sliding}$) at the wall base level, along the interface between foundation and concrete.

The factor of safety against sliding ($FoS_{sliding}$) is given by the ratio between the friction and cohesion forces and the sum of the total tangential forces acting on the base plane. The friction force is equal to the product of the friction coefficient by the sum of the total

normal forces acting on the base plane. As such, the factor of safety against sliding has been calculated using the following formula:

$$FOS_{sliding} = \frac{\sum F_N \times \tan\phi + \mathrm{L} \times \mathrm{Cu}}{\sum F_T}$$

where,

$\sum F_N$ = sum of total normal forces acting on the base plane (kN / m)

$\sum F_T$ = sum of total tangential forces acting on the base plane (kN / m)

$\tan\phi$ = friction coefficient

ϕ = angle of internal friction (º)

L = Length of the cross-section base

Cu = cohesion (kPa)

The adopted angle of internal friction and cohesion values to be used in the analysis varied according to the design scenario considered and shall be estimated based on the geotechnical survey and laboratory testing to be performed by the Contractor.

Required Factors of Safety for Sliding - Critical Structures

Site Information Category	**Load Condition Categories**		
	Usual	**Unusual**	**Extreme**
Well Defined	1,7	1,3	1,1
Ordinary	2,0	1,5*	1,1*
Limited**	-	-	-

Required Factors of Safety for Sliding - Normal Structures

Site Information Category	**Load Condition Categories**		
	Usual	**Unusual**	**Extreme**
Well Defined	1,4	1,2	1,1
Ordinary	1,5	1,3	1,1
Limited	3,0	2,6	2,2

2.1.2.3 Overturning Stability Analysis

The overturning stability analysis consists in the determination of the factor of safety against overturning ($FoS_{overturning}$) calculated about the dam toe.

The $FoS_{overturning}$ is given by the ratio between the sum of the stabilizing moments and the sum of the destabilizing moments about the wall toe. As such, the factor of safety against overturning has been calculated using the following formula:

$$FOS_{overturning} = \frac{\sum M_{stb}}{\sum M_{dstb}}$$

where,

$\sum M_{stb}$ = sum of the stabilizing moments about the wall toe (kNm / m)
$\sum M_{dstb}$ = sum of the destabilizing moments about the wall toe (kNm / m)

2.1.2.4 Floating Analysis

A factor of safety is required for flotation to provide a suitable margin of safety between the loads that can cause instability and the weights of materials that resist flotation. The flotation factor of safety is defined by the equation given below.

$$FS_f = \frac{W_S + W_C + S}{U - W_G}$$

W_S = weight of the structure, including weights of the fixed equipment and soil above the top surface of the structure

W_C = weight of the water contained within the structure

S = surcharge loads

U = uplift forces acting on the base of the structure

W_G = weight of water above the top surface of the structure

2.1.2.5 Required Strength

2.1.2.5.1 Design Strength

The required strength computed from the effects of factored loads shall be less than the design strength, calculated as;

$\sum \gamma_i L_{ni} \leq \varphi R_n$

Where:

$\sum \gamma_i L_{ni}$ = U = required strength, the effect of factored loads

γ_i = load factors that account for bias and variability in loads to which they are assigned

L_{ni} = nominal (code-specified) load effects

φ = resistance factor from ACI 318.

Rn = nominal resistance from ACI 318 and Chapter 4 in USACE EM 1110-2-2104

2.1.2.5.2 Load Factors

Minimum load factors given USACE EM 1110-2-2104 for usual, unusual, and strength is the hereinbelow table.

Minimum Load Factors

Limit State		Serviceability[6]		Strength
Load Category		U. Usual	N. Unusual	X. Extreme
Return Period, years - Critical		10	10-750	> 750
Return Period, years - Normal		10	10-300	> 300
Permanent Loads, Lp		γ_U	γ_N	γ_X
Dead	D	2.2[5]	1.6[5]	1.2[1], 0.9[2]
Vertical Earth	EV	2.2[5]	1.6[5]	1.35[1], 1.0[2]
Lateral Earth	EH	2.2[5]	1.6[5]	See Note 3
Hydrostatic (Companion Load)	Hs	2.2[5]	1.6[5]	1.0
Gravity (Mud/Ice)	G	2.2[5]	1.6[5]	1.6[1], 0[2]
Temporary Loads, Lt		γ_U	γ_N	γ_X
Peak Hydrostatic - Flood, Drought, Surge, Maintenance (Principal Load)	Hs	2.2[5]	1.6[5]	1.0 or 1.3[4]
Thermal Expansion of Ice	IX	NA	1.6[5]	1.0 or 1.3[4]
Soil Surcharge	ES	2.2[5]	1.6[5]	1.0 or 1.3[4]
Operating Equipment	Q	2.2[5]	1.6[5]	1.0 or 1.3[4]
Live Load (vertical)	L	2.2[5]	1.6[5]	ASCE 7[7]
Self Straining	T	2.2[5]	1.6[5]	ACI 318[7]
Vehicle Live Loads	V	2.2[5]	1.6[5]	AASHTO[7]
Dynamic Loads, Ld		γ_U	γ_N	γ_X
Hydrodynamic (except seismic)	Hd	2.2[5]	1.6[5]	1.0 or 1.3[4]
Wave	Hw	2.2[5]	1.6[5]	1.0 or 1.3[4]
Limit State		Serviceability[6]	Strength	
Debris/Floating Ice Impact	I	2.2[5]	1.6[5]	1.0 or 1.3[4]
Barge/Boat Impact	IM	2.2[5]	1.6[5]	1.0 or 1.3[4]
Wind	W	NA	1.6[5]	ASCE 7[7]
Earthquake	EQ	NA	Para 3.3.3	Para. 3.3.3
Hawser	B	NA	1.6[5]	NA

Table 3-1 Notes:

1. Applied when loads add to the predominant load effect.
2. Applied when loads subtract from the predominant load effect.
3. Load Factors for Lateral Earth Pressure:
   - Structures using at-rest pressure for design
     - Driving pressure = 1.35; Resisting pressure = 0.9.
     - All other structures
     - Driving (Active) pressure = 1.5; Resisting (Passive) Pressure = 0.5
     - Dynamic analysis (response spectra and time history) of earthquake (at-rest pressure) = 1.0
4. Temporary and dynamic Extreme loads shall be designed with:
   - Load factor =1.3
     - Loads that are physically limited with return periods lower than 3,000 years for normal structures or 10,000 years for critical structures.
     - Loads for which return period cannot be determined.
   - Load Factor = 1.0
     - Loads that are not limited, for which return period can be determined, with design with return periods greater than or equal to 3,000 years for normal structures or 10,000 years for critical structures.
5. For members in direction tension (net tension across the entire cross section): Usual load factor = 2.8, Unusual load factor = 2.0.
6. Load factors for serviceability limit states are intended to provide designs with stresses in the concrete and reinforcing steel that limit cracking under service loads. The load factors are not reliability based.
7. Where other standards are referenced, load cases and load factors from those standards will be used for design when those loads are primary loads. See load descriptions for details.

2.1.3 Civil Works

2.1.3.1 Design Criteria

In general, the structural design must comply with the standards specified in this document.

The design criteria adopted for reinforced concrete structures should comply with Eurocode2. The design criteria adopted for steel structures should comply with Eurocode 3 and Eurocode 4 for mixed structures. The ultimate limit states and serviceability limit states are described below.

According to the regulations, the control of safety is carried out on the basis of the theory of the limit states. **Ultimate limit states** are associated with an acceptable probability that the collapse of structures or one of their components does not occur as a result of the actions described in the project. The safety control with respect to ultimate limit states will be conducted in terms of effort, taking into account the fundamental combinations of actions.

The safety with respect to the Ultimate Limit States is generally made in terms of boundary states of structural failure based on the condition Ed < Rd, that is, Rd / Ed ≥ 1.0, where Ed and Rd denote respectively the values calculating the effect of actions and resistance.

The Ultimate Limit States shall be verified where they are relevant:

- Loss of equilibrium of the structure or any part of it, considered as a rigid body;
- Failure by excessive deformation, the transformation of the structure or any part of it into a mechanism;
- Rupture, loss of stability of the structure or any part of it, including supports and foundations;
- failure caused by fatigue or other time-dependent effects.

Verifications to the **Serviceability Limit State** include deformation and cracking control, based on frequent and quasi-permanent combinations.

The imposed loads to be considered for Serviceability Limit State verifications should be specified in accordance with the service conditions and the requirements concerning the performance of the structure.

2.1.3.2 Standards and Codes for Civil Works

2.1.3.2.1 General

The complete standards and design codes that will be proposed by the Contractor shall be subject to review and approval of the Employer and a complete (the newest versions)

set of such standards and codes in English shall be kept at the Site for the use of the Project.

2.1.3.2.2 Technical Specifications

The Contractor shall prepare technical specifications including but not limited to testing and acceptance criteria for all construction materials, permenant equipment and works. These technical specifications shall be submitted for review and approval of the Employer prior to preparation of the Detailed Design.

The Contractor shall develop a **Detailed Design** for the construction and manufacturing of the civil, mechanical, and electrical works on the basis of the reviewed and commented final design.

Submissions to the Employer or its Representative for their review and comment related to the **Detailed Design** for the civil works shall include, though not limited to, all Construction / Manufacturing Engineering Documents as applicable:

- Detailed drawing of the outdoor excavations, together with the required rock support and slopes stabilization measures, supported by the necessary geotechnical analyses;
- Drawings of underground openings excavation sequence and required rock support stabilization measures supported with geotechnical analysis;
- Detailed concrete outline drawings, showing all dimensions, first and second-stage concrete, contraction and construction joints, classes of concrete and finishing, etc.
- Concrete reinforcement drawings, showing bars diameters, and spacing, supported by the necessary structural analyses and by the equipment design data which may be necessary to check the loads and design criteria applied;
- Arrangement and details of embedded parts (water stops, piping systems, conduits, embedded parts for equipment erection, etc.);
- The dam stability analysis under all loading conditions and in temporary construction phases.
- Dynamic analysis of dam behavior under seismic loading conditions including determination of permanent displacement events;
- Analysis of landslide-induced waves in the reservoir and its impact on the project;
- Thermal analysis and detailed drawings of the dam, including dam zoning, drainages and galleries layout, grouting works, instrumentation details, dam crest works, etc.
- Detailed drawings of the spillway and downstream energy dissipater structure;
- Architectural and miscellaneous finishing drawings;
- Detailed method statements for all civil construction activities;

- Quality Management Plan for all construction materials and activities; and
- Other detailed design drawings and documents that the Employer may require.

Notwithstanding any Employer's review and comments, the Contractor shall be fully responsible for the correctness of the detailed drawings of the civil works, particularly in relation to the loads, dimensions, embedded parts, and any other interface with the equipment.

The Contractor shall submit the detailed Construction / Manufacturing Design of the civil structures in an orderly sequence, following the priorities of the construction program, so that in the time allocated for the Employer comment and review**, i.e. 28 days**, possible request of corrections and / or modifications will not cause delays, and excessive simultaneous submissions are avoided.

Any other drawing, calculation note, and design document that the Contractor may deem necessary for his own use, such as reinforcing bars bending schedules, materials lists, etc. shall be submitted to the Employer for its review or information.

2.2 NUMERICAL AND PHYSICAL MODELS

2.2.1 Hydraulic Model Studies of the Spillway System and Energy Dissipator

2.2.1.1 Spillway System:

As per the "Project Evaluation Document (PED), dated 2025"; Spillway System of the PSKEM HPP Project is consisting of Power Tunnels at the Right Bank (Construction of the Right Bank Spillway is continuing under the Lot-1 Contract) and Overflow Crest Spillway to be constructed on the Dam Body. The Spillway System of the PSKEM HPP Project has been designed to safely dischage the 10,000-year return period flood (Q10,000=1,003 m³ / s) from the Dam Reservoir to downstream.

The Contractor shall design and construct the Overflow Crest Spillway on the Dam Body. The design discharge capacity of the Spillway System (Including the Right Bank Spillway / Power Tunnels in the scope of Lot 1 Contract) shall be equal to the 10 000 years return period flood (Q10000).

The type, number, and dimensions of the structures in the Spillway System, will be specified as result of the geological, structural, and hydraulic investigations and evaluations.

When the pre-design of the selected spillway is completed, the spillway operation shall be further confirmed with detailed hydraulic investigations to be carried out within the scope of the Basic Design stage.

The hydraulic model investigations shall aim at checking and, if necessary, improving the spillway solution proposed, namely to assess the patterns of the approaching flow,

the discharge capacity, the hydraulic performance of the chute channel (surface spillway) or tunnel, and energy dissipation structure. Regarding the energy dissipation arrangement, the model shall be especially focused on the assessment of energy dissipation, to minimize possible scouring and ensure safe operation of the structure for a range of operating conditions, since the most frequent to the extreme situations.

The hydraulic model investigations shall be carried out based on physical model experiments. The physical model tests must address the following aspects:

- Definition of the headwater vs discharge curve with all the gates (if any) fully open;
- Definition of the headwater vs discharge curve for one gate (if any) partially open and all the other gates (if any) closed;
- Definition of the headwater vs discharge curve with one of the gates (if any) closed and all the others fully open;
- Analysis of the flow pattern in the approach area of the spillway and of possible interference with nearby structures;
- Analysis of the hydraulic performance of the chute channel;
- Propose geometry modifications, if necessary;
- Flow condition and discharge capacity
- Definition of downstream water level vs discharge curve

2.2.2 Structural Model of the Dam

Study of the dam safety for failure scenarios, involving contact dam-foundation and discontinuities, using a 3D finite element model, as referred to in Chapter 3.2.3.

Chapter 0130

3 DESIGN AND DOCUMENTS

3.1 GENERAL

The documents listed in the Contract Agreement constitute the base reference for the design to be performed by the Contractor. These documents define the general requirements and intended concept for the scheme and establish its basic layout and features. The Contractor will develop the Basic Design and subsequently the Detailed Design of the Works in accordance with the Contract Agreement.

The Contractor shall provide the requirements for bringing the developed projects into compliance with the standards of the Republic of Uzbekistan (Adaptation), as well as undergoing expertise in the prescribed manner based on the Resolution of the Cabinet of Ministers of the Republic of Uzbekistan No. 579, dated 17.09.2021; and also the requirements of No. 5963, dated 13.03.2020, regarding the additional measures to deepen reforms in the construction sector in the Republic of Uzbekistan.

While optimization of the Works' features and layout is permitted and encouraged, major revisions to the Works which affect and change the safety, performance, and / or reliability of the Works are subject to the agreement of the Employer.

The Employer shall undertake a review of the design and other construction documents (referred to as Contractor's Documents or "Drawings") prepared by the Contractor to ensure that the stipulations of the Employer's Requirement and other requirements of the contract are being complied with. The project must comprise two phases: Basic Design and Detailed Design

At the Basic Design stage, the geometry of all structural elements and constituent materials must be defined.

To facilitate this review, the following submission requirements shall be met by the Contractor:

- The Contractor shall submit to the Employer, for review, all drawings and documents prepared in accordance with the rules and procedures stated hereafter. No part of the equipment shall start fabrication prior to the corresponding review.
- Should the Contractor start works without having handed over specifications and drawings, and should it be ascertained that such works are not in compliance with Employer's Requirements, then this should be treated as "non-conformity" by the Employer. Treatment of the non-conformity may imply specific corrective works to be performed before final acceptance.
- Design schedule to be prepared by the Contractor, and whenever possible, shall make adequate allowance for the review period of the design documents by the Employer and other authorities concerned with the design and environmental impact aspects of the works.
- In the event of a difference in opinion regarding any subject, all efforts will be carried out in order to reach a compromise. In any case, the Contract specifications and

definitions and the criteria of these Employer's Requirements shall serve as a reference for the implementation of any of the design features.

- If, as the outcome of the inspection, the Employer articulates any comments or observations on inspected documents, the Contractor will have to either accept the observations and modify the design accordingly or justify the reasons for the nonacceptance of the proposed modifications.

Considering the tight project implementation program and in order to facilitate coordination between the Contractor and the Employer to finalize major design aspects, video conferences between the Contractor's home and site office and the Project office may be organized monthly or when agreed upon between parties.

Notwithstanding any review carried out by the EMPLOYER and / or Engineer's, the Contractor shall accept full responsibility for all aspects of the design, procurement, construction, and commissioning of the Permanent Works.

Data contained in the documents listed in the Contract Agreement may be subject to changes that are deemed suitable for the improvement and completion of the Project in accordance with these Requirements.

3.2 BASIC DESIGN

The **Basic Design** shall be performed at a more detailed level than the "Project Evaluation Document (PED) and has the main objectives of validating and optimizing the proposed layout and technical solutions, complementing parts of the project that were insufficiently developed in the PED (inclusively by using data from any additional investigations) and stabilize and approve the layout and solutions that will be developed at **Detailed Design** level.

The Basic Design shall include, though not limited to, the following elements:

- Main features of facilities for the Project;
- General plan and profile of the Project;
- Update / calculate of hydrology studies of Pskem Dam HPP taking into account the Climate Change Impacts
- Update / calculate of hydrology studies of Charvak Dam HPP taking into account the Climate Change Impacts and considering the Pskem Dam effect
- Update of the flood frequency analyses taking into account the Climate Change Impacts (including 10 000 years return period flood (Q_{10000}) and probable maximum flood (PMF));
- Survey works of the project area
- Geological and geotechnical investigations, studies, and evaluations
- General hydraulic design of spillway system and energy dissipators.

- Hydraulic model of the spillway system and energy dissipators.
- Drawings of plan and profile of main civil structures (including access and adits);
- Dam instrumentation
- Quantities of main work items of civil works;
- Technical Specifications for the Materials and Construction activities;
- Quality Management Plan for all construction materials and activities;
- Construction planning for civil works;
- Implementation schedule of the Project;
- Reservoir Rim Slopes Stability Study (if any);
- Dam Break Study;

3.3 DETAILED DESIGN

3.3.1 General

The Contractor shall define complementary data and submit the **Detailed Design** of the facilities included in the scope of work to the Employer, for its review and comment. The submission of the Detailed Design can be organized by the main project structures in order to facilitate the progression of the construction activities.

The Detailed Design shall be guided by the Basic Design approved by the Employer according to these Employer's Requirements and more generally to the Contract agreement.

The Contractor is required to submit **1 (one) month** after the Commencement Date the document organization structure of the Detailed Design and the corresponding submission schedule. The Detailed Design submission schedule must be fully compliant with the overall Project Implementation Schedule.

3.3.2 Layouts and Drawings

The Detailed Design shall include all the elements required for a full understanding by the Employer of the key features proposed, such as, but not limited to:

- General arrangement and location of the project structures.
- Detailed civil design of the structures.
- Detail design of dam instrumentation
- Detailed design of the mechanical equipment.
- Detailed design of the hydraulic steel structures.
- Detailed design of all underground openings.

- Additional geological and geotechnical investigation program (as required).

3.3.3 Reports

The Reports related to the Detailed Design shall include all calculations and studies required to justify and support the proposed technical solutions. They shall also include:

- Results of the field and laboratory investigations performed up to that moment and program for any additional investigations deemed necessary.
- Design criteria, standards, and design codes proposed for the development of the detailed design (Manufacturing / construction).
- The Technical Specifications for the Civil and Building Works, Complete.
- The Technical Specifications for the Hydraulic Steel Structures Complete.
- Finite element deformation and stress analysis including optimization of support system for all underground openings and open-air excavations.
- Geological and geotechnical investigation results and interpretations for additional investigation work.
- The two-dimensional and three-dimensional dam stability analysis including data acquired through the specific investigations and testing performed for this purpose;
- Reservoir slope stability analysis.
- Hydraulics and basic structural computations of the spillway system and energy dissipators (with corresponding drawings), so as to size and justify the main items.
- Hydraulic model test results
- Quality Assurance and Management Plan (to be submitted within **90 days** after the Commencement Date) and Manuals.

3.3.4 Program and Other Documents

As part of the Detailed Design, the Contractor shall also submit:

- A detailed program of the phases of design, material supply, and commissioning of the equipment.
- Any other requested document by the Employer to elucidate the Detailed Design and Construction implantation plans and arrangements.

3.4 "AS BUILT" DRAWINGS

The Contractor shall present, on the completion of the project, a detailed description of the project, the history of construction activities, major problems encountered, photographic report, sketches, "as built" drawings, as well as computer data and software programs used and generated during the project.

The Contractor shall provide detailed "as built" drawings for the entire Works, including all civil, mechanical, electrical, and architectural general arrangements, concrete outlines, shop drawings of major equipment, utilities, interconnection, and logic diagrams. These are to be based on Contractor's construction "marked-up" drawings and field information.

All drawings shall be provided in hard copy (4 copies), and by electronic files on compact disk using recent version "AutoCAD" software.

3.5 CONTRACTOR'S ORGANIZATION

The Contractor shall, during the early phases of the activities, submit, in accordance with the Time Schedule, the following documents related to the organization of the Works in accordance with the Contract:

- A comprehensive construction schedule in a bar chart form, inclusive of the main activities of the Works to be executed, depicting durations, interdependencies, and critical activities; scheduled updates shall be submitted in accordance with scheduled revisions.
- A general layout of the construction facilities, showing the planned arrangement of temporary roads, temporary camps, workshops, stores, fuel and explosive storages, yards, electric power station, and other facilities planned for the Works.
- Machinery and Equipment requirement schedule for the Project that the Contractor proposes and enables him to meet the Employer's Requirements, together with the productivity of the machines / equipment, capacity, and relevant information.
- An organization chart, together with complete qualifications and experience data sheets for the key personnel that the Contractor proposes to employ at the Site for the execution of the Works, indicating who is local and who is expatriate, and the position in the organization; this chart shall be accompanied by a bar graph showing the scheduled period of employment of the personnel.
- An estimate of monthly monetary requirements for the Works according to the proposed Implementation Schedule.
- Number of proposed labor force together with the basic wages expected to be paid for each labor category.
- Method Statements concerning the main activities for all sections of the Works.

Chapter 0140
4 QUALTY CONTROL AND QUALTY ASSURANCE

4.1 GENERAL

4.1.1 Work Included

This Section covers the requirements for the Quality Control and Quality Assurance of the design, material, fabrication, erection and application of works.

4.1.2 System and Procedures

The Contractor shall be solely responsible for the quality and testing of materials, workmanship and production processes in the Contract.

To this end the Contractor shall institute and operate a Quality Management Plan, which details:

- Quality control procedures
- Personnel responsibilities
- Pprocurement procedures
- Testing procedures
- Equipment and calibration
- Ffrequency of testing, calibration, etc.
- Hold points in production for inspection
- Rejection and rectification procedures
- Documentation and communication

in order to satisfy the specifications relevant to each operation pursuant to the Works in terms of the Contract.

4.1.3 Approval of System

Within twenty-eight (28) days after the Commencement Date and based on the general outline and any amendments thereto requested prior to acceptance of the Bid, the Contractor shall submit comprehensive details of the systems as proposed, making use wherever possible of diagrams, charts, organization charts, etc. in preference to lengthy description, all for the approval of the PMC. Such details shall be updated from time to time as appropriate or as directed by the PMC.

The Contractor shall commence the operation of the Quality Management Plan without delay and in accordance with the PMC's approval of the general outline and documentation examples as accepted with the Bid and shall thereafter modify the system, from time to time in accordance with the further details as approved by the PMC.

4.1.4 Provision of Materials and Equipment

- All materials and equipment intended to be incorporated in the Works shall be subject to approval by the PMC prior to order by the Contractor.
- No Plant or part thereof shall be shipped from its point of original manufacture or final shop assembly to the work site before it has been approved by the PMC.
- Proprietary Brands: Where the Specification refers to materials of a particular brand name the Contractor may offer an equivalent for the PMC's approval but the PMC is under no obligation to accept the alternative and no claims will be entertained if the alternative is not accepted.
- Testing of Materials: Unless otherwise stated in the Specifications or accepted by the PMC, all testing shall be carried out and interpreted in strict accordance with the methods specified in the relevant ASTM Standards or other international or national standards specified in the Specifications or approved by the PMC.

4.2 APPROVAL OF MATERIALS AND EQUIPMENT

4.2.1 Submission of Samples and Data

The Contractor shall furnish all information as to quality, weight, constituent substances, dimensions, levels, strength and description of the materials, equipment and work, as may be designated by the PMC and which the Contractor proposes to incorporate in the Works, and shall give the PMC such other particulars as may be required.

Before placing any order for materials for incorporation in the Works, the Contractor shall submit to the PMC for information and consent the names of the firms supplying materials giving the origin, manufacturer's specification, quality, weight, strength and description. When requested, the Contractor shall provide such samples of the materials together with the manufacturer's test certificates as the PMC requires. The samples ordered or specified shall be delivered to the PMC on the Site, allowing sufficient time for the PMC to inspect and / or test the samples before the material is required in the Works. The PMC may request the Contractor to execute such tests on the submitted samples without separate cost.

Unless otherwise specified, all proprietary materials shall be used and placed in strict accordance with the relevant manufacturer's instructions.

Items submitted shall be properly labeled to indicate the Project Contract number, Contractor's source of supply, manufacturer Contract Item number, and other data required by the Specifications.

The results of the tests shall generally indicate:

- Sample identification numbers.
- Sample origin.

- Part of the Works represented by the sample.
- Sampling date.
- Description of tests with reference to the relevant standards.
- Test results.
- Date of tests.
- Reference of laboratory undertaking the tests.
- Conclusion (Satisfactory or Unsatisfactory).

4.2.2 Inspection at the Place of Manufacture

To allow possible inspection of materials and equipment in the course of or on completion of preparation or manufacture, the Contractor shall give the PMC written notice of the workshops and places where the materials and equipment are manufactured or stored and advise him of the state of progress, so that the inspection may take place at appropriate times and without delaying the dispatch of materials and equipment to the Site.

The PMC will make or request the Contractor to make such tests on concrete, concrete aggregates, embankment materials, filter materials and other materials as he may from time to time elect, and the Contractor shall provide such samples and assistance in sampling materials at the site as the PMC may reasonably require. Testing by the PMC shall in no way relieve the Contractor of his responsibility to test materials to ensure that they meet all the specified requirements and to control their quality.

4.2.3 Manufacturer's Certificate of Compliance

In the case of standard labeled stock products of standard manufacture material which have a record of satisfactory performance in similar work over a period of not less than two (2) years, the PMC may accept a statement from such manufacturer attested by the certified laboratory certifying that the product conforms to the applicable Specifications

Unless otherwise specified, all proprietary materials shall be used and placed in strict accordance with the relevant manufacturer's instructions.

4.2.4 Mill Certificates

In the case of materials for which such practice is usual, the PMC may accept the manufacturer's certified mill and laboratory certificate.

4.2.5 Service Record

If a demonstrable satisfactory service record is available for a material, certain specified tests may be waived by the PMC.

4.2.6 Testing Laboratory Certificates

The PMC may accept a certificate from a commercial testing laboratory, satisfactory to him, certifying that the product has been tested within a period acceptable to the PMC and that it conforms to the requirements of the Specifications.

4.2.7 Material Orders

The Contractor shall provide to the PMC a list of Sub-Contractors and vendors with whom orders are to be placed for materials or equipment which will be incorporated directly into the work of the Contract

Copies of material or equipment orders and list of stock material or equipment shall be provided to the PMC. All orders and stock lists shall state the Standard Specification under which the material is to be furnished, pertinent drawing and part numbers if any, and the required delivery date, and shall state that the material is subject to inspection and testing by the PMC.

4.2.8 Acceptance of Materials

The approval by the PMC of any material or equipment shall in no way relieve the Contractor of any of his responsibilities for meeting all of the requirements of the Specifications and shall not prevent subsequent rejection if such material or equipment is later found to be defective or not conforming to the Specifications.

4.3 SITE LABORATORY

The work covers the provision and maintenance of an adequately equipped laboratory as required at the site for control of the quality of materials and of the Works

Laboratory equipment shall be provided by the Contractor for the laboratory sufficient to carry out all the field and site quality acceptance testing required in the Specifications. It shall include, but not limited to, the following:

Item	Description	Quantity
1.00	**AGGREGATES**	
1.01	Aggregate Crushing Value Impact Test Apparatus, complying with BS 812	1 pcs
1.02	Cylinder for Checking Bulk Density of the Aggregates with tamping rod, 14 L and 28 L	4 pcs
1.03	Electric Oven, thermostatically controlled, forced convection, plus stainless steel trays, grids, and replacement parts, 120 L capacity, Temperature 300°C, Sensitivity 1°C	1 pcs
1.04	Electric Oven, thermostatically controlled, forced convection, plus stainless steel trays, grids, and replacement parts, 250 L capacity, Temperature 300°C, Sensitivity 1°C	1 pcs
1.05	Electric Oven, thermostatically controlled, plus stainless steel trays and grids and replacement parts, 35 L capacity	1 pcs
1.06	Elongation Index Test Apparatus, complying with BS 812	1 pcs
1.07	Equipment for Determination of the Specific Gravity of Fine and Coarse Aggregates, complying with ASTM C127 / ASTM C128	4 pcs
1.08	Flakiness Index Test Apparatus, complying with BS 812	1 pcs
1.09	Hotplates, Rectangular with dimensions 5000 x 300 mm surface area, Circular 200 mm dia, max temp 300ºC, (1500 Watt.)	2 pcs each
1.10	Los-Angeles Abrasion Resistance Test Apparatus, complying with ASTM C131	1 pcs
1.11	Microwave Oven, 15 L	1 pcs
1.12	Riffle Box, Sample Splitter with accessories and replacement parts, slot size 50 mm as per ASTM C-702	1 pcs
1.13	Sieve Shaker; capable of accommodating 8 sieves having diameters of 200 mm - 300 mm - 450 mm, plus pan & cover, incorporate a 0 – 30 minute timer	1 pcs
1.14	Standard Sieves (wet sieving), 200 mm diameter, No. 100 (150 microns) and No 200 (75 microns)	2 sets
1.15	Standard Sieves, 200 mm diameter, A ASTM E-11 aperture sizes: 2.36, 1.18, 0.6, 0.3, 0.15, 0.075 lids and receiver	2 sets
1.16	Standard Sieves, 300 mm diameter, ASTM E-11 aperture sizes: 31.5, 25, 19, 12.5, 9.5, 4.75, 2.36, lid and receiver	2 sets
1.17	Standard Sieves, 450 mm diameter, ASTM E-11 aperture sizes (mm): 100, 75, 63, 50, 37.5, 31.5, lid and receiver	2 sets
2.00	**CEMENT & POZZOLANIC MATERIALS**	
2.01	Bulk Cement Sampler, Length ≈ 1500 mm, 40 mm Ø, approximately 3-liter capacity, complying with ASTM C183	1 pcs

2.02	Blaine Apparatus (air permeability) plus accessories and replacement parts, complying with ASTM C204-00	2 pcs
2.03	Vicat Apparatus, plus accessories and glass graduates, complying with ASTM C191-99	1 pcs
2.04	Cube Moulds for Mortar, 50 mm size or Three-gang Moulds, complying with ASTM/ C109-99	12 pcs
2.05	Mortar Mixer plus accessories, 5-liter capacity and inclusive of 1 spare bowl, complying with ASTM C305-99	1 pcs
2.06	Pycnometer Glass Jar complete with cone and rubber seal, 1 kg capacity, complying with ASTM D854	8 pcs
2.07	Sieves, 45 microns, Stainless steel, Ø50 mm, complying with ASTM C 430	2 pcs
2.08	Muffle Furnace (for loss of ignition test), Max. Temp 1200ºC, 220 - 240V, 50 Hz, 1 phase, complete with 5 No. Crucibles	1 pcs
2.09	Flow Table, flow mould, and plastic / hardwood tamper, Hand operated, complying with ASTM C230-98	1 pcs
2.10	Le Chatelier Flasks and associated liquids, complying with ASTM C188-95	5 pcs
2.11	Graded Natural Silica Sand, complying with ASTM C778-00	400 kg
2.12	Autoclave Apparatus with accessories, High pressure, 220 - 240V, 50 Hz, 1 phase, complying with ASTM C151-00	1 pcs
2.13	Drying Shrinkage and Moisture Movement Apparatus with accessories, complying with ASTM C490-00a	1 pcs
2.14	Two-gang prism moulds, complying with ASTM C490-00a.	2 pcs
2.15	Containers, Polypropylene or high density polyethylene, sized to fit into humidity oven, 25x25x250 mm long prisms	2 pcs
2.16	High-Frequency Mortar Cube Vibrator for Cement Testing	1 pcs
2.17	Soundness Testing Apparatus for Cement	1 Set
3.00	**FRESH CONCRETE**	
3.01	Air Entrainment Meter plus accessories and replacement parts, Type B (approx 8L capacity), complying with ASTM C231-97	4 pcs
3.02	Bulk Density Measure, 10 liters, have carrying handles, complying with ASTM C138	1 pcs
3.03	Bulk Density Measure, 15 liters, have carrying handles, complying with ASTM C138	1 pcs
3.04	Concrete Mixer, power-driven, 80 - 100 liters capacity.	1 pcs
3.05	Cube Moulds, 150 mm size, complying with BS 1881	36 pcs
3.06	Cylinder Moulds, 150 mm diameter by 300 mm depth, complying with ASTM C470-98	48 pcs

3.07	Flow Table with mould and tamping rod, complying with ASTM C 124 / BS 1881-105 / DIN 1048	1 pcs
3.08	Internal Poker Vibrator, Tip dimensions Ø 20 - 40 mm x 250 mm, 2000 mm flexible shaft, frequency 9000 - 15000, 50 - 60Hz	1 pcs
3.09	Internal Poker vibrator, Tip dimensions Ø 38 mm x 250 mm, with 2000 mm flexible shaft, frequency 8500 - 12500, 140 - 210Hz	2 pcs
3.10	Prism Moulds, 100 mm square cross-section, including stainless steel gage studs, complying with ASTM C490.	4 pcs
3.11	Slump Test Equipment, cone, base plate, and tamping rod, complying with ASTM C143-00	8 pcs
3.12	Specific gravity of fresh & hardened concrete complete equipment	1 pcs
3.13	Vibrating Table, 1,0 m² size, variable frequency, and amplitude, as per the relevant British Standard	1 pcs
3.14	Ve-Be Consistometer, as per the ASTM C 1170	2 pcs
4.00	**HARDENED CONCRETE & SHOTCRETE**	
4.01	Automatic Compressive Strength Testing Machine, Capacity 200 tonnes, Microcomputer controlled, Vertical clearance between platens to be sufficient for 500 mm height concrete cylinders	1 pcs
4.02	Concrete Rebound Hammer and accessories (abrasive stone and test anvil), complying with ASTM C805-97	2 pcs
4.03	Core Drilling Machine, plus replacement part, capable to drill up to 300 mm concrete core	1 pcs
4.04	Flexural Strength Testing Attachment to the Compressive Strength Testing Machine	2 pcs
4.05	Hand-held Crack Meter (crack measuring microscope), Minimum 40 x magnification, battery operated, complete with 3 spare bulbs	1 pcs
4.06	Melting Pot for sulfur, plus accessories and replacement parts, 50Hz	2 pcs
4.07	Testing Anvil, Weight ≈ 16kg. For routine checking of Concrete rebound hammer	1 pcs
4.08	Trimming / Cutting Machine, saw blades up to Ø 300 mm plus accessories	1 pcs
4.09	Universal Cylinder Capping Frame, with capping plates for Ø100 mm and Ø150 mm specimens, complying with ASTM C617-98	1 pcs
5.00	**GROUT**	
5.01	Fann Viscometer Hydrometer or Lombardy plate	1
5.02	Marsh cone	4

5.03	Support assembly, comprising stand, boss head, and circular clamp to accommodate Marsh cone	1
6.00	**SOIL & ROCK**	
6.01	Balloon Density Apparatus and accessories, complying with ASTM D2162	1 Set
6.04	California Bearing Ratio (CBR) Testing Equipment and accessories, complying with AASHTO-T193	1 Set
6.04	CBR moulds complete with collar, base plate, etc.	18 pcs
6.04	CBR plunger with penetration dial gauge holder.	1 pcs
6.04	Swell stands for holding dial gauge	9 pcs
6.05	Floor-mounted electro-mechanical load frame 5 Tonne capacity with automatic strain control	1 pcs
6.05	Surcharge weight with central hole of 2 kg weight	40 pcs
6.05	Spacer disc with a handle	2 pcs
6.05	Perforated brass swell plate with an adjustable cap on the handle	18 pcs
6.05	Dial gauges, 25 mm travel-0.01 mm/division	12 pcs
6.05	High tensile steel calibrated proving rings of 1000 kg, 2500 kg and 5000 kg capacity	1 Set
6.05	Soaking tank for accommodating 9 CBR moulds	1 pcs
6.05	Compaction apparatus (Modified Proctor) to the requirements of ASTM D1557 / AASHTO T180 complete with collar, base plate, and hammer	3 pcs
6.06	Compaction apparatus (Standard Proctor) to the requirements of ASTM D698 / AASHTO-T99 complete with collar, base plate & hammer	1 pcs
6.07	Consolidometer / Oedometer and accessories, complying with ASTM D 2435	1 Set
6.09	Direct Shear Box Testing Equipment with accessories, complying with ASTM D3080	1 Set
6.10	Dynamic Cone Penetrometer Testing Equipment and accessories, complying with ASTM D6951	1 pcs
6.11	Field Density Testing Equipment, moulds in various required diameters, and other accessories, complying with ASTM D4914 / ASTM D5030	6 Sets
6.14	Liquid Limit (Casagrande) and Plastic Limit Testing Apparatus and accessories, complying with ASTM D4318	2 sets
6.15	Nuclear Gauge for Density and Moisture Content Determination, complying with ASTM D2922 / ASTM D6031	2 sets

6.17	Point Load Testing Equipment (Rock) with accessories, complying with ASTM D5731	1 Set
6.18	Portable Shear Box Testing Equipment for Rock Test with accessories, complying with ASTM D5607	1 Set
6.20	Sand Equivalent Apparatus with relevant chemicals and equipment, complying with ASTM D2419	1 Set
6.21	Sand-Cone Density Apparatus with relevant equipment, complying with ASTM D1556	4 sets
6.23	Soil Hydrometric Analysis Testing Apparatus, with a high-speed stirrer with stainless still beaker and jar complying with ASTM E100 / ASTM D422	1 Set
6.25	Speedy Moisture Testing Equipment with carrying case and supply of reagent, complying with ASTM D4944	2 pcs
6.26	Standard Penetration Testing Equipment with solid cone attachment to fit drive end, complying with AASHTO T206	1 pcs
7.00	**GENERAL**	
7.01	Electronic Platform Scale, Capacity 300 kg, Accuracy 100 g	1 pcs
7.02	Electronic Platform Scale, Capacity 200 kg, Accuracy 100 g	1 pcs
7.03	Electronic Platform Scale, Capacity 100 kg, Accuracy 100 g	2 pcs
7.04	Electronic Balance, Capacity 20 kg, Accuracy 0.1 g	2 pcs
7.05	Electronic Balance, Capacity 10 kg, Accuracy 0.01 g	2 pcs
7.06	Electronic Balance, Capacity 5 kg, Accuracy 0.01 g	2 pcs
7.07	Electronic Balance, Capacity 500 g, Accuracy 0.01 g	2 pcs
7.08	Electronic Balance, Capacity 200 g, Accuracy 0.001 g	1 pcs
7.09	Electronic Chemical Balance, Capacity 200 g, Accuracy 0.001 g	1 pcs
7.10	Triple Beam Balance, Capacity 2610 g, Accuracy 0.1 g	2 pcs
7.11	Triple Beam Balance, Capacity 610 g, Accuracy 0.1 g	2 pcs
7.12	Stopwatches	4 pcs
7.13	Enamel trays, 600 mm x 450 mm x 50 mm	6 pcs
7.14	Enamel trays, 450 mm x 300 mm x 40 mm	6 pcs
7.15	Enamel trays, 300 mm x 250 mm x 40 mm	6 pcs

7.16	Enamel circular plates of 250 mm dia.	6 pcs
7.17	Water Stiller, 3 liter/hr, with fittings and accessories	1 set
7.18	Calibration Weight Set 1000 g, Made of brass, class M1. Complete with case	1 pcs
7.19	Calibration weights of 2 kg, 5 kg, and 10 kg, made of brass, class M1	1 pcs
7.20	Desiccator, Non-vacuum type, borosilicate glass with perforated zinc disk	1 pcs
7.21	Hygrothermographs	1 Set
7.22	pH meter	2 Sets
7.23	Handheld digital thermometer with a probe Specifications: Range -10ºC to +100ºC, resolution 0,5ºC LCD readout	5 pcs
7.24	Mercury glass or Alcohol Thermometers Specifications: Range -10ºC to +60ºC, graduated 0,5ºC	10 pcs
8.00	**ACCESSORIES**	
8.01	Aluminum Tins, 50 mm x 30 mm	36 pcs
8.02	Aluminum Tins, 55 mm x 35 mm	36 pcs
8.03	Aluminum Tins, 70 mm x 45 mm	36 pcs
8.04	Aluminum Tins, 70 mm x 50 mm	36 pcs
8.05	Aluminum Tins, 80 mm x 50 mm	36 pcs
8.06	Brushes for Sieves, Nylon, 33 mm dia.	5 pcs
8.07	Brushes, Steel, approximately 150 mm x 60 mm	3 pcs
8.08	Cans for Moisture Content Testing of Soils	50 pcs
8.09	Engineer's steel straight edge, 300 mm length	3 pcs
8.10	Glassware comprising beakers, pipettes, dishes, measuring cylinders (100 to 1000 cm^3 capacity), glass rods and funnels	12 pcs each
8.11	Ground Glass Plate for LL and PL Testing, with rounded edges 600 mm x 600 mm x 10 mm	2 pcs
8.12	Hammer, 300 g	2 pcs
8.13	Knife for Trimming	2 pcs

8.14	Pipettes fitted with pressure and suction inlets for sampling, 10 ml capacity	1 Set
8.15	Retractable Steel Tape in case, 5 m metric	10 pcs
8.16	Rubber mallet, 50 mm, minimum mass 0,6 kg	5 pcs
8.17	Rulers, Steel, 300 mm metric	10 pcs
8.18	Scoops cast aluminum 150 mm long x Ø125	3 pcs
8.19	Scoops cast aluminum 250 mm long x Ø125	4 pcs
8.20	Scoops cast aluminum 350 mm long x Ø125	4 pcs
8.21	Shovels, rounded ends	10 pcs
8.22	Shovels, square end	10 pcs
8.23	Spatula, stainless steel blade, 100 mm	3 pcs
8.24	Spatula, stainless steel blade, 150 mm	3 pcs
8.25	Spatula, stainless steel blade, 200 mm	3 pcs
8.26	Tins with lids for sampling, 100 mm diameter x 75 mm height, 0,5 kg capacity	30 pcs
8.27	Trowels, Steel, 40 x 120 mm	3 pcs
8.28	Trowels, Steel, 60 x 140 mm	3 pcs
8.29	Vernier Caliper, 300 mm length	3 pcs
8.30	Wood Saw	2 pcs
9.00	**CHEMICALS & REAGENTS**	
9.01	Barium chloride solution	
9.02	Calcium carbide powder / ampoules (speedy moisture tester)	
9.03	Clear wax	
9.04	Methylated spirits	10 liters
9.05	Naphthalene	

9.06	Reagent Grade Potassium Dichromate	
9.07	Reagent Sodium Hydroxide	5 kg
9.08	Sodium hydroxide pellets (organic impurities test ASTM C400-99)	
9.09	Sodium sulfate solution	30 kg
9.10	Sulfur powder for capping cores and cylinders	250 kg
9.11	Sulphuric acid	

Chapter 0150

5 HEALTH, SAFETY AND ENVIRONMENT

5.1 GENERAL

5.1.1 Work Included

This Section covers the requirements for the Health, Safety and Environment Management Strategies and Implementation Plans (HSE-MSIP) during the executions of the woks.

5.2 HSE MANAGEMENT STRATEGIES & IMPLEMENTATION PLANS (HSE-MSIP)

The Bidder shall submit comprehensive and concise **Health, Safety and Environment** Management Strategies and Implementation Plans (HSE-MSIP) (PCC Sub-Clause 4.18). These strategies and plans shall describe in detail the actions, materials, equipment, management processes, etc. that will be implemented by Contractor, and its Subcontractors.

The Bidder shall submit Management Strategies and Implementation Plans (MSIP) (PCC Sub-Clause 4.18) to manage the following key Health, Safety and Environment (HSE) risks.

- Plantation Plan to compensate for the loss of vegetation in the reservoir area;
- Disaster Management Plan to mitigate the severe impacts of natural disasters;
- Fisheries Management Plan for reservoir area to mitigate and manage the aquatic culture in new habitat.
- Traffic Management Plan to ensure the safety of local communities from construction traffic; and
- All other site-specific, site restoration, and rehabilitation plans refer in EIA.

In developing these strategies and plans, the Bidder shall have regard to the HSE provisions of the contract including those as may be more fully described in the following:

- HSE Works Requirements described in Section 11 - Annex B.1;
- Environmental Impact Assessment (EIA);
- Consent Conditions of environmental approval whenever issued from concerned regulatory authority;
- All Applicable Laws and Regulations of Uzbekistan Relating to Environment, Health and Safety,
- Amended Time to Time & Environmental Requirements of Other Agencies and Legislation;
- ILO's (International Labour Standards) Fundamental Conventions and Protocols.

The contractor shall prepare the HSE-MSIP document and submit to Employer and / or PMC along with all implementation strategies, implementation schedule, key

professional staff, and other relevant inputs management processes. The consultant will review and approve the draft HSE-MSIP document for its effective implementation.

5.3 CODE OF CONDUCT – HEALTH, SAFETY AND ENVIRONMENT (HSE)

The Bidder shall submit the Code of Conduct that will apply to the Contractor's employees and Subcontractors. The Code of Conduct shall ensure compliance with the HSE provisions of the Contract, including those as may be more fully described in the following:

- HSE Works Requirements described in Section 11 - Annex B.1;
- Environmental Impact Assessment (EIA);
- Consent Conditions of environmental approval whenever issued from concerned
- All Applicable Laws and Regulations of Uzbekistan Relating to Environment, Health and Safety,
- Amended Time to Time & Environmental Requirements of Other Agencies and Legislation;
- ILO's Fundamental Conventions and Protocols.

In addition, the Bidder shall submit an outline of how this Code of Conduct will be implemented. This will include: how it will be introduced into conditions of employment/engagement, what training will be provided, how it will be monitored, and how Contractor proposes to deal with any breaches.

5.4 HEALTH, SAFETY AND ENVIRONMENT (HSE) REQUIREMENTS

The contractor shall place prime importance on health, safety, and environmental (HSE) issues and requires that the Contractor and its Subcontractors subscribe to and actively pursue the highest standards of HSE performance. The contractor shall perform the Work in full compliance with the provisions relevant to the Work and shall implement HSE routines to ensure that all Personnel is fully aware of the existence, content and expectations of the HSE.

In prosecuting the work of this Contract, Contractor shall provide working conditions on each operation that shall be as safe and not injurious to health as the nature of that operation permits. All the work shall be performed in accordance with applicable local and national laws, codes, requirements and regulations including the safety, health, and welfare of persons and others. The contractor shall in general be fully conversant and comply with the relevant sections of all construction regulations enforceable by the law.

The contractor shall at all times take all reasonable precautions to maintain the health and safety of the Contractor's Personnel. In collaboration with local health authorities, Contractor shall ensure that medical staff, first aid facilities, sick bay, and ambulance service are available at all times at the Site and any accommodation for the Contractor's

and Employer's Personnel and that suitable arrangements are made for all necessary welfare and hygiene requirements and the prevention of epidemics.

The contractor shall employ a full-time safety team to help accomplish the purposes of this Clause B.1 and its Subclauses.

The contractor shall ensure each workgroup has at least one (1) Person present at all times who is fluent in both the primary language of the Worksite and the language of the workers.

5.4.1 Management System

The contractor shall have in place an HSE policy including an assurance framework. The policy shall pay due regard to the accountability of individuals, incident reporting, safety meetings, and training. The contractor shall also have established arrangements for monitoring this policy.

The contractor shall have in place a formal management system that demonstrates a commitment to continuous improvement and excellence in HSE issues and which follows the HSE applicable Regulations.

The contractor shall review its management system at least annually and update it as necessary.

Certain activities pose a higher risk to the safety of personnel, property, and the environment. Higher risk activities will accordingly demand a higher level of HSE commitment from the Contractor's management. Where the use of a Subcontractor involves the importation of higher-risk activity, the Contractor must be able to demonstrate an appropriate higher level of HSE commitment.

Risk can vary from location to location and, where the Work is being performed at more than one location, the Contractor shall observe and comply with all relevant and current Proponent directives Contractor may be required to provide different levels of HSE management for each location under the whole Lot-2 Pskem HPP Project.

The contractor shall compile an interface document, as part of the Contractor Execution Plan, documenting that Contractor has an implemented and documented Management System in compliance with the HSE Regulations listed hereunder:

- All Applicable Laws and Regulations of Uzbekistan Relating to Environment, Health and Safety,
- Amended Time to Time & Environmental Requirements of Other Agencies and Legislation,
- ILO's Fundamental Conventions and Protocols.

The contractor shall point out non-conformances / deviations related to the requirements as described above and demonstrate that the significance of the individual non-conformances / deviations have been assessed from a safety standpoint.

The contractor shall give necessary training in the understanding of the philosophy behind the applicable Acts, Regulations and Provisions.

The contractor shall identify Employer's HSE directives relevant to the Work. Personnel shall be trained in order to achieve necessary working competence within the identified Employer HSE directives. The contractor shall keep records of the training Personnel have received.

The contractor shall have put in place objectives, actions, and measurements encompassing all organizational levels at the Contractor in order to ensure that a sound health, environment and safety culture is established and maintained for the Work.

5.4.2 HSE Policy

Contractor HSE policy shall be intended to: help prevent accidents, illnesses and injuries; increase safety awareness; meet requirements of environmental, occupational health, and safety local and international laws and regulations; reduce institutional liability; and establish safety responsibilities for staff / workers at the project site and the local community. Contractor HSE policy outlines safety responsibilities and training requirements to ensure individual and institutional compliance with relevant environmental health and safety laws, regulations, policies, and guidelines.

It shall be Contractor's policy to perform work in the safest practicable manner, consistent with good local and international best practices. The occupational health and safety of the staff, workers, and all those likely to be affected by the pre-construction, construction, and operations activities is the responsibility of the Contractor(s); in addition to, adequate resources shall be made available to ensure the success of this policy. It shall be the duty of the Contractor(s) to provide safe systems of work and do everything practicable to prevent injuries, property damage, loss of life and ill health by controlling the risks arising out of construction activities. Equally, it shall be the duty of each worker / staff to exercise personal responsibility for his or her own safety and that of others and cooperate with his or her worker / staff in matters of health, and safety.

It shall be the Contractor's policy to adhere completely to the requirements of the Occupational Health and Safety at Work etc. OSHA (Occupational Safety and Health Administration) laws, Construction Regulations, and all other Acts, Regulations, and Codes of Practice, which affect the construction and operational activities.

As a minimum, the policy is set out to the commitments to:

- Apply good international industry practices to protect and conserve the natural environment and minimize unavoidable impacts;
- Provide and maintain a healthy and safe work environment and safe systems of work;
- Protect the health and safety of local communities and users, with particular concern for those who are disabled, elderly, or otherwise vulnerable;

- Ensure that terms of employment and working conditions of all workers engaged in the Works meet the requirements of the ILO labor conventions to which the host country is a signatory;
- Be intolerant of, and enforce disciplinary measures for illegal activities. To be intolerant of, and enforce disciplinary measures for GBV (Gender Based Violence), child sacrifice, child defilement, and sexual harassment;
- Incorporate a gender perspective and provide an enabling environment where women and men have equal opportunity to participate in and benefit from, the planning and development of the Works;
- Work co-operatively, including with end users of the Works, relevant authorities, contractors and local communities;
- Engage with and listen to affected persons and organizations and be responsive to their concerns, with special regard for vulnerable, disabled, and elderly people;
- Provide an environment that fosters the exchange of information, views, and ideas that is free of any fear of retaliation;
- The policy should be signed by the senior manager of the Employer. This is to signal the intent that it will be applied rigorously.

5.4.3 Labor Laws

The contractor shall comply with all the relevant Labor Laws applicable to Contractor's Personnel, including Laws relating to their employment, health, safety, welfare, immigration, and emigration, and shall allow them all their legal rights.

The contractor shall at all times during the progress of the Contract use its best endeavors to prevent any unlawful, riotous, or disorderly conduct or behavior by or amongst its employees and the labor of its Subcontractors.

The contractor shall, in all dealings with its labor and the labor of its Subcontractors currently employed on or connected with the Contract, pay due regard to all recognized festivals, official holidays, religious, or other customs and all local laws and regulations pertaining to the employment of labor.

The contractor shall pay rates of wages, and observe conditions of labor, which are not lower than those established for the trade or industry where the work is carried out. If no established rates or conditions are applicable, the Contractor shall pay rates of wages and observe conditions that are not lower than the general level of wages and conditions observed locally by employers whose trade or industry is similar to that of the Contractor.

The contractor shall inform Contractor's Personnel about their liability to pay personal income taxes in the Country in respect of such of their salaries, wages, and allowances as are chargeable under the Laws for the time being in force, and the Contractor shall

perform such duties in regard to such deductions thereof as may be imposed on him by such Laws.

No work shall be carried out on the Site on locally recognized days of rest, or outside the normal working hours, unless

- Otherwise stated in the Contract;
- The Project Manager gives consent; or
- The work is unavoidable or necessary for the protection of life or property or the safety of the Works, in which case the Contractor shall immediately advise the Project Manager.

If and when Contractor considers it necessary to carry out work at night or on public holidays so as to meet the Time for Completion and requests the Project Manager's consent thereto, the Project Manager shall not unreasonably withhold such consent. This Subclause shall not apply to any work which is customarily carried out by rotary or double shifts

Except as otherwise stated in the Specification, Contractor shall provide and maintain all necessary accommodation and welfare facilities for Contractor's Personnel. The contractor shall also provide facilities for the Employer / PMC's Personnel as stated in the Specification.

The contractor shall not permit any of the Contractor's Personnel to maintain any temporary or permanent living quarters within the structures forming part of the Permanent Works.

Contractor shall not employ any child to perform any work that is economically exploitative, or is likely to be hazardous to, or to interfere with, the child's education, or to be harmful to the child's health or physical, mental, spiritual, moral, or social development. 'Child' means a child below the statutory minimum age as specified under applicable national, provincial, or law of Uzbekistan.

The contractor shall ensure that its employees and Subcontractors observe the highest ethical standards and refrain from any form of bullying, discrimination, misconduct, and harassment, including sexual harassment and shall, at all times, behave in a manner that creates an environment free of unethical behavior, bullying, misconduct, and harassment, including sexual harassment. The contractor shall take appropriate action against any employees or Subcontractors, including suspension or termination of employment or subcontract, if any form of unethical or inappropriate behavior is identified.

The contractor shall conduct training programs for its employees and Subcontractors to raise awareness of and prevent any form of bullying, discrimination, misconduct, and harassment including sexual harassment, and to promote a respectful work environment. The contractor shall keep an up-to-date record of its employees and Subcontractors who

have attended and completed such training programs and provide such records to the Employer or the Project Manager at their first written request.

5.4.4 Competence Assurance

The contractor must be able to demonstrate competence assurance of Personnel, the scope of which will cover as a minimum training within relevant Company HSE directives including, without limitation, safe working practices, permit-to-work systems, and risk assessment including risk to the environment.

Proponent has the right to remove from the performance of the Work, any Personnel who do not fulfill expected HSE performance, which, in the opinion of Company, misconduct themselves or are incompetent or negligent in the proper performance of their duties and such Personnel shall not be again employed upon the Work without Company's Approval.

5.4.5 Reporting

Unless otherwise agreed, the Contractor shall submit a formal report quarterly and present in the Performance Review (PR) for the Work, Contactor's, and Subcontractor HSE performance in the preceding reporting period and accumulated year to date.

The contractor shall immediately inform of organizational changes relevant to the Contractor and / or the Work.

The contractor shall immediately forward internal and external audit reports conducted by the Contractor relevant to the Work.

On a monthly basis Contractor shall provide deviation permits applied for and nonconformity status.

The contractor shall report to the Employer on a quarterly basis amount and type of chemicals supplied, used, discharged, and re-injected. The report shall be made in the format specified by the Employer. The contractor shall assure that the total annual use and discharge of chemicals supplied are within the specified discharge permit.

5.4.6 Right of Audit

Proponent reserves the right to audit Contractor and its Subcontractors to assure itself that HSE matters and Management Systems are being managed and controlled in accordance with the declared requirements of these HSE provisions and Contractor Management System. The contractor shall allow Proponent auditors for full access to the Work in progress, Personnel, records, and documentation for the purpose of conducting audits. HSE inspections may be undertaken by Proponent on Contractor's systems, as and when deemed necessary by Proponent, and may be carried out without any prior notice to the Contractor.

5.4.7 Engineering and Design

The contractor shall have a system to ensure that Risk, Emergency Preparedness, Environmental, and Working Environment Analysis are carried out as an integrated part of the design and engineering process.

The contractor shall ensure that design; test and acceptance criteria are defined and documented.

The contractor shall adopt a full life cycle perspective.

The contractor shall apply inherently safer design principles.

5.4.8 Environment

The contractor shall have implemented the Environmental Management Plan described in the main EIA report of the proposed Project through an effective Environmental Management System. If a system is not in place, a commitment to comply with the standard in the future is required.

The contractor shall monitor the amount and type of discharges according to requirements, such as accidental discharges and planned and permitted discharges.

5.4.9 Health

The contractor shall ensure access to an Occupational Health Service for follow-up of sick leave, occupational illness / injury, and other focus areas within occupational health and the working environment.

The contractor shall present periodic checks of basic medical such as hearing, eyesight, etc. on all staff working under controlled environmental conditions.

5.4.10 Emergency Preparedness

The contractor shall ensure duty numbers to contact Persons are available at any time by means of a phone answering service in case of an emergency.

5.4.11 Chemicals

The contractor shall submit Material Safety Data Sheets (MSDS) for all chemicals included in the Contract and or used in the Contract period. The MSDS shall be quality checked in accordance with the HSE regulations.

If the product is evaluated not to be classified according to Health Risk Classification, the label "Not required to be classified, shall be used. The label shall be of a size and color that is readable to the user. Reference is made to the Regulation concerning the labeling of hazardous chemicals.

The contractor shall supply the Employer with relevant information for Evaluating, Purchasing, and Handling Chemicals.

The contractor shall submit a complete list of all the chemicals to be used for the Construction.

The chemicals must be categorized in accordance with the applicable system of color coding.

5.4.12 Dangerous Goods

The contractor shall have a Dangerous Goods handling system that ensures compliance with local applicable laws for transportation on roads and railroads.

5.4.13 Storage and Use of Explosives

Blasting will be permitted only when proper precautions are taken for the protection of persons, Works, and property.

Explosives shall be stored, transported, handled, and used in accordance with the recommendations of BS 5607: Code of Practice for the safe use of explosives in the construction industry. The contractor shall comply with all special rules and regulations that may be made by the authorities having jurisdiction and by the PMC regarding the construction of and storage in magazines, precautions on blasting, and the like. The contractor will be held responsible to the Employer for all claims for damage caused by blasting.

Before starting any drilling and blasting of rock, the Contractor shall submit his proposed plan in writing for such operations to the PMC for approval and, upon approval, shall not deviate therefrom without the written permission of the PMC. The contractor's plan shall include statements of minimum safe distances; means of protection of concrete and other work, and structures. Approval by the PMC of the Contractor's plan of operation shall in no case relieve the Contractor of full responsibility for the entire drilling and blasting operation, including the safety of persons and the Works.

Accurate daily records shall be kept by the magazine keepers and shall account for each piece of explosive, detonator, and equipment from the time of delivery at the magazine until its discharge in use. No explosive shall be stored or used until it has been plainly labeled for identification and accepted by the PMC as new stock in sound condition. The contractor shall also maintain a record for each blasting operation showing the blasting pattern including the location, number, and depth of holes, the inclination of the wedge cut holes, amount and strength of explosives per hole and per round, the sequence in firing, and time delays for relay firing, the actual length of pull per blast and other relevant information.

5.4.14 Radioactive Sources

The contractor shall have a documented system to ensure that the activity is in compliance with regulations and provisions stipulated by the Government of Uzbekistan for the use of radioactive material.

5.4.15 Accident and Fire Prevention

The contractor shall enforce all necessary rules and regulations for the safe prosecution of the work in order to avoid preventable accidents and to minimize injuries to his employees and those of other concerned entities. Work areas shall be adequately posted with safety signs and posters. Machinery and equipment shall be guarded and all hazards eliminated in accordance with the safety requirements stated in the Contract, and with the latest 'Manual of Accident Prevention in Construction' published by the Associated General Contractors of America, Inc. USA. He shall maintain a satisfactory system of inspection and scaling in all open-cut excavations. All reasonable precautions shall be taken against fire, and provisions shall be made for the expeditious extinguishing thereof.

In addition to the reports which Contractor may be required to file under the law, he shall file with the PMC on or before the seventh day of each month a report giving the total force employed on this Contract in man-days during the previous calendar month, the number and character of all accidents resulting in loss of time, and any other information on the classification of employees' injuries received on the work and disabilities arising therefrom that may be required by the PMC.

The contractor shall, during the entire period of his operations at the Site, provide emergency facilities with adequate medical and surgical equipment for first aid treatment and approved qualified personnel to administer such treatment to all injured persons, including the Employer's and PMC's personnel. The contractor shall designate two or more approved competent licensed physicians, one of whom will at all times be ready to answer calls to supply medical and surgical services. The contractor shall submit for the approval of the PMC and, upon such approval, install a means of rapidly summoning the physicians to the site of an accident or fire. Ambulance service to the hospital at Contractor's camp shall always be available.

No payment will be made for the services required in this Sub-Clause B.1.15 other than that made under the Contract Items applicable to the first aid and fire protection facilities required to be provided by the Contractor.

Adequately equipped and properly staffed portable dispensaries and first aid stations shall be provided by Contractor at sub-camps and other strategic locations, to administer first aid treatment at any time required and free of charge to all persons on the Site, including personnel of the PMC and the Employer. The nature, number, and location of facilities furnished and the Contractor's staff for administering first-aid treatment shall

meet the requirements of the Health Service of the Government of Uzbekistan and shall be subject to approval by the PMC.

5.4.16 Safety Devices

Safety devices shall be used as required and shall include but not be limited to those described hereinafter. Efficient safety helmets, and safety harnesses where required, shall be provided for all personnel including all authorized visitors to the Site. Excavated areas shall be properly guarded from the beginning of excavation until the status of the work removes all possible elements of danger. Cages shall be used for hoisting men, and cages or skips for hoisting materials during the construction of underground works. Full precautions shall be taken to ensure maximum safety. In addition to the telephone system, effective and reliable signaling devices shall be maintained at all times to give instant communication at strategic locations in underground works.

The contractor shall carry out underground works in accordance with the recommendations of BS 6164: Code of Practice for safety in tunneling in the construction industry. The efficiency of all safety devices shall be established by satisfactory tests acceptable to the PMC before the hoists or skips are put into service and at least once every three months thereafter.

5.4.17 Measures against Insect and Pest Nuisance

The contractor shall at all times take the necessary precautions to protect Contractor's Personnel employed on the Site from insect and pest nuisance and to reduce their danger to health. The contractor shall comply with all the regulations of the local health authorities, including the use of appropriate insecticides.

5.4.18 Site Works

In all rock excavation operations, the Contractor shall install, maintain and effectively operate appliances and use methods approved by the PMC which will effectively reduce the amount of harmful dust and he shall exercise good practice in the control of silica dust in rock drilling. The crushing of rock, the dumping of stone, the mixing of concrete, and the handling of cement, steel, and other materials shall be so conducted that these operations will not cause any injury fatal or otherwise, nor be detrimental to health.

5.4.19 Personal Protective Equipment (PPE)

PPEs are equipment worn to minimize exposure to a variety of hazards that cannot be avoided due to engineering measures (residual impact). It includes gloves, foot, and eye protection, protective hearing devices (earplugs, muffs) hard hats, respirators, full body suits, etc. The contractor shall be responsible to provide PPEs to working staff and ensure their use. The contractor shall adhere to Employer's HSE requirements related to "Personal Protective Equipment (PPEs)" in respect of personal protective equipment.

The contractor shall, at its own expense, provide Personnel for duty staff with all necessary protective clothing and equipment suitable for working conditions.

Recommended Personal Protective Equipment According to Hazard			
Sr. No	**Type of Protection**	**Workplace Hazard**	**Suggested PPEs**
1	Over All, Exterior garments	Entanglement, chemical spill safeguard, etc.	Long pants, shirt with sleeves (no tank tops or shorts)
2	High Visibility Vests	Accidental hazard etc.	A reflective vest will be worn outside of any other garments
3	Foot protection	Falling or rolling objects, pointed objects. Corrosive or hot liquids	Safety-toed footwear / boots / shoes
4	Eye and Face Protection	Flying particles, molten metal, liquid chemicals, gases or vapors, light radiation	Safety Glasses, Spectacles, and Goggles. Spectacles with side shield. Prescription Lenses. Sun Glasses. Special Helmets or shields / Face shields.
5	Head Protection	Falling objects, inadequate height clearance, and overhead power cords.	Hard hats with top and side impact protection. Hard hats shall be worn with the brim pointed forward.
6	Hearing protection	Noise, ultra-sound	Earplugs, muffs
7	Hand Protection	Hazardous materials, cuts or lacerations, vibrations, extreme temperature	Gloves (Plastic, leather, fireproof, and rubber)
8	Breathing Protection	Dust, fogs, fumes, mists, gases, smoke, vapors	Facemasks
9	Toxic Gases Protection	Health and ailment etc.	SCBA (if applicable)
10	Falling Hazard Protection	Injury and death etc.,	Safety Belt / Chains, Locks

5.4.20 Safety Signs

In order to highlight the risk and identify potential hazards at the workplace, the Contractor shall be responsible for managing the following (not limited to) sets of Safety Sign Posts and Markings in the working zones for the dual purpose of the safety of workers as well as visitor / community.

- Authorized entry only (workplace hazards);
- Caution;
- Climb with caution;
- Work personnel only;

- Contractor's gate;
- Danger;
- Dangerous conditions;
- Falling hazard;
- Hard hats;
- Hazardous area;
- Men at work;
- Moving equipment;
- Risk of serious injury;
- Emergency assembly point;
- Shock hazard;
- Trip hazard (wet / slippery surface);
- Visitors;
- Warning;
- Transport control signs;
- Security barriers.

The contractor shall make arrangements for marking / signs of hazardous goods / materials which should be posted on the boxes for haulage.

5.4.21 Safety Training

The contractor shall ensure that safety training shall be recommended, including necessary refresher courses.

The contractor shall ensure that Personnel has passed the required HSE training before going to the workplace as defined by the Employer. This course requirement shall include Personnel provided by Contractor and Subcontractors.

The contractor shall be responsible for ensuring that Personnel possess all required safety qualifications described in Employer's HSE Directive.

Personnel shall be available at all times for periodic drills, instructions on survival, lifesaving, and fire-fighting as requested and conducted by Employer at the Worksite.

The contractor's management and relevant Personnel shall attend HSE training and courses as required.

All costs, including but not limited to travel, accommodation, per diem, course fees, salary, related to the training of all Personnel shall be borne by the Contractor.

5.4.22 Security

The contractor shall comply with the Employer guidelines for Security Control.

The contractor shall be able to verify the identity of Personnel who shall perform Work at construction sites, camps, and offices, on installations, on vessels and at land-based plants, and in premises employed by the Employer. When Contractor uses hired Personnel references from earlier employment shall be verified.

The contractor shall maintain prudent office security for office areas used for projects / activities and / or staff; including access control, ID badge usage, and burglar alarm / guard arrangement.

The contractor shall maintain information security regarding Employer and Project information; including clear desk policy, sensitive documents control, and confidentiality measurements.

The contractor shall maintain computer and communications security for any computer system and network being used for handling project information; including controlled computer access, virus protection, security updates, Firewalls, and backup routines.

5.4.23 Lifting Operations

The contractor shall have a system established to ensure that Personnel who are responsible for or are involved in, the maintenance / inspection of lifting equipment and execution of lifting operations.

The contractor shall have a system implemented for systematic inspection and maintenance of lifting appliances and lifting gear in accordance with statutory requirements.

The contractor shall ensure that all Plant (RCC Dam With Bottom And Spillway Outlets System) and / or Equipment being supplied to any Worksite is to be either, placed and operated at height or placed and operated over an area where Persons are working below shall have:

In place a Dropped Objective Survey or Inspection Procedure for the Plant; o Identified those items of Plant or Equipment or other components that, if fail, have a potential to injure Persons; and

In place a method for securing primary components or parts such that should failure occur of all Equipment and their parts are not able to fall and injure Persons. This may be the primary suitable means of security or secondary retention methods. Both should be in accordance with the manufacturer's recommendations and accompanied by a Hazard / Risk Assessment.

5.4.24 Waste Handling and Tracking

The contractor shall ensure the use of Authority-approved waste treatment or disposal sites. The employer reserves the right to request the Contractor to submit supporting documentation of approved sites. The employer reserves the right to reject the use of sites not found acceptable.

The contractor shall have implemented a system for identifying, classifying, and handling waste. Hazardous waste shall be handled according to Authority regulations and household waste and production waste shall be source segregated for recycling purposes.

5.4.25 Working Environment

The contractor shall undergo particular training with regard to relevant working environment factors related to the implementation of Work, the use of work equipment, and signaling and safety signposting at the workplace shall be given to the individual employee and supervisor.

The contractor shall actively take part in the working environmental activities that are carried out at the Worksite.

The contractor shall advise and assist Employer in a pro-active manner in the implementation of the annual working environment program and provide input for the subsequent year program.

5.4.26 Contractor HSE Trained Staff

The contractor shall be responsible for identifying necessary training and verifying that all senior-level members and staff / workers of the Contractor squad are properly prepared to perform the construction work as defined in the bidding documents.

The contractor must develop and implement an HSE Training program for the Contractor squad to meet the Proposed Project requirements and Statutory Requirements.

For all construction activities Contractor staff / employees should be well-HSE trained as per local and international laws. Before starting each construction activity, the Contractor shall designate and train a sufficient number of persons to assist the other staff to perform the construction activities.

5.4.27 Contractor Staff for HSE

The Construction phase of the Project is expected to be more critical in terms of HSE considerations. The following Table illustrates the requisite deployment of the Contractor's staff for HSE during the construction phase of the proposed Project.

Sr. No.	Contractor Staff Designation	Number of Personnel	Duration	Duties

1	HSE Inspectors	01 (For each workplace site during every shift)	Whole Construction Phase	• To ensure the use of SOP during every working activity; • Ensure availability and maintenance of PPEs to each and every worker at the workplace; and • Ensure the record maintenance of each HSE-related occurrence and communicate with their authority on a regular basis.
2	HSE Engineer	01 (For Each Camp or Worker Accommodation)	Whole Construction Phase	Same as above
3	Chief HSE Engineer / HSE Manager	01 (For each Lot)	Whole Construction Phase	Same as above
4	Air and Noise Expert	01	Whole Construction Phase	Monitoring of Air and Noise Emissions: • Report any incident • Report any violation to mitigate emissions in the light of the above-mentioned standards
5	Sanitary / House Keeping Supervisors	One (01) for each component of the proposed Project	Whole Construction Phase	Responsible for supervision / monitoring of all the waste management operations and the associated staff.
6	Sanitary Workers	One (01) Sanitation worker per 500 populations*	Whole Construction Phase	Responsible for the collection handling and disposal of waste in safe, effective, and environment-friendly ways.
7	Medical Staff	One (01) for each component of the proposed Project	Whole Construction Phase	Responsible for medical waste segregation, handling, storage, and disposal in a safe and environment-friendly manner.

Note: For disposal of Construction and Demolition (C&D) waste, it is the responsibility of the Construction Contractor to engage a licensed waste contractor for disposal of C&D waste.

5.4.28 Work Permit Provisions

The importance of the work permit system in any construction project cannot be neglected. A work permit is a written form used to authorize jobs that expose workers to serious hazards. Permits only allow authorized personnel to perform those serious hazard activities at specified times and in a way set out in the permit and referenced documents. It identifies the work to be done, the hazards involved, and the necessary

preparation and precautions for the job. A permit to work might be required for activities such as:

- Electrical works;
- Hot works;
- Excavation;
- Lone working;
- Lifting operations;
- Work in confined spaces;
- Work in high-risk spaces such as laboratories, or industrial plants;
- Using nuclear-densometer gauges
- Work at height;
- Work to roofs;
- Temporary works;
- Work with asbestos;
- Demolition; and
- Work to high-pressure systems.

It is recommended that safe work permit provisions for the identified hazardous construction activities for the proposed project will be an integral part of the bidding documents. Contractors will be responsible for compliance according to the OSHA (Occupational Safety and Health Administration) permit requirements. A safe work permit will be required for construction work, maintenance of machinery, repair, or within the workplace. Permits are generally not required for work performed in office buildings and maintenance shops except for confined space entry and hot work on equipment that has been in service.

5.4.29 Non-Conformance and Penalties

HSE contractual requirements are specified in the Contract, its provisions such as EMMP and NOC conditions and additional Source Documents. Many of these requirements are procedural in nature and require the Contractor to implement processes and procedures to achieve outcomes that mitigate HSE impacts. There are some requirements that relate to standards and specifications for equipment and emissions.

Non-compliance situations and conditions may be identified through (but not limited to) audits, inspections, and monitoring. HSE non-compliance can be identified, ranked, and recorded at three levels. Once the level of non-compliance has been identified and communicated to Contractor, Contractor must provide a written response containing a plan of action, including a timeline for remediation of the noncompliance with a plan to

prevent recurrence. Penalties may be levied on the Contractor as a result of nonconformity.

A temporary work suspension for cause may be enforced in case of "Imminent Danger" or "Willful / Repeat" non-conformities. Costs associated with work suspension due to nonconformity shall be borne only by the Contractor at no cost to the Employer or its agents. In this event, the Contractor forfeits their right to a claim of delay.

The contractor shall establish, implement and maintain a procedure (s) for dealing with actual and potential nonconformity(ies) and for taking corrective action and preventative action. The procedure(s) shall define the requirements for:

- Identifying and correcting nonconformity(ies) and taking action(s) to mitigate their HSE consequences;
- Investigating non-conformity(ies), determining their cause(s), and taking actions in order to avoid their recurrence;
- Evaluating the need for action(s) to prevent nonconformity(ies) and implementing appropriate actions designed to avoid their occurrence;
- Recording and communicating the results of corrective and preventive action(s) taken; and
- Reviewing the effectiveness of corrective and preventative action(s) taken.

Any stakeholder may identify an issue of noncompliance during the course of activities. Nonconformities shall be documented and assigned a severity and timeline for remediation. If the Contractor does not remediate the nonconformity in the required timeframe, penalties may be assessed.

If PMC found any employee of Contractor or its Subcontractor(s) to be acting or working in a manner that is found to be non-compliant with the HSE requirements of the Project as specified under Article / Sections or as required by regulatory agencies of the local / state government, the Employer / PMC shall have the authority to order immediate correction or cessation of the non-compliant occurrence. Accordingly, the Contractor and its Subcontractor(s) shall take immediate steps to eradicate such non-compliance and shall perform in the manner prescribed by the Contract.

If the Contractor or any of its Subcontractor(s) fails to correct / remedy any noted health, safety and environment non-conformance(s) within the time period specified by PMC, PMC shall forthwith issue a 'Notice of Non-Compliance' to Contractor and shall exercise any of all of the following:

Removal of Contractor's or Subcontractor's employee(s) from the Project responsible for the implementation of such measure(s);

Retention of some amount as a monetary penalty from any payments due or to become due to Contractor that has been assessed / determined by the PMC to the extent of the breach of HSE principles / provisions;

Failure to the compliance after the above two, the PMC shall issue a 'Final Warning' to Contractor or its Subcontractor(s) in writing with a copy to the competent authority; and

However, if Contractor still fails to comply with any of his obligations regarding prescribed HSE requirements despite a Final Warning from PMC, such failure shall be considered as breach of the Contractor's obligations under the Contract and shall be dealt with as per Contract provisions.

5.5 ITEMS FOR HSE REGULATIONS

List of Items for HSE		
Sr. No	Item	Quantity
Consumable		
1	First Aid Kits	10 / year
2	Personal Protective Equipment	10 / lot
3	Fire Extinguishing Agents	10 for 2 years
4	Safety Lights	10 / year
5	Emergency Lights	10 / year
6	Torch	10 / year
7	Safety Tape	10 / year
8	Safety Training	10 / year
9	Breathing Appliances	5 / year
Non-Consumable		
10	Ladders	10
11	Fire Extinguishers	5
12	Fire Alarm System	5
13	Safety Signs	10

List of Items for HSE		
Sr. No	Item	Quantity
14	Logout / Tagout System	5
15	Fall Protection	10
16	Traffic Control Signs	10
17	Protective Barriers	10
18	Emergency Ambulance	1
19	Sprinkler Systems	3
20	Gas Detectors	5
21	Foam Systems	5
22	Spill Response	N / A
23	Foam Making Equipment	5
24	Fire Brigade	1
Solid Waste Handling		
25	Solid Waste Trucks	1
26	Solid Waste Handlers (Waste Disposal Services)	10
27	Incinerators	1
28	Garbage Cans	10

List of Items for HSE		
Sr. No	Item	Quantity
29	Refusal Collection Containers	10
30	Wheel Barrows	10
31	Skips for Wood and Timbers	10
32	Waste Segregation Bins With Color Coding at Construction Sites	10
33	Drums for Hazardous Waste	10
34	Steel Mesh Cage for Recyclable Waste	10
35	Waste Skips and Loaders	10
36	Recycling Truck	1
37	Waste Bins for Medical Waste	5
38	Sharp Containers	5
Liquid Waste Monitoring		
39	Water Quality Lab for Testing of Wastewater	1
40	Chemicals	N / A
41	Maintenance of Equipment	N / A
Air and Noise Monitoring		

List of Items for HSE		
Sr. No	Item	Quantity
42	Hygrometer or Psychrometer	2
43	Thermometer or Stevenson Screen	2
44	Noise Level Meter	2
HSE Staff		
45	HSE Inspectors	4
46	HSE Engineer	2
47	Chief HSE Engineer / HSE Manager	1
48	Air and Noise Expert	1
49	Sanitary / House Keeping Supervisors	2
50	Sanitary Workers	2
51	Medical Staff	3
52	Chemist	1
53	Lab Technician	2

5.6 HSE MANAGEMENT QUESTIONNAIRE – PSKEM HPP PROJECT

GENERAL INFORMATION

Name and Address of Company

Post Code

Registered office and sub-offices if different from above

Telephone Number

Fax Number

Website address

E-mail

Type of Company (e.g.: PLC, Private, Partnership, etc.)

Date Established

Incorporated in

Parent Company

Incorporated in

Ultimate Parent Company

Incorporated in

Subsidiary And Associate Companies

Names of Key Personnel

Name and Address of Bankers

Principal Business Activities

This sample questionnaire is a guideline questionnaire that will be a part of the Bidding Document and involved in the evaluation process. The questionnaire is to be completed by the Bidder and submitted with their bid offer. The objective of the questionnaire is to provide an overview of the status of Bidder's HSE management system. Bidders will be required to verify their responses noted in their questionnaire by providing evidence of their ability and capacity in relevant matters.

Please be advised that if your bid is successful you may be required to provide:

A Risk Assessment for the Project;

A Site Safety and Security Arrangements Plan;

Occupational Health and Safety Plan; and

Job Safety Assessments or Safe Work Method Statements for individual activities that have a medium to high hazard level.

Certification: The information provided in this questionnaire is an accurate summary of the company's occupational health and safety management.	
Company Name:	
Signed:	Name:
Position:	Date:
Contract Details:	
Contract Name:	Contract Number:
Name and Contact Details of the Representative:	

N / A = Not applicable or relevant to this Contract

Management Element	Bidder Response to Clarification	Evidence / Company's Clarification
1. Leadership and Commitment		
a) What is the commitment of top management towards HSE at the workplace?		
b) How does top management actively endorse a positive HSE culture in the workplace?		
c) What does top management do to ensure the health and welfare of employees are established, maintained, and given priority like accommodation, meals, rotation, medical care, recreation facilities, etc.?		
2. Policy and Strategic Objectives		
2.1 HSE Policy Documents		

Management Element	Bidder Response to Clarification	Evidence / Company's Clarification
a) Has the organization's top management documented, authorized, and issued an HSE Policy?		
b) Does the policy address legal requirements for HSE, commitment to the prevention of accidents, and provide a framework for setting and reviewing OHS objectives?		
c) Who has been identified and appointed in the organization for overall responsibility and accountability for HSE?		
2.2 Availability of HSE Policy Statements to Employees?		
a) How do you communicate your policy requirements or any amendments thereof to your employees?		
2.3 HSE Contract strategic objectives?		
a) How are HSE objectives set?		
b) How are these objectives communicated?		
c) How is the accomplishment of these objectives tracked and monitored?		
3. Organization, Responsibilities, Resources, Standards and Procedures		
3.1 Organization, structure to manage HSE		
a) How is the organization structured and resourced to manage HSE?		
b) How are lines of reporting structured and roles and responsibilities defined?		

Management Element	Bidder Response to Clarification	Evidence / Company's Clarification
c) How do you ensure the managers and supervisors understand their HSE duties and responsibilities?		
d) How have you made provisions for HSE communication meetings?		
3.2 Training		
a) How do you identify training needs including training for high-risk activities and specialized training?		
b) How do you ensure all employees have received appropriate HSE training and that it is recorded and monitored?		
3.3 HSE Competence		
a) What arrangements do you have to ensure new employees have the required knowledge of HSE, and how is this knowledge kept up to date?		
b) How are employees informed of the specific hazards arising out of the nature of their work?		
c) How do you ensure people are competent to perform a job that involves hazards and risks?		
d) How do you ensure HSE advisors are competent in presentation skills?		
3.4 HSE Standards (ISO14001 and OHSAS 18001 or equivalent e.g. OSHA)		
a) How do you identify, obtain, review, and communicate HSE legislation, regulations, external standards, and other requirements affecting the organization?		

Management Element	Bidder Response to Clarification	Evidence / Company's Clarification
b) How the company is assured that these requirements are met and verified?		

3.5 Assessment of suitability of Subcontractors / other companies		
a) How do you assess the: i) HSE competence of Subcontractors?		
ii) HSE performance record of the Subcontractors and companies with whom you place contracts?		
b) Where do you spell out the HSE requirements you require your Contractors to meet? (What standards apply?)		
c) What are the HSE terms and conditions dictated in your subcontract agreements?		
d) How do you ensure these requirements are met and verified?		.
4. Hazards and Effects Management		
4.1 Hazards and effects assessment		
a) How do you identify and document risk?		
b) How do you ensure the proper controls are in place, applied, and complied with?		
4.2 Occupational health exposure		
a) What occupational health monitoring do you do?		
b) In which areas of your business do you focus this occupational health monitoring?		
c) What health exposures do you measure and record?		
d) How do you manage occupational health exposures?		
4.3 Handling of chemicals, noise, asbestos, radiation, and other occupational health hazards		

a) How do you evaluate the health risks presented by the transport, storage, handling, and disposal of chemicals?		
b) How do you evaluate the health risks presented by noise, radiation, and / or asbestos where applicable?		
c) How do you ensure that minimal use is made of chemicals which are potentially harmful to the environment?		
d) How do you ensure the quality of the material safety data sheets (MSDS)?		
4.4 Personal protective equipment		
a) How do you manage PPE requirements?		
4.5 Waste management		
a) How have you identified your waste streams?		
b) How do you manage your hazardous waste?		
4.6 Drugs and alcohol		
a) How do you manage alcohol and drug abuse?		
b) Explain how you manage the health and well-being of your workforce?		
5. Planning and Procedures		
5.1 HSE Operations manuals		
a) Please attach an electronic copy of your HSE manual and HSE plan.		
b) How do you implement these requirements?		

c) What are the company arrangements for managing safe systems of work?		
d) How are you assured that the HSE system is fit for purpose?		
e) How are safety rules communicated and compliance monitored in the workplace?		
f) How are safety behaviors applied and monitored in the workplace?		
5.2 Equipment control and maintenance		
a) Describe the HSE Critical equipment specifically identified?		
b) How do you ensure plant and equipment are inspected, certified, valid, and safe for use?		
c) Do you have a preventive maintenance system?		
d) Please explain your equipment inspection regime.		
5.3 Road Safety Management		
a) How do you manage road safety for all company vehicles?		
b) How do you manage commuting to and from work?		
c) What standards are applied to your road safety management program?		
d) How often do you audit against the applied standard?		
e) How do you monitor non-compliance with road safety standards and rules in the company?		

f) What actions are taken by management when violations are identified or reported?		
g) How many drivers of vehicles are trained in defensive driving?		
h) How do you manage vehicle load restraining where applicable?		
i) How many Motor Vehicle incidents have you had in the last two years?		
6. Implementation and Performance Monitoring		
6.1 Implementation and active performance monitoring of work activities		
a) How do you monitor HSE performance in the workplace?		
b) What types of HSE performance indicators / measures are used in your company? Give examples!		
c) Provide examples of trending of your key HSE performance indicators!		
d) How is health performance recorded?		
e) What arrangements do you have to ensure personnel are fit to work in their designated role?		
f) How is environmental performance recorded?		
6.2 Statutory notifiable incidents		
a) How many reportable accidents have you had in the last five years? (Provide annual figures)		
6.3 Improvement or prohibition notices (in accordance with the regulations pertaining to safety and occupational health procedures)		
a) Provide details of any work prohibitions from the government or		

Employer imposed on the company?		
b) Have you ever had a contract canceled due to poor HSE performance?		
6.4 Incident investigation and reporting		
a) How do you identify the critical factors, immediate causes, underlying causes, and latent (hidden) management system failures?		
b) Who normally conducts incident investigations?		
c) How do you determine who should lead the investigation?		
d) How do you ensure that the learnings from all incidents, including near misses, are communicated?		
7. Auditing		
7.1 Auditing		
a) How do you plan and schedule audits and what range of auditing is covered?		
b) How are audit findings tracked and closed out?		
c) Who in your organization is trained and certified to conduct internal management system audits?		
8. HSE Management Performance Reviews		
a) How often are board-level management performance reviews conducted?		

g) How do you communicate corporate HSE performance findings to workers?		

9.	Insurances: Please provide a copy of the Certificate of Currency				
Insurance	Insurer / Not Applicable	Policy Name:	Policy No:	Expiry Date:	Coverage
Workers Compensation					
Public Liability					
Professional Indemnity					
Other					

10.	Certificates / Licenses / Industry Training: Please provide copies or samples			
License / Certificate:	Licensee:	License No.	Expiry Date:	Notes

11.	Company Reference (Please provide the four (04) most recent relevant contracts completed by the company)

Five (05) Contracts for International Competitive General Services, and Three (03) Contracts for National Bidders	Contract 1	Contract 2	Contract 3	Contract 4	Contract 5
Contract Description					
Employer					
Employer's Contact					
Contract No.					
No. of Key HSE Personal					
HSE Staff / Worker Intensity					
No. of Lose Time Injury					
No. of Person Days on Contract					
Total No. of Days Lost					
Contract Completion Certificate (attached Copy)					

Bidder Personnel assigned to manage the HSE hazards identified for this Contract are:

Bidder Personnel 1 (name, qualifications, experience): As per the Key personnel List

Bidder Personnel 2 (name, qualifications, experience): As per the Key personnel List

Bidder Personnel 3 (name, qualifications, experience): As per the Key personnel List

(add if required)

Quality Check

All relevant questions are answered:

YES / NO

Evidence of all necessary elements is attached:

YES / NO

Information about the insurance plan is enclosed with evidence:

YES / NO

Information about certificates / licenses / training is enclosed with evidence:

YES / NO

Information about company references is enclosed with the contract completion certificate:

YES / NO

All HSE key personnel are identified for the contract:

YES / NO

Signed by

Bidder Name: Date:

Name of Person:

CIVIL WORKS SPECIFICATIONS

Chapter 0210

6 SITE PREPARATION

6.1 GENERAL

6.1.1 Scope

This Chapter covers all operations in connection with clearing, grubbing and stripping as well as the provision for fencing and name boards for various parts of the site, namely:

- River Diversion including tunnels and coffering,
- Main RCC dam and plunge pool,
- Dam control house, power distribution house and guard house,
- Rock quarries and borrow areas.
- Temporary construction plants,
- Disposal areas,
- Temporary and permanent accesses roads, and
- Others.

6.1.2 Related Works / Sections

Chapter 0120	Environmental Codes of Practice
Chapter 0211	Dewatering and Care of Water
Chapter 0212	River Diversion
Chapter 0220	Surface Excavations
Chapter 0230	Underground Excavation
Chapter 0240	Drilling and Grouting
Chapter 0320	Fill and Backfill
Chapter 0810	Roads and Platforms

6.1.3 Definitions

Topsoil: The uppermost layers of overburden containing organic material, including roots.

6.1.4 Codes and Standards

6.1.4.1 References

"Earth Manual" of Bureau of Reclamation, US Department of the Interior

6.1.5 Quality Assurances

6.1.5.1 Tolerances

Excavation and backfill for site preparation shall be within the limit lines and grades shown in the Drawings and defined herein, however the PMC reserves the right to modify such limits and grades during the programme of the Work, as may be judged necessary by the PMC.

6.1.6 Submittals and Approvals

Forty five (45) days before the beginning of the Site Preparation works, the Contractor shall submit to the approval of the PMC:

1. A programme of work, he intends to carry out, area by area, to enable the PMC to assess the consequences of the clearing and stripping works, as regards to the relevant Authority.

2. A mass haul diagram including the various structures, and the borrow areas, quarries and disposal areas,

3. The arrangements the Contractor intends to adopt to carry out the work.

The clearing of the site shall be performed at the earliest practicable time in order to facilitate further survey works.

6.2 EXECUTION

6.2.1 Site Boundry Fencing

The minimum specification for the boundary fencing shall be:

- 1.8m high fence fitted with double strand high tensile barbed wires 250mm apart or fitted with 50mm galvanized wire mesh and topped by three (3) nos. single strand fully galvanized barbed wire 2.6mm x 2mm with the design to be submitted for the PMC's approval. Type of the respective fence shall be of agreed by the PMC.
- Bitumen-coated Y-section iron standards (2.48kg/m) installed at 20m centres to at least 300mm below natural ground level and fixed to each strand of wire.
- Three (3) wooden droppers of nominal sectional dimension 30mm diameter, evenly spaced between standards and fixed to each strand of wire separately.
- Timber straining posts of nominal section 100mm diameter with diagonal struts, etc. as required, installed at 300m centres and at changes of direction or gradient and embedded at least 500mm below natural ground level.
- All timber to be suitably treated against weather deterioration and termites, borers etc.

- Gates (standard W-pattern) to suit width of access either single or double leaf as agreed with the PMC, and of nominal 25mm diameter galvanised pipe construction each installed
- between straining posts in positions as agreed with the PMC plus durable brass security lock on 500mm long galvanised chain with at least two (2) keys each.

6.2.2 Nameboards

The design of and quality of materials used for name-boards and signs shall be agreed with the PMC. The main boards shall be a maximum of 7m x 3.5m in size and be mounted at a height of 2m. The logos/pictograms and wording shall be painted in accordance with the details agreed with the PMC.

The boards and signs shall be made up from durable materials that will not warp due to weathering and shall each be mounted on adequately braced poles and be kept neat and legible at all times. The Contractor shall keep all the name-boards and signs in good condition and shall remove them on completion of the Contract.

6.2.3 Clearing and Garbbing

In all areas, occupied by the Works, including quarries, borrow areas, and disposal areas, the clearing and grubbing shall be conducted properly as specified herein.

The clearing shall include removing and disposing of materials above ground level except those things the PMC directs to be left undisturbed. The material to be cleared shall include, but not necessarily be limited to, trees, stumps, logs, brush, undergrowth, grass crops, loose vegetable matter, structures and other obstructing materials.

The grubbing shall include removing and disposing of buried logs, stumps, roots and all unsuitable obstacles to a depth beneath the original ground surface as directed by the PMC.

6.2.4 Stripping

- Stripping shall consist of removing all top soil: rubbish, vegetal matters, debris and humus
- Stripping shall be required for all earth foundations of various types of fill and where the foundation has not been constructed by excavating.
- No separate stripping will be required in areas to be excavated and when the excavated materials will not be used in Permanent Works, unless directed by the PMC.
- The stripping shall be carried out where humus is to be kept for grassing or restoration of paddy fields as shown on Drawings or as directed by the PMC.

- The minimum depth of stripping shall be in principle 300mm or where this requirement is inapplicable, as directed by the PMC.

6.2.5 Protection of Other Areas

- The Contractor shall ensure that trees and other vegetation outside the areas of the permanent works and the minimal areas required for temporary works including access are protected and preserved from damage.
- Any additional clearing required by the Contractor for construction of temporary works, and for any other purpose shall be at the Contractor's expense and shall not be carried out without the approval of the PMC.
- The Employer reserves the right to reinstate any damage to vegetation and the surface of the ground beyond the areas of the Works (including temporary works) at the expense of the Contractor.

6.2.6 Disposal Materials

- Stumps, roots, logs and other objectionable matter removed in the site preparation operation shall be removed from the limits of the work and disposed of.
- Disposal areas shall be approved by the PMC.
- If required, felled timbers will become the property of the Employer and piled neatly in a location approved by the PMC.
- Otherwise felled timbers and other materials from clearing and stripping operations shall burnt or removed from the site well in advance of the programmed date for the start of impoundment or disposed of as approved by the PMC.
- Where materials are to be buried, they shall be disposed in horizontal layers alternatively with earth layers. They will be compacted to the maximum extent practicable by routing the haulage traffic over the area. The maximum height of these spoil materials will be 4m with slope less than 1/4 (1 vertical on 4 horizontal) in adequate conditions in regard of safety for the stability of the deposit. Vegetal matter shall be covered with 1m of earth material.
- Burning will be permitted only at times when conditions are considered favourable for burning and at locations approved by the PMC. Materials to be burnt shall be piled neatly and when in a suitable condition shall be burnt completely.
- Piling for burning shall be done in such a manner and in such locations as to cause the least fire risk. Burning shall be thorough so that burned materials are reduced to ashes. No logs, branches or charred pieces shall be permitted to remain.
- The Contractor shall at all times take special precautions to prevent fire from spreading to areas beyond the limits of the cleared areas and shall have available

at all times suitable equipment and supplies for use in preventing and suppressing fires.

- Any disposal of materials outside the site must to an area licensed for that purpose and the Contractor must submit such supporting documentation.
- The Contractor must take all necessary precautions to eliminate as far as is practicable all airborne dust.

Chapter 0211

7 DEWATERING AND CARE OF WATER

7.1 GENERAL

7.1.1 Scope

This Chapter covers the requirements for creeks and streams, dewatering and maintaining the surface and underground work areas in a dewatered state during construction.

Unless otherwise instructed by the PMC during construction, the Contractor shall investigate, design, construct and operate temporary drainage facilities as are necessary for controlling all water entering the work areas which includes seepage of ground water, surface runoff and leakage from creeks. 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 health.

7.1.2 Related Works / Sections

Chapter 0120	Environmental Codes of Practice
Chapter 0210	Site Preparation
Chapter 0212	River Diversion
Chapter 0220	Surface Excavation
Chapter 0230	Underground Excavations
Chapter 0240	Drilling and Grouting
Chapter 0320	Fill and Backfill
Chapter 0430	Conventional Concrete (CVC)
Chapter 0433	Roller-Compacted Concrete (RCC)

7.1.3 Definirions

- River diversion shall mean the all works and structures relating to the diversion and control of the Indus river during the construction.
- Minor diversion shall mean works required to divert and control other creeks or streams entering the area of the works.
- Dewatering shall mean works required to remove water out of the work areas during construction.

7.1.4 Codes and Standards

Not used.

7.1.5 Qual'ty Assurance

Not used.

7.1.6 Submittals and Approvals

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

- Design assumptions and calculations,
- Layout of diversion, coffer, protection and drainage facilities, (iii) Cross sections of coffer or dike and diversion chute or channel,
- Layout and capacity of pumps and pipes, sumps, gutters, drains and flow measurement devices, and
- Any other arrangement or installations the Contractor may propose for temporary protection of the Work and for dewatering of the working area both in surface and underground.

Not later than twenty eight (28) days prior to the scheduled start of particular work like pump/pipe installation, the Contractor shall submit to the PMC full details of equipment to be installed and all necessary construction details.

7.2 MATERIALS

7.2.1 General

All materials required by the Contractor to implement any schemes for streams to ensure effective drainage of the Works shall be approved by the PMC.

7.2.2 Coffering Fill and Concrete

Fill materials of rock for creeks or streams shall be obtained from required excavations, quarries, borrow pits or stockpiles, as determined by the PMC and shall comply with the requirements of Chapter 0320 "Fills and Backfills".

U/S starter dam and d/s cofferdam may be constructed as CSG dam, of which material shall comply with the requirements of Chapter 432 "Cemented Sand and Gravel Concrete (CSG)".

D/S starter dam may be constructed as a concrete wall, of which material shall comply with the requirements of Chapter 430 "Conventional Concrete (CVC)".

The integrated cofferdam shall be a part of the main RCC dam, of which material shall comply with the requirements of Chapter 433 "Roller-Compacted Concrete (RCC)".

All fill and embankment materials above shall be free of objectionable quantities of roots, organic and other foreign objects.

7.2.3 Grout

Materials for grout shall comply with the requirements of Chapter 0240 "Drilling and Grouting".

7.3 EXECUTION IN SURFACE WORK AREA

7.3.1 Dealing With Surface Water Including Protection Works

7.3.1.1 General

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.

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 PMC.

The Contractor shall be responsible for, and shall repair at his own expense, damage to any part of the work caused by floods, water back-up, or failure of protective works.

Excavated borrow pits shall be developed with regular profiles and graded to drain, via ditches to the nearest watercourse. Measures shall be taken when necessary to prevent watercourses from backing up into the borrow areas.

The Contractor shall do whatever is necessary to prevent water from entering excavations or from flowing over excavated slopes in overburden or rock.

Unless otherwise directed by the PMC, gravity drainage will be preferred to dewatering by pumping wherever feasible.

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

7.3.1.2 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 in impermeable and non erodible headwalls. Pipes or conduits shall have a minimum dimension of 1,000mm regardless of discharge requirement. Pipe or conduit outlets shall be suitably constructed to prevent erosion.

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

7.3.1.3 Dewatering Dykes

Foundations for rockfill coffering as the dewatering above water shall be prepared by clearing and grubbing in accordance with Chapter 0210 "Site Preparation".

Prior to executing the rock and fill embankment, the Contractor shall have all necessary rockfill quarried and ready for loading and hauling. The borrow area shall be cleared and sufficient test pits excavated to demonstrate that the required volume of impervious fill is available within the cleared area.

Fill coffering shall be constructed by first placing the rockfill zones through water to create a working level just above water level. To affect closure against the prevailing river flows, larger rock sizes shall be placed first, followed by finer sizes or broadly graded rockfill which is retained by the larger sizes.

Following completion of the rockfill section to just above the prevailing water level, the transition and impervious zones shall be placed successively to just above water level. To the extent practicable, the zones shall be constructed by building up material on the leading edge of each zone until the material falls into the water in a coherent mass, rather than dumping material into the water in a manner which promotes segregation.

Beginning just above the prevailing water level but in any case not more than 1,000mm above the water level, the fill cofferdams shall be constructed in approximately horizontal layers, with the zones compacted in thicknesses and by the number of passes of a bulldozer track as required by the Contractor.

7.3.2 Maintenace of Coffering and Dewatering Facilities

The Contractor shall maintain rockfill coffering in good condition to ensure the safety of personnel.

In the event that, after completion of the coffering, the flow in the river or streams appear, in the opinion of the PMC, to be about to exceed the capacity of the coffering, the Contractor shall place his full force of labour and equipment at the disposal of the PMC and co-operate with the PMC to take any action to ensure the safety of the Work and guard against injury or damage to persons or property at his expense.

7.3.3 Dewaterin of Surface Works Foundation

The Contractor shall provide and maintain all temporary stoplogs, coffering, dykes and other protective works and shall provide, operate and maintain any channels, flumes, drains, sumps, pumps and other drainage facilities and equipment required to dewater the areas required for the Work and maintain them free from water and ponding at his expense for such periods as are necessary for satisfactory completion of the Work.

The Contractor's methods shall be such that they do not interfere with the progress or safety of the Work.

Where existing minor streams are to be diverted, the Contractor's arrangements shall be subject to the approval of the PMC.

Subject to the approval of the PMC, the Contractor will be permitted to leave in place sumps and pipes which form part of the dewatering system, provided they are backfilled and give a tidy appearance, to the satisfaction of the PMC.

7.3.4 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.

The Contractor shall be responsible for, and shall repair at his own expense, damage to any part of the work caused by, run-off, water back-up, or failure of protective works.

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

7.4 EXECUTION IN UNDERGROUND WORK AREA

7.4.1 General

The Contractor shall perform all work necessary to collect and drain service and infiltrating groundwater, convey it to main conduits, and lead it out from underground works such as tunnels, adits or shafts. The work shall include, but not be limited to, the following:

- Design and construction of pits and trenches,
- Design, supply, operation, and maintenance of dewatering equipment including power supply,
- Relocation of dewatering facilities required during progress of the works,
- Design, construction and operation of settlement ponds with oil separators at the portals, and
- All auxiliary work required for the safe and continuous dewatering of the underground sites.

Exploration holes will be drilled as needed to provide information on the inflow of water into the tunnel or shaft as the excavation proceeds. Where the indications are that flows

are likely to be large, grouting to seal off the water flows and drilling of drainage holes may be ordered by the PMC.

7.4.2 Requirements and Design

- The Contractor shall design and provide a complete dewatering system for both the ascending and the descending headings of tunnel and adit, and in the shaft to keep the work area with no standing water. All auxiliary work required for the safe and continuous dewatering of the underground sites shall also be provided.
- Surface water including rain water shall not be drained into the descending heading tunnel.
- Discharge capacity of dewatering pump systems is discretion of the Contractor based on his construction plan and availability of his dewatering equipment. The design and installation of the dewatering systems shall be subject to the PMC's prior approval.
- In order to keep the construction areas free from water, the dewatering systems must be able to operate at any time during the whole construction period in any part of the Works at the required designed capacity.
- The Contractor shall provide adequate pumping capacity, including a sufficient number of standby pumping units, to handle all water entering into any portion of underground Works without any claim, and furthermore no time extension will be granted for work delay caused by insufficient dewatering capacity or improper operation of the dewatering system. These units shall be connected to the dewatering systems in such a way that proper and uninterrupted drainage will be guaranteed throughout the entire construction period. The Contractor shall provide the necessary power and energy for operating the dewatering system. The standby power supply shall undergo weekly trial runs lasting at least 30 minutes.
- All components of the systems shall always be maintained in ready-for-service condition and all access to pumps and other equipment shall be kept in good state under the most adverse conditions.
- The Contractor shall ensure that all drainage water will be disposed of without causing interference to his own or other contractors operations elsewhere at the Site, and that no drainage water runs into adjacent Works.
- The dewatering systems shall be designed and installed in such a way that modifications and extensions to the systems are possible while they are in full operation.
- All components of the dewatering system shall be installed and operated in accordance with the agreed method and the construction time schedule, or approved modifications thereof.

- The approval by the PMC of the dewatering systems shall not relieve the Contractor from being fully responsible for the design and operation of the dewatering systems and he shall be liable for any damage or delays caused by its failure.

7.4.3 Materials and Execution

- The Contractor shall construct, in the permanent and temporary tunnels, the drainage trenches in the inverts or elsewhere as directed, immediately following the main excavation. The lining of the trench in the adit shall be carried out as soon as practicable after adit's excavation.
- After the excavated profile has been checked and cleaned, 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 can 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 tunnel invert results from water being allowed to flow over or stand upon the sensitive or swelling material, the PMC may order the removal of the affected material and it replacement with concrete. The PMC may order installation of additional rock supports in connection with such remedial work.
- 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 where directed by the PMC.
- 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 ordered by the PMC.
- The Contractor shall perform regular checking and cleaning of the drainage trench 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 PMC.

- 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 PMC in writing. The Contractor shall notify the PMC 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 PMC.

7.4.4 Measurements and 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 PMC before they are used.
- Measuring station shall be installed and measurement of the total rate of water flow shall be made as follows:
  - In ascending tunnels (dewatering by gravity): The flow measurement shall be performed during excavation and supporting work at the entrance portal of galleries and tunnels
  - In descending tunnels and galleries (dewatering by pumping): The flow measurement shall be performed during excavation and supporting work at the portal of the specified tunnel (i.e. outlet of installed pump line or lines).
- Natural groundwater occurring in the underground Works will be remowed by the Contractor.
- Daily average flow rate shall be based on at least three (3) measurements a day during pump operation 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 or far below the limits specified in (2) and (3). The measurement of water flow rates shall be performed jointly by the PMC and the Contractor. The results shall be entered in a book kept by the Contractor for this purpose. 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 pump line(s).

7.4.5 Settlement Ponds

- The Contractor shall construct, operate and maintain settlement ponds with suitable oil separators at each point where water is discharged from the underground Works.
- Unless otherwise specified by the PMC, all water emanating from excavation for approach cuts and underground Works shall be discharged into these settlement

ponds to remove oil and sand, silt and other suspended matter. The outflow from each settlement pond shall be so arranged as to prevent any floating oil from leaving the pond irrespective of the volume of water entering the pond.

- Ponds shall be constructed using any suitable materials and shall be watertight. Earth ponds shall be lined with PVC materials or similar to prevent leakage. The inlet to the ponds shall be designed in such a way that water discharged into the pond will not stir up sediment previously deposited in that pond.
- The outflow channel from the pond shall be designed and constructed in such a way that soil erosion is prevented. If the PMC is not satisfied that the provisions in this regard are adequate, he may order the Contractor to carry out such additional work as is necessary to ensure the prevention of all erosion.
- To ensure, the continuing satisfactory operation of the system, accumulations of silt and oil shall be removed and disposed of by the Contractor at intervals approved by the PMC.
- Natural groundwater and rain from areas outside the immediate area of the Contractor's activities shall be prevented from flowing into the ponds. The Contractor shall ensure that any diversion berms or drains protecting the ponds constructed below ground are adequately maintained.
- Each pond shall be designed to satisfy the settlement requirements.

Chapter 0220
8 SURFACE EXCAVATIONS

8.1 GENERAL

8.1.1 Scope

This Chapter covers the requirements for excavation in top Common, overburden, weathered rock and sound rock for the following works:

- General stripping excavation, bulk excavation and trench excavation for the dam structures foundations, platforms, roads, quarries, borrow and spoil areas;
- Structure excavation for the foundations of the inlet and outlet of river diversion tunnel, flushing tunnel, and plunge pool;
- Platform excavation for the dam abutment and the access tunnel portals;
- Excavation for permanent and temporary access roads;
- Trench excavation and foundation excavation for miscellaneous works, including permanent drainage works and drop structures, masonry lined ditches and drains;
- Excavation in quarries and borrow areas;
- Selection, transportation and stockpiling of excavated materials suitable for future use; and
- Disposal in designated spoil areas of all excavated materials which are unsuitable for use in construction or are surplus to the required volumes of such materials.

8.1.2 Related Works / Sections

Chapter 0120	Environmental Codes of Practice
Chapter 0210	Site Preparation
Chapter 0211	Dewatering and Care of Water
Chapter 0230	Underground Excavation
Chapter 0320	Fill and Backfill
Chapter 0810	Roads and Platforms
Chapter 0820	Site Reinstatement

8.1.3 Definitions

Rock Excavation: Excavation of material which requires drilling and blasting with explosives or chemical or mechanical breaking or cutting for excavation, and breaking of boulder with volume greater than 1 m³.

Weathered Rock Excavation: Excavation of material which requires loosening by a 'D-8' class bulldozer with a ripper.

Common Excavation: Excavation of material other than weathered rock and sound rock.

Drilling and Blasting: Production blasting involving a regular pattern of blast holes.

Controlled Perimeter Blasting: Special drilling and blasting methods to produce smooth rock faces conforming to the prescribed excavation lines and to minimize blasting-induced fractures in the rock outside the excavation lines. These methods include pre-splitting, cushion blasting, smooth blasting and line drilling, defined as follows:

- **Pre-splitting:** Drilling a single row of closely spaced holes, loading the holes lightly and continuously, stemming the collar of each hole and then timing the firing to occur just prior to the adjoining main excavation blast, thus producing a crack along the line of split holes to which the subsequent primary blast can break. Whether pre-splitting is fired just prior to or separately from the main blast, blasting to remove the adjoining rock requires an accepted burden/spacing ratio, a reduced explosive charge in the line of holes nearest the split line, and a limit on the distance between these lines.
- **Cushion Blasting:** Drilling a single row of closely spaced holes with an accepted spacing/berm width ratio, loading all the holes lightly and continuously, stemming the collar of each hole and then firing them to remove the berm left in place from the previous primary blast.
- **Smooth Blasting:** Drilling a single row of closely spaced holes with an accepted burden/spacing ratio, loading all the holes lightly and continuously, stemming all holes and then firing them as the last delay period in the round.
- **Trim Blasting:** Comprises the separate removal of a protective zone of rock which has been purposely left within the required limits of excavation for flat areas and slopes.

  Drilling for trim blasting shall consist of a rectangular pattern of holes at appropriate space with appropriate holes dipping to the surface of the rock.

  The holes shall be lightly charged and detonated in relays to lift the rock progressively and form the final excavated surface. The minimum thickness of the protective zone of rock will be as indicated on the Drawings or requested by the PMC.
- **Line Drilling:** Drilling a single row of very closely spaced holes, not loading the holes except for the possible use of special explosive to split the rock webs between adjacent holes, having an accepted burden/spacing ratio, and a reduced explosive charge in the line of holes nearest the line drilled holes and a limit on the distance between these lines.

Excavation Line and Grade: The excavation line and grade shown on the Drawings, within which the volume of excavation or concrete will be measured, and is the line and

grade within which no unexcavated material will be permitted to remain. All excavations out of the line and grade shown on the Drawings shall be considered as overbreak.

Geological Overbreaks: They shall be those related to a specific and unexpected geological feature, provided that:

- The Contractor has not failed in any of his responsibilities in carrying out his works,
- The Contractor has taken all the normal precautions necessary to limit the overbreak,
- The Contractor has informed the PMC in writing within 24 hours of the occurrence of the overbreak.

All other overbreaks will not be considered to be geological overbreak when the overbreak is due to:

- The rock stratification,
- The joint directions prevailing on the site,
- The faults shown on the Bid Drawings,
- The Contractor's normal operational overbreak (measured in progressed excavations).

  Which are common and generalized features on the site. These features are deemed to be known by the Contractor who shall take their effect into account in the planning and operation of his works.

Scaling: removing loose, slabby, broken, altered or unsound rock from rock faces or surfaces.

Boulder Excavation: It is the surface excavation of boulders or isolated masses of solid rock, river boulder and existing structure solid foundations which cannot be easily classified as rock, weathered rock or common excavation, and each piece of which exceeds 1.0m³ in volume.

Trench Excavation: Including excavation of individual pits and in small or restricted areas is the surface excavation of all materials of various classes where the width of the excavated area does not exceed 3.0m at bottom, which will be carried out manually or using small equipment.

8.1.4 CODES AND STANDARDS

USBR: Earth Manual of "Bureau of Reclamation" US Department of the Interior.

8.1.5 QUALITY ASSURANCE

8.1.5.1 Laboratory Tests

The Contractor shall supply, operate and maintain the site laboratory as specified in Chapter 0140 "Quality Control and Quality Assurance", and shall carry out all tests and analyses subject to the approval of the PMC. Sampling and testing shall be in compliance with the official Standards which are specified in Chapter 0140, or with other standards approved by the PMC.

Samples of Common and rock shall be representative, taken according to the instructions given by the PMC and in sufficient number to enable the laboratory to perform any test considered necessary for the Works.

8.1.5.2 Excavation Tolerances

8.1.5.2.1 General

- Excavations shall be made to the full dimensions required and shall be finished to the prescribed lines, slopes and grades.
- If excavations are outside of excavations specified in B, the Contractor shall modify the method of excavation to meet the specified tolerances.
- Any excavation beyond the lines, slopes and grades shown on the Drawings or directed by the PMC which is performed by the Contractor for any purpose (such as for working space) shall be kept within the limits approved by the PMC. If such excavation should in the opinion of the PMC, require backfilling, such backfilling shall be done to the satisfaction of the PMC with material approved by the PMC at the Contractor's cost.
- Beneath load bearing structures, foundations and other reinforced concrete work, the filling of any over-excavation shall be of the same quality concrete as that required for the associated concrete structure unless the PMC permits leaner concrete.

8.1.5.2.2 Tolerances

The completed excavations shall be within the following tolerances of the lines and elevations shown on the Drawings and directed by the PMC:

- The slopes and inverts of the intake portal and tailrace outlet shall be excavated as follows:
  - 0, +0.2m for horizontal dimensions
  - 0, -0.1m in elevation

  of the position shown on the Drawings or instructed by the PMC.

- Excavations for the foundations of the cut-off trenches and drain trenches shall be as follows:
  - 0, +0.1m for horizontal dimensions
  - 0, -0.1m in elevation

  of the position shown on the Drawings or instructed by the PMC.
- Excavations for access roads shall be as follows:
  - 0, +0.15m for horizontal dimensions
  - 0, -0.05m in elevation

  of the position shown on the Drawings or instructed by the PMC.
- Excavations for concrete structures shall be as follows:
  - 0, +0.1m for horizontal dimensions
  - 0, -0.1m in elevation

  of the excavation line, except that under no circumstances shall unexcavated material remain within the excavation line.

8.1.6 SUBMITTALS AND APPROVALS

8.1.6.1 General

- Within twenty eight (28) days of the Commencement Date, the Contractor shall submit:
  - Copies of applications for permits required for the procurement, transportation, storage and use of explosives in the Project area;
  - Details of the explosives to be used;
  - Curriculum vitae of the blasting supervisor;
  - Copies of valid blasting certificates for the blasting supervisor and the blasters;
  - Methods of survey and setting out.
- Not less than 28 days prior to commencement of rock excavation, the Contractor shall submit for approval, the following information to demonstrate his proposed drilling and blasting procedures for each stage of excavation in each area of the Work:
  - Drilling, loading and hauling equipment;
  - The location, depth and area of blast;
  - The diameter, spacing, depth, pattern and inclination of blast holes;

- The type, strength, amount, column load and distribution of explosives to be used per hole, per delay and per blast.
- A description of the seismographs proposed to monitor peak particle velocities on the
- Permanent Works.

8.1.7 Mass Haul Diagram

- On the basis of the investigations performed on borrow areas and quarries, a separate mass haul diagram shall be made for the following works:
  - Excavation and fill of canals and embankments,
  - Excavation and fill of each concrete structure including tunnels and temporary works,
  - Excavation and fill of access roads.

  Relations, if any, between these mass haul diagrams shall be indicated.
- Each mass haul diagram shall be prepared by the Contractor and submitted in three (3) copies to the PMC at least twenty eight (28) days before starting the related works.
- Mass haul diagrams shall indicate:
  - The volume of excavated material to be placed in stockpiling in the spoil areas,
  - The volume of excavated material to be used in fill together with the location of the relevant fill,
  - The volume of excavated material to be placed in temporary stockpiling (with the location of it) before being used as fill together with the location of the relevant fill,
  - The various areas of excavation, fill, temporary and permanent stockpiling,
  - The location of the various borrow areas and the place of operation for the working of them,
  - The various qualities of excavated materials which could be used or not in fill.
- The quality of excavated materials shall be determined according to the results of the geotechnical surveys and investigations.
- The various volumes of materials shall be estimated from topographical surveys.
- For the roads, mass haul diagram shall be drafted on a longitudinal profile showing place of excavation, and place of filling per 5,000 m long section.
- Allowance for stripping shall be included in the estimated quantities.

- One copy of the file shall be returned to the Contractor by the PMC, signed by him and accompanied by his comments, if any, within fourteen (14) days of receipt by him. If any comments are made by the PMC, a new file taking these into account shall be submitted to the PMC.
- No work shall start before the PMC has notified his complete and unreserved agreement to the Contractor who may not claim any compensation in this respect.

8.1.7.1 Method of Work

- Not later than twenty eight (28) days prior to programmed commencement of the work, the Contractor shall provide the PMC with the method, sequences and equipment proposed for carrying out the work. This will include the planning of exploitation for quarries and borrow areas, drilling and blasting patterns and supporting where appropriate.
- Within fourteen (14) days of receipt of any proposed plan, the PMC will give in writing to the Contractor, approval or rejection of that plan in whole or in part. If approval is withheld the Contractor shall submit a new plan. No rock excavation shall be started in areas for which the overall plan has not been approved by the PMC.
- The Contractor shall include in detailed plan the location, depth and area of blast; diameter, spacing, depth, pattern and inclination of blast holes; type, strength, amount, column load distribution of explosives to be used per hole, per delay and per blast, the sequence and pattern of delays. Loading of holes with explosives shall not commence without the PMC's approval.

8.1.7.2 Blasting Notice

For every blast in every area of the Works, the Contractor shall submit to the PMC a Blast Notice at least twenty four (24) hours in advance. The Blast Notice shall contain the following information as a minimum:

- Date and time of proposed blast;
- Limits of blast by stations or coordinates, and elevations;
- Types, distribution and pattern of blast holes, including diameter, length, spacing and orientation;
- Total weight of explosives per delay, per hole and per blast;
- Pattern and sequence of delays.

8.1.7.3 Topographical Survey before Any Works

At least three (3) days before start of any excavation work, a topographical survey - as described in Clause 2.2 Inspection - shall be submitted to the PMC.

8.1.7.4 Topographical Survey on Completion of the Excavation Work

On completion of each type of excavation and not later than three (3) days after a topographical survey - as described in Clause 2.2 Inspection (below) - shall be submitted to the PMC.

8.1.7.5 Excavation records

The Contractor shall provide the PMC each day with one copy of the record for the previous day's work of all excavations works. When applicable the following data shall be recorded for each

- Working face together with such other data as the PMC may request:
- Volume excavated in Common,
- Volume excavated in rock,
- Location and drilling pattern for rock excavation,
- Type and amount of explosive for each lift,
- Number, length, type of rock supports installed,
- Surface of shotcrete and location,
- Number and classification of men and plant engaged,
- Unusual occurrences, rockfall, unstable or soft ground and inflows of water.

8.1.7.6 Borrow areas and Quarries

At least 28 days before any borrow area or quarry is opened the Contractor shall submit to the PMC a plan of operations for the working of the area and he shall not exploit the area until the PMC has given his approval.

All material from borrow areas and quarries to be used as aggregates shall be tested by the Contractor according to Chapter 0430 "Conventional Concrete (CVC)" and approved by the PMC.

At any time during the exploitation of a borrow area, the PMC may withdraw his approval for the continued utilization of that borrow area.

8.2 EXECUTION

8.2.1 General

The Contractor shall be responsible for the proper handling, transportation, storage and use of explosives.

The Contractor shall develop his excavation methods, techniques and procedures with due consideration for safety and the nature of the materials to be excavated and shall

take such precautions as are necessary to preserve, in an undisturbed condition, materials outside the excavation lines.

Excavated surfaces which will remain permanently exposed shall be finished off in a neat and workmanlike manner and shall be graded to provide adequate drainage.

All necessary precautions shall be taken to preserve the material below and beyond the prescribed lines for excavation in the soundest possible conditions.

Excavations needed by the Contractor's installations shall be submitted to the approval of the PMC.

The Contractor shall use excavation methods which produce a minimum of fracturing of rock beyond the excavation lines to obtain sound and reasonably uniform surfaces and to limit overbreak, giving due consideration to the geological conditions of the rock mass.

Excavations shall be to the lines, grades and dimensions shown on the Drawings or established by the PMC. During the progress of the work it may be found necessary or desirable to vary the slopes or the dimensions of the excavations from those shown on the Drawings or established by the PMC. Any other excavation, performed at the option of the Contractor, to secure access to required work, or for any purpose, shall be kept within approved limits.

Excavation work shall be planned and executed so as to ensure that damage to adjacent work, in particular concrete and shotcrete is prevented. In no case shall blasting take place within 30m of any cement grout, final shotcrete layer, or concrete less than seven (7) days old. Blasting shall be designed and monitored to ensure that peak particle velocities measured at Permanent Works, do not exceed 75mm/s.

The Contractor shall provide a seismograph manufactured by an approved manufacturer for monitoring blasts and producing blast reports.

Excavated surfaces against which concrete is to be placed shall not extend within the excavation lines. If material is excavated at the direction of the PMC beyond the limits required to receive the structure, the additional excavation shall be filled solidly with concrete, unless otherwise directed. If material is excavated beyond the lines shown on the Drawings or established by the PMC, or if excavated surfaces are damaged by the operation of the Contractor, the overexcavation shall be filled solidly with concrete.

Where shown on the Drawings or otherwise directed, open unlined catch drains shall be excavated to divert surface water away from Surfaces.

Excavated material to be wasted from excavations shall be disposed in accordance with the provisions of Clause 2.10 - Disposal of Materials from Excavation.

8.2.2 Inspection

8.2.2.1 Topographical Survey Before Works

Before the commencement of any earthworks the sites shall be surveyed by the Contractor in conjunction with the PMC to establish existing original ground levels and these agreed ground levels shall form the basis for the calculation of quantities of any subsequent excavation and filling.

8.2.2.2 Topographical Survey on Completion of Excavation Works

On completion of each type of work (common excavation, rock excavation, presplit) the areas shall be surveyed by the Contractor in conjunction with the PMC to establish the volumes excavated.

The Contractor shall record all calculations and survey results for setting out, check surveying and surveying for recording in a suitable permanent form, which shall be available to the PMC on request at all times. The Contractor shall supply an electronic file and two hard copies of any such calculations and survey results to the PMC on request.

8.2.3 Investigations

Prior to the working out of his mass haul diagram the Contractor shall perform all the related investigations as described in Chapter 0320 "Fill and Backfill", Chapter 0810 "Roads and Platforms" and Chapter 0430 "Concrete (CVC)".

These investigations will concern:

- Borrow areas for aggregates,
- Borrow areas for road fills and embankment fills,
- Quarry for rock materials.

8.2.4 Support and Protection

Rock support and reinforcement measures necessary to maintain the stability of the excavations shall be provided and installed as soon as practicable after excavation, as approved or directed in compliance with the provisions of Chapter 0330 "Rock Protection" or Chapter 0431 "Shotcrete".

All temporary slopes shall be made safe and protected if necessary. These protections shall include welded wire mesh, shotcrete with wire mesh or other temporary supports and, where necessary, the diversion of surface water and the provision and maintenance of such protections in compliance with the provisions of Chapter 0210 "Site Preparation".

Berms shall be maintained free of fallen material.

8.2.5 Care of Water

Excavations 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.

As specified in Chapter 0211 "Dewatering and Care of Water", the Contractor shall provide, install, maintain and operate such equipment and materials as required for drainage of water from the excavated surfaces, including pumps, drains, sumps, conduits, flumes, cofferdams, ditches and other temporary diversion and protective facilities. Temporary structures and facilities for the care of water shall be sufficient to permit work to be performed under dry conditions.

8.2.6 Classification of Excavations

8.2.6.1 Surface Excavation

Surface excavation is classified according to the method used to carry out the work as defined in Clause 1.3.

8.2.6.2 Common Excavation

All areas and/or sections of Common excavation will be as designated on the Construction Drawings and/or as directed by the PMC. The classification of Common excavation is subject to approval of the PMC.

Loose materials on the bottom and side slopes of Common excavation upon or against which structures are to be placed shall be tamped or rolled with suitable tools and equipment to form a firm foundation for the structures.

If, at any point in Common excavation, the natural foundation material is disturbed or loosened for any reason, it shall be consolidated by tamping or rolling, or where directed it shall be removed and replaced with selected materials, which shall be thoroughly compacted.

All excavation for foundation of structures shall be performed in the dry, unless otherwise specified or approved by the PMC. All water and other objectionable materials shall be either pumped out or removed.

8.2.6.3 Weathered Rock Excavation

All areas and/or sections of weathered rock excavation will be as designated on the Construction Drawings and/or as directed by the PMC. The classification of weathered rock excavation is subject to approval of the PMC.

Material which in the opinion of the Contractor should be classified as weathered rock shall be exposed, and the Contractor shall notify the PMC for joint survey before proceeding further.

Where, in the opinion of the PMC, weathered rock is deemed unsuitable to form a firm foundation for the structures, further excavation or other measures will be ordered by the PMC.

8.2.6.4 Rock Excavation

All areas and/or sections of rock excavation will be as designated on the Construction Drawings and/or as directed by the PMC. The classification of rock excavation is subject to approval of the PMC.

Rock excavation includes all solid rock and large boulders in place which cannot be removed until loosened by blasting or wedging.

Material, which in the opinion of the Contractor should be classified as rock, shall be exposed, and the Contractor shall notify the PMC for joint survey before proceeding further.

Should the presence of rock make excavation for foundation of structures unnecessary to the extent shown on the Construction Drawings, the Contractor shall consult the PMC before proceeding with such work. The PMC will issue a direct order in writing whether to proceed with the work as shown or to which extend the work shall be modified.

Excess excavation for the convenience of the Contractor or over-excavation performed by the Contractor without written orders of the PMC beyond the prescribed lines of excavation shall be filled with concrete or with selected materials which are approved by the PMC and tamped or rolled.

The drilling and blasting personnel shall be skilled workmen, with recent experience in similar excavation work. The Contractor shall give evidence to the PMC substantiating the experience of the crew.

The blasting supervisor shall be a certified blaster with at least five years of experience of rock excavation for works of civil engineering construction. Blasters shall act, and blasting operations shall be carried out, under the authority of the blasting supervisor.

Unless otherwise shown on the Drawing or directed by the PMC, excavation shall be carried out utilizing a controlled perimeter blasting technique as approved by the PMC, in order to produce smooth faces, conforming to the prescribed neat-lines and to prevent or minimize the occurrence of blast, induced fractures in the rock outside the excavation lines:

- Presplitting on smooth blasting shall be used for vertical or near vertical faces excavated which will be permanently exposed or which will be covered with concrete or shotcrete.
- Unless otherwise agreed, trim blasting techniques shall be used in all horizontal or sloping surfaces at the bottom of the excavations for all foundation of concrete structure or where required by the PMC.

The plans for rock excavation shall be in conformity with detailed requirements for excavation sequencing, for controlled perimeter blasting and for rock reinforcement, as described in the Specifications or as directed by the PMC. No drilling or blasting shall be carried out in any area for which the plan has not been accepted, and if acceptance is withheld, a new plan in whole or in part shall be submitted by the Contractor at least seventy two (72) hours before the commencement of drilling operations.

When necessary, the Contractor shall provide heavy duty blasting mats adequately held down to prevent damage from flying rocks.

In excavations requiring installation of rock reinforcement and shotcrete, excavation sequencing shall take into account the following mandatory requirements in the vicinity of excavation lines:

- Lifts and rounds shall be limited to 5m or such lesser height and length, respectively, as may be required to achieve satisfactory results;
- Within 6 m of portals, from in surface cuts or caverns, tunnel excavation, rounds shall be a maximum length of 1.5m;
- Scaling shall immediately follow excavation;
- Installation of rock reinforcement as shown on the Drawings or directed, shall immediately follow scaling; and
- Installation of shotcrete shall be in accordance with Chapter 0431 "Shotcrete".

At the commencement of excavation, the controlled perimeter blasting techniques shall be developed by the Contractor as specified herein. They shall then be applied and, as necessary, modified so as to maintain the tolerances specified herein throughout the excavations.

The Contractor shall provide access for the PMC to perform geological mapping, surveying, monitoring and similar activities.

8.2.7 Scaling

Immediately following each blast and at any subsequent time during the work as required, the Contractor shall scale and remove all loose, unstable and potentially dangerous materials from surfaces exposed by the blast and in the vicinity of the blast. The fact that such scaling and removal may enlarge the excavation beyond the required excavation lines or may require removal and restoration of shotcrete or welded wire fabric shall not relieve the Contractor of the necessity of performing such scaling and removal.

The Contractor shall inspect all exposed rock surfaces at least daily and scale as required.

8.2.8 Clearing, Grubbing and Stripping

As specified in Chapter 0210 "Site Preparation" clearing and grubbing are required in all areas designated on the Construction Drawings and/or as directed by the PMC. The stripping of topsoil will be required only in the area where the topsoil is usable for later stage landscaping. All costs of clearing, grubbing and stripping shall be included in the items of the common excavation in the Bill of Quantities.

Clearing, grubbing and stripping outsides of the limits indicated on the Construction Drawings shall be performed only as specified or directed by the PMC.

Within areas where open-cut excavation is to be carried out, the ground shall be cleared of all living or dead trees. All branches or tree extending into the limits shall be trimmed carefully to give a clear height as required over the Site. All trees designed by the PMC to be left intact shall be protected from damage by the Contractor's operations.

The clearing limits shall extend 5m beyond the limits of excavation, toes of embankments and spoil tips except where otherwise indicated on the Construction Drawings or directed by the PMC.

Fences, structures of any character upon or within the limits of the Works and not considered for the construction shall be removed carefully by the Contractor wholly or in part as specified or directed by the PMC. When fences are required to be removed, the property owner shall be notified sufficiently in advance to enable him to construct supplemental fences or make arrangements as required.

Stumps and roots of any cleared vegetation shall be grubbed out and taken to tips or spoil banks as specified and/or directed by the PMC.

With the exception of areas to be excavated, all depressions made below the ground surface by the removal of stumps or roots shall be refilled with suitable material and compacted to the satisfaction of the PMC.

The breaking concrete or the concrete to be broken so designed on the Construction Drawings shall not be included in this Work.

All materials from clearing and grubbing operation will remain at all times the property of the Employer and shall be piled in accordance with the requirements of the Employer. They shall be prepared for sale, burnt, buried or otherwise disposed of by the Contractor in areas as directed by the PMC.

Materials to be burnt shall be piled neatly in such a manner and in such locations as to not cause any fire risk, and shall be burnt completely so that all material is reduced to ashes.

8.2.9 Utilisation of Excavated Materials

Suitable material removed from excavations may be used, insofar as practicable, in the construction of fills, embankments, access roads, backfill and for similar purposes or as

raw materials for concrete aggregate. Suitable material may, if approved by the PMC, be placed directly into the works, or may be placed in temporary stockpiles. Coarse rock, weathered rock and overburden shall be placed in stockpiles separately from each other.

The use, location and dimensions of stockpiles shall be subject to approval by the PMC. Where so directed, top soil shall be removed from the natural ground surface prior to commencement of stockpiling.

Suitable excavated material shall not be wasted without specific written authorization from the PMC. Suitable material authorized to be wasted shall be disposed of in designated areas approved for surplus material storage or designated waste areas as directed by the PMC. The Contractor shall not deposit material outside of the designated areas.

8.2.10 Disposal of Materials from Excavation

Excavated materials authorized to be wasted, including unsuitable materials, shall be disposed of in designated waste disposal areas as shown on the Drawings or otherwise directed by the PMC. The Contractor shall make, at his cost, necessary arrangement for transportation of the excavated materials. Any facilities provided for the transportation shall be removed at the end of the transportation work as approved by the PMC.

The limits of disposal areas shall be pegged on the ground by the Contractor and shall be subject to approval before commencement of disposal operations.

Disposal material shall be deposited in layers, and randomly compacted to the maximum extent practicable by routing the haulage traffic over the area, and shall be graded to prevent ponding of water. To this extent construction or haulage equipment shall be so routed such that the mass of the equipment is brought to bear through the tires or tracks at least twice over the whole area.

During placing of material in spoil areas, adequate measures shall be taken to ensure stability of slopes and to prevent erosion of the material by surface runoff and watercourses, including a rough selection of the material forming the side slopes from the spoil to include coarser material. Adequate drainage shall be provided through and around the disposal areas according to Chapter 0211 "Dewatering and Care of Water".

Excavated materials shall be disposed so as not to interfere with the operation of any facilities. No excavated material shall be disposed of to obstruct the flow of any stream, endanger a partly finished structure, impair the efficiency or appearance of any structure, or be detrimental to the completed work in any way.

The final surface and side slopes formed from such material shall be shaped and sloped so as to provide for drainage, and seeding and mowing operations. Disposal areas shall be trimmed to reasonably regular lines to the satisfaction of the PMC. Landscaping of the spoil area shall be according to the Chapter 0820 "Site Reinstatement", or otherwise directed by the PMC.

8.2.11 Operation of Quarries and Borrow Areas

8.2.11.1 Excavation

Quarries and borrow areas shall be cleared and grubbed in accordance with Clause 2.8 above, and shall be stripped of all material which is unsuitable for use as quarried and borrowed materials in the Permanent Works. Material stripped from quarries and borrow areas shall be hauled to spoil areas or stockpiled for subsequent use as backfill.

Operations in quarries and borrow areas shall be such as to avoid contamination of material for permanent construction by unsuitable materials.

Quarries and borrow areas shall be left in a safe and neat condition to the satisfaction of the PMC.

8.2.12 Environmental Controls

Cleaning and excavation shall be carried out as necessary to prevent the entry of materials into the river. The PMC may, from time to time, direct the Contractor to modify his construction methods to ensure compliance with this requirement.

Chapter 0230
9 UNDERGROUND EXCAVATIONS

9.1 GENERAL

9.1.1 Scope

This Chapter covers the underground excavations carried out by traditional technique (Drill and Blast Method, Road header or similar equipment), for the tunnels and galleries.

9.1.2 Related Works / Sections

Chapter 0120	Environmental Codes of Practice
Chapter 0210	Site Preparation
Chapter 0220	Surface Excavations
Chapter 0232	Ventilation and Lighting for Underground Works
Chapter 0240	Drilling and Grouting
Chapter 0250	Steel Arches and Frames
Chapter 0251	Rock Bolting
Chapter 0431	Shotcrete

9.1.3 Definitions

9.1.3.1 General

Excavation as specified under this Chapter shall include when necessary all drilling, blasting, scaling down, installing supports and associated steels, removing and disposing of rock and debris from underground excavations and preparation of excavated surfaces for concrete placement. Only excavations inside Diversion tunnels, Tunnel galleries, Flushing tunnels including gate chambers and Bottom Outlet encasement in RCC main dam body shall be considered as underground excavations. All portals of tunnels shall be considered as surface excavations.

Where in this Chapter the terms ′tunnel′ or ′tunneling′ are used, such references shall also apply, as appropriate, to adits, shafts, niches, galleries, caverns, chambers etc.

9.1.3.2 Excavation Lines

As shown on the Drawings, the excavation measurement lines are defined as follows:

- The A-line or neat line shown on the Drawings is the line within which no material of any kind and no support shall be permitted to remain after excavation as designated on the Construction Drawings, except the satisfactorily applied shotcrete and firmly built steel arches and steel lagging at the approved positions as indicated on the Drawings.

- The B-line shown on the Drawings is the outside limit to which measurement for recording recording for excavation, concrete and rock supports will be made regardless of whether the actual excavation surface falls inside or outside of the B-line. Provided that volume of the lining concrete in the tunnels shall be calculated by deducting the shotcrete volume applied within the B-line. It is however noted that, in caverns and tunnels which are mostly unlined with concrete, the B-line is just on the A-line, i.e. there is no gap between the B-line and the A-line as shown in the Drawings.

9.1.3.3 Overbreak

All excavations outside the A-line shown on the Drawings shall be considered as overbreak.

9.1.3.4 Geological Overbreak

The geological overbreak is the overbreak related to a specific geological feature, which will be measured for recording of excavation and backfill or concrete, provided that:

- The Contractor has not failed in any of his responsibilities in carrying out his works,
- The Contractor has taken all the normal precautions necessary to limit the overbreak,
- The Contractor has informed the PMC in writing within twenty four (24) hours of the occurrence of the overbreak.

All other overbreaks will not be considered to be geological overbreak when the overbreak is due to:

- The rock stratification,
- The joint directions prevailing on the site,
- The overbreaks at tunnel invert,

which are common and generalized features on the site.

These features are deemed to be known by the Contractor who shall take their effects into account in the planning and operation of his work.

9.1.3.5 Enlargement for the Contractor's purposes

Excavation not shown on the Construction Drawings and not listed in the Bill of Quantities, but which the Contractor considers necessary for this own purposes, such as excavation for bends of shafts, curved corner of tunnels, mucking pits, machine turnouts, equipment spaces, depot, pump sumps, drain ditches other than those shown on the Construction Drawings, etc, may only be carried out with the prior approval of the PMC. All such excavations shall be backfilled with the same lining concrete where the tunnel is concrete-lined, or Class C20 concrete or rocks, or covered with solid concrete wall as

approved by the PMC up to the A-line prior to commencement of the final concrete lining or completion of the Work.

9.1.3.6 Scaling

The scaling is to remove loose, slabby, broken, altered or unsound rock from excavated faces or surfaces.

9.1.3.7 Round

For the purpose of these specifications, a round in underground excavations is defined as a single cycle of drilling, blasting and excavating including scaling, mucking and moving in and out.

9.1.4 Codes and Standards

9.1.4.1 References

A. "Earth Manual" of Bureau of Reclamation, US Department of the Interior.

9.1.4.2 Regulations

The Contractor shall comply with relevant Uzbekistan Acts, Regulations and Standards in all respect of explosives.

9.1.5 Qualiy Assurance

9.1.5.1 Tolerances

Tunnel and gallery excavation alignment shall be constructed within the following dimensional tolerances and deviations from the specified positions and levels.

- Position ± 300mm
- Level, Centre point of the tunnel ± 50mm

Excavated diameter of tunnel, gallery and shaft shall not be less than the diameter shown on the Drawings.

The above tolerances shall also apply to the enlargement as specified in Clause 2.6 below, unless otherwise permitted by the PMC.

9.1.5.2 Records

The Contractor shall maintain accurate records of all tunneling work performed under the contract and shall provide the PMC each day with one copy of the record for the previous day's work. The following data shall be recorded for each shift at each working face, together with such other data as the PMC may request:

- Chainage to face at start of round.
- Chainage to face at end of round and in-situ theoretical volume of rock blasted.
- Drilling pattern, including number, locations, size and lengths of holes.
- Type and amount (weight) of explosive for each round and the type, locations, and firing patterns of detonators.
- Number, location (chainage), type and weight of steel supports installed, together with the quantity and location of any lagging required.
- Number, length, location and type of rock bolts installed.
- Type, class, thickness, location and volume of shotcrete and type, location of wire mesh applied.
- Number and classification of workers and equipment/ tool engaged on each tunnel operation round and list of equipment at site on standby and out of order.
- Elapsed time for moving and setting up, drilling, loading, blasting, ventilation, installation of supports, excavation.
- Excavated profiles: joint records of the Contractor and the PMC.
- Geological map and relevant geotechnical data of cutting face prepared by the Contractor.Air contamination check record required in Chapter 0232 "Ventilation and Lighting".Unusual occurrences, rockfalls, unstable or soft ground and inflows of groundwater.

9.1.6 Submittals and Approvals

9.1.6.1 Method statement

9.1.6.1.1 Tunnels

Not later than sixty (60) days prior to the programmed commencement of tunnel excavation at portal, the Contractor shall submit the method statement of his excavation procedures and sequences on all tunneling works and general statement on excavation of the relevant caverns and chambers, to the PMC for approval. The method statement shall include but not limited to the following:

- Diameter, spacing, depth, pattern and orientation of blast holes
- Type, strength, amount, column load, and distribution of explosives to be used per hole, per delay, and per blast and type of detonators, and sequence and pattern of delays to be used per blast
- Sequence of individual works and corresponding time requirements in typical one round excavation for various classes of rock and various sizes of tunnels
- Method of scaling and clearing after blasting

- Loading and transportation method of excavated materials.
- Disposal and stockpiling plan of the excavated materials including criteria to classify the materials for disposal and stockpiling, and stockpile and disposal area development plan
- Installation method and sequence of rock supports including criteria for applying different type and quantities of rock supports such as shotcrete, rock anchors, rockbolts (dowels) and steel arches
- List and details of equipment to be employed
- Comprehensive plan of compressed air supply, water supply, electric power supply and communication system for all tunnels connected and supplied from the relevant tunnel portal
- Comprehensive plan of drainage, ventilation and lighting systems for all tunnels connected to the relevant tunnel portal
- Description and purpose of any special method to be adopted by the Contractor

9.1.6.1.2 Caverns, Chamber and Shafts

Not later than ninety (90) days prior to the programmed commencement of cavern, chamber or shaft excavation, the Contractor shall submit the method statement regarding his excavation procedures and sequences on all caverns, chambers and shafts, to the PMC for approval. The method statement shall include but not limited to a) to k) listed in A. above, provided the word "tunnel" shall be read as "cavern, chamber and shaft".

9.1.6.2 Use of Explosive

At an early stage, in advance of the proposed use of explosives, the Contractor shall notify the Employer, the PMC, third parties, statutory authorities and services which have an interest in or are likely to be affected by blasting operations, of the general nature of the operation. The Contractor shall subsequently give a minimum of twenty eight (28) days' notice to the PMC and others described above of the proposed use of explosives. With this notification the Contractor shall submit to the PMC a detailed method statement on all aspects of the proposed storage, handling and use of explosives, including treatment of misfires.

9.1.6.3 Supply of Rock Support Materials

Before procuring or shipping the materials to the Site, the Contractor shall submit to the PMC for approval the following regarding rock support system:

- All pertinent information regarding the type and quality of rock anchors, rock bolts and dowels (grouted un-tensioned rock bolts) proposed by the Contractor to use

together with manufacturer's instructions and certificates, methods of installations and testing the suitability, testing equipment, and the grouting system for grouted rock bolts.

- The Contractor may propose alternative types of rock bolts to those described in Chapter 0251 "Rock Bolting" but acceptance by the PMC will be subject to full demonstrations of the adequacy of alternative.
- Complete details concerning type, and materials of the post-tensioned rock anchors proposed by the Contractor to use together with manufacturer's instructions and certifications, methods of installation, corrosion protection, stressing equipment, grouting method and equipment, proposal for anchor testing, stressing tests and equipment. The proposed anchor shall meet the requirements in Chapter 0252 "Post Tensioned Rock Anchors",
- Design, calculations and fabrication details of steel arches and frames and lagging proposed by the Contractor, including size, steel quality, details of ties and accessories and methods of installation together with certified copies of manufacturer's reports. The Contractor may propose multi-hinged steel supports with appropriate fittings for adaptation of the rib form and its installation as close as possible to the rock surface. The proposed steel arches shall meet the requirements in Chapter 0250 "Steel Arches and Frames".
- Material delivery time schedules proposed for the above rock support systems.

Any amendments to the delivery schedule as the work proceeds shall also be approved by the PMC. None of the materials shall be delivered to the Site without PMC's prior consent. Delayed delivery of the materials shall not be the ground of any time extension and cost.

9.2 EXECUTION

9.2.1 Safety of Works and Persons

9.2.1.1 General

Safety in the underground works shall comply in addition to the requirements of this Chapter.

9.2.1.2 Control of Access

The Contractor shall establish and maintain effective check-in/check-out system to control access to the underground works by all persons including the Employer's and PMC's persons. No one shall enter the underground work site without registering at the entrance portal. Anyone coming out from the underground work site shall also be recorded at the portal. The system of control used by the Contractor shall be to the

approval of the PMC. The PMC reserves the right to withdraw such approval if he is not satisfied that the systems are being applied and enforced adequately.

No person shall be allowed to approach the excavation face and no face operation shall commence until the Contractor's authorized person in charge of the operation has given permission.

9.2.1.3 Noise Control

The Contractor shall take all reasonable steps to reduce the overall level of noise to below 85dB measured at 100m outside of the tunnel portal. Such measures shall include:

- Placing of covers over the source of noise.
- Fitting adequately sized mufflers to ventilation and other equipment.
- Iinstall temporary noise control barriers where appropriate

The Contractor shall provide a noise level measuring device and shall regularly calibrate such equipment. Measurements shall be taken regularly as requested by the PMC, and a full report of readings made shall be submitted to the PMC within 24 hours.

The Contractor shall provide suitable ear protectors to his entire workforce and other persons in the underground work site.

9.2.1.4 Vibration Control

The Contractor shall take all reasonable steps to reduce ground vibration velocity (peak particle velocity, ppv) to below 4cm/s (=4 kine) at the existing and completed concrete structure including cavern, chamber and tunnel. The Contractor shall provide a ppv measuring device and shall regularly calibrate such equipment. Measurements shall be taken regularly around the relevant structure at the time of blasting performed nearby, and a full report of readings made shall be submitted to the PMC within twenty four (24) hours. If the measured ppv is approaching 2cm/s, the Contractor shall submit a proposal of countermeasure to reduce ppv to the PMC for approval.

9.2.1.5 Safety Notices for Underground Work

The Contractor shall obtain, erect and maintain all the required safety notices for underground work in accordance with the standard pictograms or other approved safety notices.

9.2.1.6 Stores, Offices and Workshops

The erection of stores, offices and workshops in the underground works will not be permitted without the prior agreement of the PMC.

9.2.1.7 Communication

Any time someone is working underground either from the Contractor, the PMC or the Employer including guests, at least one designated person must be on duty above ground. This person is responsible for calling for immediate assistance and keeping an accurate count of persons who remain underground in the event of an emergency.

The Contractor shall install a telephone communication system between the underground works, the tunnel/ adit portals, medical clinic or first aid post and the site exchange, and shall ensure that such system is in working order at all times. A new shift shall not be sent underground if the telephone system is out of order unless an alternative effective communication system is in operation. Irrespective of the type of system installed, the underground communication stations shall always be within 100m of the places where work is being carried out and shall be located in sound proof wall mounted bubble kiosks. The portal stations shall be manned at all times that work is proceeding in the underground works.

9.2.1.8 Combustion Engine

Underground use of internal combustion engines burning gasoline or liquefied petroleum gases (propane, butane, propylene, and butylene) is forbidden.

The Contractor shall demand proof from prospective suppliers of diesel-powered equipment for use underground that the proposed equipment conforms to the requirements of the U.S. Bureau of Mines, or equivalent requirements as approved by the PMC and shall provide these to the PMC and have his approval prior to the equipment being delivered to the Site

9.2.2 Excavation

9.2.2.1 General

- Excavation shall be carried out in a uniform and controlled manner; over-cutting shall be kept to a minimum consistent with the need to maintain the necessary clearance for construction of the Works. After each round a mutual check of the excavated profile shall be made by means of a template or other method proposed by the Contractor and approved by the PMC. Any protrusion within the 'A' line shall be removed
- The invert of the tunnel shall be protected against damage and deterioration which may be caused by construction traffic. Any other surfaces which deteriorate or are damaged shall be made good to a standard agreed with the PMC.
- Excavation shall be carried out in sections limited to such lengths, depths and widths as may be safely executed having regard to all the circumstances and as appropriate to the ground conditions and the equipment and method of construction being used.

- In water-bearing strata the Contractor shall use such methods and take such steps as are necessary to control flows and maintain the stability of the excavation.
- Where necessary to ensure the safety and security of the Works, excavation shall be continuous by day and night.
- Weekends and general holidays will require the Works to be made safe and inspected by the Contractor at intervals agreed with the PMC.
- Where agreed or required by the PMC, temporary support shall be left in the Works. Untreated timber shall not be left permanently in the Works.
- The Contractor shall be constantly aware of the possibility of slips and ground movement which may be caused by his method or order of excavation. He shall maintain on site material for use in ensuring the stability of the face. He shall also perform all remedial work required in these excavations throughout the duration of the Contract, to ensure that all excavated rock surfaces are maintained in a stable and safe condition
- On exposure of a fresh rock face, the rock strata in the face walls and roof shall be mapped by the PMC, and the Contractor shall provide access for mapping.
- Any unsound areas of rock shall be reported to the PMC immediately together with a record of the Contractor's action. The face shall not be advanced until the area is properly secured. The Contractor shall inspect regularly the excavated surfaces of underground works under his jurisdiction and shall forthwith remove and dispose of any rock which the Contractor or the PMC deems loose, unsound and disintegrated.
- Any face of exposed ground, where excavation is to be discontinued for whatever reason shall be supported by rock-bolts, shotcrete or other means agreed with the PMC.

9.2.2.2 Drilling and Blasting Method

- In order to preserve the structural integrity of the excavations, the Contractor's excavation methods shall be such as to produce smooth and sound rock surfaces with a minimum of fracturing of the rocks beyond the excavation line. All necessary precautions shall be taken to achieve this result.
- The Contractor shall develop, by trial, controlled perimeter drilling and blasting techniques which result in a minimum of overbreak and a minimum of fracturing of the rock beyond the excavation lines, and thereby produce sound and reasonably uniform surfaces in the completed excavations. For this purpose, the Contractor's initial blasts in each area shall be performed as trials, and the burden, drill hole pattern, hole depth, explosive type and quantity, blasting sequence and delay pattern shall be modified to achieve the specified requirements. The controlled perimeter drilling and blasting techniques shall be developed by the Contractor at

the commencement of excavation and shall then be applied and improved upon if required to maintain the specified tolerance throughout the underground excavation.

- When a round of drilling and blasting results in excavated surfaces which do not comply with specifications, the Contractor shall modify his drilling and blasting methods by drilling perimeter holes at different spacing, charging holes differently or as otherwise required by the PMC until the excavated surfaces do comply with these specifications.
- Blasting shall be permitted only after the necessary precautions have been taken for the protection of all persons, work and property. Generally, blasting within 30m from permanent work formed concrete will be permitted only after concrete is seven (7) days old and only after the submission by the Contractor and approval by the PMC of a plan showing the relative positions of structures areas and the area to be blasted, the Contractor's proposed drilling and blasting plan together with an outline of precautions to be taken. All concrete work and other completed work shall be protected by limiting the size of blasts.

9.2.2.3 Explosives

- The Contractor shall only use explosives for blasting in connection with the work only at such times and places and in such manner as described in the submitted work method or as the PMC may approve.
- Handling, charging etc. shall be performed by experienced personnel using approved equipment in accordance with the relevant local statutory regulations.
- Under no circumstances shall any holes be charged until completion of all drilling operations at the face.
- The shot-firer must keep a record of the number of shots fired, their time of firing, type and weights of explosives used and the type and number of detonators used, together with a record of the post blast situation for each and every location. A copy of the record shall be available to the PMC at the end of every shift on which shots are fired.
- Detonators with protected bridging or other acceptable precautions shall be used in all blasting operations done by electric firing. The maximum permissible voltage shall not exceed that recommended by the Manufacturer.
- The power circuit used for electric firing shall be hung on supports, other than those used for electric power or communication lines and on the opposite side of the tunnel.
- Control of this circuit shall be by means of a locked switch with one key thereto.
- A standard blasting warning signal shall be used in connection with all blasting.

- Communication facilities from the tunnel portals to the working face shall be provided and maintained by the Contractor.
- Specific arrangements shall be made for transmitting warnings of approaching electrical storms. No charging operations shall be carried on during thunderstorms or other electrical disturbances.
- Sparks or open fires of any nature shall not be permitted underground.

9.2.3 Support and Protection

9.2.3.1 Initial Support

As soon as practicable after blasting and without undue delay the Contractor shall install or apply such support as may be necessary to safeguard the excavation and personnel.

These protections shall consist of supports including steel arches and frames, laggings, rock bolting, wire netting or shotcrete, where necessary, the diversion of surface water and the provision and maintenance of such protection.

If steel arches and frames, rockbolts, anchor bars or shotcrete are considered to be appropriate as additional stabilizing arrangements, steel arches and frames shall be in accordance with the Chapter 0250, rock bolting and wire netting shall be in accordance with the Chapter 0251 "Rock Bolting" and shotcrete shall be in accordance with the Chapter 0431 "Shotcrete" and shall be applied as soon as practicable after excavation.

9.2.3.2 Upgrading of Support

Should the monitoring of excavations show that additional support may be required such support shall be installed as agreed necessary between the Contractor and PMC.

This additional support will generally be installed away from the forward area and the Contractor will be required to carry out this work in parallel with other operations such that the advance of the face is not disrupted.

With regard to the final upgrading of the access adits as detailed on the Drawings, this work should be carried out after excavation is complete to suit the Contractor's programme.

9.2.3.3 Maintenance of Support

The Contractor shall be responsible for checking the rock support periodically at intervals to be agreed with the PMC and maintaining it in a sound condition.

Maintaining rock support shall include inter alia the removal of any cracked or defective sprayed concrete and any loosened material caught by mesh reinforcement and the subsequent reinstatement of such support. The correct seating of faceplates and tightness of nuts shall be ensured.

9.2.4 Tunnel Portal Excavation

Commencing at each portal face, the Contractor shall be required initially to start the excavation using a technique approved by the PMC.

Before starting the tunnel excavations, the Contractor shall, if necessary, install rock bolts in the portal areas to reinforce the periphery of the excavation and to prevent overbreak and minimize the occurrence of blast induced fractures.

The Contractor shall provide heavy-duty blasting mats adequately held down to prevent damage from flying rocks, if surrounding concrete work has to be protected.

9.2.5 Scaling

Immediately following blasting and at any time during the contract, all loose materials which appear to be unsafe or which may endanger workmen or structures or equipment shall be scaled down and removed.

The fact that such scaling and removal may enlarge the excavation beyond the required excavation lines shall not relieve the Contractor from the necessity of making such scaling and removal.

All materials loosened by scaling shall be removed from underground excavation areas to the satisfaction of the PMC.

9.2.6 Tunnel Enlargement

Conditions may be encountered in a given area which requires a change in 'A' lines from those shown on the Drawings. Such special sections will be determined by the PMC, who will give the Contractor notice in writing of the required change.

These enlargements may be requested before or after excavation of the relevant portion has been completed to the lines.

9.2.7 Dental Excvation

Dental excavation shall be performed only where approved or directed by the PMC.

The work may include removal of material by pneumatic tools and cleaning with hand tools and air water jets.

Following dental excavation, the exposed seam or cavity shall be filled and sealed with concrete, shotcrete or grout.

Rock bolting and wire mesh reinforcement shall be used as approved or directed by the PMC to provide permanent support.

9.2.8 Cleaning Excavations

The Contractor shall wash down exposed rock surfaces in the roof and side walls of the underground excavations, where directed by the PMC.

This washing down shall be carried out initially for inspections when required by the PMC and again during final cleanup in areas which will receive concrete lining or where shotcrete is required, including invert of the section.

Initial washing down of any section of the work shall not commence in any section of the excavation until the blasting for excavation has been completed for a minimum distance of 15m from that section or as required by the PMC.

Washing down of the rock surfaces shall be done by directing a stream of water and air at the rock surfaces with a pressure not less than 0.50MPa, so as to remove all loose rock fragments, dust and debris from the surfaces.

All excavation spoil shall be removed from the invert down to the excavated rock surface, or as directed by the PMC.

9.2.9 Excavation for Construction Purposes

9.2.9.1 Enlarged Excavations

As stated in Cause 1.3 above, the Contractor is permitted to carry out excavation other than that shown on the Drawings to facilitate construction work. All such additional excavations and related construction shall be subject to the PMC's approval; however, the cost of such additional excavation and backfilling with concrete or other approved materials shall be borne by the Contractor.

9.2.10 Control of Water

Control of water in the underground works is specified in the Chapter 0211 "Dewatering and Care of Water"

9.2.11 Drilling and Grouting

9.2.11.1 General

Drilling and grouting equipment and works are specified in Chapter 0240 "Drilling and Grouting". Particular requirements for underground excavations are given hereunder.

9.2.11.2 Probe Drilling

Probe holes not less than NX size shall be maintained at least 10m ahead of all excavated faces when deemed necessary during excavation to locate changes in geological conditions accumulations of gas or water.

The holes may be drilled from the face or from enlargements off the tunnel.

Unless a single hole located on the axis of the tunnel is drilled, at least two (2) holes located approximately on opposite sides of a horizontal diameter shall be drilled. Holes on opposite sides may be staggered but shall be overlapped to effectively probe each side over the full length of the tunnel.

Holes angled outwards shall remain with 4m of the tunnel periphery.

Probe drilling may be done using percussion rock drilling equipment except when rotary drilling with core recovery is ordered by the PMC for geological investigations.

Records of drill cuttings, water inflow and pressure test measurements and testing for methane shall be kept by the Contractor.

9.2.11.3 Consolidation Grouting

Where necessary, consolidation grouting will be required or approved by the PMC according to Chapter 0240 "Drilling and grouting".

9.2.11.4 Pressure Relief Holes

Pressure relief holes shall be drilled as required or approved by the PMC for the purpose of relieving groundwater pressure or for draining groundwater from rock adjacent to the underground excavation.

9.2.12 Disposal of Materials from Excavation

It may be possible to use, partly or fully, the rock materials excavated in the underground works as raw material for concrete aggregate and materials for road pavement, rockfill or backfill. The use of the excavated materials is the Contractor's discretion, however, maximum utilization of available materials should be considered. If the Contractor intends to use the excavated materials, he shall make trial tests to verify adequacy of the materials and submit the test report to the PMC for approval of use of the materials.

If the excavated materials are partly usable for construction purposes, the Contractor shall classify them at the excavation site and transport them partly to the Contractor's stockpile area and partly to the disposal area.

The disposal area is shown in the drawings. The Contractor shall make, at his cost, necessary arrangement for transportation of the excavated materials. Any facilities provided for the excavated material transportation shall be removed from the Site at the end of the transportation work as approved by the PMC.

Disposal areas shall be well drained and left in tidy, safe and stable conditions. They shall comply with the requirements indicated in Chapter 0210 "Site Preparation".

9.2.13 Control

9.2.13.1 Inspection

At intervals during the construction of the underground excavations, the PMC will carry out geological mapping of the excavated surfaces.

The Contractor shall provide whatever assistance and incidental materials may be required to facilitate this inspection and to permit a geological survey and mapping of the excavated surfaces in suitable conditions.

Prior to this mapping the excavated surfaces shall be cleaned and washed to the satisfaction of the PMC.

9.2.13.2 Topographical Survey

A topographical survey, for the purpose of measurement for control and recording, shall be jointly carried out by the Contractor and the PMC.

The distance between two (2) cross sections shall not be more than twice the mean diameter of the tunnel.

Each cross-section shall include at least sixteen (16) measurement

Chapter 0232

10 VENTILATION AND LIGHTING FOR UNDERGROUND WORKS

10.1 GENERAL

10.1.1 Scope

The Contractor is responsible for providing temporary ventilation systems effective for all the Contractor's underground work sites. The Contractor is further responsible for operating and maintaining the systems as to meet the requirements for underground work, and for removing the systems at completion of the works.

Permanent ventilation systems (HVAC systems) are to be installed by the Contractor in the dam galleries and tunnel galleries. The permanent HVAC systems shall become ready for permanent operation not later than two (2) months prior to the start of the reservoir impoundment.

10.1.2 Related Works / Sections

Chapter 0230 Underground excavations

Chapter 0240 Drilling and Grouting.

Chapter 0250 Steel Arches and Frame.

Chapter 0251 Rock Bolting

10.1.3 Codes and Standards

BS EN 60079-18: 2004 Electrical apparatus for explosive gas atmospheres. Construction, test and marking of type of protection encapsulation "m" electrical apparatus

10.1.4 Quality Asssurance

10.1.4.1 Records

A written record of all readings regarding the air conditions in the underground works shall be kept by the Contractor.

10.1.4.2 Ventilation Requirement

10.1.4.2.1 Ventilation requirements for Work Area

The Contractor shall install, operate and maintain a ventilation system in the underground works to enable the Works to be constructed in healthy, well ventilated conditions. Dust shall be abstracted at or adjacent to the source.

To minimize the dust hazard arising from drilling operations in rock excavations, all holes shall be wet drilled unless otherwise approved. Water sprays or atomizers shall be used to prevent dust rising during drilling and mucking operations including keeping the floors of haulage ways damp.

The Contractor shall check at the face and elsewhere for concentrations of noxious or other harmful gases or dust at least weekly and more regularly if necessary and when called upon to do so by the PMC. The concentrations shall not exceed the following limits:

- Carbon dioxide 5,000 parts/million by volume.
- Carbon monoxide 50 parts/million by volume.
- Nitric oxide 25 parts/million by volume.
- Nitrogen dioxide 3 parts/million by volume.
- Hydrogen sulphide 10 parts/million by volume.

The above values shall relate to average concentrations over an eight (8) hour working shift. The maximum possible limit at any time underground shall be the following:

- Carbon dioxide 15,000 parts/million by volume.
- Carbon monoxide 100 parts/million by volume.
- Nitric oxide 35 parts/million by volume.
- Nitrogen dioxide 5 parts/million by volume.
- Hydrogen sulphide 15 parts/million by volume.
- Flammable gas Refer to Clause 1.4.3 below.

The Contractor shall at all times comply with both the average and the maximum concentration levels.

In the case of air breathed by persons in the underground works the air shall not contain more than the following concentrations of total respirable airborne particles of dust (sizes from 5.0 to 0.2 microns).

- Quartz content < 1% 8 mg/m³
- Quartz content > 1%, < 4% 4 mg/m³
- Quartz content > 4% 0.15 mg/m³

These values shall relate to average concentrations over an 8-hour working shift. When dust concentrations exceed the above, all persons in the affected area shall be notified and be required to wear respirators.

The ventilation system used during construction shall ensure that at all times a minimum oxygen content of 20% by volume is available in any underground works. Furthermore, the minimum fresh air requirements given herein refer to the required ventilation conditions and additional provision shall be made to account for any losses, e.g. due to leaks in the ducts, for which the Contractor shall make provision in the ventilation calculations.

Instruments to register all the various noxious gases and dust shall at all times be available on the Site in good working order and condition. These shall be supplied and maintained by the Contractor, throughout the duration of the underground work.

The Contractor shall be responsible for operating the ventilation system in the underground works until all construction work is completed, including all work to be carried out by other contractors.

Ventilation Quantities and Work Place Wet Bulb Temperatures

The ventilation system in each section of the Works shall ensure that the following minimum air quantity requirements are provided at all times:

- 3.0m³/min for each person or worker in the underground works.
- 6.0m³/min for each installed kW power of diesel plant or equipment working in the underground works.
- The average air velocity in all excavation areas shall not be less than 0.3m/s.
- Notwithstanding the above the minimum quantity of fresh air delivered at the advancing face shall be 7m³/s.

The ventilation, and where necessary cooling, arrangements shall be designed to ensure a working environment such that:

- At any time the weighted mean wet bulb temperature at all workplaces in any one tunnel drive shall not exceed 27.5°C (the average being calculated on the basis of the number of persons and the wet bulb temperature at the work place of each person).
- Similarly the weighted mean wet bulb temperature at all workplaces within 100 m of the advancing face of any one tunnel drive shall not exceed 27.5°C.
- The wet bulb temperature at any one workplace does not exceed 32.5°C.

To ensure compliance with the foregoing, the Contractor shall provide all necessary equipment to measure the wet bulb temperatures at regular intervals during each working shift or such other interval agreed with the PMC.

Additionally, if the wet bulb temperature at any one workplace exceeds 30°C, the Contractor shall inform the PMC of the additional corrective measures he plans to adopt to counter the risks to health in general and of heat stroke in particular.

10.1.4.3 Hazardous Gas

10.1.4.3.1 General

The Contractor shall continuously monitor the underground works for the presence of hazardous gases and when they occur they shall be strictly controlled and on no occasion shall the concentration exceed 10% of the lower explosive limit of that gas.

For this purpose the Contractor shall supply, use and keep in good order sufficient equipment and apparatus to comply with the requirements specified hereunder. Where the term methane is used it shall be construed to mean any potentially explosive or hazardous gas.

10.1.4.3.2 Methane Detection

The following minimum methane detection procedures are required:

- Testing for methane to be carried out at each probe hole, and in the case of upward inclined probe holes at the back of the hole. Particular attention shall be paid for testing of methane when deep fractures are intersected by the probe hole.
- Testing for methane to be carried out continuously during drilling or boring operations.
- Continuous methane monitoring device(s) to be provided in ventilation columns with automatic alarm system.
- Regular methane inspections of headings and tunnels whether discontinued or in use for access to the rearward of the advancing face are to be carried out.

10.1.4.3.3 Ventilation Equipment

Ventilation equipment shall be provided in accordance with the requirements of Clause 3 and in addition the following is required:

- Ventilation fans shall be flame proofed in accordance with BS 5501 Part 5, flameproof enclosure «d» Group 1.

10.1.4.3.4 Contractor's Equipment

In addition to the requirements noted above the following other minimum requirements are to be adhered to:

- Sufficient calibrated methanometers of an approved type or other approved gas detection devices shall at all times be provided.
- Automatic warning and cut off devices to be provided to all applicable electrical installations.
- All equipment to be suitably earthed.
- All diesel driven plant to be fitted with effective scrubbers to the exhaust systems.
- In the case of excavation by drill and blast, no mechanical equipment to be brought to the face until the examination for methane has been completed.

10.1.4.3.5 Personnel

The following minimum requirements are to be adhered with:

- At all times personnel shall be present in each working tunnel that have passed a gas testing course acceptable to the PMC.
- Appropriate precautions shall be taken to prevent the entry of unauthorized persons to the underground works.
- Appropriate precautions shall be taken to prevent persons bringing into the underground works open flames and to prevent smoking in the underground works.

10.1.4.3.6 Acceptable Concentrations of Methane

Should methane be detected in any part of the underground works then all work in that part shall immediately be halted and the PMC shall be informed without delay. The Contractor shall then decide in conjunction with the PMC the appropriate action to be taken.

Generally should the percentage of methane recorded be less than 10% of the lower explosive limit then work may be restarted immediately on notification to the PMC of the occurrence but only with the PMC's approval. In this case monitoring for methane shall be pursued continuously during all operations to detect any increase in the level of methane.

10.1.4.4 Lighting Requirement

The Contractor shall install, operate and maintain a lighting system in the underground works until completion of the Works. The lighting along all tunnels and enlargements shall consist of at least 40W waterproofed fluorescent lamps at intervals not exceeding 15m fitted along the one side wall of the tunnel such that illumination on a horizontal plane at floor level is not less than 10 lux and no significant area of the floor is in shadow. All hazards shall be clearly illuminated at all times.

The first 50m from the portal of each adit shall be lit to double the above intensity. Broken lamps shall be replaced every shift.

Each working face shall be brightly illuminated to not less than 160 lux by one or more additional high intensity moveable lamps.

In addition where stationary machinery is used or in the case of a tunnel boring machine the area shall be so illuminated so that all external moving parts are illuminated to a level of 160 lux.

Suitable high intensity movable lamps shall also be provided by the Contractor to illuminate any area in the underground works where the PMC may wish to carry out testing or other inspection e.g. at a monitoring station or to inspect geological features.

Broken high intensity lamps shall be replaced immediately from a reserve stock which shall be kept as close as practicable to the working face but in any case no further from the face than the portal.

After excavation of any tunnel, modifications may be required to the lighting system to allow for subsequent construction and the Contractor shall make due allowances for this in his planning and bid rates.

No person shall work or travel in any underground working unless a light is carried. All safety helmets used underground shall be equipped with suitable brackets for mounting the light. The light shall be a sealed lamp of an approved type.

10.1.4.5 Safety Precautions

All electrical equipment used underground shall be grounded to an approved installation extending throughout the underground workings and connected to ground outside the tunnel portal.

Cables shall be securely and safely fastened in place above floor level and well maintained.

The Contractor shall make available rescue teams with suitable arrangements and necessary equipment to efficiently ensure prompt rescue and give general first aid.

Separate circuits shall be provided for lighting and power purposes and these circuits shall be controlled by automatic earth leakage relays and all electrical installation shall be kept clear of signal and telephone cables.

10.1.5 SUBMITTALS AND APPROVALS

No later than twenty eight (28) days prior to programmed commencement of any underground works, the Contractor shall provide the PMC with his overall method of lighting and ventilation including specifications of equipment.

Two copies of the records shall be submitted to the PMC on a weekly basis unless otherwise instructed.

10.2 PRODUCT

10.2.1 Electrical Equipment

All electrical equipment fittings shall be waterproof and spark proof without any leakage. All lighting and power cable shall be adequately insulated and armored if necessary.

10.2.2 Control Devices

Testing devices for measuring carbon monoxide, nitrogen dioxide, methane, siliceous dust and oxygen shall be available all the time in the vicinity of the place of work.

10.3 EXECUTION

10.3.1 VENTILATION IN DRILL BLAST DRIVES

In drill and blast drives an exhaust ventilation system shall be provided.

With this system, blasting fumes shall be extracted as close as possible to, and not more than 30 m from the excavation face. Exhaust air and blasting fumes shall be discharged in such a way that they cannot enter into any other working place or be recirculated in the fresh air supply system.

An additional secondary ventilation system, of the forced overlap type shall be provided to ensure an adequate ventilation of the area between the excavation face and the air intake of the exhaust system. The intake to this fresh air forced supply shall be located at a sufficient distance from the excavation face to ensure that blasting fumes do not permeate into this area and cause a recycling of blasting fumes. The capacity of the secondary forced ventilation system shall be at least 70% of the capacity of the exhaust ventilation system.

Should the Contractor wish to institute a more extensive forced ventilation system the written approval of the PMC will be required and the Contractor shall ensure that the following aspects are enforced:

- All labor shall evacuate the underground works before blasting and only re-enter the underground works after blasting fumes have been completely removed from the working area by ventilation and discharged from the underground works, or
- Blasting fumes are diluted adequately to ensure that concentrations of noxious or other harmful gases or dust do not exceed the limits in Clause 1.4.2 above.

10.3.2 VENTILATION IN MACHINE BORED DRIVES

In machine bored drives either an exhaust or forced ventilation system shall be provided. With either system dust shall be extracted as close as possible to the cutting head.

The system adopted shall take recognition of the requirements of the Specifications with regard to the detection and treatment of hazardous gases and shall be subject to the approval of the PMC.

10.3.3 MAINTENANCE OF VENTILATION SYSTEMS

All equipment and ducting shall be maintained in sound working order at all times. Any damage to ducting shall be repaired without delay.

Failure by the Contractor to comply with the above requirements or to maintain the prescribed ventilation standards will entitle the PMC to order a temporary halt of all work within the affected area until the specified requirements are met, without any extension of time and cost being granted.

10.3.4 USE OF INTERNAL COMBUSTION ENGINES

No internal combustion engine other than a diesel engine shall be used in the underground works. Any diesel engine used in the underground works shall be provided with a means, which shall be maintained in efficient order, of cooling exhaust gases and reducing the concentration of toxic gases in the exhaust gases to acceptable levels and prevent emission of flames or sparks. Notwithstanding the Contractor's compliance with the above requirements for ventilation, the operation of all diesel engines in the underground works shall be discontinued and ventilation improved or other acceptable measures taken if any of the limits stated in Clause 1.4.2 above are exceeded.

No diesel equipment shall be allowed underground if the exhaust gases contain more than 2,000 parts of carbon monoxide or 1,000 parts of oxides of nitrogen per 1 million by volume.

The engines of diesel powered equipment underground shall not be kept running idle except while being tested or during brief halts while in use. No equipment shall be refueled underground, unless proper precautions are taken.

10.3.5 MODIFICATIONS TO VENTILATION SYSTEMS

After excavation of any tunnel which will be lined, the ventilation system used for the excavation phase may have to be modified to allow for the construction of the concrete lining and installation, welding together, concreting in and painting of the steel-lined sections. Any such modifications shall be allowed for by the Contractor in his design of the ventilation systems for the underground works.

These allowances shall also include for localized ventilation during concreting and grouting operations and during the time that subcontractors or others are carrying out welding or painting operations in the underground works.

The ventilation system shall be so operated after concreting of linings to maintain satisfactory conditions for proper curing of the concrete.

10.3.6 DRILLING

Only wet drilling will be used.

All rock surfaces or broken rock at working places shall be kept wet.

10.3.7 CONTROL

Readings for carbon monoxide shall be taken by the Contractor at least once during each shift and additional readings shall be taken when required by the PMC.

Readings for nitrogen dioxide shall be taken as required to ensure proper safety of the work as required by the PMC.

The free silicon dioxide content of dust shall be determined from collected samples representative of the dust from the various work areas. Record measurements shall be made at least once in each shift when requested by the PMC. The PMC may reduce the frequency of samplings, whenever he is satisfied that the Contractor is maintaining the underground atmosphere free from dust.

Chapter 0240

11 DRILLING AND GROUTING

11.1 GENERAL

11.1.1 Scope

This Chapter covers the requirements for the following items of work for the river diversion tunnels, the flushing tunnels and all surface and all underground works for the RCC type main dam under the Contract, but not limited to, the works, as instructed by the PMC:

- Drilling for exploratory holes with or without core recovery,
- Drilling for instrument installation holes,
- Drilling for anchors, rock bolts and dowels,
- Drilling for drain holes,
- Drilling for all grouting holes and grout check holes, with or without core recovery in soil, rock and concrete,
- Grouting as listed below;
  - Contact grouting for construction joint of the diversion tunnel plug concrete,
  - Cavity grouting to fill gap between rock and tunnel crown concrete and between rock and tunnel galleries, diversion tunnels, flushing tunnels, and exploratory adit plugging,
  - Consolidation grouting for main dam foundation, tunnel galleries, diversion tunnels, flushing tunnels, exploratory adit portals and fault treatments, and
  - Sub-curtain and curtain grouting for main dam, diversion tunnel plugs, and flushing tunnels,
- Water pressure tests in boreholes, and
- Borehole deviation measurements.

11.1.2 Related Works / Sections

Chapter 0220 Surface Excavation

Chapter 0230 Underground Excavation

Chapter 0251 Rock Bolting

Chapter 0252 Post-tensioned Rock Anchors

Chapter 0260 Drainage of Structures

Chapter 0710 Instrumentation

Grouting in holes for rock bolts and dowels is included in Chapter 0251. Grouting for post-tensioned rock anchors is included in Chapter 0252.

11.1.3 Definitions

- Flushing hole: the cleaning of a drill hole by injecting water or water and air at the bottom of the hole until all cuttings and sludge are removed from the drill hole and the return water runs clear.
- Comprehensive water pressure tests: water tests carried out in grout holes, drain holes or exploratory holes directed by the PMC to determine the permeability of the rock mass and the effectiveness of the grouting operations. The water is pumped into the hole in three (3) incremental stages up to the pressure specified by the PMC and then reduced in the same stages to zero pressure.
- Abbreviated water pressure tests: water tests carried out in holes directed by the PMC to determine the effectiveness of the grouting operations. The water is pumped into the hole until the pressures rises to the water pressure specified by the PMC.
- Downstage method: procedure of drilling a hole to a limited depth, setting a packer and grouting the hole, permitting the grout injected around the hole to set sufficiently to prevent its entering the hole when the hole is cleaned, cleaning the hole, drilling the hole to a deeper stage, setting a packer at the bottom of the previously grouted stage or elsewhere as directed by the PMC, grouting a new stage, and thus continuing in as many cycles of drilling and grouting as required.
- Upstage method: procedure of drilling a hole to full depth in one operation and grouting from the end of the hole towards the surface in successive stages by setting the packers at predetermined depths.
- Cavity grouting: systematic filling of all cavities, voids and spaces remaining unfilled outside of the in-situ concrete lining or plug of tunnels, tunnel galleries and exploratory adits, through holes drilled or systems of embedded piping and outlet.
- Contact grouting: consists of pressure grouting into gap between concrete lining and concrete plug of tunnels, embedded steel structures, steel lining and surrounding concrete, through holes drilled in concrete or through systems of embedded piping and outlet.
- Consolidation grouting: systematic filling of joints, fissures, and any discontinuity in rock with grout through drilled holes to strengthen the rock mass and reduce the permeability. This includes the consolidation grouting of faults and portals of the exploratory adits.
  - For main dam foundation: Open-air works
  - For tunnel galleries, diversion tunnel plugs and flushing tunnels: Underground works
- Sub-curtain and curtain grouting: systematic pressure grouting through drilled holes in an extended plane in rock to minimize seepage of water across the plane.

- Split spacing method: the procedure of closing a grout hole by drilling and grouting a hole midway between two (2) holes which have previously been drilled and grouted.

11.1.4 Codes and Standards

The following table lists the Standards and Specifications of the American Society for Testing and Materials (ASTM). These or similar Standards and Specifications in internationally recognized, such as International Society for Rock Mechanics (ISRM), shall be used.

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 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 C150	Specification for Portland Cement

11.1.5 Quality Assurance

11.1.5.1 Experience, Skilled Staff

The Contractor shall satisfy the PMC that he is experienced in drilling and grouting, that he has previously successfully carried out similar work of comparable magnitude and that he possesses the necessary equipment and skilled staff; otherwise, the Contractor shall employ an experienced specialist sub-contractor to carry out the drilling and grouting work.

The Contractor shall provide an engineer with not less than fifteen years' experience in drilling and grouting to supervise the work, together with foremen with not less than fifteen (15) years similar experience.

11.1.5.2 Quality Control of Materials

- The cement used for injection shall be tested as specified in Chapter 0430.
- The following checks shall be carried out for each delivery of bentonite:
  - Plasticity index.
  - 50-micron sieve passing.
  - Cement compatibility (28-day grout strength).

11.1.5.3 Tests for Grout

- The PMC may direct that tests on proposed grout mixes be performed in the laboratory to demonstrate the grout properties, prior to grouting. Grout samples shall be obtained during grouting, for testing in the laboratory. Grout sampling will be on at least a daily frequency at the start of grouting, but may be less frequent when consistent, adequate quality of grout is demonstrated. The PMC may direct that changes be made to the grout mix, based on the results of sample testing.
- The Contractor shall make six (6) - 50 mm grout cubes per test. These cubes shall be compression tested at the Site laboratory to determine the rate of gain of strength of the grout. Sampling and testing of grout shall be in conformance with ASTM C109.
- The Contractor shall perform the following routine tests during the course of the work to confirm that the grout meets and continues to meet the requested characteristics:

Test	**Frequency (Linear m of hole)**
Time of setting (ASTM C191)	1 test per 500 m (at least twice per month and per type of grout)
Compressive strength (ASTMC109)	1 test per 500 m (at least twice per month and per type of grout)
Bleed and expansion (CSA 23.2-1B)	Once per day and per type of grout
Viscosity (CSA 23.2-1B)	Once per day and per type of grout
Density	Once per day and per type of grout
Particle size analysis (ASTMD422)	1 test per cubic meter of sand used in the grout

- The Contractor shall prepare on approved forms records of these tests, which shall be submitted to the PMC on a daily basis.
- During the grouting, the Contractor shall control permanently the pressure and record any variation.

11.1.5.4 Tolerances

- Holes shall be drilled to within a limit of 20 cm from the indicated position, and - 0 of the depths specified or directed. Grout holes shall be collared within 100 mm of their specified locations.
- Except otherwise directed by the PMC, the holes shall not deviate more than 3° from the specified orientation as specified in Clause 3.8.

11.1.6 Submittals and Approvals

- At least 56 days prior to the programmed start of drilling and grouting operations, the Contractor shall submit to the PMC the following for approval:

- The proposed equipment and installation methods for executing and monitoring drilling, water testing and grouting,
- The technical references of the Contractor and of his personnel to be employed on drilling and grouting works.
- Manufacturer's test certificates for all materials to be used for grouting.
- Provisional programme for grout mix design for each specific work and results of the trial mixes for grout.

- At least twenty eight (28) days prior to the scheduled date of commencement, the Contractor shall submit for approval a detailed method statement and program for drilling, water testing, and grouting operations, showing proposed methods of access, the sequence of works, the maximum grouting pressure, the rate at which the grout is injected, the pressure application (continuously or by stages) and the composition of the grouts for each specific work. The method of execution for grouting will be defined by preliminary in situ tests which shall be carried out under the continuous supervision of the PMC.
- At least twenty eight (28) days prior to the scheduled date of commencement; the Contractor shall submit for approval Quality Assurance Manual detailing the measures proposed to ensure the specified quality, including control and tests.
- Field progress records for all grouting work shall be submitted at the end of each shift, giving the data as described in Clause 3.7.
- Drilling records and hole logs as described in Clause 3.2.4 shall be submitted to the PMC for exploratory holes and instrument installation within forty eight (48) hours of the completion of such holes.
- Water pressure test records as described in Clause 3.3 shall be submitted to the PMC within twenty four (24) hours of completing such tests.
- Records of grout tests described in Clause 1.5.3 shall be submitted to the PMC with forty eight (48) hours of testing.
- Fifty six (56) days after the end of each section of work defined by Clause 1.1 above, the Contractor shall submit to the PMC quality control reports.

11.2 MATERIALS

11.2.1 Cement

Cement used in grout shall be Portland cement as specified for concrete in Chapter 0430.

11.2.2 Water

Water for grout mixtures shall comply with the requirements for mixing water for concrete which are given in Chapter 0430.

11.2.3 Sand

Sand shall conform to ASTM-C33, "Specification for Concrete Aggregates", as to the quality. The fineness of the sand required for grouting shall be as follows: 100% shall pass a U.S. Standard No.16 sieve size, not less than 10% nor more than 30% shall pass the No.100 sieve size, and not more than 5% shall pass the No.200 sieve size.

11.2.4 Admixtures

The use of commercially available admixtures such as expanding and retarding agents shall be subject to prior approval by the PMC. They shall comply with the specifications given in Chapter 0430.

The Contractor's request for the use of an admixture shall accompany the results of relevant laboratory tests demonstrating the effectiveness and advantages of the product. Products of which chemical composition is not known to the PMC will not be approved for use in grout.

11.2.5 Bentonite

- Bentonite to be used in grouting work shall not contain anything capable of inhibiting cement setting and particles exceeding 80 microns.
- Bentonite shall have a Plasticity Index greater than 400%.
- Bentonite shall be delivered in bags which shall be stocked in accordance with the provisions laid down for cement (Chapter 0430).

11.2.6 Chemical Products

Chemical products like silicate gels, organic resins or soda silicates may be permitted to use if advantageous, harmless and accepted by the PMC.

11.2.7 Grout Mixes

11.2.7.1 Composition

- Proportions of materials used in grout mixtures and any adjustments thereto during grouting operations shall be only as approved by the PMC. Proportions shall be varied to suit actual conditions encountered at Site.
- Where bentonite is required in the mix, the bentonite shall be mixed with water to make slurry prior to the addition of cement.

- The grout mix design process for each kind of grouting work shall include the following tests, as described in Clause 1.5.3:
  - Settling measured as the ratio between the volume of water appearing above the grout and the total volume in a 1 liter, 6 cm dia test tube, after 20, 40, 60, 80, 100 and 120 minutes and after setting.
  - Setting time.
  - Viscosity with standard Marsh cone (4.75 mm dia) (API 13.B).
  - Density.
  - Flexural and uniaxial compressive strength at 28 days on 4x4x16 specimen (NF P 15-413).
  - Compatibility between the various components.
- Trial mixes shall be produced by site mixers and using the same materials as those which will actually be used on site.
- The composition of the grout shall be adjusted depending on the actual conditions encountered.
- Grout mixes shall be stable grout mixes.

11.2.7.2 Criteria

- Settling time less than 24 hours.
- Settling after 2 hours lower than 5%.
- Viscosity: to be adjusted for each specific work within the range 30-50s, with a tolerance on the specified viscosity of + or - 5 s.
- Uniaxial compressive strength after 28 days:
  - Contact and consolidation grouting, cavity grouting, steel linings and embedded items injections: > 5 MPa.
  - Others works (curtain grouting): > 2 MPa.

11.2.8 Dry-Pack Mixes

Dry-pack shall be composed of a mix of 1 part of cement, by volume, to 2.5 parts, by volume, of fine aggregate passing a 1.2 mm square sieve, together with sufficient water to produce a mortar which will just stick together when moulded into a ball by light pressure of the hands and will not exude water, but will leave the hands damp.

11.3 EXECUTION

11.3.1 Equipment

11.3.1.1 Drilling Equipment

- All drilling equipment shall be subject to the PMC's approval. It must be suitable for operation on open-air as well as in underground location, in any direction.
- Rotary and 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. When coring is not required, 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. Use of dry drilling machine is not permitted in underground works to minimize dust hazards unless specifically approved by the PMC.
- The following table lists suitable sizes of double-core barrels. These or similar sizes specified in internationally recognized Standards shall be used.

Type	**Drill Core (mm)**	**Drill Hole (mm)**	**Bit Dia.**	**Reamer Dia.**
			Internal/External (mm)	**External (mm)**
EX	20.64	38.10	21.46 /37.08	37.32
AX	30.16	49.21	30.10 /46.37	48.01
BX	41.28	60.33	42.04 /59.18	59.94
NX	53.98	76.20	54.74 /74.80	75.96
2 3/4 x3 7/8	68.26	98.42	63.33 /97.54	98.43
4 x5 1/2	100.01	139.70	100.84 /136.05	139.57
6 x7 3/4	150.81	196.84	151.64 /194.44	196.05

- 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.

11.3.1.2 Grouting Equipment

- 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 PMC, 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. Automatic

recorders for pressure and volume of grout are required for all types of grouting works to be carried out.

- The mixing and pumping equipment shall be installed in one or two central stations to enable continuous, undisturbed work, independent of weather conditions and to guarantee a constant mixture as required.
- For the grouting operations underneath the dam or in underground works, reliable telephone communication between the main working stations and the central grout mix and pump stations is required.
- 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.
- 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.
- **Jumps:** All grout mix shall be pumped with electric / hydraulic 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 4.0MPa (40kg/cm²), 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 satisfactory accommodate discharges from 2 liters per minute up to 150 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.
- Special emphasis shall be given to the control devices for pressure and volume of grout and for water pressure tests. For all curtain grouting works, automatic recording devices are required for both pressure and quantity. For contact grouting between steel or concrete linings and rock, for consolidation of rock around tunnels or in the vicinity of structures, and for grouting to support excavation works, an automatic pressure meter and manual records of the grout rate shall be satisfactory.
- Grouting of anchors may be performed without recorded control except for indications of pressure and grout rate in the reports.
- The pressure applied shall be measured at the borehole head and transmitted to appropriate automatic recording instruments.

- 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).
- All pressure gauge used shall permit accurate reading to within 0.1MPa (1bar) of the true value; thus 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 PMC and shall be checked against calibrated gauges at intervals as requested by the PMC.
- **Mixers:** Batching of grouting components shall be in the following order: water, bentonite slurry, cement, and sand (if used in the mix). Bentonite shall be premixed with water 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. The equipment for mixing the grout materials shall be capable of effective mixing and stirring at high speed (colloidal type). The minimum rotational speed of the mixer shall be 1,200rpm. The mixers shall be provided with an accurate meter for controlling the volume of mixing water and other liquids such as bentonite slurry which are used as mix components at an accuracy adequate to the volume of the containers. In addition to the grout mixer, hold-over agitator tanks with stirring propellers shall be provided. At least three compartments with high speed, colloidal mixers shall be supplied. The grout shall be mixed in one compartment and discharged into a separate compartment. The third compartment provides reserve capacity. A screen shall be inserted between the holding tank and the suction side of the grout pump. The grout in the holding tank shall be continuously agitated. A water meter shall be provided for accurate measurement of the water to be used for mixing. The holding tank shall be provided with a volume measuring device to record the grout take. The capacity of each grouting unit shall not be less than 120 liter/min. when operating at a discharge pressure of 10kg/cm².
- **Pipes:** 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 PMC. 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. Pipes shall be cut individually to the exact length so that the outer end remains flush with the finished concrete surface as indicated on the Drawings. The outer end shall be provided with a screw joint to enable connection to a grout pipe, where required. The buried end shall be cut to a flare or provided with a joint to obtain a safe anchorage. Both ends shall be protected to keep them from being filled with concrete during pouring of concrete.

- **Packers:** All packers used shall guarantee proper sealing of the respective borehole section and shall then be capable of withstanding water pressure exceeding the maximum grout or water pressure to be used at the level of the packer without leakage. This may require the use of different types and sizes of packers, such as double-tube packers, hydraulic packers, pneumatic packers or self-sealing packers, each in accordance with the local rock conditions. The type of packer used is subject to approval by the PMC, and the Contractor shall have all types required available on Site for immediate use.
- **Pressure and Rate Gauges**: If and where the PMC directs, automatic recording gauges, the tapes of which indicate time, pressure and rates of absorption, shall be installed during grouting operations and shall be calibrated with reasonable accuracy as approved by the PMC. After each usage, they shall be cleaned and recalibrated at frequent intervals. According to the standard techniques or upon direction of the PMC, pressure gauges of adequate accuracy shall be placed at pumps and borehole collars or wherever else required. Accurate master pressure gauge for different pressure ranges shall be furnished to check periodically the accuracy of all gauges used. 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 PMC. 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.

11.3.2 Drilling

11.3.2.1 For Grouting

- Grout holes shall not be smaller than 46 mm diameter or as shown in the Drawings or as approved by the PMC.
- The location, direction and depth of each grout hole for curtain grouting or consolidation grouting shall be as directed by the PMC 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 PMC.
- 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.
- 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.
- he use of rod dope, grease or other lubricants on drill rods shall not be permitted. No drilling water additives of any kind shall be used without written permission.

- On completion of drilling of each hole, the hole shall be flushed with pressure water until the return water becomes clear, and no drill cuttings, rock fragments or any other solid materials are found.
- On completion of drilling and flushing of grout holes the Contractor shall immediately cap 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.
- Drilling for curtain grout holes or consolidation grout holes shall not commence until seventy two (72) hours after completion of cavity grouting within 10m.
- In the downstage holes, or instructed by the PMC, 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.
- It may be necessary to install casing in portions of holes drilled for grouting in order to ensure the stability of the hole. Wherever possible, any casing that is installed for the purpose of keeping the grout hole open or for the grouting itself shall be removed immediately prior to or simultaneously with the grouting process. All casings shall be subject to the approval by the PMC.

11.3.2.2 For Drain Holes

- Drainage holes shall be drilled with percussion or rotary type drills or by other means approved by the PMC.
- Drain holes shall be drilled as shown on the Drawings or as directed.
- Drain hole diameter shall be NX (76 mm) or as shown in the Drawings or as approved by the PMC.
- 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 PMC where the geological conditions so require.
- Drain holes shall be drilled not sooner than seven (7) days after completion of all grouting which is within 20m of the drain holes to be drilled.
- Drain holes shall be cleaned with water.
- 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.
- Where directed by the PMC, slotted drain pipes shall be installed in the drain holes.

11.3.2.3 For Anchors or Rockbolts

The Contractor shall drill the hole according the specification Chapters 0251 and 0252.

Cap the hole until just prior to anchorage operations.

11.3.2.4 For Core Drilling

- The Contractor shall, where and as directed by the PMC, drill core holes, such as exploratory holes, check holes, instrument Installation holes, to determine the condition of the foundation rock or the effectiveness of the grouting operations or for any other purpose. Permeability testing may be carried out in these holes. The holes may be drilled at various specified inclinations between vertical and horizontal.
- All core drillings shall be performed with rotary-type hydraulic fed core-drilling equipment, using hole diameter of 56mm to 76mm (NX size) or approved equivalent size, bottom discharge diamond bits and double / triple core barrel. Holes will be required to be drilled to varying depths. The Contractor shall ensure that cores obtained are in as good a condition as possible from all holes.
- 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.

11.3.2.5 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 PMC. The log shall include at least the following data:

- Location and coordinates
- Borehole number
- Type and diameter of boring
- Ground level
- Iinitial, intermediate and equilibrium groundwater levels with times and dates; note on color and losses, etc.
- Description and state of weathering of rock and the levels of boundaries between different rock types
- Percentage of core recovery
- Fracture log
- The results and levels of all in-situ testing
- A record of the driller's observations on progress of boring, rate of penetration, type of bit and speed of rotation bit

- Water pressure test results
- Location of sample extraction (water / core material) for tests and change in strata
- Diameter of casing and depth to which taken
- Depth of termination of borehole

The Contractor shall inform the PMC as to all changes in drilling pressures, loss or gain of drill water, and all other pertinent data.

11.3.2.6 Logging and Preservation of Cores

- The Contractor shall provide the logging of core samples on an accepted form.
- The Contractor shall provide strong (wood or sheet metal) 1.05 m long core boxes to the approval by the PMC. Each box shall hold cores for 5 m length of hole and shall be provided with fastenable lids. All boxes shall be uniform in size.
- The Contractor shall space the core in the box in the correct sequence upon extraction from the core barrel. The core at the bottom of each lift shall immediately be marked as soon as 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. 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 PMC.
- Core shall be color photographed in the core boxes, one box per photograph, with labels clearly indicating the project name, drillhole number and initial and final depths of the drillhole covered by the core in each box.
- The Contractor shall supply all core boxes and core loss blocks, and they will become the property of the Owner when the core has been permanently placed therein. The Contractor shall furnish the labor and equipment to transport the filled core boxes from the drilling site to the approved storage area.
- Where directed by the PMC, the drilled holes shall be grouted in accordance with the requirements of Clause 3.4.

11.3.3 Flushing and Water Pressure Testing

- Immediately before grouting 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 PMC to be clean.
- Prior to grouting, the PMC may require the water pressure testing of a certain number of holes. Water pressure testing shall also be performed in exploratory holes when directed.

- The general procedure for water testing shall be as follows:
  - The length of the test section of hole shall be 5 m or as directed, 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.;
  - Water used shall be clean.
  - Water is to be pumped into the section and pressure adjusted by stage to reach the constant effective pressure.
  - 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 PMC when the pressure is not taken directly from the packer.
- When directed by the PMC, abbreviated water pressure tests will be performed in holes immediately before grouting. Abbreviated water pressure tests shall be performed as follows:
  - For any test section, the maximum water pressures shall be 10 bar in maximum or the same as the maximum pressure to be used for grouting that section or as specified by the PMC.
  - 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 PMC.
  - 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.
- For exploratory holes, check holes, instrument installation holes and when instructed by the PMC, comprehensive water pressure tests are to be performed. Water shall be pumped into the hole in three (3) incremental stages up to the pressure specified by the PMC and then reduced in the same stages to zero pressure. The pressure shall be maintained constant for five (5) minutes at the end of each pressure increment or decrement and the rate of flow shall be measured and recorded at one (1) minute intervals. The pressure at which flow commences on the incremental stage and the pressure at which flow stops on the decremental stage are to be carefully observed and recorded.
- The Contractor shall prepare daily water pressure testing records, on approved forms, of all water pressure testing carried out. For each test, information provided at least following subjects shall include:
  - Identification of the hole,
  - Level(s) of the packer(s),

- Level of water (if any) in the borehole before and after the test;
- Level of water (if any) above the packer during the test;
- Level of pressure gauge;
- Head loss between the pressure gauge and the tested section (in pipes, tees, bends, joints, valves);
- Pressure measured at the collar of the hole;
- The volume of water injected at each pressure stage and the total quantity of water injected;
- Duration of each pressure stage of the test;
- Any observed flow from adjacent holes, joints or other openings, and
- Test results by Lugeon values.

11.3.4 Grouting

11.3.4.1 General

- Grouting pressures, pumping rates and sequence in which holes are quoted will be determined in the field and shall be agreed with the PMC. Careful control of pressures will be required during grouting as excessive local pressures could crack or buckle the concrete or steel linings or hydrofracture the rock.
- Grouting shall be performed in stages of 5m, if not otherwise specified by the PMC, and using packers to seal the borehole for each stage. It is expected that the grouting will be done mostly from the bottom to the top of the boreholes, i.e. upstage method; however, other cases may require special procedures.
- Different grouting pressures will be applied for different sections in most of the grout holes. After fixing the packers in their respective positions, the borehole shall be water pressure tested and grouted starting with a rate to be indicated by the PMC.
- Grouting shall conclude with the minimum allowance rate which shall not exceed about 1 lit/min/stage. Upon completion, the packer shall remain in place until there is no back pressure. Unless otherwise specified by the PMC grouting of holes shall continue without interruption.
- Grouting in the gallery, packer shall be set in the lining concrete for the first (shallowest) stage of the holes.
- Immediately before the start of grouting, the holes shall be thoroughly washed under pressure, then, water pressure test should be done if needed. 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.

- Any damage due to exceeding the allowable pressure shall be the direct responsibility of the Contractor who shall effect for the repair deemed necessary at his own expense. The same is applicable for damages caused by force.
- The PMC has the right to prohibit the start of grouting work or to stop it completely. The Contractor has no right to claim in case of malfunctioning of the pressure and grout rate control which produce unsatisfactory results.
- Except annulus grouting, no grouting shall be carried out within 20m of the end of an incomplete section of concrete works nor within 20m of any concrete less than twenty eight (28) days old.
- 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 fixed in laboratory by setting time tests for each mix type. Grout having remained longer time in tanks, pumps or pipes shall be discarded.
- After completion of grouting works for each hole, the hole should be filled thoroughly by grout.
- Records of grouting works shall be submitted daily to the PMC 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.

11.3.4.2 Surface Leaks and Inter-hole Connections

If during the grouting works, grout is found to flow from adjacent grout holes, such holes shall be capped temporarily. If grout is found to flow from any part of structures, such leaks shall be plugged by the Contractor as directed. In the case that grout flows between adjacent boreholes, the affected boreholes shall be thoroughly cleaned before the grout has set in order to ensurevproper subsequent grouting of such hole.

11.3.4.3 Cavity Grouting

- Cavity grouting should be done through drilling holes or steel grout pipes embedded in the concrete at crown of tunnel lining or plug concrete, or at closed space left between steel liner and second stage concrete.
- 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 PMC.
- Low pressure cavity grouting shall be carried out to ensure that all voids be filled between the concrete lining and rock surface, liner plates or lagging.
- The concrete lining shall have been poured at least 30 consecutive days prior to commencement of grouting.

- Mortar and grout shall be placed at low pressures not exceeding 0.2MPa for each section, if notbotherwise directed by the PMC. No pressure washing or testing will be required prior to injecting grout.
- Unless otherwise directed by the PMC, a sanded mortar grout shall be used. The amount of sand used in the mix shall be as directed by the PMC. The grouting of any hole shall not be considered complete until in the opinion of the PMC all voids have been filled to the maximum extent practicable. Vent pipes for the release of air and water during grouting of crown overbreak cavities which cannot be filled with concrete shall be provided as indicated.
- Unless otherwise directed by the PMC, after the completion of the grouting of any hole the pressure shall be maintained by means of a stopcock or other suitable device until the grout has set to the extent that it will be retained in the hole.
- After completion of grouting, all grout pipe heads shall be plugged with hard mix mortar to make smooth surface.

11.3.4.4 Consolidation Grouting for Main Dam Foundation

- The rock surrounding the borehole may be consolidated by grouting in order to seal defects caused by blasting, excavations or to seal and homogenize fissured and fractured rock.
- The consolidation grouting should be done generally by upstage method, or directed by the PMC. The maximum grouting pressure shall be 1.5 to 3 bar for the first stage (shallowest stage) and 3 to 15 bar for other deeper stages, or directed by the PMC.
- Immediately before the injection of grout into any hole, the hole shall be thoroughly washed under pressure and pressure-tested as directed by the PMC.
- All intersected rock crevices, seams or faults containing clay or other washable materials shall be completely washed with water and air under pressure to remove as much of such materials as possible. Such materials shall be ejected from one or more holes by pressing water into an adjacent hole.
- In the case that grout cap concrete, such as lean concrete, dental concrete, will be available, drilling for the consolidation grouting shall be done from such concrete surfaces in general. Then, the grouting packer should be set in the concrete. If the areas are not covered by such concretes, the packer should be set at the surface rock zone within 30cm in depth.
- In general, if the foregoing test indicates a tight hole, grouting shall be started with a thin mixture; if an open hole condition exists, the water / cement ratio shall be reduced accordingly and, with the grout-pump operation as nearly as practicable at constant speed at all times, the ratio shall be reduced further, if necessary, until the required pressure has been reached.

- Should the pressure rise too high, as determined by the PMC, the water / cement ratio shall be increased as directed.
- If, due to the size and continuity of openings, the desired results are not obtained with the thickest pumpable mix, grouting in the hole shall be discontinued, when so directed by the PMC. In such event, the hole shall be cleaned, the grout allowed to set and additional drilling and grouting shall be done in this hole or in the adjacent area, as directed, until the desired resistance is built up.
- The grouting of any holes shall be continued until the hole or grout connection takes grout at a rate of less than 1 lit/min/stage of the grout mixture.
- So far as practicable, the full grouting pressure shall be maintained constantly during grout injections. However, so as to avoid a risk of rock or concrete displacement or while grout leaks are being caulked, the PMC may require the reduction of the pumping pressure or the suspension of pumping.
- After the grouting of the holes or connections is completed, the pressures 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.
- Any faulty stage or zone shall be re-grouted with grout which may differ from that originally used until a satisfactory result is obtained or, if this is unattainable, the depth concerned shall be grouted using immediately adjacent holes a satisfactory result is obtained in the original hole. Grouting of a hole shall not be considered as complete until approved by the PMC. The completed hole shall then be filled with thick grout.

11.3.4.5 Consolidation Grouting around Tunnels

11.3.4.5.1 For the tunnel galleries:

Pressure grouting around the tunnel lining shall be performed after completion of the cavity grouting as follows or directed by the PMC:

- Holes shall be drilled in each case to a depth of 5m or more into rock as shown in the Drawings,
- 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 PMC. The maximum grout pressure at bottom of the pressure shaft will be lower than 4MPa,
- Before grouting, abbreviated water pressure test shall be done.

11.3.4.5.2 For the plug section of diversion tunnel:

The same manners for the curtain grouting mentioned in Sub-Clause 3.4.8 shall be applied. The consolidation grouting shall be done after completion of the cavity grouting. Grouting pressure will be lower than 4MPa, as directed by the PMC.

11.3.4.5.3 For the flushing tunnels:

Pressure grouting around the tunnel lining shall be performed after completion of the cavity grouting as follows or directed by the PMC:

- 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 10 bars;
- The holes shall then be drilled to a depth of 8m and grouted up to a maximum pressure of 15 bars with a packer at a depth of 3m.

11.3.4.6 Contact Grouting for Construction Joints of Concrete

- Contact grouting shall be carried out behind the tunnel plugs after the plug concrete reaches stable temperature. Grout shall be injected into the spaces between the plug concrete and the tunnel lining or concrete construction joints through grout piping system to be embedded in the plug concrete.
- Piping system for contact grouting shall consist of supply headers, return headers, washing headers, vent headers and vent return headers, all being steel pipes of more than 38mm in diameter, and of steel riser pipes of more than 19mm in diameter which connect supply headers to grout outlets and vent headers to air grooves. Valves shall be attached at the ends of all headers.
- Both upstream and downstream ends of the plug shall be sealed by water stop to prevent grout leak.
- Grout outlets of the approved type shall be set on the inner face of the tunnel lining at the middle of each lift height at the 2m horizontal intervals at the maximum.
- At the crown of the tunnel section, air vent shall be provided at the maximum 2m horizontal intervals. The air vent with groove shall consist of a offset pipe of more than 19 mm in diameter branched from air vent pipe which has a bevel end to be inserted in a 250mm deep drilled hole with loose paper wadding at the mouth of the hole.
- All grout system to be embedded such as pipes, grout outlets and air vents, etc. shall be firmly set in the proper positions to prevent from its breaking or damage due to the pressure of the plug concrete placement.
- Prior to the concrete placement, all piping system shall be cleaned inside and outside free from any objectionable materials in a manner satisfactory to the PMC. Prior to the grouting, all pipes and openings along the contact surface shall be thoroughly washed with clean water injected first through washing header and then

through supply header under a pressure not more than the allowable maximum pressure of the grouting.

- Allowable maximum pressure of the contact grouting is provisionally specified at 600 kPa which may be adjusted by the PMC taking into account the effectiveness of the grout at Site.
- The pressurized water shall be kept in the pipes and if leakage of water is found on the surface of the plug or any other locations, it shall be caulked effectively in a manner satisfactory to the PMC. The water in the piping system shall be drained off before grouting is commenced.
- Grout shall be a neat cement grout, unless otherwise approved, consisting of cement and water in proportion directed or approved by the PMC. The changing manual of cement/water ratio of the grout shall be directed by the PMC. Cool water shall be used to prevent quick setting of the grout.
- Grout for contact grouting shall be injected through the supply header. When the injected grout leaks from the end of the return header or washing header, the valve attached to the header shall be closed and the grouting shall be continued for ten (10) minutes after the injection rate has decreased to zero under the allowable maximum pressure of the grouting, then the valve of supply header shall be closed.
- Not later than sixty (60) days before placing each concrete plug, the Contractor shall submit to the PMC for his approval method statement for contact grouting of the plug concrete.

11.3.4.7 Contact Grouting behind Steel Linings

- Steel linings of waterways embedded in concrete shall provide with standard threaded holes of which locations are indicated on the Drawings. The Contractor shall screw connecting pipes and grout the contact between steel and concrete to a pressure specified by the PMC.
- A knocking test jointly undertaken by the PMC and the Contractor may be performed to locate voids where additional holes shall be drilled, threaded and supplied with plugs, all at the expense of the steel liner supplier. The Contractor shall then grout through such holes until the knocking sound of the hammer at the lining produces a solid uniform sound everywhere.
- After completion of this grouting as shown or directed, the Contractor shall drill holes into the contact zone between rock and the backfill concrete using the hole provided in the steel lining and grout this zone with cement mortar or cement suspension until this contact is sealed satisfactorily.
- If required, the drilled holes shall be further extended into the surrounding rock as shown or directed by the PMC and grouting shall be done after washing and testing the holes; this washing and testing should be carried out in sections not longer than

4m at a time. Shorter sections shall be used if drilling water does not return. In this case, the drill hole shall be grouted at the depth reached.

- Water tests indicating a loss of water of more than 1 liter per minute shall be cause to grout such section, unless otherwise ordered by the PMC. During grouting of such areas, ungrouted sections shall be protected by packers left in position.
- The grout injection pressure shall be built up gradually by thickening the mix, but if pressure builds up rapidly, the consistency shall be thinned immediately in order to avoid plugging. In no case shall the pressure of the contact grouting exceeds 0.5 bar.
- The Contractor shall then fill the hole with grout, clear the threaded holes in the steel lining and screw the standard plugs back into position.

Sub-curtain Grouting and Curtain Grouting for Main Dam Foundation

- The curtain grouting shall be performed after completion of the sub-curtain grouting. The same work manner mentioned below shall be applied for both sub-curtain grouting and curtain grouting.
- The general purpose of curtain grouting is to achieve a permeability criterion of 2 to 5 Lugeon units. During execution of the Works, the PMC shall determine the admissible values of Lugeon unit for specific areas, which are above or below 2 to 5 Lugeon units. The proposed Lugeon criteria at different depths and the built up of the grouting curtain will be as shown on the Drawings or as directed by the PMC and shall be measured from the final foundation level.
- The grouting procedure will be concurrently adapted to the results of the test fields and to observations made during the curtain grouting itself.
- Initial details of suitable borehole directions, spacing, row distance, inclination and depth of curtain grout holes will be determined during performance of grouting tests at locations as indicated on the Drawings, or as directed by the PMC.
- Curtain grouting of any portion of the foundations shall be carried out using the following criteria, unless otherwise directed by the PMC.
  - 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 PMC. 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 PMC.
  - Grouting shall be carried out in stages adapted to properties of the rock (jointing, etc.) and the grout to be used, but the stages shall not be exceed 5m (except as allowed below) and shall be performed using the upstage method except

where the PMC determines that the downstage method is necessary for satisfactory grouting.

- Packer shall be set in the concrete lining for the first stage (shallowest stage) of the hole.
- In downstage grouting, sufficient time shall be allowed for the grout to set before the next stage is commenced.
- The water pressure test shall, where directed by the PMC, be carried out in stages before grouting. Permeability shall be measured in Lugeon units at the point 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 PMC.
- The grouting of each stage shall commence with a lean 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.
- Unless otherwise directed by the PMC, hydro-jacking shall be avoided. The maximum grouting pressure shall be 10 bar for the first stage and 10 to 20 bar for other deeper stages.
- 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.
- The PMC may instruct, as an alternative to changing the grout type, the technique of hydrojacking to be adopted to increase the spread of the grout. The maximum grout pressure may be increased providing that surface heave is avoided. The hydrojacking technique shall not be used in holes under or adjacent to concrete structures.
- 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 PMC 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.
- 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 PMC 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.

- Grouting of a hole shall not be considered as complete until approved by the PMC. The completed hole shall then be filled with thick grout.

11.3.4.8 Curtain Grouting Around Tunnels

The curtain grouting shall be performed after completion of the consolidation grouting for both tunnels.

11.3.4.8.1 For Diversion Tunnel

The same manners for the curtain grouting mentioned in Sub-Clause 3.4.8 shall be applied.

11.3.4.8.2 For Flushing Tunnels

Pressure grouting of the grout curtain shall be performed as follows or directed by the PMC:

- The 1st stage, i.e. 0-5m stage, shall be done by downstage grouting. Holes shall be drilled in each case to a depth of 5m into rock, and packer shall be set in the concrete lining, then grouted at that depth up to a maximum pressure of 10 to 15 bar.
- The holes shall then be drilled to a depth of 20m and grouted by upstage grouting up to a maximum pressure of 15 to 20 bar. The grouting stage length shall be 5m in maximum.

The same manners for the curtain grouting mentioned in Sub-Clause 3.4.8 shall be applied in principle.

11.3.5 Restoration And Cleen-up of Surfaces

- 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 PMC.
- 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.

- If any hole shows signs of weeping water after being stemmed the hole shall be drilled out, regrouted and re-stemmed without any additional payment.
- Except otherwise requested by the PMC, 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.

11.3.6 Check Holes

- 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 PMC.
- Cored check holes to check the effectiveness of grouting operations shall be drilled as required by the PMC 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.
- Except as otherwise required by the PMC, check holes shall be grouted by the same manners as for the grouting holes, to the same requirements as the original holes.

11.3.7 Records of Grouting Works

Records of grouting work to be prepared by the Contractor shall include at least the following:

- Type of grouting operation (such as curtain, foundation, tunnel lining, anchor, slope stabilization or other);
- Location, depth and orientation of holes and hole identification;
- Packer position and length of stage;
- Date and time of drilling;
- Date and time of grouting;
- Grout pressure (plot of recorder);
- Grout take (plot of recorder);
- Grout mix;
- Observations, e.g. connections to adjacent grout holes.

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

11.3.8 Borehole Deviation Tolerance

Holes to be specified by the PMC shall be sounded to their alignment at 5m intervals with a multishot 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.

11.3.9 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 PMC, 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:

- All transportation of equipment to and from Site and any shifting of the same from one place of operation to another;
- Orderly disposal of any debris or spoil resulting from drilling, grouting or testing operations;
- Supply of all flushing or other water at the working area and removal of surface water encountered at the place of operation;
- All plant and equipment required for the adequate performance of the works;
- Liighting of the working area, as necessary;
- All equipment for communication between the mixing plant and the location of grouting activities.

Chapter 0241
12 COLUMN JET GROUTING (CJG)

12.1 GENERAL

12.1.1 Scope

This Chapter covers the requirements for the mainly following items of work for the foundation treatment works by the Column Jet Grouting (CJG) method under the Contract, but not limited to, the works, as instructed by the PMC. CJG is a process of improving the foundation of the upstream starter dam by cutting it with high pressure jet(s) and mixing and replacing the resulting slurry with cement grout:

- Execution of column jet grouting trial,
- Execution of main column jet grouting,
- Coring and Standard Penetration Test (STP), and
- Control of ground and utility movements.

12.1.2 Related Works / Sections

Chapter 0211	Dewatering and Care of Water
Chapter 0212	River Diversion
Chapter 0220	Surface Excavation
Chapter 0240	Drilling and Grouting
Chapter 0260	Drainage of Structures
Chapter 0430	Conventional Concrete (CVC)

12.1.3 Definitions

The objective of the column jet grouting is to improve the soil mass by using a tool equipped with one or more high pressure jets to erode and hydraulically excavate soils, while mixing cement grout with the insitu soils, creating soil-cement columns or soil-cement panels.

12.1.4 Codes and Standards

The Contractor shall comply with the requirements of BS EN 12716 – Execution of Special Geotechnical Works – Jet Grouting.

The CJG mentioned in this Chapter applies to mass treatment for the sand and gravel layer of river deposit to meet the strength and stiffness criteria. If it is used for other applications, the Contractor shall apply relevant codes to the acceptance of the PMC.

The following table lists the Standards and Specifications of the American Society for Testing and Materials (ASTM). These or similar Standards and Specifications in

internationally recognized, such as International Society for Rock Mechanics (ISRM), shall be used.

ASTM D 2113- 08	Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation
ASTM D 4220	Standard Practice for Preserving and Transporting Soil Samples
ASTM C 33	Specification for Concrete Aggregates
ASTM C 109	Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2 in. or 50 mm Cube Specimens)
ASTM C1 50	Specification for Portland Cement

12.1.5 Quality assurance

12.1.5.1 Experience, Skilled staff

- The Contractor shall satisfy the PMC that he is experienced in drilling and grouting, that he has previously successfully carried out similar work of comparable magnitude and that he possesses the necessary equipment and skilled staff; otherwise, the Contractor shall employ an experienced specialist sub-contractor to carry out the drilling and grouting work.
- The Contractor shall provide an engineer with not less than fifteen years' experience in drilling and grouting to supervise the work, together with foremen with not less than ten (10) years similar experience.

12.1.5.2 Quality Control of Materials

- The cement used for injection shall be tested as specified in Chapter 0430: Conventional Concrete (CVC).
- The following checks shall be carried out for each delivery of bentonite:
  - Plasticity index.
  - 50-micron sieve passing.
  - Cement compatibility (28-day grout strength).

12.1.5.3 Tests for Grout

- The PMC may direct that tests on proposed grout mixes be performed in the laboratory to demonstrate the grout properties, prior to grouting. Grout samples shall be obtained during grouting, for testing in the laboratory. Grout sampling will be on at least a daily frequency at the start of grouting, but may be less frequent when consistent, adequate quality of grout is demonstrated. The PMC may direct that changes be made to the grout mix, based on the results of sample testing.

- The Contractor shall make six (6) - 50 mm grout cubes per test. These cubes shall be compression tested at the Site laboratory to determine the rate of gain of strength of the grout. Sampling and testing of grout shall be in conformance with ASTM C109.
- The Contractor shall perform the following routine tests during the course of the work to confirm that the grout meets and continues to meet the requested characteristics:

Test	Frequency (Linear m of hole)
Time of setting (ASTM C191)	1 test per 500 m (at least twice per month and per type of grout)
Compressive strength (ASTM C109)	1 test per 500 m (at least twice per month and per type of grout)
Bleed and expansion (CSA 23.2-1B)	Once per day and per type of grout
Viscosity (CSA 23.2-1B)	Once per day and per type of grout
Density	Once per day and per type of grout
Particle size analysis (ASTM D422)	1 test per cubic meter of sand used in the grout

- The Contractor shall prepare on approved forms records of these tests, which shall be submitted to the PMC on a daily basis.
- During the grouting, the Contractor shall control permanently the pressure and record any variation.

12.1.6 Submittals and Approvals

- At least fifty six (56) days prior to the CJG works, he Contractor shall submit a detailed method statement for the grouting works. It shall include the minimum information required in BS EN12716. The method statement shall also include:
  - The target strength and stiffness of the piles,
  - Ground movement monitoring plans, and
  - Proposals for a CJG trial including the location and monitoring of the trial.
- The method statement shall be reviewed in the light of the results of the trial and if necessary resubmitted for the acceptance of the PMC prior to the commencement of the main CJG works.
- At least twenty eight (28) days prior to the scheduled date of commencement, the Contractor shall submit for approval Quality assurance manual detailing the measures proposed to ensure the specified quality, including control and tests.
- Field progress records for all grouting work shall be submitted at the end of each shift, giving the data as described in Clause 3.6.
- Records of grout tests described in Clause 1.5.2 shall be submitted to the PMC with forty eight (48) hours of testing.

- Fifty six (56) days after the end of each section of work defined by Clause 1.1 above, the Contractor shall submit to the PMC quality control reports.

12.2 MATERIALS

12.2.1 Cement

Cement used in grout shall be Portland cement as specified for concrete in Chapter 0430.

12.2.2 Water

Water for grout mixtures shall comply with the requirements for mixing water for concrete which are given in Chapter 0430.

12.2.3 Sand

Sand shall conform to ASTM-C33, "Specification for Concrete Aggregates", as to the quality. The fineness of the sand required for grouting shall be as follows: 100% shall pass a U.S. Standard No.16 sieve size, not less than 10% nor more than 30% shall pass the No.100 sieve size, and not more than 5% shall pass the No.200 sieve size.

12.2.4 Admixtures

The use of commercially available admixtures such as expanding and retarding agents will be subject to approval by the PMC. They shall comply with the specifications given in Chapter 0430.

In support of the request for the use of an admixture, the Contractor shall submit the results of relevant laboratory tests demonstrating the effectiveness and advantages of the product. Products whose chemical composition is not known to the PMC will not be approved for use in grout.

12.2.5 Bentonite

- Bentonite to be used in grouting work shall not contain anything capable of inhibiting cement setting and particles exceeding 80 microns.
- Bentonite shall have a Plasticity Index greater than 400%.
- Bentonite shall be delivered in bags which shall be stocked in accordance with the provisions laid down for cement (Chapter 0430).

12.2.6 Chemical Products

Chemical products like silicate gels, organic resins or soda silicates could be used if necessary and accepted by the PMC.

12.2.7 Grout Mixes

12.2.7.1 Composition

- Proportions of materials used in grout mixtures and any adjustments thereto during grouting operations shall be only as approved by the PMC. Proportions shall be varied to suit actual conditions encountered at Site.
- Where bentonite is required in the mix, the bentonite shall be mixed with water to make slurry prior to the addition of cement.
- The grout mix design process for each kind of grouting work shall include the following tests, as described in Clause 1.5.3:
  - Settling measured as the ratio between the volume of water appearing above the grout and the total volume in a 1 liter, 6 cm dia test tube, after 20, 40, 60, 80, 100 and 120 minutes and after setting.
  - Setting time.
  - Viscosity with standard Marsh cone (4.75 mm dia) (API 13.B).
  - Density.
  - Flexural and uniaxial compressive strength at 28 days on 4x4x16 specimen (NF P 15-413).
  - Compatibility between the various components.
- Trial mixes shall be produced by site mixers and using the same materials as those which will actually be used on site.
- The composition of the grout shall be adjusted depending on the actual conditions encountered.
- Grout mixes shall be stable grout mixes.

12.2.7.2 Criteria

- Settling time less than 24 hours.
- Settling after 2 hours lower than 5%.
- Viscosity: to be adjusted for each specific work within the range 30-50s, with a tolerance on the specified viscosity of + or - 5 s.
- Uniaxial compressive strength after 28 days:
  - Contact and consolidation grouting, cavity grouting, steel linings and embedded items injections: >5 MPa.
  - Others works (curtain grouting): >2MPa.

12.3 EXECUTION

12.3.1 Equipment

12.3.1.1 Drilling Equipment

- All drilling equipment shall be subject to the PMC's approval. It must be suitable for operation on open-air as well as in underground location, in any direction.
- Rotary and 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 shall be used only for open-air operation. When coring is not required, rotor-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.
- 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.

12.3.1.2 Grouting Equipment

- 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 PMC, 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. Automatic recorders for pressure and volume of grout are required for all types of grouting works to be carried out.
- The mixing and pumping equipment shall be installed in one or two central stations to enable continuous, undisturbed work, independent of weather conditions and to guarantee a constant mixture as required.
- For the grouting operations underneath the dam or in underground works, reliable telephone communication between the main working stations and the central grout mix and pump stations is required.
- 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.
- 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.

12.3.1.3 Drilling and Grouting

- The drilling and grouting plant shall be equipped with automatic, data logger collection system(s) to allow the operating parameters to be checked and recorded continuously during drilling and grouting operation.
- All the measuring devices shall be calibrated before the start of the work, and the records of the calibration submitted to the PMC.
- Materials used as a flushing medium for drilling or as part of the grout mix shall be non-toxic and subject to the acceptance of the PMC.
- Materials data sheets for each material shall be submitted to the PMC for acceptance.
- All drilling and grouting effluent shall be collected in trenches, pits or tanks and not allowed to spread over or outside the Site. Measures shall be taken to ensure that the effluent cannot enter the Indus River.
- All effluent shall be removed from the Site and disposed of in accordance with the regulations.

12.3.1.4 Column Jet Grouting Trial

- Before carrying out the proposed main CJG, the Contractor shall carry out a CJG trial to demonstrate the suitability of the proposed method. This shall be carried out in full accordance with the Contractor's method statement.
- One (1) minimum trial test shall be carried out at the Site for the sand and gravel layer. The trial CJG shall consist of a minimum of six (6) overlapping columns formed at the depth and in similar ground conditions as the proposed CJG.
- The effectiveness of the trial grouting shall be demonstrated with a minimum of four (4) boreholes used to obtain cores through the full depth of the grouted block. Of the four (4) boreholes, one (1) shall be targeted at the centre of a pile, one (1) at a point two third (2/3) of a pile radius from the centre, and the remaining two (2) at the overlapping areas of the piles. The cores shall be fully logged and shall be tested for strength and stiffness. A minimum of three (3) samples shall be taken from top and middle and bottom of each core for strength and stiffness testing.
- If Total Core Recovery (TCR) fails to achieve 85% or any of the strength or stiffness tests fail the target value, the CJG trial is deemed to fail, further trial(s) with more conservative operation parameters shall be carried out.
- A minimum of three (3) Standard Penetration Tests (SPT) at the overlapping areas of the piles shall be carried out at each borehole. The strength and stiffness test results shall be used to correlate with SPT values. The correlation shall be agreed with the PMC, and used only as supplementary to the more direct TCR, strength and stiffness tests for the subsequent quality control.

- A grid of settlement/heave monitoring points shall be established over the trial area, at a spacing of not greater than 5m. The foundations and the utilities within a distance of 1.5 times the maximum depth of grouting shall also be monitored for movement. All points shall be monitored at least twice per day when drilling or grouting work is in progress.
- The Contractor shall submit the results of the trial CJG to the PMC, together with an interpretative report assessing the results of the trial and proposing any necessary changes to his method statement.

12.3.2 Quality Control of CJG Works

- The operating parameters shall be checked and recorded continuously by the automatic, data logger collection system(s), which shall include the following as a minimum:
  - All fluids (pressure, flow rate) being injected at any time including air, water and grout,
  - All pressure gauges in hydraulic oil lines to quantify a "specific drilling energy" from the rig power unit. Parameters are to include torque and thrust (down),
  - Drilling head, including rotation speed, depth, lifting speed, and mast inclination mounted on the drilling head, and
  - Drill string, including borehole deviation to clearly demonstrate the borehole orientation/inclination at all depths (horizontal location and inclination).
- The continuously recorded data shall be monitored by suitably qualified personnel who shall take necessary action should any data falls below the designed working parameters.
- Recorded data shall be provided to the PMC in both hardcopy and electronic format compatible with Microsoft Excel. The format shall be agreed upon and approved by the PMC before commencement of the works. The recorded data shall be submitted to the PMC within twenty four (24) hours after the completion of each JGP.
- The grout mix shall be checked by measuring the specific gravity using a mud balance. This shall be done at random, but not less than twice a day per rig.
- The specific gravity and viscosity of the effluent return shall be checked using mud balance and Marsh cone. This shall be done at least once per pile, during grouting.
- The quality of CJG shall be confirmed by SPT and coring.
- There shall be eight (8) boreholes for each 1,000m³ (rounded up to the nearest whole number of boreholes) of treated soil. The boreholes shall be at the overlapping area of the piles. In each borehole, SPT shall be done at the top, middle and bottom of the treated zone. SPT may be replaced by Cone penetration tests to the acceptance of the PMC.

- There shall be four (4) numbers of coring through the full depth of the piles for each 1,000m³ (rounded up to the nearest whole number of cored holes) of treated soil. The cores shall be taken from the overlapping areas of the piles.
- The cores shall not be less than 50mm in diameter. The quality of the CJG shall be determined from TCR and the strength and stiffness of the recovered core. TCR shall not be less than 85%. Where TCR is found to be less than 85%, two (2) additional cores to the adjacent JGP shall be carried by the Contractor. In the event that either of the additional coring fails to conform to the requirements, CJG work is deemed to have failed.
- A minimum of three (3) samples shall be taken from top and middle and bottom of each core for strength and stiffness testing. The selection of coring locations shall be determined by the PMC.
- The strength and stiffness shall comply with the minimum requirements specified in the design. The cored holes shall be backfilled by cement bentonite grout. If either of the strength or stiffness test fails to achieve its target value, two (2) additional samples in the same core shall be tested for strength and stiffness by the Cıntractor. In the event that either of the additional samples fails to conform to the requirement, CJG work is deemed to have failed.
- If CJG work is deemed to have failed, the Contractor shall propose remedial measures to the acceptance of the PMC. The Contractor shall re-assess the design parameters of JGP and carry out the design checks to evaluate his original design to the acceptance of the PMC.
- The quality, strength and stiffness of JGP will have a major impact on the overall behavior of the temporary works, especially in the case of sacrificial JGP layers. All data relating to JGP quality tests shall be assessed by the Contractor responsible for the design of temporary works. The Contractor shall ensure that the upper bound and lower bound values of the strength and stiffness of the as built JGP have been catered for in his original design.
- The Contractor shall submit a full report on the testing results, including his assessment of the results and any proposals for remedial work, to the PMC.

12.3.3 Control of Ground and Utility Movements

- The Contractor shall propose measures to control ground movements during CJG works.
- Unless accepted otherwise by the PMC, the following measures to control ground movements shall be implemented, as a minimum requirement:
  - Minimize the angle of inclination of the grout monitor, as far as is practical,
  - Use a casing of not less than 200mm diameter during grouting,

- Ensure that the lower end of the casing is no higher than 3.5m above the lowest grouting jet during grouting,
- Pre-cut the Jet Grout column with water jetting, and
- Ensure that there is a free flow of effluent at all times.

- The empty bore above JGP shall be filled with grout during the extraction of the grouting monitor.
- The Contractor shall immediately cease CJG works when settlement or heave trigger levels are exceeded at any monitoring point, or there is any visible damage to foundation or utilities, during CJG works. He shall not recommence CJG work until he has proposed additional measures to control the ground movements.

12.3.4 Records of CJG Works

- A record sheet shall be made for every jet grout pile installed. This record sheet shall include:
  - Reduced levels for the ground level, the top and base of the pile,
  - Inclination of the pile,
  - Operating parameters as used for the pile installation,
  - Details of casing size and length,
  - Length of drilling,
  - Type of flushing medium,
  - Duration and timing of each major activity,
  - Ttotal materials used, for example, Delivery Order, and
  - Observations on slurry return, breakdowns, interruptions during drilling or grouting and any other relevant events
- The format of records shall be submitted by the Contractor to the acceptance of the PMC prior to the commencement of works at the Site.
- At the completion of CJG, a summary report shall be submitted to the PMC. This report shall provide:
  - As-built drawings showing the layout, inclination and installed depth of each Jet Grout Piles (JGP),
  - The results of all site investigation carried out related to CJG works,
  - The location and final values of all monitoring carried out during and after CJG works, and
  - The results of the quality control testing carried out at the Site.

Chapter 0250

13 STEEL ARCHES AND FRAMES

13.1 GENERAL

13.1.1 Scope

This Chapter covers the requirements for the steel arches and frames required as underground rock supports for construction of tunnels, shafts and caverns.

However, the Contractor is encouraged to propose in his bid the use of lattice girders in lieu of the steel arches and frames to ensure earlier effectuation of rock support than the steel arches and frame. The proposed type and size of lattice girders will be taken into consideration for final design of lattice girders to be incorporated in actual construction.

13.1.2 Related Works / Sections

Chapter 0230	Underground excavations
Chapter 0232	Ventilation and Lighting for Underground Works
Chapter 0431	Shotcrete
Chapter 0420	Reinforcing Steel

13.1.3 Definitions

Steel arches and frames shall be supplied together with any accessories necessary for assembling the supports including wall plates or lagging, footbeams, footplates, distance bars, and other structural steel members, and with such bolts, nuts and tie rods and other accessories as are necessary to provide a fully effective installation.

Lattice girder is a three-cord lattice having an isosceles triangular section with a larger diameter steel bar at the apex and two smaller diameter bars at the base corners. Those bars are separated by small diameter sinusoidally or diagonally bent bars that are welded at each node to main bars. Entire girder is curve to fit the tunnel excavation arch face. The girders can be jointed in tunnel to make full length girders. A four-cord lattice is used infrequently. Reinforcing steel bars conforming to the requirements in Chapter 0420 can be used as lattice girder bars.

13.1.4 Codes and Standards

ASTM A36M	Standard Specifications of Carbon Structural Steel
BS 4360	Specification for Weldable Structural Steels

13.1.5 Quality Insurance

13.1.5.1 Tolerances

The intrados line of the steel arches and frames to be kept in concrete lining shall not be more than 150mm inside the "A-line" of the excavation profile.

13.1.6 Submittals and Approvals

Not later than fifty five (45) days prior to commencement of the underground works, the Contractor shall submit to the PMC for approval of the characteristics of the steel arches and frames together with the drawings showing full details of the typical steel rib supports and laggings that the Contractor proposes to fabricate and use to support rock faces exposed by underground excavations and the overall methods regarding the underground excavation in unstable conditions.

In case that the lattice girders as rock supports proposed in the Contractor's bid has been evaluated to be advantageous in the opinion of the PMC, the Contractor will be requested to submit, within three (3) months after the request, the following for the PMC's approval:

- Type, shape, size and materials of lattice girders to be used
- Manufacturing method and manufacturing place of lattice girders
- Name of experienced manufacturer to be employed by the Contractor for lattice girder manufacturing (or name of experienced personnel of the Contractor with list of his experience)
- Proposed relationship between rock classes and lattice girder sizes in different tunnel sections based on the calculations or experiences
- Proposed method of initial trial test to demonstrate applicability of lattice girders
- Proposed method of quality control of lattice girder manufacture and installation

In case that all submissions are satisfactory to the PMC to guarantee the quality of the lattice girders, the steel arches and frames will be replaced partly or fully with the lattice girders.

Any material delivered at the Site without prior approval of the PMC shall not be accepted.

13.2 MATERIALS

Steel and Steel Sections

- Steel arches and frames shall be of rolled H-shape profiles with the dimensions shown on the Drawings or other different shape approved by the PMC. The steel materials shall comply with the requirements of ASTM A36M or other equivalent standard.
- Bolts for connecting the steel arches and frames shall be of high strength type complying with ASTM A325 Type 2.
- Steel lagging shall consist of standard steel shapes having a thickness ranging from 2 to 5mm, and width ranging from 20 to 35cm, complying with ASTM A 283, Grade C.

13.2.1 Supply of Arches

The quantity of steel arches delivered to Site and kept in the storage depot, shall be based on the expected distribution of ground conditions requiring arches, as shown on the Drawings, and the Contractor's anticipated rate of advance in these areas with due allowance for normal delivery periods as agreed with the PMC prior to ordering these materials.

13.3 EXEXUTION

13.3.1 Location

The Contractor shall install such steel rib supports as are necessary for the safety of the work.

The Contractor shall obtain on the presentation of the evidence that rock bolts alone would not provide the necessary support the prior approval of the PMC before installing steel rib supports and lagging.

For emergencies, the Contractor shall install the steel rib support and shall inform the PMC as soon as possible.

13.3.2 Shapes of Steel Arches and Frames

The steel arches and frames shall be unpainted and delivered to Site pre-shaped, such that the outside profile of each arch or frame is shaped to a dimension greater than the dimensions of the theoretical excavation profile so as to allow for inaccuracies of installation without affecting the dimensions of the final lining. The extent of this enlarged dimension shall be decided by the Contractor after discussion with the PMC. Changes to the shape of any arch or frame on Site shall only be carried out with the agreement and approval of the PMC. Any method used to achieve the desired shape and which may cause deterioration of the steel in the arch or frame shall not be allowed, e.g. bending after heating.

13.3.3 Fitting for Steel Arches and Frames

Steel arches and frames shall be fitted with footing plates and long splice-plates, both of which shall meet the structural needs of the steel sections and location of installation. Arches and frames shall be fastened together with distance bars immediately after erection. If necessary adjacent arches and frames shall be cross-braced with flat bars or sections or arch profile which shall be welded on.

Where invert struts are required, they shall be fastened or bolted securely to the lower legs of the steel arch sections. The connections shall be designed in such a way that buckling is not induced in the arches by the presence of the invert struts.

Steel supports, which are not placed or erected satisfactorily shall be altered or replaced will not be accepted by the PMC.

13.3.4 Installation of Steel Arches and Frames

Where steel arches are to be used with footing plates and no invert arch sections, the founding for the footing plate shall be prepared prior to installation of the arch to ensure that the arch can be transmitted evenly through the footing plate. Where the founding material is not sound it may be necessary to cast concrete footing pads or strips.

When steel arches or frames are used in conjunction with shotcrete and mesh reinforcement, immediately after excavation a layer of shotcrete shall be applied to the excavated surface, followed by fixing of the mesh reinforcement. The steel arches or frames shall then be installed in position, cross braced and then backfilled with shotcrete, including the space between the arches. The arches shall then be fastened securely in place by means of rockbolts drilled close to the arch rib each side along the ribs, the washer or bearing plate of the bolt being used to clamp the arch in place.

Where arches are used without shotcrete and mesh reinforcement or without lagging and backfill then immediately after erection, the steel arches of frames and invert arches where required, shall be wedged and supported against the excavated surface at least every 1.0 m along the periphery if the arch section. As soon as possible after the erection, the space between the excavated surface and the steel arch, frame or invert strut along the complete periphery of the arch, frame or strut shall be filled up with concrete or shotcrete. Wooden wedges used during the initial assembly and erection of the steel anchors and frames shall be removed before the final concrete or shotcrete filling is carried out.

Chapter 0251
14 ROCK BOLTING

14.1 GENERAL

14.1.1 Scope

This Chapter covers the requirements for

- The supply of rock bolts and dowels
- The installation of the same in all surface and underground structures under the Contract
- The testing of the rock bolts and dowels.

The specifications for the rockbolts cover the resin or cement grouted or mechanically anchored rockbolts. Some of the requirements not applicable to the relevant type of rockbolt shall be disregarded.

The Contractor is encouraged to propose in his bid the use of the threaded bars in lieu of the tensioned rock bolts made from the reinforcing steel bars that have reduction of effective area when machined to make threads. The proposed thread bars may be utilized in actual construction if the proposed bar sizes are applicable to replace the presently designed bars and are more advantageous in cost.

14.1.2 Related Works / Sections

Chapter 0220	Surface excavations
Chapter 0230	Underground excavations (Traditional method)
Chapter 0240	Drilling and grouting
Chapter 0250	Steel arches and frames
Chapter 0810	Roads and platforms

14.1.3 Definitions

- **Rockbolt** is a high yield strength deformed bar of specified diameter and length (in rock) which is end anchored with resin grout, fully column bonded with either resin or cement grout, equipped with a faceplate, hemispherical washer and nut and tensioned to a specific load. The use of resin or cement grout for the column grout shall be at the contractor's discretion.

  Alternative materials with equivalent service characteristics, such as mechanically anchored rock bolts or Swelex type rock bolt, may be proposed to the agreement of the PMC. It is intended that, in general, rock reinforcement will be provided mainly by tensioned rock bolts.

  Threaded bar is a high yield strength threaded bar of specified diameter of which effective area of threads in full length (or part) is not smaller than bar area and length (in rock) which is end anchored with grout, fully column bonded with either resin or

cement grout, equipped with a faceplate, hemispherical washer and nut and tensioned to a specific load. The use of resin or cement grout for the column grout shall be at the Contractor's discretion.

In this Specification, the term of "rockbolt" includes "threaded bars" unless specifically noted.

- **Dowel** is a high yield strength deformed bar of specified diameter and length (in rock) for which the protruding portion may be either straight or bent, which is fully grouted with either resin or cement grout. Dowels shall generally be fitted with a face plate and nut, but shall not be tensioned. The use of resin or cement grout shall be at the Contractor's discretion. "Dowel" may be called "grouted rock bolts", "grouted anchor bar" or "full bond rock bolt" in the Drawings or the Bill of Quantities.

Rock bolts and dowels shall be installed in portions of the work where the stability of rock faces exposed by the excavations will not be maintained naturally, or where anchorage of concrete or steel structures to rock are required. The term 'rock bolting' as used here shall exclude rock anchors specified in Chapter 0252 "Post Tensioned Rock Anchors".

14.1.4 Codes and Standards

The works included in this Chapter shall comply with the requirements of the following standards and codes, except where this Specification differs from these standards and codes, in which case the requirements of the Specification shall take precedence.

14.1.4.1 American Concrete Institute

ACI 318 Building Code Requirements for Structural Concrete

14.1.4.2 American Society for Testing and Materials

ASTM A1064	Standard Specification for Carbon-steel and Welded Wire Reinforcement, Plain, for Concrete
ASTM A 370	Test Methods and Definitions for Mechanical Testing of Steel Products
ASTM A 615	Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
ASTM F432	Standard specification for rock bolts and accessories
ASTM 04435	Standard method for rockbolt anchor pull test
ASTM C150	Portland cement

14.1.5 Quality Asssurance

14.1.5.1 Tests and Controls

- The Contractor shall make trial tests of rock bolts and dowels before any installation proceeds.

- The trial programme shall include sufficient pull out tests to failure, or to such lesser load as the PMC may approve, of rockbolts and dowels anchored in suitable rock to determine the adequacy of the anchorage used and the correct torque or tension where appropriate to apply to the rock bolts. The trial assemblies shall show that the bolt, the anchorage system and the tensioning system proposed by the Contractor will be suitable for the work.
- The effectiveness of the installation procedure shall be checked by testing to yield load a minimum of 1 bolt in 100 installed.

14.1.5.2 Tolerances

Position ± 150 mm

Alignment ± 5°

14.1.6 Submittals And Approvals

14.1.6.1 Type of Rockbolt

In case that the threaded bar as tensioned rock bolt proposed in the Contractor's bid has been evaluated to be advantageous in the opinion of the PMC, the Contractor will be requested to submit, within three (3) months after the request, the following for the PMC's approval:

- Proposed shape, size, length and materials of threaded bars conforming to ASTM F432.
- Name and place of the proposed manufacturer
- List of the manufacturer's experience (project names, locations, quantities) of the threaded bars used
- Proposed method of quality control of threaded bars

In case that all submissions are satisfactory to the PMC to guarantee the quality of the threaded bars, the tensioned rock bolts will be replaced with the threaded bars.

14.1.6.2 Method Statement

Not later than 56 days prior to commencement of excavation in which the rock bolts (or threaded bars) are necessary, the Contractor shall submit the following to the PMC for approval.

- A plan showing the different types and characteristics of dowels, rock bolts or threaded bars nd accessories he intends to use.
- For exposed rock bolts and accessories, details of the protective coating compound the Contractor intends to have applied at the factory with possibility of recoating at site if required.

- Drilling method and equipment
- Grouting material, equipment and method.
- Method and equipment for insertion of rock bolt or dowel into hole
- Method, timing, equipment and tools for tensioning rock bolts or tightening dowels
- Temporary protection method of rockbolt and dowel heads

14.1.6.3 Schedule for Grouting of Rock bolts and Dowels:

Prior to starting, the Contractor shall submit a schedule for grouting bolts for the PMC's approval. All mechanically anchored grouted rock bolts shall be grouted in place immediately prior to backfilling or concreting or, in the case of permanently exposed faces, upon completion of the work in any area, unless otherwise required by the PMC.

14.2 MATERIALS

14.2.1 Tensioned Rock Bolts

- Rock bolts shall be manufactured from hot rolled deformed bars with a characteristic strength of not less than 415MPa complying with ASTM F432, in various lengths and diameter as specified.
- The bar length specified shall be the required length of bar to be bonded to the rock and due extra allowance in the cutting length shall be made for any length including the threaded portion protruding from the rock as required for installation. One end shall be threaded for at least 150mm with coarse cut thread which shall not reduce the overall specified bar diameter by more than 3mm. The other end shall be chamfered to facilitate installation.
- Rock bolts shall be provided with face plate, hard steel flat and hemispherical washers and nuts.
- The face plate shall be domed load indicating type and fitted with hemispherical washer to permit seating of the face plate at inclinations up to 30° from normal to the bolt, with the following minimum dimensional characteristics:
  - For 20mm dia rockbolt, diameter 120mm and 8mm thick plate,
  - For 25mm dia rockbolt, diameter 150mm and 8mm thick plate.
- Couplings for connecting adjacent sections of a rock bolt shank and rock bolt extensions shall have a centre stop so that each section is connected by an equal length of thread. Such threads shall be capable of transferring the yield load of the bolt from one section to the other without, in any way, overstressing the coupling or the threads of the bolt shank or extension. Couplings for hollow core bolts shall be such as not to interfere in any way with the flow of grout through the core of the bolt.

- Mechanically anchored rock bolts shall be supplied with suitable tubes for injecting grout and permitting release of air from the hole. Bearing plates for rock bolts to be grouted shall be supplied with holes to accommodate the grouting and venting tubes. Alternatively, groutable rock bolts having a hollow core may be used, in which case the bearing plates shall have one hole for the grouting or air venting tube.
- For all rock bolts which will be permanently exposed, all portions of the rock bolts, the bearing plates, and accessories which will be permanently exposed shall be coated after installation with an approved protective coating compound. The PMC may nevertheless require grouting to be used for protection of the shank.

14.2.2 Dowels

Dowels shall be manufactured from hot rolled deformed bars with a characteristic strength of not less than 420MPa, in various lengths and diameters as specified.

Dowels shall be either straight bars or shall have the protruding end bent to facilitate the specified connection between the rock and surrounding concrete or shotcrete when so detailed on the Drawings.

Dowels for installation with resin or cement cartridge shall be threaded at one end sufficiently for attachment of the installation equipment. The other end shall be chamfered to facilitate installation.

14.2.3 Wire Mesh

- Wire mesh shall be of a standard approved by the PMC.
- Welded wire mesh shall comply with ASTM A 185.

14.2.4 Grout

- Resin grout shall be a commercially produced epoxy product in capsule form with both fast and slow setting times as applicable especially formulated for use with rockbolts or dowels, and transported, stored and utilized in accordance with the manufacturer's recommendations.
- Cement grout shall be a commercially prepared product in capsule form especially produced for use with rockbolts or dowels. The product shall not contain any material which could corrode the rockbolts or dowels.
- Alternatively, where a pumped cement grout is acceptable to the PMC for the installation of dowels, the materials shall comply with the requirements of Chapter 0240 "Drilling and Grouting".

14.2.5 Reserve Supply

To be able to perform the excavation work without delay, the Contractor shall always have in stock sufficient quantities of rock bolts of various types and length, wire mesh and other accessories.

As the work progresses the Contractor shall supply additional bolts to site as instructed by the PMC.

14.2.6 Torque Wrench

The Contractor shall provide a standard torque wrench for calibrating impact and torque wrenches used in the work. This controlled torque impact wrench shall have a control device that can be set to cut off over the required range of torques. This wrench shall not be used for any other purpose. All impact and torque wrenches shall be calibrated at least once every month.

14.2.7 Pullout Test Equipment

The Contractor shall provide two sets of approved pullout test equipment for use in making tests, to comprise of a suitable hydraulic jack, having a centre bore in the ram for installation of the jack concentrically over the longitudinal axis at the bolt, hydraulic pump, and all other required accessories.

14.3 EXECUTION

14.3.1 GENERAL

- Rock bolting shall be carried out in the pattern and sequences as indicated on the Drawings or as directed or as proposed by the Contractor and agreed by the PMC.
- Where open-cut excavation is carried out in successive lifts or benches, support of each newly exposed rock face shall be completed prior to blasting of the next bench unless otherwise authorized by the PMC.
- Rock bolts required to support the underground excavations shall be set and tensioned at agreed locations, as soon as practicable after each round is excavated and before the face is further advanced. Any rock bolt, which is damaged by blasting or other operations to the extent that it can no longer be effectively re-tensioned, shall be replaced as required by the PMC.
- Before grouting, the Contractor shall check the tension of all mechanically anchored rock bolts in underground works and re-torque where necessary.
- In areas where underground excavation is not carried out in a full tunnel heading method, the Contractor shall submit, for the PMC's approval, his schedules and procedures to be used to meet the requirements of this section.

- Preset bolts shall be installed as shown on the Drawings to reinforce rock in the underground excavations, portals or any other excavation.

14.3.2 DRILLING

- Standard percussion drilling equipment may be used for drilling rock bolts.
- Holes for rock bolts shall be drilled to the depths and at locations and orientations shown on the Drawings, directed or as agreed by the PMC.
- Unless otherwise proven acceptable by site trials, the bolts shall be installed in holes of diameter from 10mm to 15mm greater than the maximum diameter of the bolt, and will be such that, for the anchorage used, the load capacity of the bolt at the yield point of the steel can be developed. In cases where it is necessary to couple lengths of grouted bolts to achieve the total length of bolt required, the diameter of the hole around and above the coupling shall be sufficient to allow the free passage of grout.
- The holes shall not be more than 100mm longer than the grouted length of the rockbolt unless otherwise proven acceptable by site trial.
- Immediately prior to installation of any bolt, the hole shall be flushed with water and cleaned of all drill cuttings and debris to the satisfaction of the PMC.

14.3.3 INSTALLATION AND TENSIONING OF BOLTS

14.3.3.1 Installation and Tensioning of Bolts

14.3.3.1.1 Installation

- The method of installation and tensioning of bolts shall be to the approval of the PMC. Manufacturer's instructions for the use of proprietary components shall be followed wherever appropriate.
- Rock bolts shall be inserted in the hole and the anchorage firmly seated and tightened. No damage shall be caused to the thread of the protecting end of the rock bolt
- Prior to installing the bolts, the rock surface shall be prepared to provide a uniform bearing at right angles to the longitudinal axis of the bolts.
- For resin grouted rock bolts, a sufficient number of cartridges shall be used to ensure that the annulus around the rockbolt is completely filled over the full length of the hole.

End cartridges for the anchorage zone shall be of fast setting resin whilst the column shall be filled with slow setting resin or cement cartridges. Tensioning shall be carefully controlled to ensure that it takes place after setting of the end cartridges but prior to commencement of setting of the column grout.

14.3.3.1.2 Tensioning

- The hexagonal nut of the tensioning end of the bolt shall be free running on the thread of the bolt and shall be tightened to a torque required to cause a load in the bolt equal to two third of the capacity of the bolt. The requisite torque for the bolts shall be determined by in place testing of the bolts or, where the case warrants, in accordance with the bolt Manufacturer's directions. Bolts which are damaged or overstressed by over-torqueing shall be replaced by the Contractor.
- All necessary preparation of a bolt for grouting shall be made during the initial installation of the bolts. After the bolt has been tensioned, the tension shall not be relaxed for grouting or any other purpose.
- If it is found that any bolt will not take the required torque without anchorage slip, another bolt shall be installed in a new hole drilled in the immediate vicinity of the unsatisfactory bolt.
- If, at any time, the PMC or Contractor finds that any rock bolts have become loose or have lost their tension, the Contractor shall re-tension all such bolts by reapplying the specified torque.

14.3.3.2 Installation of Dowels

The method of installation of dowels shall be to the approval of the PMC. Manufacturer's instructions for the use of proprietary components shall be followed wherever appropriate.

Holes of diameter from 10mm to 15mm greater than the maximum diameter of the dowel shall be drilled and cleaned to the approval of the PMC. The gauged amount of cement grout or cartridges of resin or cement grout shall then be inserted and the bar driven firmly into the hole (by spinning in the case of resin cartridges). If cement grout is used, the grout shall be inserted using a tremie pipe pushed down to the bottom of the hole and withdrawn slowly as the grout is placed. After installation the bar shall be vibrated for a short period to ensure the complete distribution of the grout around the full length of the bar. Additional grout shall be added to make up any shortfall.

14.3.4 TESTING OF ROCK BOLTS AND DOWELS

14.3.4.1 General

Prior to the installation of rockbolts in the Works the Contractor shall carry out a series of tests as agreed with the PMC to prove the capacity of the system and the Contractor's capability to correctly install and tension the rockbolts.

- For the purpose of these tests, anchorage slip shall be deemed significant if an outward movement of the bolt anchorage occurs and continues without increase in the hydraulic jack loading, or with a decrease in the hydraulic jack loading.

- If a bolt fails to meet the pullout test requirement, another bolt shall be installed in a new hole drilled as close as practicable to the unsatisfactory bolt.
- The tests shall demonstrate:
  - The number of resin cartridges required to provide the end anchorage with an applied load equal to the bars characteristic yield strength and taking into account the overlength variation of holes.
  - Tthe number of resin or cement cartridges to fill the annulus around the rockbolt over the length of the hole between the anchorage and collar of the hole.
  - The strength of the resin grout to fully anchor the bars up to the characteristic strength of the rockbolts.
  - The composition of the cement grout.
  - The capacity of the equipment to install the longest fully grouted rockbolts
  - The equipment for tensioning the bolts to the specified loads.
  - The capability of each crew to correctly install and tension the rockbolts.

The Contractor shall undertake the tests with the equipment to be used on the Works and shall install the test bolts in a suitable rock face in a steeply upward direction.

The Contractor shall provide a suitably calibrated direct tensioning jack and/or load cell of capacities in excess of the characteristic strength of the rockbolts. Loads and deformations shall be recorded during the tests.

14.3.4.2 Tensioned Rock Bolts

- A final torque test of rock bolts shall be made in the presence of the PMC during the final inspection of the work, and immediately prior to any grouting of rock bolts. The number of bolts to be tested will be determined by the PMC, with consideration given to the total number of bolts installed and the results of such tests.
- The Contractor shall make a pullout test of each bolt that does not retain the applied torque, as determined by the PMC. All pullout tests shall be made in the presence of the PMC. A pullout test result which indicates that the anchorage will take a tension equal to 90 percent of the yield strength of the rock bolt shank, as determined by trial tests, without significant anchorage slip, will be acceptable.
- All rock bolts which are installed and tensioned within 15m of subsequent blasting work shall be tested after each blast within such longer period as may be approved by the PMC.

14.3.4.3 Dowels

At locations designated by the PMC, the Contractor shall conduct pullout tests in the presence of the PMC. A pullout test which indicates that the rock bolts will take a tension equal to 90% of its yield strength without significant slip will be acceptable.

14.3.5 CEMENT GROUTING OF ROCK BOLTS AND DOWELS

- The grouting shall be performed in accordance with the specifications in Chapter 0240 "Drilling and grouting". The Contractor shall supply all plant and materials required to grout the rock bolts in place after nstallation.
- Where a tube system is proposed by the Contractor for the grouting of rock bolts, such system shall be subject to the PMC's approval, and the Contractor shall demonstrate to satisfaction of the PMC that the proposed system will provide complete filling of the annular space around the bolt.
- The grouting of dowels will be in principle by pumping a thick grout into the hole by inserting a grout tube to the end of the hole and slowly withdrawing the tube as the grout is pumped in, the dowel being then pushed fully into the hole.
- The water/cement ratio by weight shall be between 0.30 and 0.45. Special agreed admixture shall be added to the grout to prevent shrinkage. This non shrink admixture shall be added strictly as recommended by the Manufacturer. Calcium chloride will not be permitted. Grout shall be forced into the drill hole at the appropriate point to completely fill the space all around the rock bolts. All air shall be vented from the drill hole during this operation. The grouting pressure shall be no more than sufficient to fill the drill hole adequately. If during the grouting of any bolt, grout is found to flow from points in the rock surfaces adjacent to the bolts such leak shall be plugged or caulked. Grout which has not been injected into a hole within one (1) hour of mixing shall not be used.
- The Contractor shall ensure that grouted rock bolts are neither loosened nor disturbed in any way until at least seven (7) days after completion of grouting.

14.3.6 WIRE MESH FOR TEMPORARY PROTECTION

- Where wire mesh will be placed for temporary protection for safety of person and equipment, it shall be securely fastened to the bearing plates or rock bolts.
- Overlaps in the wire mesh shall not be less than 300mm and shall be secured with wire clips. Additional wire mesh anchors shall be used to secure wire mesh to the rock surface between rock bolts and to secure the edges of wire mesh and provide anchorage at overlaps and where sagging may occur. These wire mesh anchors patterns shall be approved by the PMC.

- Debris, rock fragments, and other materials which accumulate between the wire mesh and the protected surface shall be cleaned out to prevent overloading the wire mesh.
- Unless otherwise agreed by the PMC, wire mesh shall be removed from all surfaces scheduled to be covered with concrete. The removal of the wire mesh shall not proceed more than 3 m ahead of the concrete surface according to the field conditions.
- Wire mesh provided as shotcrete reinforcement is specified and paid under Chapter 0420 "Reinforcing Steel"

Chapter 0252

15 POST-TENSIONED ROCK ANCHORS

15.1 GENERAL

15.1.1 Scope

This Chapter covers the requirements for detailing, supply and installation of post-tensioned rock anchors consisting of strand cables or thread bars in the underground caverns as designated in the Drawing or elsewhere directed by the PMC.

Manufacturing of the anchor materials shall be by specialist subcontractor. Installation shall be carried out by the post-tensioned rock anchor manufacturer's specialists, or by the Contractor's specialists after due training by the Manufacturer.

The PMC may instruct to adjust the required tension force to be permanently effective in each anchor. The Contractor shall be responsible for detailing of the anchor system and selecting the anchor materials for his work

15.1.2 Related Works / Sections

Chapter 0220	Surface Excavation
Chapter 0230	Underground Excavation
Chapter 0240	Drilling and Grouting
Chapter 0251	Rock Bolting
Chapter 0431	Shotcrete
Chapter 0710	Monitoring Instrumentation

15.1.3 Definitions

- Post-tensioned rock anchors are constituted by high strength cables bound with grout in the rock mass and a head for post tensioning. They are provided to ensure the overall stability of the excavation in addition to the rock bolts,
- "Design strength of anchor" means sixty percent (60%) of the breaking strength of a tendon consisting of strand cables in one (1) anchor hole.
- Longitudinal steel beams are the beams installed between the anchor heads and the rock face to improve the stress distribution on the rock surface. They are specified in Chapter 0510.
- Cable consists of a bundle of 7-wire prestressing steel strands.
- "Tendon grouting" consists of injecting cementitious liquid grout into the hole to provide bond transfer and corrosion protection for the anchors.
- The anchor length is the full length of anchor including the fixed anchorage length embedded in rock, but excluding part protruding out from anchor head.

- The free length is defined as being the length in hole, after installation, between the excavated rock face and the nearest point of the fixed anchorage.

15.1.4 Codes and Standards

The work included in this Chapter shall comply with the requirements of the following standards and codes, except where this Specification differs from these standards and codes, in which case the requirements of the Specification shall take precedence:

ASTM A722	Uncoated High-Strength Steel Bars for Prestressing Concrete
ASTM A416M	Uncoated Seven-Wire Steel Strand for Prestressed Concrete
ASTM C109	Test for grout

and technical recommendations such as American PTI; or equivalent.

15.1.5 Quality Assurance

15.1.5.1 Pull-out Trials

- At least three (3) pull-out trials with load and head displacement measurement as agreed with the PMC shall be performed for each rock anchor types to determine the required fixed anchorage length. These trials shall be done at a location approved by the PMC as being representative of the rock in which the fixed anchorage lengths are to be located.
- The pull-out trials shall consist of testing various anchorage lengths for loads up to the yield strength of the anchors. The anchor and resin or grout shall be exactly the same as that which shall be used to carry out the works. The free length for the pull-out trial shall be 4 m regardless of the anchorage length.
- The fixed anchorage length determined from these trials shall give a minimum factor of safety of 1.4 based on the breaking load.
- The Contractor shall provide all equipment required for the trials.

15.1.5.2 Routine Acceptance Testing

- Tensioning of any anchor shall not start until the resin or grout has attained an acceptable strength as determined from pull-out trials. The working load for a rock anchor shall be 50% of the theoretical yield load of the anchor. Anchors shall be initially be tensioned to 125% of their working load which shall be maintained for at least ten (10) minutes after which the anchors shall be locked-off at 110% of working load. Provision shall be made for the measurement of the extension of the anchor to an accuracy of 0.1mm during these tests.
- All anchors shall be retested between twenty four (24) hours and forty eight (48) hours after installation.

- Retesting shall comprise re-tensioning the anchor until the upper anchorage head just lifts clear of the bearing plate and residual load at this point shall be recorded. If this residual load is greater than working load plus 5%, the test shall be considered satisfactory. If the residual load is below working load plus 5% but not less than 80% of the working load, the anchor must be re-tensioned to working load plus 10% and retested after twenty four (24) hours.
- If after three such retests the anchor still fails to maintain a load above the design working load it shall be condemned and replaced or otherwise dealt with as directed by the PMC. If after the first twenty four (24) hour test the residual load is below 80% of the working load, it shall be condemned and replaced or otherwise dealt with as directed by the PMC. All replacements shall be made by the Contractor.
- Throughout the tensioning operations accurate measurements of the actual anchor extensions shall be taken and recorded. All necessary equipment shall be provided by the Contractor.
- Acceptance of rock anchors will be based on the results of the above tests and criteria determined by the PMC for the rock conditions encountered at the site.

15.1.5.3 Grout Tests and Records

The Contractor shall make six (6) 50mm grout cubes per grout batch. These cubes shall be compression tested at the Site laboratory to determine the rate of gain of strength of the grout. Sampling and testing of grout shall be in conformance with ASTM C109.

The Contractor shall prepare daily tendon grouting records, on accepted forms, of all tendon grouting carried out. Information provided shall include:

- Amount of grout placed in each duct;
- Water/cement ratio;
- Types and proportions of additives;
- Grout pressure;
- Type of mixer; and
- Name of the Contractor's grouting foreman.

15.1.5.4 Tolerances

- The drillholes for post-tensioned anchors shall commence at the location shown on the Drawings or as directed by the PMC within a tolerance of $\pm$ 150 mm.
- The initial alignment of the drillhole shall be as shown in the Drawings or as directed by the PMC within an angular tolerance of $\pm$ 2°.
- The deviation of the drilled hole at any point shall not vary from the initial alignment by more than 3% of the length of the hole to that point, as measured by the PMC.

15.1.6 Submittals and Approvals

- The Contractor shall submit the following information to the PMC, for approval, not later than ninety (90) days in advance of the programmed commencement of the application of the post-tensioned anchor trials:
  - Post tensioned rock anchor manufacturer, with all mechanical characteristics and specifications of the proposed rock anchor, and all details of accessories (heads, coupling system, corrosion protection, etc.), grout injection system and mix, anchor installation and post-tensioning procedures, and drilling diameter recommended by the manufacturer.
- The Contractor shall submit the following information to the PMC, for approval, not later than twenty eight (28) days in advance of the programmed commencement of the application of the post-tensioned anchor trials:
  - The methods for installation, grouting and post-tensioning in relation with the excavation schedule.
  - A list of personnel proposed for installing and grouting anchors, giving their names and xperience, qualifications in this work and previous projects worked upon in which they installed post-tensioned tendons.
  - Consignment bills and test certificates giving details of manufacture, composition, yield stress, modules of elasticity, ultimate stress and relaxation characteristics of steel used in threadbars or cables. Bills and test certificates shall be capable of identification with individual threadbars or cables at the site.
  - Results of the pull-out trials.
- The Contractor shall submit the following information to the PMC, for approval within twenty four (24) hours of the completion of the relevant operation:
  - Specified daily tendon grouting records.
  - Anticipated lock-off loss due to seating of anchor nut into bearing plate.
  - Calibration data for hydraulic jacks.
  - Sequence of stressing of individual tendons and results of the routine acceptance tests within forty eight (48) hours of completion of relevant operation.

15.2 MATERIALS

15.2.1 Post-Tensioned Anchors

Post-tensioned anchors will be constituted by threadbars or cables and shall comply with ASTM Standards.

15.2.1.1 Cable Anchors

The post-tensioned cables shall be a bundle of 7-wire strands of Grade 1860 in ASTM A416M. One tendon consists of four (4) 17.8 mm diameter 7-wire stands or equivalent approved by the PMC.

Bearing plates shall be suitably sized for bearing on steel longitudinal beams and shall be compatible with the approved post-tensioning system. Anchorage components shall be capable of resisting at least 125% of the minimum guaranteed breaking load of the tendon.

15.2.1.2 Corrosion Protection

Corrosion protection of the rock anchors shall be ensured during the construction period by cement grout, grease, corrugated polyethylene sheath and other approved protection.

Non-corrosive spacers shall be installed along the full length of the rock anchor to keep it centered in the hole during installation and grouting.

15.2.2 Tendon Grout

- Tendon grout shall consist of Portland Cement Type III and water conforming to the requirements for these materials for concrete as specified in ACI 318.
- Admixtures for grout shall be a non-expansive balanced blend of fluidization and water reducing agents. They shall not contain calcium chloride, nitrates or other chemicals that could cause corrosion of the steel.
- Unless otherwise required, grout shall consist of a mixture of Portland cement and water, plus up to one percent by mass of admixtures. Tendon grout shall have a water/cement ratio by mass of 0.35 to 0.45, and a 28-day minimum compressive strength of 35MPa.
- Tendon grout shall be mixed in a mechanical mixer that provides for straining and re-agitating of grout. Re-tempering of grout will not be permitted.

15.3 EXECUTION

15.3.1 Delivery, Storge and Handling of Post-Tensioning Steel

Post-tensioning steel including cables must be transported dry. For transportation by sea, the posttensioning steel shall be sprayed with corrosion protection, prior to leaving the warehouse in order to protect the steel from potential corrosion due to moisture from the ocean environment. Any damage to the steel surface, such as notches, abrasions, etc. shall be absolutely avoided. The steels shall not be thrown or dumped from a truck. Hemp ropes or steel reinforced nylon slings shall be used for loading or unloading.

Post-tensioning steel shall be stored in a dry indoor place and shall be protected against damage, contamination and moisture. Sufficient ventilation shall be provided to avoid

condensation of water, especially when steel is covered with plastic sheets (avoid direct contact between plastic sheet and steel). Post-tensioning steel shall not be stored directly on the ground, only on wooden blocking. A plastic sheet shall to be placed beneath the blocking to protect the steel from ground humidity.

No welding shall be performed on or near post-tensioning steel. Care shall be taken to avoid high temperatures or dropping of hot welding sparks on the steel.

Bundles of cables shall be opened so as to avoid damage to the steel surface.

Cables accessories shall be protected against moisture and contamination. During loading and unloading they shall be handled with care.

15.3.2 Plant for Post-Tensioned Anchor Installation

15.3.2.1 Grouting Equipment

The equipment for mixing grout shall be of an approved type and size and shall be capable of mixing and stirring the grout effectively and of placing it into the metal duct in a continuous, uninterrupted flow.

The mixer shall be mechanically operated and provided with an accurate meter reading in liters for controlling the amount of mixing water used in the grout. In addition to the grout mixer, a hold-over mechanical agitator tank shall be provided.

The arrangement of the grouting equipment shall be such as to provide a supply line and return line from the grout pump to the hole. Provision shall be made for continuous circulation and accurate control of grouting pressures and grout flows into tendon ducts.

The grouting equipment shall be maintained in an accepted manner so as to ensure continuous and efficient performance during any grouting operation.

15.3.2.2 Tensioning Equipment

Hydraulic jacks shall be used for tensioning of tendons. The jack stroke shall be capable of stressing the tendon in a single operation without resetting.

Each jack shall be equipped with a pressure gauge for determining jacking force and shall be calibrated immediately prior to its use on Site. The pressure gauge shall have a dial of at least 50mm diameter. Calibration certificates for each jack used shall be available upon request.

A dial gauge and all necessary mountings shall be provided to enable accurate measurement of tendon extension. The dial gauge shall be capable of being zeroed and shall have divisions marked to 25 microns.

15.3.3 Installation of Post-Tensioned Anchors

15.3.3.1 General

The Contractor shall employ workmen skilled and experienced in tendon installation and shall use only approved equipment, materials and methods. Tendons shall be installed in accordance with procedures recommended by the manufacturer.

Pre-mixed grout shall be stored in the manufacturer's sealed containers, with seals and labels intact, in a weatherproof, damp proof building with a raised floor, and in accordance with the manufacturer's instructions.

15.3.3.2 Drilling and Water Testing

- The drill hole diameter shall comply with the recommendations of the post tensioned anchor manufacturer.
- Drilling specifications will be in accordance with the Chapter 0240 "Drilling and Grouting".
- Inclined holes shall be drilled 300mm longer than the anchors to provide a sump for debris that cannot be washed out.
- Holes for rock anchors shall be tested for watertightness by checking the total water loss along the full length of the hole. Where the water loss exceeds 5 liters/minute at a pressure of 100 kPa in excess of the local water table (which shall be measured) over a period of 10 minutes, the hole shall be cement grouted as specified in the Chapter 240, redrilled and retested until the water loss is less than this criterion.

15.3.3.3 Sequence for Installation of Post-tensioned Anchors

- The sequence for installation of post-tensioned rock anchors shall comply with the recommendations of the manufacturer.
- Preparations for grouting of tendons, such as attachment of grout and vent tubes, grout seals or other accessories, shall be made prior to placement of the tendon in the duct.
- Bearing plates and steel longitudinal beams shall be installed in position prior to grouting.
- Tendons shall not be tensioned until the grout surrounding them has reached a minimum compressive strength of 30MPa.
- Elongation measurements shall be made at each stressing location to verify that the tendon force has been properly achieved. Measured elongations shall agree with calculated elongations within ±7% as per ACI 318. Discrepancies exceeding ±7% will be resolved with the PMC.

- Stressing records shall be noted during the tensioning operation, and shall include the following minimum information:
  - Location of tendon installation.
  - Row level and elevation of the bottom of the excavation.
  - Tendon identification mark.
  - Required elongation.
  - Gauge pressure to achieve required elongation as per supplied calibration chart.
  - Actual elongation achieved.
  - Actual gauge pressure.
  - Date of stressing operation.
  - Name and signature of the stressing operator or inspector.
  - Serial or identification number of jacking equipment.
  - Date of approved shop drawings used for installation and stressing.

Stressing records shall then be turned over to the PMC for verification and safekeeping.

15.3.3.4 Grouting of Post-Tensioning Systems

- Tendons shall be bonded to rock by grouting after stressing and lock-off of the post-tensioned anchors
- Prior to grouting, thoroughly flush and blow out the grout pipe to ensure that the pipe is clean and free of deleterious materials that could interfere with the grouting procedure.
- Ensure that cement and admixtures used in the grout are free from lumps.
- All materials shall be carefully proportioned by mass and added slowly in the order, water - cement - admixture.
- Grout shall be continuously agitated to prevent the formation of lumps and settling. Grout which has not been used within 30 minutes after mixing shall be discarded.
- The anchors shall be column grouted at a uniform rate from the bottom upwards, in one operation.
- If necessary, the free length of the bar will be fully grouted by secondary column grouting after the rock anchor has been tensioned.
- Grouted tendons shall remain undisturbed for a minimum of 48 hours to allow the grout to set.

15.3.4 Protection of Rock Anchor Heads

The Contractor shall at all times be responsible for the protection of anchor heads against damage of any sort. Should such damage occur, then the Contractor shall restore the anchor to the satisfaction of the PMC.

For monitoring of the rock anchor behavior after installation, Chapter 0710 shall be observed.

Chapter 0253

16 HIGH TENSILE STEEL FOR PRE-STRESSED CONCRETE

16.1 GENERAL

16.1.1 Scope

This Chapter deals with the requirements governing the supply, cutting, placing and tensioning of high tensile steel for the pre-stressed concrete structures shown in the Drawings and/or required by the PMC.

Pre-stressed concrete is foreseen for the construction of concrete girders for the support by the post-tensioning method in which the reinforcement, composed of high tensile steel tendons, is tensioned after the concrete has reached the specified strength.

Post-tensioned tendons shall also be supplied and installed by the Contractor for the anchoring to the Bottom Outlet regulating gates.

Basically, the construction shall be performed according to the following steps:

- The tendon assembly shall be placed in the formworks and tied in place.
- The normal reinforcing bars and embedded steel elements shall be installed.
- Conventional Concrete (CVC) shall be poured and cured until the strength specified for tensioning the tendons is developed.
- Tendons shall be tensioned by hydraulic jacks.
- The space around the tendon shall be filled with cement grout under light pressure.
- The recess where the anchor fittings are housed shall be filled with concrete.

The design force of the high tensile steel for the pre-stressed concrete are tentatively calculated and shown on the Drawings as reference. The Contractor will be responsible of the detailing of the high tensile steel upon confirming the steel structure engineer of the Contractor.

16.1.2 Related Works / Sections

Chapter 0240	Drilling and Grouting
Chapter 0420	Reinforcing steel
Chapter 0430	Conventional concrete (CVC)
Chapter 0510	Miscellaneous Structural Steel Works and Metalworks

16.1.3 Quality Assurance (Sampling and Testing of Steel Strands)

Manufacturer's certified report in quadruplicate for the strands shall accompany each reel of material supplied. Two (2) copies of this certificate shall be submitted to the PMC.

The manufacturer's certified report shall describe:

- Geometrical characteristics

- Mechanical characteristics:
  - Minimum ultimate tensile strength
  - Minimum 0.2% proof stress
  - Minimum elongation after rupture
  - Minimum reduction of area after rupture
- Technological characteristics
- Lack of defects
- Reverse bend test results

The tests shall be conducted in accordance with ASTM A-370 Designation "Mechanical Testing of Steel Products".

Strand from each reel shipped to the Site, shall be assigned an individual lot number and shall be tagged in such a manner that each lot can be accurately identified at the Site.

Samples of strand for each size, lot or reel, not less than 2.5m long, shall be taken for tests by the Contractor following the PMC's instructions.

16.1.4 Submittals and Approvals

16.1.4.1 General

Complete Detailed Drawings, detailed calculations, method statements, catalogues of materials and any other pertinent information on the pre-stressing system shall be prepared by the Contractor and submitted to the PMC for approval at least fifty six (56) days before the beginning of construction. The submittal shall fully illustrate all materials and equipment which the Contractor proposes to use in the pre-stressing operations, including any addition or rearrangement of the normal reinforcing steel from that shown in the Construction Drawings.

The submittal shall also outline the method and sequence of stressing and shall include complete specifications and details of the pre-stressing steel and anchoring devices, working stresses, anchoring stresses, type of ducts (sheaths), and any other data pertaining to the pre-stressing operation, including the proposed arrangement of the pre-stressing steel in the members, pressure grouting materials and equipment.

The Contractor shall also:

- Submit to the PMC data and calculations on the tensioning resistances, on the foreseen elongations during stressing operations and on the nature and magnitude of any loss for which an allowance is required;
- Show the methods of handling, storage, transportation and installation of the materials for the pre-stressed concrete.

16.1.4.2 Design of the Post-tensioned Anchoring for the Structures

For the relevant structure, the required anchoring forces will be computed by the Contractor and approved by the PMC.

The Contractor shall then develop the detailed design of the post-tensioned anchors. The complete design, including all required detailed calculations, shall be submitted for approval to the PMC.

16.2 MATERIALS

16.2.1 Pre-Stressing Steel

Pre-stressing steel shall be uncoated wire strand in accordance with ASTM A-416 "Standard Specifications for uncoated seven-wire stress-relieved strand for pre-stressed Concrete", Concrete class C35.

Steel shall be free from grease, oil, paint and other foreign matter.

16.2.1.1 Anchorage and Bearing Plate

All post-tensioned steel tendons shall be secured at their ends by means of approved type anchoring devices.

These anchoring devices shall hold the post-tensioned steel at a load up to the breaking strength of the same steel.

The load from the anchoring device shall be distributed to the concrete by means of a bearing plate, which shall meet the following requirements:

- The final compressive stress on the concrete directly underneath the bearing plate shall not exceed 20N/mm² or 2/3 of the specified compressive strength of the concrete, whichever is lower.
- Bending stresses in the plates or assemblies induced by the pull of the pre-stressing steel shall not exceed the yield point of the material or cause visible distortion in the anchorage plate when 100% of the ultimate load is applied.

The anchor grips shall be capable of being re-stressed or de-tensioned.

The anchoring device shall be recessed into the concrete member so that the ends of the prestressing steel and all parts of the anchoring device will be at least 50mm inside of the end surface of the member, unless a greater embedment is shown in the Drawings.

Following post-tensioning the recesses shall be filled with concrete and finished flush.

16.2.1.2 Ducts Enclosures

Duct enclosures for pre-stressing steel shall be flexible metallic galvanized tubing especially designed for use with pre-stressed concrete, or equivalent tubing approved by the PMC. The metal tubing shall have a minimum thickness of 0.4mm.

The anchorage assembly and duct shall be provided with pipes or other suitable connections for the injection of grout after post-tensioning.

Ducts shall have a minimum inside diameter 8.0mm larger than the diameter of the tendon.

Ducts may be fabricated with either welded or interlocked seams and shall have sufficient strength to maintain a uniform section and a correct alignment during the pouring of concrete.

No joint shall be permitted between the two anchorage assemblies and the ducts shall be watertight enough to prevent any leakage from low-slump concrete into the tubing.

16.2.2 Tendon Grout

- Tendon grout shall consist of Portland Cement Type III and water conforming to the requirements for these materials for concrete as specified in ACI 318.
- Admixtures for grout shall be a non-expansive balanced blend of fluidization and water reducing agents. They shall not contain calcium chloride, nitrates or other chemicals that could cause corrosion of the steel.
- Unless otherwise required, grout shall consist of a mixture of Portland cement and water, plus up to one percent by mass of admixtures. Tendon grout shall have a water/cement ratio by mass of 0.35 to 0.45, and a 28-day minimum compressive strength of 38MPa.
- Tendon grout shall be mixed in a mechanical mixer that provides for straining and re-agitating of grout. Re-tempering of grout will not be permitted.
- Quick setting resin cartridges or quick setting cement grout cartridges of similar viscosity may be used for the fixed anchorage of the monobar anchors after PMC's approval.
- Portland cement shall comply with the specifications of Clause 2.3, Chapter 0430.
- Plasticizer admixture shall comply with the specifications of Clause 2.5, Chapter 0430 or equivalent admixture approved by the PMC.
- Water shall comply with the specifications of Clause 2.6, Chapter 0430.

16.3 EXECUTION

16.3.1 Handling of Storage of Steel Materials

All pre-stressing materials shall be protected against physical damage and heavy rust or other effects of corrosion at all times from manufacture to grouting.

Pre-stressing materials shall be packaged in water proof containers or other shipping forms for the protection of the steel against physical damage and corrosion during shipping and storage. When reels of strand must be kept for any length of time, they shall be stored indoors. Reels stored outdoors shall be supported on timbers 200mm minimum above the ground and covered with tarpaulins.

Pre-stressing steel with physical damage or that has heavy rust or other effects of corrosion, shall be rejected, removed from the Site and replaced by the Contractorwithout any claim.

16.3.2 Ducts and Strand Installation

Ducts shall be free from grease, paint or other foreign matter before being installed.

Ducts for pre-stressing steel shall be securely fastened in place to prevent any movement during concrete pouring. After installation in the forms, the end of ducts shall be plugged to prevent at all time the entry of water or debris.

All ducts shall be vented by means of 12mm minimum diameter standard pipe unless otherwise shown in the Drawings. The vents shall be mortar tight, firmly connected, and shall provide means for injection of grout through the vents where required in the Drawings. Ends of vents shall be removed flush with the beam after grouting has been completed.

The pre-stressing steel shall be placed after concrete pouring. Before introducing the strand into the duct, the latter shall be blown out or flushed and blown out immediately prior to installation of the steel.

All water used for flushing ducts shall contain either quick lime (calcium oxide) or slaked lime (calcium hydroxide) in the amount of 0.01kg/liter. All compressed air used to blow out ducts shall be oil free.

No welds or grounds for welding equipment shall be made on the forms or on the steel in the member after the pre-stressing steel has been installed.

16.3.3 Pre-Stressing

16.3.3.1 Required Concrete Strength

Concrete forms shall be removed before pre-stressing operation. Unless different instructions are given by the PMC, concrete members shall not be pre-stressed until the compressive strength of the concrete has reached its design value. Subject to prior

approval by the PMC, a portion of the total pre-stressing force may be applied to pre-cast girders when the strength has reached at least 21N/mm² in order to move the element.

16.3.3.2 Hydraulic Jacks

Tensioning shall be carried out by means of hydraulic jacks, equipped with pressure gauges. The hydraulic jacks shall have a loading capacity not less than the ultimate strength of the tendon to be tensioned. The pressure gauge shall have an accurate reading dial, 150mm minimum in diameter, with one (1) ton graduations and a measuring accuracy of ±0.5% of the tendon stress.

Each jack and its gauge shall be calibrated as a unit with the cylinder extension in the approximate position that it will occupy at the final jacking force, and shall be accompanied by a certified calibration chart. The certified calibration charts shall be checked before and during tensioning operations as required by the PMC.

16.3.3.3 Tensioning

The tensioning shall be carried out in accordance with these Specifications and with the recommendations of the steel manufacturer. Unless otherwise specified or shown in the Drawings, the average working stress in the pre-stressing steel shall not exceed 60% of the specified minimum ultimate tensile strength or 80% of the nominal yield point stress.

The maximum temporary tensile stress (jacking stress) in the pre-stressing steel shall not exceed 80% of the specified minimum ultimate tensile strength of the pre-stressing steel. The pre-stressing steel shall be anchored at stresses (initial stresses) that will result in the ultimate retention of working forces not lower than those shown on the Drawings, but in no case shall the initial stress exceed 70% of the specified minimum ultimate tensile strength of the pre-stressing steel.

Working stress and working force shall be considered as the stress and force remaining in the prestressing steel after all losses, including creep and shrinkage of concrete, elastic compression of concrete, creep of steel, losses in post-tensioned pre-stressing steel due to the sequence of stressing, friction and take up to anchorages, and all other losses peculiar to the method or system of pre-stressing have taken place or have been provided for.

The tensioning process shall be so conducted that the elongation of the pre-stressing steel may be measured at all times. A record shall be kept of gauge pressures and elongations and shall be submitted to the PMC. Elongation shall be measured within a tolerance of ± 3mm or 1% of the theoretical elongation, whichever is smaller.

Pre-stressing force shall be determined by measuring the tendon elongation and also by checking the jack pressure on a calibrated gauge. A difference of 5% between the stress computed from the jack pressure and that computed from the measured elongation is acceptable. When there is a difference of over 5% between the steel stress determined

from elongation and from the gauge reading, the cause of the discrepancy shall be ascertained and corrected.

Pre-stressing tendons of girders shall be tensioned by jacking simultaneously from both ends of the tendon. All strands of a tendon shall be stressed simultaneously.

The tensioning of each tendon shall be applied in two (2) stages. Each tendon shall be first tensioned to 80% of the maximum temporary tensile stress (jacking stress) and anchored against the anchor plate. Each tendon shall be re-stressed to the required initial stress after a time of at least ten (10) days has elapsed from the application of the previous pre-stressing force. During this operation the tendon shall be stressed to the maximum tensile stress (jacking stress) for three (3) minutes.

16.3.3.4 Grouting

Post-tensioned pre-stressing steel shall be bonded to the concrete by completely filling the entire void space between the duct and the tendon with grout.

Grout shall consist of Portland cement, water, and plasticizer admixture. The mixture shall have approximately a water/cement ratio of 0.45 and plasticizer admixture in the quantity of 2% by weight of cement. Proportions of grouting materials shall be based on results of tests made on fresh and hardened grout prior to beginning work. Grout shall have the consistency of thick cream or heavy paint. When permitted to stand until setting takes place, grout shall neither bleed nor segregate. Sand use in the grout may be accepted by the PMC after grout testing.

Water shall be added first to the mixer followed by the cement and admixtures. The grout shall be mixed in mechanical mixing equipment of a type that will produce uniform and thoroughly mixed grout. Grout shall be continuously agitated until it is pumped. All grout shall be passed through a No.14 ASTM screen prior to being introduced into the grout pump.

All ducts shall be clean and free of deleterious materials that might impair bonding of the grout.

Grout shall be pumped into the duct as soon as possible after mixing. Grout that is not injected for any reason within one hour after mixing shall be accepted as wasted by the Contractor. Grouting equipment shall be capable of grouting at a pressure of at least 7bar and shall be furnished with a pressure gauge having a full-scale reading of about 10bar. Grout shall be pumped through the duct and continuously wasted at the outlet until no visible slugs of water or air are ejected and the efflux time of ejected grout is not less than thirty (30) seconds. The outlet pipe shall then be closed and the pumping pressure held momentarily to a pressure of 5-6bar. The valve at the inlet shall then be closed while maintaining this pressure.

Grout injection pipes shall be fitted with positive mechanical shutoff valves. Vent pipes shall be fitted with valves, caps or other devices capable of withstanding the pumping pressure. Valves and caps shall not be removed or opened until the grout has set.

Sequence of grouting shall be planned to insure complete filling.

Pre-stressing steel shall be normally grouted within forty eight (48) hours after completing prestressing operations. Pre-stressing steel not grouted within five (5) days may be subject to the rejection because of rust.

16.3.3.5 Recess Finishing

After the grout is set, the excess length of the strands outside the girder shall be cut off. Flame cutting shall not be permitted. If a recess is provided for the anchoring devices it shall be filled with concrete of the same Class of the girder / of the structure unit and finished flush.

The surface of concrete members against which this concrete is to be placed shall be chipped until the coarse aggregate is exposed.

16.3.4 Personnel

The personnel engaged in pre-stressing operations shall be experienced in this class of work. Every precaution, to the satisfaction of the PMC, shall be taken to ensure safety to personnel during tensioning.

16.3.5 Record of Pre-Stressing Operations

A daily report shall be kept by the Contractor of all operations, from the time the ducts are placed until the tendons are installed and fully tensioned. The report shall include description of tendon construction, duct installation, tensioning, grouting, results of controls, and other data required by the PMC. The report shall be submitted to the PMC within seven (7) days from the conclusion of the grouting operation.

16.3.6 Tendons Not in Compliance with the Specifications

Tendons which, during the placing and tensioning, turn out to be damaged or inadequate to stand the required stresses shall be replaced.

Tendons which during the tensioning operations have strands tensioned over the allowed jacking stress shall be rejected. The rejected tendons shall be replaced by the Contractor without any claim.

16.3.7 Pre-Cast Pre-Stressed Components

Pre-cast pre-stressed components shall be transported from the casting site to the sites of storage, if so required, and to the erection sites in such a manner that they are not damaged in any way.

Care shall be exercised in handling, hoisting and during storage of the components to prevent cracking and other damages. Units damaged by improper handling, transportation, storage and erection shall be replaced by the Contractor.

A daily log, available for inspection at any time shall be kept by the Contractor of all pre-stressing operations from the time pre-stressing work is started until the units are fully incorporated into the structure. The log shall include information on placing of concrete, stressing, curing, release of stress, stripping, handling, delivery, results of tests and erection data of each member.

Each pre-stressed unit shall be identified by an appropriate designation throughout the entire operation and the results of tests shall be designated in a manner that will identify them with their respective units.

The type of log and method of identifying the pre-stressed units and tests shall be approved by the PMC prior to the start of the concrete placing operations.

Chapter 0260

17 DRAINAGE OF STRUCTURES

17.1 GENERAL

17.1.1 Scope

This Chapter covers the supply and installation and tests of pipes, fittings and valves for the piping, surface drains, under-drains, coated paper, gravel drains, geotextile and weep-holes shown in the Drawings or required by the PMC. This Chapter particularly covers the requirements for drainage of the bridge decks, the roofs and floors of Dam control chambers and gate hoist chambers and gate chambers, and the backfill behind training walls.

17.1.2 Related Works / Sections

Chapter 0211	Diversion, Dewatering and Care of Water
Chapter 0320	Fill, Backfill and Embankment Construction
Chapter 0330	Rock Protection
Chapter 0430	Conventional Concrete (CVC)
Chapter 0433	Roller-Compacted Concrete (RCC)
Chapter 0510	Miscellaneous Structural Steel Works and Metalworks

17.1.3 Definitions

The works to be carried out under this Chapter shall include, but not necessarily be restricted to the following:

- Steel pipes, fittings and valves for embedded and exposed piping for domestic water systems.
- Steel pipes, fittings and valves for embedded and exposed piping for service water system.
- Cast iron pipes and fittings concerning embedded piping for outdoor sewage systems.
- Polyvinyl-chloride pipe and fittings concerning embedded and exposed piping for drainage, sewage and vent systems.
- Precast concrete pipes and drain ditches for sewage and drainage systems.
- Stone pitched ditches and chutes

17.1.4 Codes and Standards

17.1.4.1 General

The Work included in this Chapter shall comply with the requirements of the following standards and codes, except where the Specification differs from these standards and codes, in which case the requirements of the Specification shall take precedence:

AASHTO American Association of State Highway and Transportation Officials Division II Construction.

AISC American Institute of Steel Construction.

ASME Section VIII Pressure Vessels, Division 1.

17.1.4.2 American Society for Testing and Materials (ASTM)

ASTM A53	Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A123	Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
ASTM A216	Specification for Steel Castings, Carbon Suitable for Fusion Welding for HighTemperature Service.
ASTM B62	Specification for Composition Bronze or Ounce Metal Castings.
ASTM C76M	Standard Specification for Reinforced Concrete Culvert, Storm Drain and Sewer Pipe [Metric]
ASTM C444M	Standard Specification for Perforated Concrete Pipe [Metric].
ASTM C443M	Standard Specification for Joints for Circular Concrete Sewer and Culvert Pipe, Using Rubber Gaskets [Metric]
ASTM C508	Specification for Asbestos-Cement Under drain Pipe.
ASTM C913	Standard Specification for Precast Concrete Water and Wastewater Structures.
ASTM D2729	Specification for Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings.
ASTM D3034	Specification for Type PSM Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings.

17.1.5 Quality Assurance

The PMC may direct that piping both exposed and embedded shall be tested at completion of roughing or at other time. Embedded piping and protected piping shall be tested before embedment or before making protection.

Casting iron and reinforced concrete pipes shall be tested at a hydrostatic pressure of 1 kg/cm² for a period of at least two (2) hours, with no loss in pressure or visible leaks.

All metal and PVC pipes shall be tested at a pressure not less than 150% of the service pressure, for a period of at least four (4) hours with no loss in pressure or visible leaks.

All welders assigned to the work shall have passed a qualification test conforming to the AWS "Standard Qualification Procedure". If, at the Site, in the opinion of the PMC, the

work of any welder appears questionable, such welder shall be requalified. The Contractor shall furnish all test steel and all welding electrodes required for making the qualification tests. All expenses in connection with qualification and requalification of welders shall be borne by the Contractor.

17.1.6 Submittals and Approvals

Prior to ordering any material for piping works, the Contractor shall submit to the PMC for reference and approval complete shop and installation drawings on the basis of the data shown in the Drawings and/or the instructions given by the PMC.

Cutting of structures shall be done only with the written permission of the PMC and shall be done in such a manner as not to weaken the structural portions of the structures.

Damage to structures, piping, or equipment as a result of cutting for installation shall be repaired by workmen skilled in the trade involved, at Contractor's cost.

17.2 MATERIALS

17.2.1 General

All materials for piping, valves and fittings shall be new and the best grade and quality for the purpose used. All manufactured items shall be standard commercial products of reputable manufacturers.

Where materials are shown in the Drawings, but not specifically covered by a standard or specification, the Contractor shall furnish high class commercial grades of material or items acceptable to the PMC. When two or more items of the same material or equipment are required, similar items of the same size shall be products of a single manufacturer.

All castings shall be true to dimensions, free from cracks, porosity, excessive shrinkage and other injurious defects.

Gaskets for water service shall be rubber impregnated cloth approximately 1.5mm thick. Ring gaskets shall be used for joints with raised face and full face gaskets for flat face flanges.

Joint compound for use with water services shall be a graphite base.

All gaskets shall be painted with a proper compound, allowed to dry and a second coat of compound applied at the time the joint is made.

17.2.2 Steel Pipes

All welded, galvanized steel discharge and drainage pipes shall conform with AISC standards and ASTM Specification A53.

Corrugated steel pipe shall be used for culverts requiring a diameter larger than 1000 mm.

Culverts shall be bolted, nestable culvert, complying with ASTM A762, and shall consist of corrugated, galvanized and bitumen coated steel sheets bolted into rings to form a pipe of the required diameter. The corrugations shall have a pitch of 100 mm and a depth of 20mm.

The sheets shall be hot dip galvanized after fabrication to ensure a coating weight of not less than 750 g/m_2. Where the zinc coating has been damaged, such damage shall be repaired with two coats, not less than 0.1 mm thick of an approved zinc-rich primer containing at least 92% fine zinc powder. The surfaces shall be prepared and the primer applied in accordance with the manufacturer's instructions.

17.2.3 Polyvinyl-Choloride Pipes

Polyvinyl-chloride (PVC) pipes and fittings shall be in accordance with ASTM D 2729 or D 3034.

The material shall be free from scratches, cracks, bubbles or other imperfections. The piping shall be designed for 5 kg/cm² service pressure.

17.2.4 Concrete Pipes

Concrete pipes shall be in accordance with the following requirements:

- Reinforced pipes: ASTM C 76 Class II, Wall A;
- Non-reinforced pipes: ASTM C 14, Class 2;
- Non-reinforced perforated pipes: perforation ASTM C 444, Type 1 or Type 2; pipes ASTM C 14, Class 2.
- Reinforced perforated pipes: perforation ASTM C 444. Type 1 or Type 2; pipe ASTM C 76, Class II, Wall A.

17.2.5 Stndard Valves

Standard valves from 12 mm (1/2") to 76 mm (3") size shall be bronze gate valves with solid wedge, screwed bonnet, rising stem type or bronze globe valves with solid seat valve-head, renewable composition disc inside screwed spindle. End connections may be both screwed or flanged as required.

These valves shall be designed for 15 kg/cm² service pressure. The bonnet, disc, stem, stuffing box, packing nut and body shall be of bronze in accordance with ASTM B 62.

Standard valves over 76 mm (3") shall be cast steel gate or globe valves with flat flanges, and designated for 15kg/cm² service pressure.

These valves shall be made of carbon steel, conforming to ASTM A 216.

17.2.6 Geotextile

Geotextile sheet filters or drains shall be furnished and installed as shown on the Drawings or directed by the PMC. The geotextile sheet shall be non-woven polypropylene geotextile or other synthetic membrane approved by the PMC and shall meet the following requirements:

- Mass : 600 g/m² or more (approx. thickness 3mm or more)
- Ultimate tensile strength (warp) : 300 kN/m or more (ASTM D4595)
- Elongation at ultimate strength : 10% or less (ASTM D4595)
- Flow rate (percolation rate) : 60 l/sec/m² or more (ASTM D4991 vacuum method)

17.2.7 Weepholes

The pipes for the weepholes shall be of PVC and not less than 50 mm inside diameter as shown on the Drawings.

17.2.8 Joints and Connections

17.2.8.1 Cast Iron Pipes

Joints for sewerage cast iron pipes shall be made with coal tarred oakum or virgin pig lead as approved by the PMC. A joint runner shall be used and so installed that after pouring, the lead will finish flush with the hub. Joints shall be tightly caulked, leaving not less than 30mm of lead in the hubs. Each joint shall be run full at one pouring.

Where embedded pipes cross expansion or contraction joints, a hub caulked with oakum but not leaded shall be installed. The end of the hub shall be flush with the plane of the concrete joint.

Where connections are required between exposed steel pipe and embedded bell and spigot pipe, the exposed steel pipe shall be provided with a steel ring to for a spigot end.

17.2.8.2 Steel Pipes

Joints for galvanized pipes shall be made by threading, while joints for black pipes shall be made by welding or bolted flanges.

17.2.8.3 Threaded Joints

All threads shall be cut with clean, sharp dies accurately set.

Dies shall be run over any threads damaged during delivery or storage. All threads on galvanized pipe shall be run over with dies before use.

All pipe threads shall be cleaned and wiped dry to remove any oil, grease or dirt which would prevent adherence of the thread seal compound.

Threads shall be cut full and shall be free from torn or ragged surfaces and no more than three threads on the pipe at any joint shall remain exposed after installation.

Threaded joints shall be made up with joint compound applied to the male threads only.

The use of thread cement or caulking of thread joints to stop or prevent leakage shall not be permitted. No sharp toothed pipe wrench or similar wrench shall be used in making up galvanized pipe.

17.2.8.4 Welded Joints

Joints in welded piping shall be made by the oxy-acetylene or electric arc process in accordance with the Standard Codes as formulated by American Welding Standard (AWS). The pipe ends and all welding fittings shall be cleaned thoroughly and shall be free from foreign matter before assembly and prior to welding operation.

Before welding, the piping or their fittings shall be carefully aligned so that no part is offset with respect to the adjacent part by more than 2% of the pipe diameter with a maximum of 3mm.

The alignment shall be preserved during welding.

If tack welds are used, they shall be of the same quality and made by the same procedure as the completed weld.

Weld metal shall not project into the pipe so as to restrict it seriously or be in danger of loosening and falling into the pipe.

Welded branch connections to any pipe shall be made such that the joint is clean and smooth inside, with no obstruction of the inserted branch pipe into the main pipe run.

17.2.8.5 Flanged Joints

Flanged joints shall be made with gaskets properly centered in the joint and fiber gaskets shall be given two coats of lubricant compound before assembly. Bolts, studs and nuts shall be lubricated with flange bolt lubricant so that the nuts can be run by hand. Care shall be taken to prevent excessive initial tension to the bolts and studs and that the tension applied is as nearly uniform as possible.

The rust preventive compound applied to the faces of flanges before shipment shall be removed before installation. The use of acid or tools that may damage the finished surfaces of the flanges shall not be permitted.

17.2.8.6 Polyvinyl-Chloride Pipe Joints

Polyvinyl-chloride pipes shall be fitted with a connecting system comprising a socket and a rubber ring seal.

For minor PVC network the sealing of coupling may be carried out using a paste as indicated by the PVC pipe manufacturer, if approved by the PMC.

17.2.8.7 Concrete Pipes

Concrete pipe joints, except the perforated ones, shall be mortared to obtain a ring around the pipe having a thickness of 5cm and a width of approximately 20cm. The mortar shall be stiff and composed of one (1) part of cement and two (2) parts of sand.

17.2.8.8 Geotextile Sheets

Jointing of the geotextile sheet shall be lap joint. Method of jointing, clipping, sewing and taping shall be based on the manufacturer's instruction. Fixing of the geotextile sheet to rock, concrete or other shall be by steel nailing with steel plate belt or washer or by binding with iron wires

17.2.9 Graded Gravel

This material shall consist of natural gravel or crushed rock, clean and well graded from 5mm to 20mm in size and may contain up to a total of 10% of particle smaller than 5mm size. The quality for the material shall conform to the requirement specified in Chapter 0430 "Conventional Concrete (CVC)".

17.2.10 Stone Pitching

Stone for pitching shall be clean, hard, durable un-weathered boulders or rock fragments, with no stone less than 150 mm in minimum dimension, except that smaller pieces or spalls may be used for filling spaces between the larger stones. The shapes of the rocks or stones shall be as to form a stable projective layer of the required thickness.

All stone intended for use on a particular pitching job shall be subject to the prior approval of the PMC.

Spaces between the stones shall be filled with cement mortar as provided in Clause 3.6 below.

17.3 EXECUTION

17.3.1 General

- The Contractor shall install the pipes and fittings in a thorough and workmanlike manner in accordance with the Drawings or as instructed by the PMC. Pipes and fittings to be embedded in concrete shall be held firmly in position and protected from damage while the concrete is being placed and until it has thoroughly set. Pipes and fittings shall be clean and free from foreign matter before assembly. Pipe shall be cut by power hacksaw or by circular cutting machine using an abrasive wheel. All pipes after being cut shall be reamed and all burrs removed.
- Care shall be taken to prevent the piping from becoming clogged during the progress of the work. Should any pipe become either partially or wholly clogged before the

expiry of the Defects Notification Period, it shall be cleaned out by the Contractor in a manner satisfactory to the PMC, or shall be replaced by and at the expense of the Contractor.

- During manufacturing, transporting, storing, and laying of concrete pipes, the pipes shall not be dropped or handled in a way that might crack the wall or otherwise cause damage. The pipes shall not be moved until after the specified curing period. Any length of pipe that, in the opinion of the PMC, is damaged beyond repair shall be removed from the Site and replaced by the Contractor at his expense.
- Open ends of the piping shall be plugged or otherwise suitably closed when the work is suspended for any reason. All pipe ends stubbed out of concrete for future connections shall be adequately protected by providing suitable caps, covers, plugs or blank flanges as required by the PMC and as shown in the Drawings. A reducing fitting shall be used where any change in pipe size occurs, bushings shall not be used. All exposed piping shall be properly supported as shown on the Drawings, or as required by the PMC. Generally, piping shall be supported by adjustable clevis type ring hangers or hanger rods attached to channel inserts.
- Pipes located in ground shall be supported firmly through its entire length, by means of a bedding layer of lean concrete or sand, 100mm minimum thickness, as shown in the Drawings.
- Backfill around pipes shall be carefully placed and tamped so as not to disturb the pipe. No coarse material will be permitted in contact with the pipe.
- Loads up to the design loading of AASHTO H-20 will not be permitted to travel over the pipes until backfill and embankment material have been placed to a minimum thickness of at least 0.50m over the top of the pipe. This minimum cover requirement being not always adequate during construction when equipment heavier than design traffic loads is routed over or close to the installed culverts, the Contractor shall be responsible for providing the additional cover necessary to avoid damage of the pipes due to such loads.
- The gutters and downpipes required for draining the roofs shall be as shown in the Drawings and shall be installed as per the manufacturer's instructions or as directed by the PMC.

17.3.2 Drainage of Backfill Behind Training Walls

The Contractor shall provide and install perforated, reinforced concrete pipe along training walls according to the line and levels and at the locations as shown in the Drawings, or otherwise directed by the PMC, to collect and discharge water which infiltrates the backfill behind the training walls. The pipes shall be properly jointed using a bell and spigot type arrangement, or approved alternative.

The perforated concrete drainage pipe shall be installed so as to be completely surrounded with drain and filter material, as shown in the Drawings, and shall conform to the requirements of Chapter 0320. Compaction of the drain and filter material shall be by tamping or other approved methods.

Access to the main drainage pipes will be provided by 1.8m wide by 1.2m long reinforced concrete manholes at the locations indicated as the Drawings or as instructed by the PMC. Removable steel covers and access ladders to be provided in accordance with Chapter 0510 "Miscellaneous Structural Steel Construction and Metalworks".

The minimum depth of cover over the pipe shall be 1.5m before heavy construction equipment is permitted to pass over the pipe.

Care shall be taken during the installation of the perforated concrete drainage pipe. The cost of any remedial work required for the pipe and its installation shall be to the Contractor's account.

17.3.3 Drainage of Top of Bridges

Drainage of the top of the bridge decks shall be by 100mm diameter galvanized steel pipes placed at 3.0m centers as shown in the Drawings.

The Contractor shall be responsible for the supply, installation and proper functioning of the drainage provisions to the PMC's satisfaction.

17.3.4 Roof Drainage of Chambers and Houses

The roofs shall be sloped at 2% downwards towards the reservoir. The lower roof edges shall have a 120mm x 120mm roof gutter discharging at the end of canal center side down a 100mm diameter drain pipe. The Contractor shall be responsible for the Works to the satisfaction of the PMC.

17.3.5 Weepholes for Concrete structures

The Contractor shall provide weep-holes as shown on the Drawings or as directed by the PMC. Drain pipe used for constructing weep-holes shall be polyvinyl-chloride (PVC) pipe not less than 50mm diameter and shall be positioned at the locations, intervals and spacing as shown on the Drawings. All pipes shall be placed and held accurately in position. Where weep hole ends are covered with soil on backfill side, graded gravel (5-20mm size) shall be placed in the immediate area of the weep-holes at backfill side. Use of geotextile sheet may be indicated on the Drawings where required for securing filtering effect. Drain holes provided for in the rock cut shall be performed according to those specified in Chapter 0240 "Drilling and Grouting".

Drain holes which become plugged during construction must be made operational either by washing or re-drilling, to the PMCs satisfaction.

17.3.6 Drain Ditches

Drain ditches shall be constructed true to line, grade and cross section, as shown in the Drawings or as directed by the PMC, and shall be so maintained for the duration of the contract.

In the laying out and construction of the drainage system, particular attention is to be paid to the prevention of soil erosion.

Where steep drains have to be constructed in erodible material, suitable precautions such as concrete lining, stone pitching, construction of steps, or any other means shall be taken to prevent scour or erosion, all as shown in the Drawings or as directed by the PMC.

Care shall be exercised to avoid excavation below the required grade for the drains, and any excavation carried out below the required grade shall be backfilled with suitable material and compacted to at least 95% of the maximum dry density as determined by ASTM D698 when the drain is in soft material. Over excavation in hard material shall be backfilled with concrete all by the Contractor.

17.3.6.1 Concrete Drain Ditch

The Contractor shall design and construct concrete drain ditches where shown on the Drawings. The form and dimensions of the various ditches and trenches are shown on the Drawings. The drain ditches shall be formed according to the lines, grades and dimensions shown on the Drawings and trimmed to attain smooth surfaces for the reception of mortar bed.

Prior to placing or constructing the ditches, the foundation surface shall be cleaned of all adherent soil, dust and earthy or organic impurities. On the cleaned foundation, gravel bedding or other bedding materials shall be placed and compacted as shown on the Drawings.

Concrete for the ditches shall meet the requirements in Chapter 0430 Conventional Concrete Work in these

Specifications. Finished concrete shall be adequately cured and protected. Earth backfill shall be as shown on the Drawings.

17.3.6.2 Wet Masonry Ditch

The Contractor shall form wet masonry drain ditches where shown on the Drawings. The ditches shall be lined with stone paving set in mortar as stipulated in Chapter 0610 Masonry Work. The form and dimensions of the ditches are shown on the Bid Drawings.

Stones or rock fragments for masonry shall be selected from required excavation or quarries. They shall have the same properties and qualities as material for masonry, and shall be chosen such that they have a reasonably flat upper surface when laid. Stones

for masonry in mortar shall not be less than 15 cm thick and not less than 30 cm² in area. Mortar for wet masonry shall comprise three parts of clean fine aggregate to one part of cement by volume. Fine aggregate and cement shall meet the requirements specified in Chapter 0430 Conventional Concrete Work.

The ditches shall be formed according to the lines, grades and dimensions shown on the Drawings and trimmed to attain smooth surfaces for the reception of mortar bed. Prior to placing, the stones shall be cleaned of all adherent soil, dust and earthy or organic impurities, and wetted sufficiently to saturate it, but leaving the surface in a damp condition.

Stones shall be placed on a mortar bed of minimum thickness of 5 cm and carefully arranged such that the minimum of voids remain between rocks. No continuous horizontal or vertical joints shall exist and the largest rocks shall be evenly distributed.

After stone placing, the joints shall be completely filled with mortar. Splashing of exposed rock surfaces with mortar shall be avoided and where splashing does occur, the surface of the rock shall immediately be cleaned down with a sponge and clean water. Finished surfaces shall be adequately protected against rainfall until the mortar has set.

17.3.7 Stone Pitching

When, owing to the nature of the material and the slope of the ditch, there is a definite possibility of scouring by flow, grouted stone pitching of the toe and slopes of the ditch will be carried out as follows:

- Commencing at the bottom of the trench, the stone shall be laid and firmly bedded into the slope and against adjoining stones. The stones shall be laid with their longitudinal axes at right angles to the slope and with their surfaces in contact so as to break joints,
- The thickness of the pitching, at right angles to the surface shall be not less than 150mm,
- Spaces between the stones shall be filled with cement mortar composed of one (1) to three (3) parts sand. Before the mortar is applied, the surfaces of the stones shall be thoroughly cleaned of adhering dirt and clay and then moistened. The mortar shall be placed in a continuous operation for any day's run at any one location. The mortar shall be worked into the pitching so as to ensure that all spaces or voids between the stones are completely filled with mortar to the depth of the stone pitching.
- After the grout has been placed, the stages shall be thoroughly brushed so that their top surface are exposed. The grouted pitching shall be cured with wet sacking or other approved wet cover for a period of not less than four (4) days after grouting, and shall not be subject to loading until adequate strength has developed. Where required, wheepholes shall be formed in the pitching.

17.3.8 Pits

The Contractor shall supply and install reinforced concrete inspection pits in the sewerage and drainage lines, at the locations and of diameters as shown on the Drawings.

Concrete shall meet the requirements specified in Chapter 0430 Conventional Concrete Work.

Where required on the Drawings, removable cover shall be installed. The cover shall be of cast iron with ring seat, diameter 40 or 60 cm capable of withstanding road traffic. Cover and ring seat shall receive 2 coats of bituminous paint after careful cleaning.

17.3.9 Defective Works

If inspections or tests show defects, leaks, etc., such defective work or material shall be replaced and the test repeated at the expense of the Contractor.

All repairs to piping shall be made with new material. No caulking of screwed joints or holes will be accepted.

17.3.10 Cleaning

At the completion of the Works, all parts of the installations shall be thoroughly cleaned.

All pipes and fittings shall be cleaned of grease, welding metal, metal cuttings and sludge which may have accumulated by operation of the system for testing.

Any stoppage or discoloration or other damage to parts of structures, their finish or furnishing due to the Contractor's failure to properly clean the piping system shall be repaired by the Contractor at no additional cost.

17.3.11 Corrosion Protection

The exterior surface of the steel pipe to be placed in the ground shall be cleaned, primed and coated with two (2) coats of coal-tar with a fiber-glass felt wrapper bonded into the two (2) coasts. All such material and application shall be approved by the PMC. Each coal-tar coat shall not be less than 2mm in thickness.

Any uncoated area, pinholes, torn, abraded or mutilated spots in the corrosion protection of the pipe and any burning of the corrosion protection due to welding shall be repaired. In cases where the bond between the original coating and the pipe has been broken, the original coating surrounding the affected area shall be removed to bare metal and the edges of the original coating beveled or feathered and retreated.

Where the bond has not been affected, a patch may be applied over the original treating. Before any patching is done, all whitewash, dirt or other foreign material shall be thoroughly removed from the area to be treated.

Alternatively, the Contractor may propose the use of galvanized steel pipes. The galvanization shall be in the conditions as specified in Chapter 0510 "Miscellaneous Structural Steel Construction and Metalworks".

17.3.12 Painting

The exposed surface of steel pipes and valves, excluding piping which is insulated, protected against corrosion or embedded, shall be painted according to the provisions set forth in Chapter 0510 "Miscellaneous Structural Steel Construction and Metalworks".

17.3.13 Colour Coding

Steel piping shall be marked with bends and arrows of colored tape or paint to designate the contents and flow direction. General specifications requirements for the markings shall be instructed by the PMC.

Color code bends and arrows shall be applied at the points of entering and leaving a space, at all valves and at intermediate locations for convenience as determined by the PMC.

Chapter 0320

18 FILL AND BACKFILL

18.1 GENERAL

18.1.1 Scope

This Chapter covers the following earthworks:

- Fill and backfill of the Dam Structures
- Roads embankment and backfill.
- Backfill of trenches and behind walls.

18.1.2 Related Works / Sections

Chapter 0210	Site Preparation
Chapter 0212	River Diversion system
Chapter 0220	Surface Excavation
Chapter 0260	Drainage of Structures
Chapter 0810	Roads and platforms
Chapter 0820	Site Reinstatement

18.1.3 Definitions

Fill and backfill work as specified under this Chapter shall include filling or backfilling with random or selected materials approved by the PMC and built up in horizontal layers, the thickness of which shall be determined according to trials carried out by the Contractor or as directed by the PMC before the beginning of any filling work.

18.1.4 Codes and Standards

18.1.4.1 General

- The Work included in this Chapter shall comply with the requirements of the following standards and codes, except where this Specification differs from these standards and codes, in which case the requirements of the Specification shall take precedence:
- "Earth Manual" of Bureau of Reclamation, US Department of the Interior.

18.1.4.2 American Society for Testing and Materials (ASTM).

ASTM D421	Standard practice for Dry preparation of soil samples for particle-size analysis and determination of soil constants
ASTM D422	Standard test method for particle-size analysis of soils
ASTM D4318	Standard methods test for liquid limit, plastic limit and plasticity index of soils

ASTM D698	Standard test methods for laboratory compaction characteristics of soils using standard effort (12,400ft-lbf/ft3 (600kN-m/m3))
ASTM D854	Standard test methods for specific gravity of soil solids by water pycnometer
ASTM D1556	Standard test method for density and unit weight of soil in place by sand cone method
ASTM D1557	Standard test method for laboratory compaction characteristics of soils using modified effort (56,000ft-lbf/ft3 (2,700kN-m/m3))
ASTM D2167	Standard test method for density and unit weight of soil in place by the rubber balloon method
ASTM D2216	Standard test methods for laboratory determination of water (moisture) content of soil and rock by mass
ASTM D6938	Standard test methods for in-place density and water content of soil and soilaggregate by nuclear methods (shallow depth)
ASTM D4253	Standard test methods for maximum index density and unit weight of soils using a vibratory table.

18.1.5 Quality Assurance

18.1.5.1 Tests and Controls

All the controls required in the Specifications shall be performed in the laboratory by the Contractor's staff under the supervision of the PMC.

18.1.5.2 Tolerances

- 1. All fill and backfill shall be constructed to the lines and dimensions shown in the Drawings or as required by the PMC.
- 2. For compacted fill and backfill, the following tolerances shall be required unless otherwise shown in the Drawings or as directed by the PMC:
  - Level (vertical) =+ 0, - 5 cm,
  - Dimension (horizontal) =+ 15, - 0 cm (on the dimension of fill).

18.1.6 Submittals and Approvals

- A mass haul diagram of the fill and backfill works shall be submitted to the PMC in the form and following the description given in Chapter 0220 - Surface Excavations.
- This mass haul diagram shall be drafted and submitted together with the general mass haul diagram of specified in Chapter 0220.
- At least twenty eight (28) days before starting the filling operations, the Contractor shall submit a complete programme showing the proposed filling program including quantities and origin of materials (excavations for cuttings, borrow area, stockpiles if any, etc.).
- At least twenty eight (28) days before starting the filling operations, the Contractor shall submit to the PMC a detailed method statement covering the embankment construction with special emphasis on material placement.

- On a weekly basis, the Contractor shall submit to the PMC summary sheets giving the results of all controls performed during the week on a format to be agreed with the PMC.
- The Contractor shall provide the PMC each day with one copy of the record for the previous day's work for all fill work including:
  - Qquantity and type of materials placed (selected fill, selected rockfill, random rockfill),
  - Location of the material placed,
  - Origins of material placed,
  - Number and classification of men and plants engaged,
  - Weather conditions.
  - Inflows of water or any other unusual occurrence.

18.2 MATERIALS

18.2.1 General

Fill and backfill materials shall be sourced, as far as practicable, from excavations of nearby structures.

These materials shall be well graded and shall be subject to the PMCs approval prior to placement.

18.2.2 Selected Compacted Fill

The material shall comply with the following requirements:

- D_{max}= 100 mm.
- Organic matter content < 0.2%.
- Fraction passing 0.074 mm sieve (square openings) between 0 and 15%.
- Plasticity index PI $\leq$ 15.

18.2.3 Selected Compacted Rockfill

- The material shall comply with the following requirements:
- D_{max} = 250 mm.
- Organic matter content < 0.2%.
- Fraction passing 0.074 mm sieve (square openings) between 0 and 5%.

18.2.4 Random Compacted Rockfill

The material shall comply with the following requirements:

- D_{max} = 600 mm.
- Organic matter content < 2%.

Maximum particle size of the top layer of embankments shall be 250 mm.

18.2.5 Sand and Gravel Bedding and Gravel Fill

The materials shall be as specified in Clauses 3.6 and 3.7 respectively.

18.3 EXECUTION

18.3.1 Inspection

- Before the commencement of any fill works the site shall be surveyed by the Contractor in conjunction with the with the PMC to establish existing ground levels and these agreed ground levels shall form the basis for the calculation of quantities of any subsequent filling.
- No fill shall be placed in any embankment section until the foundation has been inspected and approved by the PMC.
- Placing of a layer shall not be done until the preceding layer has been inspected and accepted by the PMC.

18.3.2 General

- All backfill operations shall be performed in dry conditions.
- Prior to the commencement of placing backfill materials adjacent to structures, the backfill areas shall be cleared of all remaining concrete forms, other temporary works and unsuitable materials, and shall be subject to the approval of the PMC.
- The backfill materials shall be placed in such manner as to ensure that they can be satisfactorily compacted without damage to the structure.
- The sequence of filling behind or around a structure and the maximum difference in height at any time between fill levels shall be approved by the PMC.
- Sheeting and timbering supporting the excavations shall be removed, step by step, to prevent any settlement.
- Where instructed by the PMC, timbering and sheeting shall be left in place.
- Unless otherwise directed by the PMC, backfill material shall not be placed and compaction shall not be permitted adjacent to concrete for fourteen (14) days after the placing of concrete, and compaction of backfill material placed above buried

concrete shall not be permitted to be carried out with vibrating rollers within 50 cm vertically of the surface of the concrete.

- Where instructed, selected granular fill material approved by the PMC shall be placed around structures.
- A special care shall be given to compaction along concrete structures and at all locations where easy access is not possible. At these locations all the required criteria for each type of fill shall be fulfilled.

18.3.3 Selected Compacted Fill

18.3.3.1 Placing and Compaction

- Selected compacted fill shall be placed in layers not exceeding 250mm and at least 1.5 times D maximum.
- Each layer shall be compacted by suitable means as approved by the PMC so as to achieve a dry density at least equal to 95% of the maximum dry density as determined by ASTM D698.
- Placement moisture content of the material shall be so that:

  $-2 \leq W - W_{opt} \leq +2$

  where:

  W : placement moisture content measured on the compacted layer;

  W_{opt} : optimum moisture content of the standard Proctor compaction test.
- Two compaction tests shall be made on the first layer placed in order to determine the suitability of the equipment used and the number of passes required.
- If changes occur in the nature or the origin of the fill material used during the Works or at the request of the PMC, new tests shall be performed.

18.3.3.2 Control

Final acceptance of materials shall only be made after they have been dumped, spread and compacted.

18.3.4 Selected Compacted Rockfill

18.3.4.1 Placing and Compaction

- The maximum lift thickness shall be 400 mm and at least 1.5 time D maximum.
- Each layer shall be compacted by suitable means as approved by the PMC so as to achieve a relative density in the range 60 to 70%.
- The relative density shall be determined by the USBR Method Designation E12.

- If necessary, to achieve the compaction requirements, the material shall be wetted.
- Two compaction tests shall be made on the first layer placed in order to determine the suitability of the equipment used and the number of passes required.
- If changes occur in the nature or the origin of the fill material used during the Works, or at the request of the PMC, new tests shall be performed.

18.3.4.2 Control

Final acceptance of materials shall only be made after they have been dumped, spread and compacted.

18.3.5 Random Compacted Rockfill

18.3.5.1 Placing

- The maximum lift thickness for random rockfill shall be 600mm.
- Placing shall be performed so as to obtain homogeneous fill without segregation.
- The rockfill shall be dumped on top of the new layer, back from the advancing edge and pushed over on the lower layer with bulldozer blades.
- Any oversize particles which protrude from the layers shall be removed before compaction.

18.3.5.2 Compaction

Unless otherwise directed by the PMC,

- Compaction of rockfill shall be performed with an approved single or double smooth drum vibrating roller with the following characteristics:
  - Minimum static weight: 10 t
  - Drum diameter: not less than 1500 mm
  - Maximum drum length: 2200 mm
  - Minimum static weight per m of drum: 4.5 t
  - Minimum total applied compacting force at rated vibration frequency: 30 t
- Rollers shall not travel at speeds exceeding 4 km/h.
- 3. The roller shall perform four passes, unless otherwise instructed by the PMC after compaction testing.

18.3.5.3 Controls

Final acceptance of materials shall only be made after they have been dumped, spread and compacted.

18.3.5.4 Top Part of Embankment Platform

- The final top meter of the embankment platform shall include:
  - 0.7 m of random rockfill, with D max limited to 250mm at lower elevations, overlain by
  - 0.3 m of selected fill as specified in Clause 2.2 "Selected compacted fill".
- Placing, compaction and control of the above-mentioned materials shall be done according to the related Specifications.

18.3.6 Sand and Gravel Bedding

Reasonably well-graded sand and gravel shall be used for trench backfilling for pipes, cables and ducts, bedding for rock riprap and structural foundation, etc. The maximum particle size shall not exceed 75 mm and fraction passing 0.074mm sieve (square openings) shall be between 0 and 5% by weight. The material shall be spread in layers of 200mm vertically at the maximum and compacted by the approved means.

18.3.7 Gravel Fill

Gravel fill shall be clean of the gravel with particle size of 38 mm to 75 mm hand-tamped and good hard composition free from vegetation or other foreign matter.

Chapter 0330

19 ROCK PROTECTION

19.1 GENERAL

19.1.1 Scope

This Chapter covers the requirements for the supply and placement of rock riprap protection and gabion baskets and mattresses.

19.1.2 Related Works / Sections

Chapter 0211 - Dewatering and Care of Water

Chapter 0212 - River Diversion

Chapter 0220 - Surface excavations

Chapter 0320 - Fill and Backfill

Chapter 0810 - Roads and platforms

19.1.3 Codes and Standards

The work including in this Chapter shall comply with the requirements of the following standards and codes, except where this Specification differs from these standards and codes, in which case the requirements of the Specification shall take precedence.

- California Division of Highways Test Methods No. Calif-206-D and Calif-229-E
- "Earth Manual" of Bureau of Reclamation, US Department of the Interior.

19.1.4 Quality Assurance

19.1.4.1 Tests and Controls

The minimum rate of control of rock protection material shall be as follows:

The sample subject to weight grading of the rip rap shall be at least twenty (20) times P50 with:

Test	Number of tests per m³ of material
Unconfined compressive strength	1 test per 2000 m3
Los Angeles abrasion	1 test per 2000 m3
Bulk specific gravity	1 test per 2000 m3
Water absorption	1 test per 2000 m3
Weight Grading	1 test per 2000 m3

P_{50} = ¾ (D50)3 x γ

D_{50} : Diameter in decimeter of the passing sieve opening for 50% of the specified gradation

γ : Unit weight in kg/m³

P_{50} : weight in kg

The frequency of the tests may be amended as required by the PMC depending on the results of the previous tests and material variations.

19.1.4.2 Tolerances

- All rock protection shall be constructed to the lines and dimensions shown on the Drawings or as required by the PMC.
- Tolerance of rock protection shall be +200 mm; -0 unless otherwise shown on Drawings or ordered by the PMC.

19.1.5 SUBMITTALS AND APPROVALS

- A mass haul diagram shall be submitted to the PMC in the form and following the requirements given in Chapter 0220 "Open air excavations".

  This mass haul diagram shall be drafted and submitted together with the general mass haul diagram of Chapter 0220.
- The Contractor shall provide the PMC each day with one copy of the record for previous day's work including:
  - Quantities of material placed with their type,
  - Location of material placed,
  - Number and classification of men and plants engaged,
  - Weather during the day,
  - Inflows of water or any other unusual occurrence.
- On a weekly basis, the Contractor shall submit to the PMC summary sheets giving the results of all controls performed during the week on a format to be agreed with the PMC.
- Prior to the beginning of works, the Contractor shall submit to the PMC the methods and plants used for placing the rock protections.

19.2 MATERIALS

19.2.1 Riprap

- Material for use as riprap shall be selected from the designated quarry and shall consist of strong, hard, dense rock, free of fissile material, cracks and seams, and resistant to abrasion.
  - Apparent specific gravity of the stone shall not be less than 2.5
  - Absorption shall be less than 2%.
  - Los Angeles abrasion shall be less than 45%.

- Unconfined compressive strength shall not be less than 50MPa.

- The shape of riprap particles shall be such that the largest dimension of individual pieces shall not exceed two and half (2.5) times the shortest dimension. Elongated or flat stones shall not be used.
- Rip rap is defined by its design stone size D_{50} as follows:

  Rip rap type R1: D_{50} = 30 cm

  Rip rap type R2: D_{50} = 50 cm

The distribution of particle sizes for riprap shall lie within the following limits. Particle sizes shall be determined as the equivalent spherical diameters, determined by weight and specific gravity.

$D_{50\ min} = 0.9 \times D_{50}$

$D_0 = 0.67 \times D_{50\ min}$

$D_{15\ min} = 0.82 \times D_{50\ min}$

$D_{15\ max} = 1.15 \times D_{50\ min}$

$D_{50\ max} = 1.3 \times D_{50\ min}$

$D_{85\ min} = 1.15 \times D_{50\ min}$

$D_{85\ max} = 1.58 \times D_{50\ min}$

$D_{100} = 1.7\ D_{50\ min}$

All riprap material shall meet the criteria of the California Division of Highways Test Methods No. Calif-206-D and Calif-229-E in respect of the Durability Absorption Ratio (DAR) and Durability Index, as follows:

- The material is acceptable if the DAR exceeds 23
- The material is unacceptable if the DAR is less than 10
- If the DAR is between 10 and 23, the material is acceptable if the Durability Index is 52 or greater.

19.2.2 GABIONS

19.2.2.1 Baskets

The materials for Gabions shall be galvanized steel, triple twist, wire mesh baskets with a maximum mesh size of 76mm x 102mm with a minimum wire size of 3mm diameter. Frame reinforcement shall be of a minimum wire size of 5mm. Gabion baskets shall be 0.5m or 1.0m thick, as required, and supplied with sufficient diaphragms to provide compartments 1m wide x 1m long. Sufficient amounts of the 2.2 mm diameter lacing or tie wire shall be supplied to tie the Gabion baskets together and to each other. All galvanizing shall provide a minimum zinc coating of 260g of zinc per square meter of wire surface area

19.2.2.2 Rockfill for Gabion Baskets

The Contractor shall procure, load, haul and place the necessary rockfill for the Gabion baskets and Reno mattresses. Clean, hard, dense, rounded and durable rock shall be used, ranging in size from 100mm to 200mm.

19.3 EXECUTION

19.3.1 Inspection

Foundation preparation for Gabion baskets and Reno mattresses will comply with the requirements specified in Chapter 0220 "Surface Excavation", Sub-Clause 2.2.

Before placing rock protections, the foundation shall be surveyed in conjunction with the PMC in order to form basis for the calculation of quantities for recording.

No rock protection shall be placed in any section until the foundation has been inspected and approved by the PMC.

Geotextile sheet shall be provided where shown on Drawings or requested bythe PMC asspecified in Chapter 0260 "Drainage of structures".

19.3.2 Riprap

Riprap shall be placed in areas as shown on the Drawings or where directed by the PMC, so as to form a stable interlocked layer. The thickness of riprap bedding shown on the Drawingsshall be the minimum layer thickness provided.

There shall be no areas or patches of undersized stone. If in the opinion of the PMC segregation of the riprap material or displacement of the bedding layer occurs, the Contractor shall remove the unsuitable material and modify the placement procedure to ensure that the specification requirements are consistently satisfied.

19.3.3 Gabions

The Gabion baskets and Reno mattresses shall be assembled to the shapes shown on the Drawings and placed in the proper locations at the structure site as shown on the Drawings or instructed by the PMC.

Any objectionable material shall be removed from the foundation surface prior to placement of the Gabion's and rockfill. The Gabion's shall be assembled, placed, tied and filled to the PMC's satisfaction.

The Gabion baskets shall be filled with the rock in progressive layers. The rockfill in one Gabion shall not exceed the rockfill in the adjacent Gabion baskets by more than one-half the depth of the Gabion baskets. Each layer of rock placed in the Gabion basket shall be hand arranged to minimize the voids. Extreme care shall be taken to ensure that the placement of rocks in the Gabion basket does not cut, bend or damage the Gabion mesh.

The galvanized Gabion lids will be placed on the properly filled Gabion baskets and Reno mattresses and pulled down to meet the sides. The tie or lacing wire shall bind the Gabion lids shut with all sides and with all diaphragms. The Gabion lids shall be tied to the filled Gabion baskets and Reno mattresses as shown on the Drawings and to the satisfaction of the PMC.

Chapter 0410

20 FORMWORK AND SURFACE FINISHES

20.1 GENERAL

20.1.1 Scope

This Section covers the requirements for the design, material, fabrication, erection and removal of formwork for concrete.

20.1.2 Related Works / Sections

Chapter 0430 Conventional Concrete (CVC)

Chapter 0433 Roller-Compacted Concrete (RCC)

Chapter 0440 Concrete Structure Joints and Bearings

20.1.3 Definitions

20.1.3.1 General

- The Contractor is fully responsible for concrete formwork. The Contractor shall design, supply and install in order to produce concrete parts meeting specified shape, dimensional and position requirements, without defects or irregularities and within the prescribed tolerance limits.
- Abrupt irregularities refer to any local irregularity resulting from incorrect alignment or relative displacement of the formwork, unsatisfactory condition of formwork or any other cause. Abrupt irregularities will be measured directly or using a rule or a template of 200mm long.
- Gradual irregularities: refer to any other difference between the theoretical and actual lines of the concrete faces. They shall be measured with a 3m long straight rule for plane surfaces and with an appropriate template for curved surfaces of 1.50m long.
- Honeycombs, grout losses and surface plucking shall not be considered as irregularities but as defects.
- Formwork required to form construction joints in concrete to facilitate placement of the concrete is termed bulkhead formwork.

20.1.3.2 Classes of Finish for Formed Concrete

The classes of finish for formed concrete surfaces are designated by use of symbols F1, F2 and F3. Bag rubbing or sand blasting will not be required on formed surfaces, other than that necessary for the repair of surface imperfections. The surface finish to be achieved on formed concrete surfaces shall be as shown in the Drawings and is defined hereunder.

20.1.3.2.1 Finish F1

Finish F1 applies to formed surfaces upon or against which fill material or concrete is to be placed. Except for construction joints, the surfaces require no treatment after form removal except for repair of defective concrete and filling of holes left by the removal of fasteners for the ends of tie rods. Correction of surface irregularities will be required for depressions only, and only for those which, when measured exceed 30mm.

20.1.3.2.2 Finish F2

Finish F2 is for tunnel linings unless otherwise specified and for surfaces which are permanently exposed to view but where the highest standard of finish is not required. Surface irregularities shall not exceed 4mm for abrupt irregularities or 10mm for gradual irregularities. While minor surface blemishes and discolorations will be permitted, large blemishes, stains and discoloration shall be corrected where directed by the PMC.

In tunnel linings, except where otherwise approved by the PMC, steel forms shall be specifically manufactured for this intended use, except for bulkheads.

20.1.3.2.3 Finish F3

Finish F3 is for surfaces which will be in contact with flowing water and for surfaces prominently exposed to view where good appearance is of special importance.

To achieve this finish the formwork shall be faced with steel, or plywood or equivalent material in large sheets. The sheets shall be arranged in an approved uniform pattern. Wherever possible, joints between sheets shall be arranged to coincide with architectural features or changes in direction of the surface. All joints between panels shall be vertical and horizontal unless otherwise directed. Suitable joints shall be provided between sheets to maintain accurate alignment in the plane of the sheets. Unfaced sheeting or standard steel panels will not be permitted for F3 Finish unless authorized by the PMC or where specifically detailed on the Drawings.

After stripping of forms all projections shall be removed, irregularities repaired and the surface rubbed or treated to form a smooth finish of uniform texture, appearance and color. Surface irregularities shall not exceed 2mm for abrupt irregularities or 5mm for gradual irregularities. Abrupt irregularities will not be permitted at construction joints. Plastering of cement or mortar on the concrete face is prohibited unless specifically approved by the PMC.

20.1.3.3 Classes of Finish for Unformed Concrete

The classes of finish for unformed concrete surfaces are designated by the symbols U1, U2 and U3, and are defined hereunder:

20.1.3.3.1 Finish U1 (Screeded Finish)

Finish U1 applies to unformed surfaces that will be covered by fill material or concrete. Finish U1 is also the first stage of finish U2. Finishing operations shall consist of sufficient

leveling and screeding to produce even, uniform surfaces. Surface irregularities shall not exceed 10mm.

20.1.3.3.2 Finish U2 (Floated Finish)

Finish U2 applies to unformed surfaces not permanently concealed by fill material or concrete and not required to receive U3 Finish. Finishing operations shall consist of sufficient leveling and screeding to produce even surfaces in which the surface irregularities shall not exceed 10mm. Floating with hand or power driven equipment shall be started as soon as the screeded surface has stiffened sufficiently to prevent formation of laitance, and shall be the minimum necessary to produce a surface that is free from screed marks and uniform in color and texture. Abrupt irregularities will not be permitted.

20.1.3.3.3 Finish U3 (Trowelled Finish)

Finish U3 applies to unformed surfaces exposed to high velocity flowing water or other locations where accurate alignment and evenness of surfaces is required. Finish U3 shall be screeded and floated as indicated for finishes U1 and U2. Stage 3 shall consist of steel trowelling the floated surface as soon as it has hardened sufficiently to prevent excess of fine material being drawn to the surface. Steel trowelling shall be performed with firm pressure to flatten the sandy texture of the floated surface and produce a dense, uniform surface, free from blemishes and trowel marks. Surface irregularities shall not exceed 2mm for gradual irregularities. Abrupt irregularities will not be permitted.

20.1.4 Codes and Standards

The Work included in this Section shall comply with the requirements of the following standards and codes, except where this Specification differs from these standards and codes, in which case the requirements of the Specification shall take precedence:

20.1.4.1 American Concrete Institute (ACI)

ACI SP-4 : Formwork for Concrete

ACI 347 : Recommended Practice for Concrete Formwork

20.1.4.2 American Society for Testing and Materials (ASTM)

ASTM C805 : Rebound Number of Hardened Concrete.

20.1.5 Quality Assurance

20.1.5.1 Inspection

Temporary openings shall be provided at the base of forms as necessary to facilitate cleaning and inspection. After inspection, these openings shall be closed in such a

manner that leakage during concreting is prevented and that the concrete surface finish is not impaired.

After construction of the falsework and formwork, and prior to the placing of reinforcing steel and/or placement of concrete, the Contractor shall inspect the falsework and formwork. Dimensions shall be controlled, unevenness of surface shall be corrected and special attention shall be paid to the accuracy and tightness of bolts, ties and bracings as well as to the soundness of the foundation.

20.1.5.2 Tolerances

Where tolerances, if any, detailed in the Drawings differ to those specified below, then those detailed in the Drawings shall apply.

The tolerances given below shall be the maximum permissible deviations from the specified dimensions, levels, alignment, positions, etc., as shown in the Drawing of the structure or structural elements.

In addition, at the junction with mechanical components, concrete surfaces shall be finished flush and shall also meet any additional tolerances required by the mechanical design.

Tunnels	Position		± 300 mm
	Level	Centre point of the tunnel	± 50 mm
	Leading dimension	Lined diameter	± 30 mm
Shafts	Position	Plan	± 100 mm
	Vertically (in any orientation)		± 1%
	Leading Dimensions	Lined Diameter	-0 +100 mm
		Surfaces	as given in Clause 1.3
Columns, Beams, Slabs and Walls	Position	Plan	10 mm
		Alignment	Of individual members and column groups: 2 minutes
	Leading dimensions	Cross-section	+ 15 mm -5 mm
	Levels	Inverts and soffits	± 5 mm
	Vertically		2 mm/m, 30 mm max
Precast Units (except segments for tunnel)	Position		5 mm
	Alignment		2 minutes
	Leading dimensions	Plan	± 5 mm
		Cross-section	± 5 mm
	Level of Unit		± 5 mm
	Irregularity		as given in Clause 1.3
	Bow per meter of length		1 mm
	Camber		Maximum difference in level of soffits of adjacent beams when placed side by side: 10 mm

In addition, units in prominent view shall be to a straight line or smooth continuous curve such that deviations of line and levels are not visible by eye.

20.1.6 Submittals and Approvals

- The Contractor shall design and be responsible of all formwork and falsework. Notwithstanding any approval given to the Contractor by the PMC, the Contractor shall remain responsible for the safety and structural soundness of all formwork and falsework.
- The Contractor shall submit the design and details of all formwork and falsework to the PMC for his approval. Formwork design shall conform to Chapter 1 of ACI 347. The design tables in ACI Special Publication No.4, 'Formwork for Concrete' or other equivalent publication may be used provided that the characteristics of the lumber to be used are established to the satisfaction of the PMC. Drawings submitted for approval shall clearly indicate the dead live loads assumed for the design, the maximum permissible rate of rise of concrete in the form, the dimensions of all structural members and the capacity of all ties, and anchors and hangers.
- Lift heights are subject to the approval of the PMC.
- Tunnel formwork and related equipment shall be designed by the Contractor and shall be submitted to the PMC for approval.
- If used, the sliding formwork and related equipment shall be designed by the Contractor and shall be submitted to the PMC for approval.
- Bulkhead formwork used for vertical construction joints shall be submitted to the PMC with all documentation, tests results and sample for approval.

20.2 MATERIALS

20.2.1 Forms

- All materials used in the fabrication and erection of forms shall be of adequate strength and quality for their intended purpose, to the approval of the PMC. Suitable local timbers shall be used.
- Forms shall consist of plywood sheets or timber boards of suitable thickness. Boards shall be of suitable dried timber that will not warp, distort or cause discoloration of the concrete. Steel forms may be used only with the approval of the PMC. All forms other than metal forms shall be new when they are first used on site.
- All materials used in formwork shall be of a type and strength sufficient to withstand the pressures due to the concrete, reinforcement and embedded parts as well as additional loads resulting from the rate of concreting, the lift cast in one operation and the method of placing and compaction.

- Where finishes F2 or F3 are specified, forms may be of plywood sheathing or lining, or tongue and groove lumber, to the approval of the PMC. However, each structure must be uniformly treated insofar as external visible surfaces are concerned.
- Curved and double curved forms shall be sanded down and all joints filled with an approved wood filler so that the surface is perfectly smooth and tight.
- Panels may be reused on site on condition that they are carefully cleaned, reconditioned or surfaced from time to time and if they will be capable of producing concrete surfaces conforming to the specifications. After repeated use, the PMC may require the Contractor to scrub the form or to provide new ones.

20.2.2 Form Ties

Internal ties shall be bolts and rods and they shall be straight and so arranged that when the forms are removed, no metal shall be left closer than 50mm to any exposed surface for all finishes. Form ties shall not be fastened to reinforcing steel or embedded parts. Wire ties will not be permitted.

20.2.3 Form Oil

All form surfaces shall be thoroughly cleaned before erection and shall be coated with a nonstaining mineral oil or lacquer. All excess oil shall be wiped off prior to concreting and no oil shall be permitted on the reinforcing steel or other embedded items. The use of all form coatings or lacquers shall be subject to the approval of the PMC, and the Contractor shall be required to provide proof of compatibility between the product to be employed, the concrete itself, and any subsequent treatment that the formed surface is to receive. All form coating shall prevent ingress of wood resins into the concrete surface.

20.2.4 Excavated Surfaces as Forms

- At the Contractor's request, and after the PMC has given his approval, the lateral forms of buried parts of concrete structures may be omitted with the concrete being placed directly against the excavated surfaces.
- In cases where the omission of formwork is accepted, the dimensions of the concrete parts shall be increased by 3cm on each face in contact with the excavated surfaces at the expense of the Contractor.
- At the direction of the PMC, a layer of blinding concrete or shotcrete shall be spread over the excavated surface to be filled with concrete at the expense of the Contractor.

20.3 EXECUTION

20.3.1 Formed Surfaces

20.3.1.1 General

- The construction of forms shall adhere to the Contractor's approved design and shall conform to the shapes, lines and dimensions of the structure as shown in the Drawings. Failure or misalignment of the forms and any damage caused thereby shall be corrected by the Contractor.
- At all unformed construction joints wooden strips shall be secured to the inside of the forms at the location of each joint to ensure a uniform finish to the outside edges of any lift of concrete. The upper layer of concrete shall be worked up to and under these strips so as to provide smooth edges.
- Unless otherwise shown in the Drawings, exposed areas including corners at construction and contraction joints shall be chamfered 25mm.
- Formwork shall be designed to be sufficiently rigid to ensure that the specified dimensional tolerances can be achieved under the combined action of self-weight, dead loads and imposed loads as well as the additional loads resulting from the rate of concreting, the lift cast in one operation and the method of placing and compaction.
- Formwork shall be of such tight construction that the concrete can be placed and compacted without undue loss or leakage of the mortar component of the concrete.
- The joints between contiguous formwork elements shall be tight fit and, where necessary, if undue leakage is expected, the joints shall be caulked, taped or packed with a sealing gasket by the Contractor.
- Where overhangs in formwork occur, means shall be provided to permit the escape of air and to ensure that the space is filled completely with fully compacted concrete.
- Supports for formwork may be bolted to previously placed concrete provided the type and position of the bolt used is acceptable to the PMC. If metal ties, through either concrete previously cast or to secure formwork for the pour abut to be cast, are used the metal left in shall not be closer to the face of the concrete than the cover specified for the reinforcement. Metal ties shall only be used in conjunction with shutter cones as approved by the PMC.
- After cleaning, the forms shall be coated with a dressing material in accordance with the manufacturer's instructions.
- The forms shall be protected from dust and dirt, after the above treatment.
- Construction joints/levels shall be provided with battens of the sizes designated by the PMC defining the limits between two concrete lifts, where directed by the PMC.

- Formwork for successive vertical lifts must make good contact with the concrete in the preceding lift, such that there will be no irregularity, bulges, tears or other outward signs of a faulty junction such as grout leakage.
- Boxouts, inserts and embedded items should be properly identified, positioned and secured.
- The formwork construction shall permit accurate erection and easy stripping without shock, disturbance, and damage to the cast concrete.
- Forms shall be thoroughly cleaned and repaired to the satisfaction of the PMC prior to re-use. Except where F1 finish is specified, metal patches shall not be allowed in the repair of forms.

20.3.1.2 Falsework

The Contractor shall make his own assessment of the allowable bearing pressure on the foundation material and shall design the footings and falsework to guard against overloading, differential settlement and unacceptable overall settlement. In assessing the allowable bearing pressure, due consideration shall be given to the effect which wetting has on the foundation material. In the design of falsework cognizance shall also be taken of the redistribution of load that may occur due to the effect of temperature, wind force, prestressing of curved and skewed structures, stage construction, flooding, debris and construction equipment.

20.3.1.3 Sloping Surfaces

Formwork shall be provided for concrete surfaces at slopes steeper than 30° to the horizontal. Surfaces at slopes less than 15° may be finished by screeding. Surfaces at slopes between 15° and 30° shall generally be retained with formwork unless the Contractor can demonstrate to the satisfaction of the PMC that such slopes can be screeded with the use of special screed boards to hold the concrete in place during vibration.

20.3.1.4 Sliding Formwork

- Prior to fabrication or bringing the assembly and auxiliary equipment to the Site, the Contractor shall submit drawings of the complete sliding formwork assembly to the PMC for acceptance. The drawings shall show full details of the forms, jacking frames, access ladders, hanging platforms, safety rails and curing skirts, as well as details of the jacks and jack layouts.
- The Contractor shall be required to submit to the PMC, before sliding commences, instruction manual wherein the sliding technique, jacking procedure, methods of keeping the formwork level, procedure to be adopted to prevent bonding of the concrete to the forms and method to release the forms in the event of bonding, the

instrumentation and monitoring of the slide, correcting for verticality, twisting and levelness, etc. are described in detail.

- The formwork panels shall be inclined to give a small taper and the forms shall be slightly wider at the bottom than at the top to complete with the specified concrete thickness taking into account the pressure of concrete.
- The spacing of the jacks with their rods must be so designed that the dead load of the sliding formwork assembly, the frictional load and the mass of materials, personnel and equipment are evenly distributed and within the design capacity of the jacks used.
- Concrete sections with dimensions smaller than 200 mm shall not be formed with sliding formwork, unless approved by the PMC.

20.3.1.5 Tunnel Formwork

- Formwork (shutter) for tunnel linings where segments or telescopic shutter are not applied shall be of robust construction consistent with the number of re-uses required and shall incorporate a purpose made retractable transporting unit. Operations of the shutter shall be hydraulic unless otherwise agreed by the PMC.
- Length of the shutter is at the Contractor's discretion unless joint spacing is specifically shown on the Drawings. However, to reduce the number of stop-end joints (bulkhead joints), the Contractor is encouraged to use a longest shutter as much as convenient. Formwork for the stop-end faces where no waterstop is required shall not be subject to measurement for recording.
- The Contractor may use a telescopic type formwork to ensure the construction program for the conventional excavation section where he deems it necessary. Provided that full details of the form assemble shall be submitted with his Bid.
- Access doors at least 600mm wide x 400mm high shall be provided in both sides and crown at approximately 2.5m longitudinal centers for placing of concrete. Doors shall be flush fitting, correctly profiled and incorporate rubber seals and locking clamps to prevent inadvertent opening during concreting and operation of shutter mounted vibrators and ensure on completion a surface free form irregularities and loss of grout.
- The forward and rear ends of shutter units shall be matched unless a flexible panel is provided at the rear end of the unit to achieve close contact over the full perimeter of the previously cast concrete.
- Stop-end shutters shall be prefabricated units rigidly connected to the lining shutter, incorporating adjustable timber pieces or expanded metal at the outer perimeter for closure against the irregular rock or sprayed concrete surface. The complete shutter shall be capable of withstanding, without distortion, the concrete pumping pressure necessary to force the concrete into overbreak cavities. The shutter shall be capable

of being adjusted accurately to the prescribed alignment and shall comply with the specified tolerances.

20.3.1.6 Formwork for Precast Units

Moulds for precast units shall be designed such that they do not distort during use and are tight against loss of mortar and shall be constructed so that units may be removed without sustaining any damage.

20.3.1.7 Curved Surfaces

For curved surfaces where F2 or F3 finishes are called for, the formwork face shall be built up of splines cut to make a tight surface which shall then be dressed to produce the required finish.

Except for tunnel linings and for structures requiring a special hydraulic shape and unless otherwise indicated, a curved surface of a radius greater than 2m may be formed of a series of chords with a width of less than 1/20th of the radius, provided that the dimension tolerances of the relevant formwork class are always respected.

Alternatively single curvature surfaces may be faced with steel, plastic or plywood linings firmly attached to the backing. Linings shall not bulge, wrinkle or otherwise deform when subjected to temperature and moisture changes.

20.3.1.8 Bulkhead Formwork

Bulkhead formwork for vertical construction joints may consist of any suitable material as agreed with the PMC including expanded metal mesh. In general, bulkhead formwork shall be used only where shown in the Drawings, where called for by the PMC, or as agreed with the PMC during emergency stoppages in concreting operations.

Bulkhead formwork shall be removed while the concrete is green. The formed face shall be thoroughly cleaned by air and water pressure jets.

If necessary the formed face shall be given a bush or hammered until the surface is free from laitance and debris and the aggregate is exposed.

20.3.1.9 Protection of Surfaces

The Contractor shall ensure that permanently exposed concrete surfaces are protected from rust marks, spillage and stains of all kinds and from other damage during construction.

20.3.2 Unformed Surface Finishes

Unless otherwise directed by the PMC, all surfaces which would normally be horizontal and exposed to the weather, shall be sloped for drainage at approximately 10 mm/m.

20.3.3 Removal of Formwork and Falsework

- Forms shall be removed as soon as practicable and the recommendations contained in Section 2.7 of ACI 347 shall be used as a general guide for determining the time for stripping.
- In all cases, formwork shall not be removed without the approval of the PMC. Notwithstanding this approval, the forms shall not be moved or removed until the concrete has acquired sufficient strength to support its weight and the construction or design loads that it may be required to bear, and sufficient hardness to prevent spalling of the surface. Generally speaking, the forms and supports of suspended structures shall not be removed until the ratio of the compressive strength of test specimens kept under similar conditions to those of the structure considered to the specified strength is greater than the ratio of the deadweight plus construction loads to the design load, with a minimum value of 0.50.
- Stripping shall take place without impact or vibration to the concrete and care shall be taken not to damage the concrete surfaces.
- Stripping operations may be decided in relation to the results of compression tests on specimens kept under conditions similar to those of the structure considered. These test specimens shall be taken in addition to the test pieces specified in section on concrete.
- Concrete compressive strength tests may be replaced by sclerometer measurements (as per ASTM C 805).
- The removal of formwork shall also take into account the temperature gradient limitations given in Chapter 0430 "Conventional Concrete (CVC)".
- Where the structure is constructed in stages, the falsework and supporting formwork shall be removed as specified on the Drawings or as directed by the PMC.
- Notwithstanding the recommendations of ACI 347 and following periods for stripping, forms or sections containing waterstops shall not be removed within twenty four (24) hours after the placing of concrete.
- In general, formwork shall be left in place for the following period after the concrete is cast, unless the Contractor can demonstrate to the satisfaction of the PMC that shorter periods are sufficient to fulfill the conditions of strength and hardness:
  - Minimum of thirty six (36) hours: vertical surfaces of piers and columns,
  - Minimum of thirty six (36) hours: vertical surfaces of footings, and walls,
  - Minimum of fourteen (14) days: suspended beams and slabs having spans up to 6m
  - Minimum of twenty (20) days: suspended beams and slabs having spans over 6m,
  - Minimum of twelve (12) hours: tunnel linings,

- Minimum of seven (7) days: arch roof of underground chambers.

The times above specified shall have elapsed from the end of concreting. According to the results of the laboratory tests and site trials, the aforesaid minimum times may be reconsidered by the PMC. In all cases, the Contractor shall demonstrate that removal of formwork will not in any way adversely affect the concrete of permanent work and shall be held responsible for all injury, and shall make good any damage arising from premature removal of the falsework and and formwork will be born by the Contractor.

20.3.4 Remedial Work to Defective Surfaces

If the concrete surfaces after stripping have certain local defects (such as honey combs or surface defects) or irregularities, the Contractor shall advise the PMC before undertaking any repairs so that the said defects and irregularities can be inspected and notified in a jointlysigned report.

Repair of concrete is specified in Chapter 0430 "Conventional Concrete (CVC)", Clause 3.1.

No repair of defective concrete shall commence without prior inspection and agreement with the PMC. If repair has been done without prior agreement, concrete block containing the repaired part shall fully be replaced with new concrete.

Chapter 0420
21 REINFORCING STEEL

21.1 GENERAL

21.1.1 Scope

This Chapter covers the requirements for supply and installation of steel reinforcement, including steel bars and welded wire mesh, in any concrete required for the permanent work as shown on the Drawings or directed by the PMC as well as for the temporary works as directed by the PMC. This Chapter further covers the requirements for the Detailed Reinforcement Drawings and Bar bending schedules based on the PMC's Principle Reinforcement Drawings.

21.1.2 Elated Works / Sections

Chapter 0410	Formworks and Surface Finishes
Chapter 0430	Conventional Concrete (CVC)
Chapter 0431	Shotcrete
Chapter 0433	Roller-Compacted Concrete (RCC)
Chapter 0440	Concrete Structure Joints and Bearings

21.1.3 Definitions

- Principle Reinforcement Drawings: These are Construction Drawings prepared by the PMC giving the principle of the structural reinforcement issued from time to time. They give diameters and spacing of bars structurally required, but not the detailing nor the construction steel bars.
- Detailed Reinforcement Drawings (DRD): These are reinforcement drawings prepared by the Contractor based on the Principle Reinforcement Drawings and used for the construction and the preparation of the bar bending schedule, taking into account all construction methods, levels of concrete lift and any other construction joints. DRD shall be subject to the PMC's approval. Support bars and metals should not be shown in DRD.
- Bar Bending Schedules (BBS): They shall be prepared by the Contractor in accordance with the Detailed Reinforcement Drawings. Reinforcing bars shown in the Detailed Reinforcement Drawings shall be identified and listed on the BBS in accordance with the standard reinforcing bar shapes shown in the Drawings. BBS shall identify the drawing number of the applicable detailed drawing. Bars scheduled on the BBS shall be accurately dimensioned in an approved manner. BBS shall be subject to the PMC's approval. The approved BBS will become the basis of measurement for control and recordingrar.
- Design calculations for reinforced concrete structures will be carried out in accordance with the following codes and standards.

- Unless otherwise shown in the Drawings or directed, reinforcement shall have a minimum clear protective cover to the face of the concrete in accordance with the recommendations given in ACI 318 and ASCE Design Guide No2.

21.1.4 Codes and Standards

The work included in this Chapter shall comply with the requirements of the following standards and codes, except where this Specification differs from these standards and codes, in which case the requirements of the Specification shall take precedence:

21.1.4.1 American Concrete Institute

ACI 301	Specifications for Structural Concrete for Buildings
ACI 318	Building Code Requirements for Reinforced Concrete

21.1.4.2 American Society for Testing and Materials

ASTM A82	Steel Wire
ASTM A36	Round Bars
ASTM A185	Steel Welded Wire Fabric, Plain, for Concrete Reinforcement
ASTM A615M	Deformed and Plain Billet Steel Bars for Concrete Reinforcement (metric)
AWS D 1.4	Structural Welding Code - Reinforcing Steel

21.1.4.3 American Society of Civil Engineering

Technical Engineering and Design Guidelines No2 : Strength Design for Reinforced-Concrete hydraulic Structures

21.1.5 Quality Assurance

21.1.5.1 Test and Controls

- If the Contractor does not have the Supplier's Certificate or mill certificates, or if the reinforcement appears to be in a deteriorated condition in the PMC's opinion, the Contractor shall bear the cost of arranging for tests to be carried out in an approved laboratory.
- The tests will cover the following characteristics:
  - Diameter (determined by weighing)

- Tensile strength
- Bending tests

- Six samples per diameter shall be taken for determining each of the above-mentioned characteristics.
- If two tests of a given characteristic give unsatisfactory results, the reinforcement bars concerned shall be considered defective.
- If one test of a given characteristic gives an unsatisfactory result, a new sampling of six (6) samples from the same batch shall be taken for a new series of tests on the characteristic in question. If the results of the new tests are all satisfactory, the reinforcement bars will be accepted. If this is not the case, the bars shall be considered defective.

21.1.5.2 Tolerances

The following tolerances shall apply to the final location of reinforcing steel embedded in concrete:

- Tolerance on length of bars: + 4 cm except when these bars are in a discontinuity zone (support surface, etc.) where the tolerance will be + 1.5 cm.
- Cover for reinforcing steel ± 5mm (-15%, +30%)
- Variation in indicated position of reinforcement:
  - starter bars 1 bar diameter
  - slab and walls 1/4 of the indicated spacing
  - beams and columns ±5mm
- Location of bent bars:
  - stirrups and ties± 5mm of specified location
  - other bars ±10mm

21.1.6 Submittals and Approvals

21.1.6.1 Mill Test Reports

With each shipment of reinforcing steel, a certified copy of mill test reports of the steel supplied shall be submitted. This certified copy shall show the physical and chemical analysis of the steel.

The PMC will require that random samples of reinforcing steel are tested to confirm tensile strength complies with the Specification.

21.1.6.2 Welding of Reinforcement Bars

A welding programme shall be submitted to the approval of the PMC.

Certificates of steel reinforcement weldability.

21.1.6.3 Spacers and Mechanical Couplers

Spacers shall be submitted to the approval of the PMC.

Mechanical couplers shall be subject to the approval of the PMC.

21.1.6.4 Placing Diagrams, Bar Lists and Bending Schedules

Detailed Reinforcement Drawings (DRD and Bar Bending Schedules (BBS) shall be prepared by the Contractor in conformity with the size and spacing of the reinforcement shown on the Principle Reinforcement Drawings issued by the PMC. If the Contractor proposes to use bar sizes other than those shown on the Drawings, any costs for design work will be backcharged to the Contractor. The DRD and BBS shall be submitted to the PMC for approval.

Not less than fourteen (14) days before the placement of reinforcement shown in the Detailed Reinforcement Drawings, the Contractor shall submit copies of the reinforcing bar list for that Drawing, together with copies of the Detailed Reinforcement Drawing marked up with each bar identified in accordance with the bar list.

21.2 MATERIALS

21.2.1 Reinforcing Steel

- The following types of steel shall be used for reinforcement:
  - Steel for reinforcing deformed bars shall comply with ASTM A615 M grade 420.
  - Round bars shall comply with ASTM A36
  - Welded wire fabric shall comply with ASTM A185.
- Bar diameters will be detailed in metric sizes. Nominal diameters in mm are normally as follows:

  6, 8, 10, 12, 14, 16, 18, 20, 25, 28, 32, and 36. For any metric diameter the Contractor may substitute the inch diameter bar immediately superior without altering the spacing or number of bars.

21.2.2 Welded Wire Mesh

1. Welded wire mesh shall comply with ASTM A185.

2. Welded wire mesh shall be 100mm x 100mm, having a minimum wire diameter of 4mm of steel,

or otherwise directed by the PMC.

21.2.3 Reinforcement Spacers

- Spacers may be made of metal, concrete, cement mortar or plastic.
- Metal spacers or metal chairs shall not come into contact with the formwork.
- Concrete or cement mortar spacers shall be of sufficient size to remain stable and shall be of equivalent quality to that of the concrete.
- Unless their actual shape makes them perfectly stable, all spacers shall be provided with systems for attaching them to the reinforcement.

21.3 EXECUTION

21.3.1 Delivery, Storage and Handling of Reinforcing Steel

- Bars shall be delivered to Site bundled by size, with each bundle clearly tagged for easy identification. They must be straight, without bends or windings, without stains or other damage. Bars accidentally bent will be rejected; however, after removal of the bent parts, the remaining straight sections could be accepted if the available length is sufficient.
- Bundles shall be stored on racks or other suitable supports that will permit easy access for identification and handling and prevent contamination with deleterious material.
- Storage yards shall be clean and designed in such a manner that none of the steel reinforcement is in contact with the ground or subject to damp conditions.
- The steel reinforcement already shaped and assembled shall be transported to the place of use with great care to ensure that parts will not be permanently deformed.

21.3.2 Fabrication of Reinforcement

21.3.2.1 Cutting and Bending

- Cutting, bending, splicing and placing of reinforcement shall comply with the requirements of ACI 318.
- Reinforcement shall be cut and bent to conform to the standard bending details shown on the Drawings and to the dimensions of the bar bending schedules. All bending operations shall be in accordance with approved standard practice and by approved machine methods.
- Bending of bars other than cold worked bars with the aid of heat shall not be performed unless the PMC has given permission. This permission may be granted on specific request and following submission by the Contractor of his proposed

method, including precautions to ensure that the steel bars will not undergo any injury.

- Bending of bars diameter more than 40 mm shall not be required.
- Bar bending schedules shall conform in general to the concrete lifts shown in the Drawings. In the event that changes in lift height are requested and approved, the placing drawings and bar bending schedules shall be revised to accommodate the changed lift heights.
- Bars shall be cold bent in the field or shop and shall not be straightened or rebent in a manner that will alter the material properties.
- Partially embedded bars shall not be straightened or rebent without approval.
- Bars containing bends or kinks not shown on the Drawings shall not be used.

21.3.2.2 Splicing and Coupling

- Joints or splices in reinforcing bars or welded wire fabric shall be made at the positions shown on the Drawings. Additional joints or splices will be permitted at positions other than those shown on the Drawings, subject to prior approval, and provided that the joints and splices in adjacent bars are staggered, if so directed. Additional joints or splices shall be in accordance with the requirements of ACI 318.
- Except as shown in the Drawings or otherwise directed for the purpose of providing electrical continuity, welding of reinforcing bars will not be permitted.
- The use of screwed couplings or other mechanical couplings elsewhere than directed by the PMC shall be submitted for PMC's approval.
- Where directed, welding to provide electrical continuity shall consist of tack welding of approximately 25% of individual bars to adjoining bars at not less than 2 points. Welding shall comply with AWS D 1.4.

21.3.3 Placing of Reinforcement

- Before reinforcement is placed, the surfaces of bars and surfaces of metal bar supports shall be cleaned of heavy rust, loose mill scale, dirt, grease and other objectionable foreign substances. Heavy, flaky rust that can be removed by firm rubbing with burlap, or equivalent treatment, is considered objectionable.
- After being placed, reinforcing bars or wire mesh shall be maintained in a clean condition until they are completely embedded in concrete.
- Reinforcement will be inspected for compliance with the requirements as to size, shape, length, splicing locations, position and amount after it has been placed. Concrete placement shall not commence until the in place reinforcement has been approved.

- Reinforcing bars: Reinforcing bars and wire mesh shall be accurately placed and secured in position, such that they will not be displaced during the placing of the concrete, and the Contractor shall ensure that there is no disturbance of bars or mesh in concrete that has already been placed. Chairs, hangers, spacers, or other approved metal, plastic or concrete supports may be used for supporting reinforcement. Concrete supports, if used, shall conform to the concrete requirements of this Specification.

  Reinforcement in structures shall be so placed that there will be a clear distance of at least 30 mm between the reinforcement and any anchor bolts or other embedded metalwork. Bars shall be tied at all intersections, and splices be tied at several points, by using annealed iron wire more than 0.9mm in diameter or suitable clips approved by the PMC.

- Wire mesh: When provided as shotcrete reinforcement, welded wire mesh shall be retained firmly against the rock surface or the initial layer of shotcrete, as appropriate, by means of additional bearing plates and nuts on rockbolts, grouted dowels or anchor pins.

  Wire mesh shall be supported on approximately 1m centers or as otherwise directed to ensure close contact with the rock surface and complete encapsulation by shotcrete. Wire mesh shall be lapped at least 150mm at sheet edges and retained at the lap.

Chapter 0430

22 CONVENTIONAL CONCRETE (CVC)

22.1 GENERAL

22.1.1 Scope

This Chapter covers the requirements for materials, mix design and procedures to be followed in the provision, placing, curing and protection of Conventional Concrete (CVC) of all parts of the works (surface and underground structures, and all classes of CVC).

Requirements of formwork, finishing and reinforcement are covered separately in relevant chapters of the Technical Specifications.

22.1.2 Related Works / Sections

Chapter 0220	Surface excavation
Chapter 0230	Underground Excavation
Chapter 0240	Drilling and grouting
Chapter 0410	Formworks
Chapter 0420	Reinforcing Steel
Chapter 0431	Shotcrete
Chapter 0433	Roller-compacted concrete (RCC)
Chapter 0440	Concrete structure joints and bearings
Chapter 0510	Miscellaneous Structural steel Works and metalwork

22.1.3 Definitions

- **Structural concrete** is any class of CVC which is used in unreinforced, reinforced or prestressed concrete construction, which is subject to structural loading.
- **Non-structural concrete** is composed of materials complying with the Specification which is used only for filling voids and for similar purposes.
- **First-stage** concrete (or Primary concrete) means the initial structural concrete placed prior to erection of equipment or embedded parts.
- **Second-stage** concrete (or Secondary concrete) means structural or non-structural concrete placed after the erection of equipment or embedded parts in block outs or pits left in the first stage concrete.
- **Formed surfaces** are faces which concrete has been cast against formwork.
- **Unformed surfaces** (or free surfaces) are horizontal or inclined surfaces less than 15° from the horizontal finished without using formwork.

- **Pour** or placement refers to any particular unit or part thereof which is concreted in a continuous operation, and also to the volume which has to be filled in a continuous operation. Pours in vertical succession are also referred to as "lifts".
- **Fine aggregate** is defined as aggregate in which the maximum nominal particle size is 5mm.
- **Coarse aggregate** is defined as aggregate in which the minimum nominal size is 5mm and which is reasonably well-graded from 5mm to the largest size of 50mm required in the work in which the material is being used.
- **Pre-embedded and embedded steel parts**: The metalwork parts to be supplied, placed and embedded in the concrete by the Contractor.

22.1.4 Codes and Standards

22.1.4.1 General

The work included in this Chapter shall comply with the requirements of the following standards and codes except where this Specification differs from these standards and codes, in which case the requirements of this Specification shall take precedence.

In this Specification, all or part of the standards and recommendations as listed in ACI 301 are applicable.

22.1.4.2 American Society for Testing and Materials (ASTM)

ASTM A416	Specification for Uncoated Seven-Wire Stress-Relieved Steel Strand for Pre-stressed Concrete
ASTM A421	Specification for Uncoated Stress-Relieved Wire for Pre-stressed Concrete
ASTM A615	Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
ASTM C29	Test Method for Unit Weight and Voids in Aggregate
ASTM C31	Practice for Making and Curing Concrete Test Specimens in the Field
ASTM C33	Specification for Concrete Aggregates
ASTM C39	Test Method for Compressive Strength of Cylindrical Concrete Specimens
ASTM C40	Test Method for Organic Impurities in Fine aggregates for Concrete
ASTM C42	Method of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
ASTM C70	Test Method for Surface Moisture in Fine Aggregate
ASTM C88	Test Method for Soundness of Aggregate by Use of Sodium Sulphate or Magnesium Sulphate
ASTM C94	Specification for Ready-Mixed Concrete
ASTM C109	Test Method for Compressive Strength of Hydraulic Cement Mortars
ASTM C114	Methods for Chemical Analysis of Hydraulic Cement
ASTM C117	Test Method for Material Finer than 0.075 mm Sieve in Mineral Aggregates by Washing
ASTM C125	Definition of Terms Relating to Concrete and Concrete Aggregates

ASTM C127	Test Method for Specific Gravity and Absorption of Coarse Aggregate
ASTM C128	Test Method for Specific Gravity and Absorption of Fine Aggregates
ASTM C131	Test Method for Resistance to Degradation of Small Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C136	Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C143	Test Method for Slump of Hydraulic Cement Concrete
ASTM C150	Specification for Portland Cement
ASTM C151	Test Method for Autoclave Expansion of Portland Cement
ASTM C172	Method of Sampling Freshly Mixed Concrete
ASTM C183	Method of Sampling and Acceptance of Hydraulic Cement
ASTM C185	Test Method for Air Content of Hydraulic Cement Mortars
ASTM C190	Test Method for Tensile Strength of Hydraulic Cement Mortars
ASTM C191	Test Method for Time of Setting of Hydraulic Cement by Vicat Needle
ASTM C192	Practice for Making and Curing Concrete Test Specimens in the Laboratory
ASTM C204	Test Method for Fineness of Portland Cement by Air Permeability Apparatus
ASTM C227	Test Method for Potential Alkali Reactivity of Cement Aggregate Combination (mortar-bar method)
ASTM C231	Test Method for Air content of Freshly Mixed Concrete by the pressure Method
ASTM C309	Specification for Liquid Membrane-Forming Compounds for Curing Concrete
ASTM C311	Sampling and testing Fly ash or Natural Pozzolans for use as a mineral admixture in Portland Cement C concrete
ASTM C348	Test Method for Flexural Strength of Hydraulic Cement Mortars
ASTM C349	Test Method for Compressive Strength of Hydraulic Cement Mortars (Using Portions of Prisms Broken in Flexure)
ASTM C360	Test Method for Ball Penetration in Fresh Portland Cement Concrete
ASTM C403	Test Method for time of setting of concrete mixtures by Penetrations Resistance
ASTM C441	Effectiveness of Mineral Admixtures or Ground Blast-Furnace Slag in preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction
ASTM C451	Test Method for Early Stiffening of Portland Cement (paste method)
ASTM C469	Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression
ASTM C494	Specification for Chemical Admixtures for Concrete
ASTM C496	Test for Splitting Tensile Strength of Cylindrical Concrete Specimens
ASTM C535	Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C566	Test Method for Total Moisture Content of Aggregate by Drying
ASTM C595	Specification for Blended Hydraulic Cements
ASTM C596	Test Method for Drying Shrinkage of Mortar Containing Portland Cement
ASTM C618	Specification for Fly ash and Raw or Calcined Natural Pozzolans for use as a Mineral Admixture in Portland Cement Concrete
ASTM D75	Practices for Sampling Aggregates
ASTM D2419	Test Method for Sand Equivalent Value of Soils and Fine Aggregate

22.1.4.3 American Concrete Institute (ACI)

ACI 104	Preparation of Notation for Concrete
ACI 121	Quality Assurance Systems for Concrete Construction
ACI 207.1R	Mass concrete
ACI 207.2R	Effect of Restraint, Volume Change, and Reinforcement on Cracking of Massive Concrete
ACI 209.R	Prediction of Creep, shrinkage and Temperature Effects in Concrete Structures
ACI 211	Recommended Practice for Selecting Proportions of Concrete
ACI 212	Admixtures for Concrete and Guide for Use of admixtures in Concrete
ACI 214	Recommended Practice for Evaluation of Compression Test Results of Field Concrete
ACI 221.R	Guide for Use of Normal Weight Aggregates in concrete
ACI 224.R	Control of Cracking in concrete Structures
ACI 301	Specification for Structural Concrete for Buildings
ACI 304	Recommended Practice for Measuring, Mixing, Transporting and Placing Concrete
ACI 305	Hot Weather Concreting
ACI 308	Standard Practice for Curing Concrete
ACI 309.1R	Behavior of Fresh Concrete During Vibration
ACI 309.2R	Identification and Control of Consolidation-Related Surface Defects in Formed Concrete
ACI 311.4R	Guide for Concrete Inspection
ACI 318	Building Code Requirements for Reinforced Concrete.
ACI 347	Recommended Practice for Concrete Formwork
ACI 439.3R	Mechanical Connections of Reinforcing Bars

22.1.4.4 United States Bureau of Reclamation (USBR)

USBR	Concrete Manual
USBR	Designation 22 Method of Slump Test
USBR	Designation 26 Mixer Performance Test

22.1.5 Classes of CVC

- The classes of CVC to be used in the works are defined in the following table:

Class	Use	Max. size of Aggregate (mm)	Specified Strength, f'c (MPa) *	Age of strength test (days)	Max. water/ cement ratio (%)
C35	Pre-stressed or precast elements	25	35	28	45
C28	High stress slender elements	25	28	28	45
C25	Ordinary stress slender elements	25	25	28	55

C20	Low stress structural elements	25	20	28	50
C15	Thin layer of non-structural lean concrete	25	15	28	55

- The characteristic strength f'c is the compressive strength at 28 days measured on 150mm diameter cylinder for all CVC classes.
- These typical applications for the use of the different classes of concrete are for guidance only. The class of concrete required to be used in any specific location shall be as shown on the Construction Drawings, or as directed by the PMC
- The PMC reserves the right to specify different consistencies where required by the nature of the works.
- Slump limits shall be proposed to suit work conditions before mix design for approval of the PMC. Slumps shall be measured at the Concrete Batching Plant and CVC placing site (When required by the PMC). Slump test executed on minus 38mm fraction of concrete.

22.1.6 Quality Control

22.1.6.1 Laboratory Tests

- The Contractor shall supply, operate and maintain the site laboratory as specified and shall carry out all tests and analyses subject to the approval of the PMC.
- As per the approved Quality Management Plan of the Contractor, samples shall be taken jointly from the concrete ingredients according to the agreed sampling program and be tested at an accredited approved third-party laboratory.
- The Contractor shall supply supervision, labor, materials and equipment necessary to sample and transport materials to the site laboratory from any part of the project area.
- Samples will mainly be of aggregates, cement, water, admixtures and concrete, both fresh and cured. Samples shall be representative, taken according to the instructions given by the PMC and in sufficient number to enable the laboratory to perform any test considered necessary for the Works.
- The Contractor shall appoint an engineer experienced in concrete technology, with not less than fifteen years of relevant experience, as laboratory supervisor. The laboratory concrete engineer shall be authorized by the Contractor to sign for acceptance, all documents related to laboratory activities.
- The requirements for, and the methods of taking samples and testing concrete and components of concrete shall be in compliance with the Standards specified, or with other standards approved by the PMC.

- The PMC may, at any time, sample and test cement, which shall not be used without prior approval. The Contractor shall furnish and install facilities satisfactory to the PMC for procuring representative test samples of the coarse and fine aggregates.
- Sampling and Testing of Admixtures
  - Each load of admixture will be sampled in the presence of the PMC upon arrival at the site.
  - Tests for pH, density and solids content will be carried out as required by the PMC.

22.1.6.2 Quality Control of Materials

22.1.6.2.1 Cementitious Materials

The delivery of each batch of cementitious material shall be accompanied by the manufacturer's specification conformance test report which shall be submitted to the PMC.

The Contractor shall take a sample of extender and proceed with the following quality control tests once a week:

- Fineness (45 micro sieve)
- Specific gravity
- Variability in fineness and specific gravity

The Contractor shall take a sample of the blended mixture of Cement and extender and proceed with the following tests:

Daily:	- percentage of extender (of blended mixture before batching)
Every month:	- percentage of extender (of blended mixture before batching) - initial and final setting time on pure paste - Blaine specific surface - heat of hydration - flexural and compressive strength at 2 and 28 days
Every 500t, with a minimum of 1 every 6 months:	- chemical analysis - mortar bar shrinkage - alkali reactivity - autoclave expansion

Each characteristic shall be taken as equal to the average of three (3) measurements made under each test.

A weekly 5kg sample of the blended cement and extender shall be kept in the laboratory for reference purposes until needed or for the duration of the Contract.

No cement shall be used before the flexural and compressive strength at two (2) days, the initial and final setting times, and the Blaine specific surface are known.

22.1.6.2.2 Quarry Rock for Concrete

The frequency of sampling will be set by the PMC from time to time as the work proceeds to suit the production rate in the quarries. In general, the Contractor shall take for each quarry a sample of rock for testing from each 1,000t of rock quarried, and in any event not less frequently than once a day during quarrying operations.

The samples of rocks will be tested as follows:

No.	Designation of test:	Frequency
1	Compressive strength	7-day
2	Tensile strength (Brazilian Test)	7-day
3	Apparent specific gravity	7-day
4	Water absorption	7-day
5	Los Angeles Abrasion test	15-day
6	Petrographic analysis	1-months

22.1.6.2.3 Aggregates

Tests to be performed on the aggregates:

Characteristics	Method ASTM	Field of application	Frequency
Grain size analysis	C136	Fine aggregates	Minimum twice a week
Grain size analysis	C136	Coarse aggregates	Minimum twice a week
Water content	C 566	Fine aggregates	Minimum twice a week
Water content	C 566	Coarse aggregates	Minimum twice a week
Fineness modulus	C 136	All aggregates	Minimum twice a week
Water absorption	C 127	Coarse aggregates	Minimum twice a week
Water absorption	C 128	Fine aggregates	Minimum twice a week
Los Angeles	C 131-C535	Aggregates > 2.5 mm	Minimum once a week
Organic matter	C 40	Fine aggregates	Minimum twice a week
Sand equivalent	D 2419	Fine aggregates	Minimum twice a week
Soundness	C 88	All aggregates	Minimum once a week
Flakiness Coefficient	NF P 18-561	Aggregates > 4 mm	Minimum twice a week

The tests shall be performed on samples taken in accordance with the PMC's instructions.

22.1.6.2.4 Water

The Contractor shall take a sample of water for chemical analysis from the CVC batch plant every three (3) months or as directed by the PMC.

22.1.6.2.5 Action in the Event of Non-compliance

In the event that tests on samples indicate non-compliance with the specifications, the PMC may order further sampling and testing or rejection of the material concerned.

If the rejected material has already been used in the construction of the Works, the PMC may call for testing of the material in the structure, testing the performance of the structure or ultimately, the demolition and reconstruction of the portion of the structure concerned.

22.1.6.3 Control of CVC Quality

Unless otherwise directed by the PMC, samples of CVC for making test cylinders shall be taken by the Contractor from the CVC mixer, but the PMC may also require that samples be taken at the location of concreting.

The methods to be used in sampling, preparing, curing and testing of CVC samples will comply with the appropriate ASTM Standards.

Sampling frequency:

- Definitions

  Lot: a lot of CVC is a structure or part thereof or set of structures or parts of similar structures cast in a single lift using CVC of the same class.

  Sampling: a given sampling is affected on a single batch and one batch can give rise to only one sampling.

  Result: a result is the average of the measurements made on all the samples taken for a given sampling (generally three).

- The number of samplings made shall be as follows
  - Samples shall be taken from each produced concrete class,
  - Samples shall be taken from each pouring,
    i. One (1) set of sample for a lot of less than 50m³;
    ii. Two (2) set of sample for a lot of 50 to 250m³;
    iii. Three (3) set of sample for a lot of more than 250m³;

  The sampling frequency shall be greater at the beginning of the works in order to confirm quality levels as early as possible, and during periods when, in the PMC's opinion, quality is considered doubtful.

  The PMC may, at his discretion, vary the frequency of sampling. The PMC may direct the Contractor to take samples at any particular time during the casting of concrete.

Tests to be carried out on fresh concrete samples:

- The following tests shall be carried out during each sampling:

- Three (3) samples 150mm diameter cylinder for determination of compressive strength at twenty eight (28) days (ASTM C 39).
- Three (3) samples for determination of the compressive strength at seven (7) days.
- One (1) measurement of air content (ASTM C 231).
- One (1) consistency measurement (ASTM C 143).
- One (1) temperature measurement.
- Additional tests may be required by the PMC, especially when the CVC consistency varies to a significant extent.

- On average every five samplings in addition to the preceding tests and in accordance with instructions given by the PMC:

  Three (3) samples for determination of the tensile strength at twenty eight (28) days (ASTM C 496).

- On average every fifty (50) samplings and in accordance with instructions given by the PMC, twelve (12) samples for determination of modulus of elasticity, compressive and tensile strength at 90-day and 365-day, (six (6) samples at 90-day and six (6) samples at 365-day).

Concrete acceptance criteria:

- A lot shall be deemed to conform to specifications when the following conditions are satisfied:
  - Consistency: the test result(s) come within the specified tolerances.
  - Compressive strength after twenty eight (28) days:
    i. No individual strength test falls below fc by more than 3.5 MPa.
    ii. In the event of three or more samplings from a lot, the average of the results is greater than fc.
- A concrete of a given class shall be deemed to conform to the specification when the average of any three (3) consecutive results (not necessarily from the same lot) is higher than fc.

The slump of CVC as placed when tested in accordance with ASTM C143 and ASTM C172, shall not exceed the specified limits for the various approved mix designs. In general, the slump, workability and temperature of each class of CVC being produced shall be measured and recorded from every trans mixer at the beginning of the concrete production until a stable production quality is achieved. Then, with the agreement of the PMC, measurements can be made less frequently such as every three (3) or five (5) trans mixers.

Use of 7-day Tests for any mix, a correlation between 7-day and 28-day strength may be developed in the laboratory for each class of CVC, and shall be continuously updated during the period of the Contract. On the basis of this correlation, the results of the 7-day tests may be used as an index of the compressive strengths which should be expected at 28 days. If 7-day tests show compressive strengths that are too low, remedial measures may be directed at once, without waiting for the results of the 28-day tests.

Basis of Acceptance

- Acceptance of strength test results shall be in accordance with ACI 318 and/or ASTM C94. No mix shall be used in the Works without the written consent of the PMC.
- Once consent by the PMC has been given for the use of a particular mix, the proportions of cement, aggregate, water, extenders, and admixtures shall not be changed without prior agreement by the PMC.

Non-Conformity

- If the consistency of CVC is outside the specified limits, the composition of the fresh CVC shall be checked immediately, in particular the water content of the aggregates and quantity of water in CVC. The Contractor shall make all necessary adjustments to recover the right consistency.
- Fresh concrete not complying with the requirements of the Specifications will be rejected.
- If the 28-day test results assessed from 7-day test results is abnormally low the Contractor shall stop concreting, establish the reasons for the strength decrease and take the necessary remedial action.
- If the 28-day test confirm the assessment from 7-day test that the characteristics of CVC do not conform to the Specifications the volume of CVC represented by the samples shall at the discretion of the PMC be subject to one or more of the following provisions:
  - Cores from the suspected portions of the structure shall be drilled and tested in accordance with ACI 318, ASTM C42 to determine whether the equivalent cylinder strength of the in-situ concrete satisfies the specified strength requirements.
  - If the results of test on the cores taken in terms of above item indicate that the CVC does not satisfy the specified requirements, the PMC will decide whether or not full-scale load tests or an ultrasonic pulse velocity investigation may be carried out.
  - If in the opinion of the PMC, the load tests are impracticable, or if a tested portion of the structure fails to pass the tests the Contractor shall, on the instructions and directions of the PMC, and if possible, strengthen by approved means each

section that failed or which contains CVC that failed, as relevant and also any other section, irrespective of strength requirements, the functional purpose of which is affected.

- If the reinforcement or strengthening of the structure is not possible, the defective works shall be demolished and reconstructed by the Contractor.

- During the continuation of the concreting activities, if the coefficient of variation of 28-day compressive strength test results for a particular class of CVC is found more than 14%, with the agreement of the Contractor and the PMC, cement content of the relevant concrete mix shall be optimized / adjusted to maintain the nominal strength of CVC with the specified rate of failure.

22.1.6.4 Tolerances for Concrete Construction

Refer to Technical Specifications, Chapter 0410 "Formworks and surface finishes".

22.1.7 Submittals and Approvals

22.1.7.1 General

- Submittals listed herein are related to items which require the approval of the PMC and are to be made by the Contractor before the appropriate work may proceed.
- Within fifty six (56) days from the Commencement Date, but before procuring or mobilizing to the Site the equipment, the Contractor shall submit to the PMC updated and detailed plans and descriptions, consistent with those submitted with his Bid and any subsequent amendments and additions agreed to by the Employer/PMC and the Contractor, of the following:
  - Plant Yard Layout : Layout of each plant yard on surveyed contour maps and showing excavation and embankment outlines, rain water and waste water drainage systems in the yards including settlement ponds and access layout to the yards.
  - Aggregates Processing Plant: Description, flow diagrams and drawings in sufficient details to indicate layout, type and capacity of crushing, screening, washing, conveying and other aggregate processing and handling equipment.
  - Batching and Mixing Plants: Description, flow diagrams, and drawings of the plant, and details of the equipment the Contractor intends to use to determine and control the amount of each separate concrete ingredient and mixing thereof into uniform mixture.
  - Concrete Cooling Plant: Details of refrigeration and ice plants and methods which the Contractor proposes to use to comply with concrete temperature requirements

- Transport and Placing of Concrete: Full details of the equipment and methods for transporting the concrete from the concrete plant to the final point of placing, including numbers, type and capacity of transport vehicles, a concrete pumps and details of standby plants to be installed.
- Quality Control Program: Detailed program for quality control of CVC work, list and details of equipment for sampling and testing, and qualification and experience of the proposed personnel.

- At least twenty eight (28) days prior to procuring or dispatch to the Site of the particular item of work to which the submittal relates, the Contractor shall submit to the PMC the following:
  - Details covering the properties and performance, including the certified copies of reports of all tests made by the manufacturers of waterstops, expansions joint filers, and joint sealing compounds along with material samples of the products
  - Details of curing compounds
  - Details of epoxy mortar for concrete repair
- Drawings showing the location of construction joints proposed by the Contractor which differ from those shown on the Construction Drawings, including formwork and reinforcement details, shall be submitted to the PMC at least twenty eight (28) days prior to commencement of work on that particular structure.
- During the performance of the concrete work, the Contractor shall keep a diary which shall record the construction procedures related to concreting. This diary shall be made available to the PMC upon request. The records shall contain at least the following:
  - Beginning and ending times of concreting operation of various parts of the structures
  - Quantities and quality of aggregates and cement provided, and the storage from which they were drawn
  - Temperature of air, water, cement, aggregates, and concrete
  - Meteorological conditions and humidity of air at mixing plant and placing site
  - Sampling and testing performed and summary of results
  - Workers employed during various stages of the concreting operation and name of the responsible foreman
  - Name and signature of the PMC's inspector(s)
  - List of equipment used
  - Written directives received from the PMC or the PMC's assistants
  - Any special material or procedures employed

- The PMC reserves the right to require any additional information deemed necessary to be included in the submitted documents.

Specific requirements for certification, source and site testing and approvals of materials used in the production and for quality control of CVC, shall be as specified in Clause 2 "Materials" and Clause 3 "Execution" below.

22.1.7.2 Submittal - Testing and Certification of Cement

- Twenty eight (28) days before the use of cement in CVC, mortar or grout, the Contractor shall submit typical mill test reports for approval before use, including the physical and chemical properties of the cement proposed. The Contractor shall also deliver with each shipment of cement, a certificate guaranteeing compliance with the Specifications. Such certificate shall indicate the date of arrival of each shipment at the plant, the quantity shipped, and the identification of the silo, lot or bin at the factory where the cement originated.
- Chemical and physical analyses for each make
- Copy of the cement storage record-book submitted at the end of each week.

22.1.7.3 Submittals - Water and aggregates

Water - test report for approval before any use

Aggregates - test report for approval before any use.

22.1.7.4 Submittals - Admixtures

The Contractor shall submit the manufacturer's technical specifications with a 2-litre sample of each admixture intended to be used, at least ninety (90) days before the start of concreting.

The Contractor shall submit charts of the manufacturer of the water-reducing set-retarding (WRSR) admixture showing dosage in relation to increase in slump at fixed temperature, as well as a chart showing the effect of CVC temperature on the decrease of slump with time.

The Contractor shall submit written confirmation that admixtures furnished by different manufacturers are compatible before using in the same batch of CVC.

22.1.7.5 Submittals - Equipment

Where this Specification requires specific types of materials or equipment to be used or specified procedures to be followed, such requirements are not to be construed as prohibiting use of alternative types of materials, equipment or procedures. Before giving approval for the use of alternatives, the PMC may request the Contractor to submit proof that the use of such alternatives will not reduce the quality of CVC obtained. The

Contractor shall not use such alternatives without having first obtained the approval of the PMC.

Not less than twenty eight (28) days prior to the installation of the plant and equipment for processing, handling, transporting, storing and proportioning CVC ingredients, and for mixing, transporting, placing and consolidating CVC, the Contractor shall submit, drawings showing the general plant arrangement together with a description of the plant proposed, including intended production capacity, in such detail as may be deemed necessary by the PMC.

After completion of installation, the operation of the plant and equipment shall be subject to testing and trial operation by the Contractor to demonstrate that these facilities are capable of providing the quality and quantity of Work and Materials required by the contract, at the rates of production consistent with the construction schedule and /or Dates specified in Particular Conditions.

Approval of plant and equipment or their operation, or of any construction procedure, will not waive or modify any provisions or requirements contained in this Specification governing the quality of the materials or of the finished Work, nor relieve the Contractor of his responsibilities under the Contract.

22.1.7.6 Submittals - Alkali Aggregate Reaction (AAR) tests

At the early stage of the contract, the Contractor shall submit an AAR testing program to be performed in a specialized laboratory subject to approval of the PMC for all the CVC classes with all types of aggregate to be used, and the proposed cement.

At least ninety one (91) days before placing CVC in the Works, the Contractor shall submit to the PMC testing results showing that the proposed mix with appropriate cement, extenders and additives is appropriate to prevent deleterious AAR.

22.1.7.7 Submittals - Mix design

At least ninety one (91) days before placing CVC in the Works, the Contractor shall propose mix designs including proposed admixtures and extenders, for laboratory testing and for a series of CVC trial mixes to be carried out in the presence of the PMC. Trial mixes will be conducted in accordance with the test procedures to be used throughout the period of the Contract. As a result of the trial mixes, the PMC may direct that the mix proportions or admixtures be changed.

Notwithstanding any approval by the PMC to use a CVC mix, the Contractor shall be responsible for ensuring that the required strength and other specified properties are achieved.

22.1.7.8 Submittals - Execution

The Contractor shall submit for the PMC's approval detailed drawings of the phases of concreting showing embedded parts, specifying the locations of the various construction joints, any particular arrangements which may be required, and the order of implementation of the different phases.

The Contractor shall submit to the PMC once a week a record of the CVC placed in the work. The record shall include class and quantity of CVC placed, location of pour, date of pour, ambient temperature and CVC temperature measured where the CVC is placed, moisture content of aggregates, cement/water ratio, mass of aggregates and cementitious materials, amount of ice added, if any, batch numbers, and location of test sample points. The position of construction joints not shown on the Drawings shall be recorded.

Placement schedules shall be submitted at the end of each work week and shall cover all CVC works planned for the following week giving the detailed locations of placement, approximate placement volume and type of mix, and anticipated date / time of placement;

Prior to placing CVC in any location, the Contractor shall provide the PMC with written notice, using a standard notice form approved by the PMC, that the preparation of formwork, reinforcing steel, electrical conduit, piping or other embedded items for the placement have been completed, and advising the composition of the crew and equipment to be used for CVC placement. No CVC shall be placed until the PMC has given written approval of preparations for placing.

The Contractor shall allow the PMC at least twenty four (24) hours from the time the above notice is received, for checking and approval of the preparations for each CVC placement. No CVC shall be placed in any location until all transport and placing arrangements, formwork, installation of reinforcement and embedded parts, and preparation of surfaces against which the CVC is to be placed have been approved by the PMC.

22.2 MATERIALS

22.2.1 Composition of Concrete

CVC shall be composed of fine and coarse aggregates, water, cement and cementitious materials and approved admixtures.

Mix proportions shall be designed by the Contractor to obtain a workable mix, suitable for the specific conditions of placement and a product which, after proper curing and adequate setting time, will have acceptable durability, impermeability and the required strength.

22.2.2 Sources of Materials

- Choice of the rock material sources is the Contractor's discretion. Potential rock quarries in the Project Area as shown in the Drawings can be used for and processed fine and coarse aggregate production, but the Contractor may also propose to the PMC other sources.
- The Contractor shall propose materials sources to the PMC for approval upon confirming for himself that necessary tests prove that materials from such sources meet the requirements specified in this Chapter.
- Approval of the source of aggregates shall not be construed as constituting approval of all materials taken for that source and the PMC can at any time suspend previous approvals if the laboratory tests establish that the material is no longer suitable.
- The Contractor shall clear and strip quarries and/or borrow areas from which aggregates are to be produced. Stockpile areas shall be cleared, stripped and prepared to the approved standard, regardless of aggregate source.

22.2.3 Cement

22.2.3.1 Types

Cement shall comply with ASTM C150, Type I for general concrete construction unless otherwise directed or agreed by the PMC for control of heat gain or other purposes. Where required to control heat gain in mass pours and to improve durability, or where specified herein or directed by the PMC, one of the followings shall be used upon approval of the PMC and in accordance with the manufacturer's specifications.

- Portland cement Type IV of ASTM C150,
- Hydraulic cement Type LH of ASTM C1157,
- Natural pozzolan, rock flour or Fly ash

Cement used in a given part of the Works shall be from the same manufacturer, unless otherwise approved in writing. The Contractor shall advise the sources of cement in writing, including test reports showing results of tests carried out at the cement manufacturer's works or in a laboratory approved by the PMC. These should be provided at least fifty six (56) days in advance of purchase, indicating the shipping schedule and the estimated quantity to be obtained from each source.

22.2.3.2 Form of Delivery

Cement may be delivered in bulk or standard 40kg or 50kg sacks, "super-sacks".

Cement in sacks shall be delivered in strong, well-constructed containers, factory sealed and undamaged. Individual paper sacks which vary by more than 5% from the nominal weight shall be rejected.

Cement may be delivered in bulk provided that the Contractor furnishes adequate transportation, weighing devices and all the necessary facilities to ensure the good condition of the material and to permit accurate weighing as the shipments arrive at the site storage bins.

22.2.3.3 Transportation

Transportation methods shall be subject to approval. The temperature of cement, as delivered to the storage at the Site, shall not exceed 55°C.

The transportation of bulk cement shall be by trucks with clean watertight compartments, sealed and adequately designed to protect the cement from exposure to moisture.

The method of transportation of sacks, shall equally guarantee protection against moisture.

Cement damaged during transportation, handling or storage shall be removed immediately from the Site.

22.2.3.4 Storage

- Cement shall be stored immediately upon arrival at the Site. All storage facilities shall be subject to approval.
- Sufficient storage capacity shall be provided, and cement stored to meet the requirements for the subsequent twenty one (21) days of concreting.
- Cement in sacks shall be kept in closed damp proof and well-ventilated stores.
- Stores shall have wooden floors at least 300mm above the ground and provided with a waterproof membrane. Storage of cement in bags on the ground will not be permitted under any circumstance. Each delivery of cement in bags shall be stacked together in one place; the height of the stack shall at no time exceed 3m. The bags shall be closely stacked so as to reduce air circulation and shall not be stacked against an outside wall. Different types of cement in bags shall be clearly distinguished by visible markings and shall be stored in separated stacks. Cement from broken bags shall not be used in the Permanent Works.
- Bulk cement shall be kept in airtight silos which will be emptied for cleaning at regular intervals not exceeding four months, or as otherwise directed.
- Cement of different quality shall be stored in separated sections of the store, or in separate silos.
- The Contractor shall keep for every silo or store a cement storage record-book in which the following will be noted:
  - The quantity of cement in store at the end of the week.

- The quantities, origin and location of storage of the various batches delivered during the week.
- The quantities used daily and the structures in which the cement is used.

- Cement shall be used in the same chronological order as delivered to the Site. Cement, which has been stored at the Site for more than fifty six (56) days, may be randomly sampled by the PMC and if the test results are not satisfactory, the cement shall be removed from the site.
- Cement shall not contain lumps or any other evidence of deterioration at the moment of use. Cement which has become stale, or otherwise unsuitable through absorption of moisture from the atmosphere or otherwise, shall be removed from the Site.
- The temperature of cement, as delivered to the mixers, shall not exceed 55°C.

22.2.4 Cementitios Materials

22.2.4.1 Pozzolan/Rock flour

Pozzolan shall meet the requirements for ASTM C618, Class F, including the supplementary optional chemical requirement regarding the available alkalis.

The Contractor shall advise the sources of pozzolan in writing, including test reports showing results of tests carried out at the manufacturer's works, or in a laboratory approved by the PMC. These shall be provided at least fifty six (56) days in advance of purchase indicating the shipping schedule and the established quantity to be obtained from each source.

Delivery, transportation and storage requirements shall be the same as for cement.

22.2.4.2 Fly ash

Fly ash shall meet the requirements of ASTM C618, class F, for fly ash for use as a mineral admixture in Portland Cement Concrete.

- Carbon content: characteristic loss-on-ignition (LOI) not more than 5% when tested in accordance with ASTM C311.
- Sulphate content: not more than 2.5% by mass when expressed as SO^3.
- Fineness: characteristic fineness not more than 12.5% (retained on a 45 μm sieve) when tested in accordance with ASTM C430.
- Variability: not more than 5% variation in specific gravity and fineness from the average of previous tests.
- Autoclave expansion or contraction: not more than 0.8%.
- Deliveries of fly ash shall be accompanied by the manufacturer's quality assurance certificates.

- Available alkalis as Na^2O: not more than 1.5%.
- Delivery, transportation and storage requirements shall be the same as for cements.

22.2.4.3 Blended Cement and extender

Unless otherwise approved by the PMC, the extender shall be natural pozzolan or fly ash.

The Contractor will not be permitted to blend cement and extender in the CVC mixer, unless otherwise approved by the PMC. Unless a pre-blended mix is provided to the Site, the Contractor's blending equipment shall be capable of continuous production of a thoroughly blended mixture of materials in the specified proportions and in accordance with the Specification.

The percentage of extender will be determined in agreement with the PMC on the basis of the concrete trial test results. It is expected that for the mass, and lightly reinforced concrete the percentage of fly ash by weight shall not be more than 25% unless approved by the PMC.

22.2.5 Admixtures

22.2.5.1 General

Only approved admixtures shall be used in the CVC. When more than one admixture is to be used, each admixture shall be batched in its own batcher and added to the mixing water separately before discharge into the mixer. Admixtures shall be delivered in suitably labeled containers to enable identification.

The Contractor shall use a water-reducing set-retarding (WRSR) admixture in all CVC. Such admixture shall be an approved brand of lignosulphonate type, conforming to the requirements of ASTM C494 when tested with the particular materials for CVC to be used in the Works.

The use of other admixtures shall be as approved or directed, to ensure the compliance of the CVC with the provisions of this Specification.

The use of admixtures, including, but not limited to, type, amount used and the method of introducing the admixture into the CVC, and the transporting, handling, forming, finishing and curing of such CVC, shall be subject to approval.

22.2.5.2 Storage

Stored admixtures shall be protected against excessive temperatures, contamination and deterioration.

Sufficient admixture shall be stored on Site for ninety one (91) days of CVC production.

Soluble admixtures shall be diluted and agitated continually to keep solids in suspension.

22.2.6 Mixing Water

- Water used for mixing, rinsing and curing CVC and processing CVC aggregates, shall be clean and free from oil, acid, organic matter, and shall be as cool as is practically obtainable. The water turbidity shall not exceed 2,000 parts per million and the pH of the water shall be between 5.8 and 8.6 based on JSCE-B101.
- The total quantity of sulphates, expressed in sulphur anhydride, alkali-carbonates and bicarbonates shall not exceed 1 g/liter.
- The suspended solids shall not exceed 2 g/liter
- Dissolved salts shall not exceed 500 parts per million.
- The aggregate free-water content shall also be considered as mixing water and shall be determined in compliance with ASTM C70.
- If water from local natural sources should contain, at certain times, quantities of impurities in excess of the above limits, the Contractor shall take whatever measure may be necessary for ensuring its purity before use.

22.2.7 Aggregate

22.2.7.1 Fine Aggregate

- Fine aggregate for CVC, grout and mortar shall be processed sand or other approved material.
- Fine aggregate shall be to ASTM C33, except as otherwise specified herein.
- Fine aggregate shall consist of clean, hard, dense, durable uncoated rock fragments and shall be free from injurious amounts of dust, lumps, soft or flaky particles, shale, alkali, organic matter, loam and other deleterious substances. The percentage of deleterious substances in the fine aggregate shall not exceed the following values:

Item	Percentage by Weight
Material passing 0.075 mm square mesh sieve	5.0%
Material lighter than specific gravity 2.0	2.0%
Clay lumps	1.0%
Other deleterious substances	2.0%

- The sum of all deleterious substances as delivered to the mixer shall not exceed 7% by weight.
- Fine aggregate may be rejected if:
  - It produces a color darker than the standard in the calorimetric test (ASTM C40) for organic impurities;
  - The specific gravity (dry basis) is less than 2.56;

- The portion retained on 0.30mm square mesh sieve when subjected to 5 cycles of the sodium sulphate test for soundness, shows a weighted loss of more than 8% by weight.

- The fineness modulus of the fine aggregate shall be greater than 2.30 and less than the following values:
  - 3.10 for natural sand;
  - 2.80 for manufactured fine aggregate;
  - A value between 3.10 and 2.80 which is proportional to the constituent materials, where a mixture of natural sand and manufactured fine aggregate is used.
- Fine aggregate shall be well graded, conforming to the following limits based on ASTM E11:

Sieve Size (mm) / US Standard Sieve Designation (No)	Percentage Passing by Weight
9.53 (3/8 inch)	100
4.76 (No 4)	95 - 100
2.38 (No 8)	80 - 95
1.19 (No 16)	50 - 85
0.6 (No 30)	25 - 60
0.3 (No 50)	10 - 30
0.15 (No 100)	5 - 15
0.075 (No 200)	0 - 2*

Note (*) If material finer than No 200 sieve consists of rock dust free from clay or silt, this percentage may be increased to 8, and gradation of fine aggregate shall be adjusted accordingly with the approval of the PMC.

- To achieve an acceptable particle shape for manufactured sand, the fine aggregate shall be manufactured using crushers specially adapted to suit the type of material available.
- In order to produce clean and well graded fine aggregate, the Contractor shall take necessary measures at the fine aggregate crushing and screening plant including washing system.
- Alternatively, after performing the necessary mix trials, the use of a fine corrector sand may be accepted to satisfy the Specification requirements and to improve the workability of the CVC.
- Fine aggregate shall not have a moisture content value more than 6.0% when processed and shall be protected from sunshine and rain.

22.2.7.2 Coarse Aggregate

- The coarse aggregates shall be divided in the following classes:

Class	Minimum size	Maximum size
	d (mm)	D (mm)
Class 1	5.0	12.5
Class 2	12.5	25.0
Class 3	25.0	50.0

- Coarse aggregate shall be to ASTM C33, except as otherwise specified herein.
- Coarse aggregate shall consist of clean, hard, fresh, well-shaped, dense, durable, uncoated rock fragments, free from injurious amounts of deleterious substances. The percentage of deleterious substances in any size of coarse aggregate shall not exceed the following values:

Item	**Percentage by Weight**
Material passing 0.075 mm square mesh sieve	0.5%
Material lighter than specific gravity 2.00	2.0%
Clay lumps	0.5%
Other deleterious substances	1.0%

- The sum of the percentage of all deleterious substances in coarse aggregate, as delivered to the mixer, shall not exceed 3% by weight.
- Coarse aggregate may be rejected if:
  - the loss, using grading A in the Los Angeles abrasion test (ASTM C131), exceeds 10% at 100 revolutions or 40% by weight at 500 revolutions;
  - the weighted loss of the aggregate, when subjected to 5 cycles of the sodium sulphate test for soundness, is more than 10% by weight;
  - the specific gravity (dry basis) is less than 2.56.
- Coarse aggregate shall be separated into nominal sizes of 5mm to 12.5mm, 12.5mm to 25mm, and 25mm to 50mm and shall be well graded in accordance with the following table. For mass concrete, aggregate up to 50mm may be permitted based on ASTM E11.

Sieve Size (mm) / US Standard Sieve Designation	**Per cent passing by weight**		
	5/12.5mm	**12.5/25mm**	**25/50mm**
50.8 mm (2 inches)	-	-	100
38.1 mm (1 1/2 inch)	-	100	90-100
25.4 mm (1 inch)	-	90-100	35-65
19.1 mm (3/4 inch)	100	35-65	0-3
12.7 mm (1/2 inch)	90-100	3-10	-
9.53 mm (3/8 inch)	35-65	0-3	-
4.76 mm (No.4)	3-10	-	-

2.38 mm (No.8)	0-3	-	-

22.2.7.3 Properties of Aggregates

- **Apparent Specific gravity**

  The apparent specific gravity shall not be less than 2.60.

- **Soundness**

  When tested in accordance with ASTM C33 and C88, coarse aggregates shall not show a loss in mass of more than 15% and fine aggregates not more than 10% (ASTM C33) after 5 cycles using magnesium sulphate.

- **Shape of Aggregates**

  The sum of the Flakiness and Elongation Index (F.I. & E.I.) of the coarse aggregate must be kept below the limit of 25% at all times when using the BS812 methodology.

- **Water absorption**

  Coarse and fine aggregates shall not have a water absorption of more than 2% when tested as per ASTM C127 for coarse aggregates, and ASTM C128 for fine aggregates.

- **Los Angeles (LA)**

  Aggregates of more than 2.5mm size shall have a Los Angeles (LA) Abrasion Loss Value of less than 40 when tested as per ASTM C131 for fine aggregates, and ASTM C535 for coarse aggregates.

- **Total chloride and sulphate content**

  The total chloride content arising from all ingredients in a mix including cement, water and admixtures shall not exceed the following limits, expressed as chloride ion and as a percentage of the mass of cement in the mix:

  - For prestressed concrete, steam cured CVC or CVC containing sulphate resisting or supersulphated cement: 0.05%
  - For any other reinforced concrete 0.3% in 95% of all test results providing no result is more than 0.5%.
  - The total sulphate content expressed as SO3 of all the ingredients in a mix including cement, water and admixtures shall not exceed 4.0% of the mass of cement in the mix.

- **Sand Equivalent (ESV)**

  The fine aggregates shall be kept clean at all times. The equivalent sand value (ESV) shall be greater than 75 when tested in accordance with ASTM D2419. Fine aggregates having an ESV lower than the specified value may be accepted if the

blue value (BV) measured according to standard NFP 18-592 is less than 1 g per 100 g of fines passing through the 80 micron sieve.

22.2.7.4 Transport and Storage of Aggregates

The transport and storage methods shall be such as to guarantee a stable and uniform water content and to avoid any segregation.

The different classes of aggregates shall be stored separately in silos or on a concrete platform or by any other means guaranteeing an equivalent level of cleanliness. The storage area must be designed to ensure effective drainage of the aggregates. The aggregates shall be stored sheltered from rain and protected from solar radiation.

The capacity of the storage specified in Sub-Clause 2.7 for each class of aggregates shall be sufficient to ensure progress of work on the site for a duration of eight (8) days.

22.2.8 Mix Design

- The proportions in which the various ingredients are to be used for different parts of the work shall be as approved from time to time during the course of the work.
- Mix proportions, including the use of pozzolan, fly ash and admixtures, shall be determined by the Contractor and shall be selected to obtain CVC having suitable workability, impermeability, durability, and the required strength, whilst also minimizing the heat rise due to hydration.
- The Contractor shall prepare laboratory trial batches, as specified in ACI 301 and as recommended by ACI 211.1 to determine proportions of concrete components. The Contractor shall submit to the PMC full details of his proposal for mix design, including type and source of each ingredient, and results of tests on the trial mixes 56-day before starting concreting.
- The Contractor shall furnish samples of all concrete components for verification of mixes to the site laboratory, 56-day before start of concreting. The Contractor shall submit new samples, as directed by the PMC, whenever the characteristics of any of the components change from previously submitted samples. Sample size shall be as required by the PMC.
- Alkali reactivity; By appropriate mix design to be tested for alkali-aggregate reaction (AAR) in a specialized laboratory to be approved by the PMC, the Contractor shall ensure that the total amount of alkali of all CVC classes with all types of aggregates is in accordance with the standard to prevent deleterious alkali-aggregate reaction (AAR).
- The actual amount of water used in the CVC shall be the minimum necessary to provide CVC of the proper consistency and shall be regulated to adjust for any variation in the moisture content or grading of the aggregates as they enter the

mixer. Addition of water to overcome stiffening of the CVC before placing will not be permitted. Uniformity in CVC consistency from batch to batch will be required.

- The consistency of the CVC shall be such that it can be placed using the site facilities and compacted so as to enclose completely the reinforcement bars and embedded parts and completely fill the formwork, with neither void nor segregation.
- Concrete Suitability tests; The Contractor shall carry out a program of suitability tests on site at least forty (40) days before making any CVC for the permanent works to verify:
  - That the approved design mixes produce CVC, using the aggregates and CVC plants delivered to the site, that satisfied the specification,
  - That the CVC composition, considering the installations it is envisaged to use, will enable the structures to be built in a satisfactory manner,
  - That the characteristic of the plant are in conformity with those submitted to the PMC's approval.

  Three (3) batches of the nominal composition will be made for suitability tests. The tests shall be interpreted on the same basis as the design tests.

  The suitability tests, performed under representative site conditions, shall be used to also determine:
  - the sequence of filling the mixer
  - the duration of mixing, which shall be enforced during the Contract period
  - a check on CVC composition in terms of consistency, strength and precise weights of each component

22.3 EXECUTION

22.3.1 General Requirements

Unless otherwise specified, concrete work shall be performed according to the latest edition of ACI 301, Specifications for Structural concrete for Buildings.

Concrete works shall be constructed to the lines, grades and dimensions shown in the Drawings and to the tolerances and finishes specified herein.

22.3.2 Batching and Mixing

- The aggregates, water, cement and additives shall be mixed in an automatic concrete-mixer with batching by weight, equipped with:
  - A printed register for recording the date and time of batching, the weight of cement, admixture, aggregates and the water-cement ratio, and
  - A continuous moisture measuring device for sand.

- The output of the plant shall be adapted to the program of work and shall be at least 100m³ per hour.
- The mixing operation shall be under the control of a suitably experienced supervisor.
- The sequence of filling a mixer with the concrete ingredients shall be studied during the initial tests and subject to the approval of the PMC and unless otherwise authorized, the same sequence of filling shall be followed throughout the work.
- Water shall be added before, during and following the mixer-charging operations. Excessive mixing, requiring the addition of water to preserve the required consistency, will not be permitted. After the CVC has been mixed, no subsequent addition of water in the course of concreting will be tolerated. CVC which has been retained in any mixer for more than sixty (60) minutes after the addition of water shall be wasted.
- The quantity of mixed materials per batch shall not exceed the manufacturers rated capacity of the mixer, and shall be further reduced for fluid concrete.
- Mixing time shall be adjusted according to mix compositions and the mixers used and shall be at least forty five (45) seconds after all components have been added. In the case of CVC containing admixtures, a minimum mixing time of sixty (60) seconds shall be observed. The PMC may direct that the mixing time be varied whenever the charging and mixing operations fail to produce a CVC batch having the ingredients uniformly distributed and constant consistency.
- At intervals decided by the PMC, but which normally be once per day for coarse aggregates and at different intervals for sand, the Contractor shall carry out tests by an approved method to determine the free moisture content of the aggregates. Based on these tests, adjustments shall be made to the quantity of water added to the mix to maintain the specified water cement ratio.
- On commencing work with a clean mixer, the first batch shall contain only half of the normal quantity of the coarsest aggregate category and 10% extra cement so as to compensate for the fine material and cement which is left sticking to the drum. This batch shall be mixed for at least one minute longer than normal.
- The mixer shall be completely emptied before being charged with the materials for the succeeding batch.
- Weight tolerances:

Cement and water		± 2%
Aggregates	Fine aggregate	± 3%
	Coarse aggregate	± 5%
	Total of the aggregate	± 3%
Admixture		± 5%

- Checking of weighing scales

The precision of the weighing scales of the batching plant shall be checked at the beginning of each month in the presence of the PMC. The Contractor shall appoint an agency approved by the PMC to check the precision at his own cost.

If the precision falls outside the specified tolerances, the batching plant shall not be used again until the scales have been adjusted or repaired as necessary.

- Mixer performance

  Mixer performance shall be determined in accordance with ASTM C 94 to determine the uniformity of the mixture

22.3.3 Transportation

CVC shall be conveyed from the mixer to the place of final deposition by methods which will prevent segregation or loss of ingredients or damage by exposure to the elements. Plant, such as buckets, cars, transit mixer trucks, conveyors and pumping equipment which may be used for conveying CVC shall be of such size, design and condition as to ensure an even and adequate supply of CVC at the point of delivery.

22.3.4 Weather Requirements

22.3.4.1 Hot Weather Requirements

- Concrete operations shall be in accordance with the recommendations contained in ACI 305 R-77 "Hot Weather Concreting".
- Precautions shall be taken at all times to avoid premature stiffening of the fresh mix and to reduce water absorption and evaporation losses. Since the temperature of the surrounding air is frequently likely to rise higher than 30°C, the following additional requirement shall apply unless otherwise approved.
- Aggregate stockpiles shall be shaded and water-sprayed as required to reduce the temperature of ingredients prior to mixing;
- Formwork shall be continuously sprayed with cold water in advance of concreting, and excess water shall be removed from inside the forms immediately prior to placement of CVC;
- Reinforcement and metal formwork shall be protected from the effects of hot winds and direct sunlight;
- The Contractor shall take all measures necessary to ensure that the temperature of CVC at the time of placing in the Works does not exceed
  - 25°C for massive structures, i.e. structures with a thickness more than 0.60 m, and in-situ tunnel lining
  - 30°C for other structures of which the thickness is 0.60m or less,

by the use of ice, chilled mixing water or/and by spraying the aggregate with cold water;

- Suitable barriers shall be provided to protect the freshly placed CVC from wind until the CVC is sufficiently hard to allow it to be covered as described in the following paragraph.
- CVC shall be mixed, transported, placed and consolidated, as rapidly as possible to reduce the loss of moisture to the minimum possible and shall then be covered with an impervious membrane or wet hessian until moist curing begins;
- After CVC in any part of an area has been placed, the specified curing process shall be commenced as soon as possible.
- Curing compounds shall not be used as an alternative to the requirements of Clause 3.8.

22.3.4.2 Cold Weather Requirements

- In cold weather, the concrete shall, on account of retarded hardening and possible permanent impairment of its properties, have a specified minimum temperature at the time of placing. When placed, the concrete shall be protected from heat loss, freezing and drying for a specified length of time.
- For all concrete the temperature of the concrete when being placed shall not be less than 4°C in moderate weather or 10°C in weather during which the mean daily temperature drops below 4°C.
- Concrete ingredients shall not be heated to a temperature higher than that necessary to keep the temperature of the mixed concrete, as placed, from falling below the specified minimum temperature during placement. Whenever hot water is required the temperature of the water entering the mixes shall not exceed 74°C. The concrete ingredients shall be free of ice, snow, and frozen lumps before entering the mixers, and the forms shall be free of snow and ice before placement of concrete.
- Method of heating concrete ingredients and protection after deposition shall be subject to approval.
- The Contractor shall include the cost of these requirements in his unit prices for the various items of concrete.

22.3.4.3 Other adverse weathering conditions and protective measures

- No concreting shall take place in the open during storms or in heavy rain. In places where such conditions are likely to occur, the Contractor shall arrange for adequate protection of the materials, plant and formwork so that the work may proceed under proper cover. Where strong winds are likely to be experienced, additional precautions to ensure protection from driving rain and dust shall also be taken.

- The PMC may withhold approval of commencement of concreting until he is satisfied that full and adequate arrangements have been made.
- The protective measures required in any particular case depend primarily on the weather conditions, the ingredients and the composition of the concrete, as well as on the nature and dimensions of the components and the formwork.
- Fresh concrete shall not be placed against concrete parts or soil surfaces that are frozen. Concrete damaged by frost shall be removed before concreting is continued. Aggregates for concrete shall not be used in the frozen condition. If necessary, the water shall be pre-heated, and if conditions require, also the aggregate.
- The conditions for the temperature of the fresh concrete stated shall be satisfied. If necessary, water with a temperature of more than 70°C shall first be mixed with the aggregates before cement is added. More particularly for finely dimensioned components, the Contractor shall increase the surrounding air temperature, using heat-insulating formwork, stripping the formwork later than would otherwise be necessary, enclosing the place of work, supplying heat, etc. At the same time, the concrete shall not be deprived of the water needed for curing.
- All such protective measures shall be prepared in advance so as to be ready in case of need.

22.3.5 Forms and Finishes

- **Forms**

  Refer to Chapter 0410 "Formwork and Surface Finishes"

- **Finishing of Non-shuttered Concrete Surfaces**

  Surfaces shall be finished using a simple screed, a vibrating screed, a float, etc. or by any other means enabling the required quality to be obtained. Screed guiding devices and supports shall be submitted for the PMC's prior approval. Surface of concrete walkway with slope of 10% or more shall be roughened by screeding to prevent slipping.

  Surfaces shall be provided with a slope to allow water to drain off, as provided for in the Drawings or as instructed by the PMC.

22.3.6 Preparation for Placing

22.3.6.1 General

- Documents to be submitted by the Contractor prior to placing are listed in Clause 1.7 "Submittals and Approvals".
- CVC placement shall not commence prior to receipt of written approval by the PMC;

- Concreting of any part of the work will be authorized only after verification and acceptance of the following items:
  - the characteristics of the CVC mix to be used;
  - the concreting program, type and quantity of equipment for placement and compaction, including the hourly placement rates;
  - the availability at the site of equipment and material necessary for finishing, curing and protection of CVC;
  - the condition and cleanliness of forms, adjacent CVC or other surfaces, reinforcement and embedded parts;
  - conformity of reinforcement and embedded parts with the Drawings;
  - conformity of the installation, including shoring and scaffolding, with the formwork drawings.

22.3.6.2 Condition of Adjacent Surfaces

- Before placing CVC on the rock or common soil, the foundation surfaces shall be smooth and free from a loose material, foreign items, oil, dust, ice, mud and water accumulations.
- Local cavities, holes, depressions and geological over break larger than 0.5 m in depth shall be filled with concrete Class C20 or other class directed by the PMC in advance of placing of structural concrete thereon to minimize shrinkage crack.
- Rock or hardened concrete surfaces shall be thoroughly cleaned and moistened before placing fresh concrete. Soil surfaces shall be compacted to 95% maximum density in accordance with ASTM D698 and covered, by polyethylene sheet or other approved manner prior to commencing placement.
- Lean concrete or polyethylene sheet shall be placed on adjacent surfaces as directed by the PMC. Lean concrete shall be tamped and screeded to a level surface. Polyethylene sheets shall be lapped by 150mm.
- Surfaces of construction joints and surfaces of blockouts shall be washed thoroughly with air water jets prior to placement of adjoining CVC, so as to reveal the mosaic of CVC, without dislodging the coarser aggregates, nor the reinforcement bars or other embedded parts. Moistening of rock or concrete surface for a minimum duration of twenty (24) hours before concreting shall be ensured. Pools of water shall be removed from the surfaces of construction joints before new CVC is placed.
- Surfaces of contraction joints shall be cleaned thoroughly of accretions of CVC or other foreign material by scraping, chipping or other approved means.

22.3.6.3 Condition of Reinforcement and Embedded Parts

- Reinforcing steel and embedded parts shall be prepared as indicated under Chapter 0420 "Reinforcing Steel".
- Reinforcing steel and embedded parts shall be clean and free of dried concrete, oil and scaling rust.
- The dimensions shown in the Drawings shall be maintained between reinforcing steel and forms. Reinforcing steel and embedded parts shall be fixed firmly so as to avoid displacement during concreting.

22.3.6.4 Handling and Placing Equipment

- Equipment for transporting, handling and placing CVC shall be clean and free of hardened CVC and shall be capable of delivering CVC without segregation or modification of its basic properties.
- Equipment available shall have sufficient capacity to avoid cold joints and to ensure a constant rate of delivery at the point of placement. Handling equipment shall be supported independently of reinforcing steel and formwork, unless allowed for in the formwork design.
- Equipment available shall be the minimum required to place the specified volume of CVC. Increasing slump by addition of water or over sanding mixes for the purpose of accommodating deficient handling equipment is strictly prohibited.
- The following equipment provisions shall also apply:
  - Troughs shall be lined with metal sheeting and shall have rounded shape;
  - Conveyors shall be sufficiently wide to avoid overflow. Their slopes shall be kept flat so that CVC does not slide back on the belt surface;
  - Conveyor systems will be approved only if CVC at the discharge point conforms to Specifications;
  - Only chutes having a diameter sufficiently large to permit free flow of CVC, without the assistance of vibrators shall be used;
  - Buckets for handling CVC shall have a discharge area not less than 60% of the cross-section area of the bucket. Gates shall close tightly and open easily to control the rate of discharge;

22.3.7 Placing

22.3.7.1 General

- The methods and equipment used for placing CVC shall not cause appreciable segregation of coarse aggregate in CVC as it is delivered into the Work. All proposed placing equipment and methods shall be submitted to the PMC for approval.
- The CVC mix design shall not be altered for placement by concrete pump or belt conveyor. Concrete pump or belt conveyor placement shall not be used unless it can be demonstrated by actual operation that such equipment is capable of placing CVC of the specified mixes and slumps in the Work without variations in grading of coarse aggregate and consistency exceeding the limits specified for mixers in ASTM C94. Samples of CVC for determining such variations will be obtained at various intervals as CVC is deposited into the forms and compared to samples taken at delivery to the placing equipment.
- CVC shall be deposited as closely as possible to its final position and such as to avoid segregation or modification of other properties. Bouncing CVC off forms, reinforcing steel or any other obstruction is prohibited.
- CVC shall be moved within the formwork by shovels and not simply by flow induced by vibration which is forbidden. Any accumulation of gravel shall be dispersed within the mass of concrete. Any water shall be removed as and when it appears.
- CVC shall be placed and compacted in such a manner as to avoid any movement of formwork, reinforcement bars, embedded parts or parts to be embedded.
- On rocky surfaces, immediately before concreting, a 3cm thick layer of CVC Class C15 without coarse aggregate shall be placed over the entire surface and in any fracture joints, so as to ensure an effective rock-CVC bond. The necessary arrangements shall be adopted to cover this mortar with CVC before it has started setting. The requirement of this paragraph shall not apply to tunnel linings.
- If required by the PMC, the first layer of fresh CVC placed on hardened CVC shall consist of a mix which is the same as that of the new lift but without the larger nominal category of coarse aggregates. This layer shall be between 4 and 10cm thick as directed and shall be covered before it has started setting.
- CVC pour sizes, CVC pour temperature, lift thicknesses, curing methods and the time lapse between pours shall be submitted to the PMC for his approval. For massive concrete, the submission shall be such as to limit peak temperature of placed concrete to 53°C and the temperature difference of the surface concrete and the interior concrete at any section to 20°C at any time in order to limit the risk of thermal cracking, and to limit the shrinkage stresses.
- The positioning of construction joints not shown in the Drawings shall be subject to approval by the PMC.

- CVC shall be placed in a continuous operation. Each layer shall be covered with a new layer of fresh CVC before the start of initial set. The PMC has the sole right to judge whether initial set has started.
- CVC shall not be allowed to free fall more than 1.5m without being enclosed in chutes.
- CVC which does not meet the Specification regarding slump will be rejected.
- Within each lift, CVC shall be placed in horizontal layers not exceeding the lesser of 500mm in thickness or the vibrating length of the vibrator needle, but the layer shall not be less than four times the maximum nominal size of aggregate in thickness. Before it is covered by a new layer, each layer shall be fully compacted but shall not have begun to set.
- CVC shall be placed in lifts less than the maximum thickness listed below, unless otherwise shown on the Construction Drawings or approved by the PMC and shall as far as possible, have a uniform thickness over the plan area of the pour.

No.	Location	Maximum permissible thickness of one lift	Minimum time between successive lifts
1	Massive concrete (more than 4 m thick)	2.5 m	72 hours
2	Walls, pillars, columns less than 4m thick	2.5 m	48 hours

- CVC shall not be placed during rain that is sufficiently heavy or prolonged to waste mortar from coarse aggregate on the exposed sloping faces of fresh CVC. In the event of heavy rain occurring during concreting operations, the Contractor shall take all necessary steps to protect CVC. The Contractor shall have protective coverings readily available for these purposes. The construction program shall allow for occasional heavy rain, especially during certain periods of the year, and for the consequential interruptions to the placing of CVC.
- If a placement is stopped before completion for reasons accepted by the PMC, bulkheads shall be used to make an emergency vertical construction joint and the concrete surface shall be treated as a construction joint. Any unconsolidated CVC shall be removed before completing the placement.
- During placement, and until curing as specified in Clause 3.8 "Curing and Protection of CVC" has been completed, CVC shall be protected to the satisfaction of the PMC, against the harmful effects of exposure to sunlight, wind and rain.

22.3.7.2 Consolidation

- CVC shall be thoroughly consolidated, immediately after placing in the form, with high frequency large amplitude mechanical immersion-type vibrators. For mass concrete, vibrators shall have 100mm, or larger, head and a minimum frequency of 12,000 rpm. For other concrete, vibrators with a minimum frequency of 9,000rpm, shall be used.

- Vibrators shall be inserted vertically and shall penetrate the previous layer of CVC by 100mm to 200mm. CVC shall not be placed under any circumstances until the underlying layer has been thoroughly consolidated. The vibrators shall be withdrawn slowly, so as not to allow the formation of any void.
- Displacing CVC horizontally with vibrators is prohibited. Vibrators shall not be applied to reinforcing steel, embedded parts or formwork. Where F2 and F3 finishes are specified, the vibrating head shall be kept 50mm clear of the formwork.
- CVC shall be carefully vibrated into position around waterstops, all large stone in their immediate vicinity being removed. Particular care shall be taken to ensure that CVC is completely compacted around waterstops.
- Vibration shall continue until the rise of air bubbles has practically stopped, and shall be stopped as soon as laitance or excess water appears.
- The total consolidating capacity, in cubic meters of CVC per hour, of all vibrators in effective operating condition, and employed on concrete consolidation in the Works, shall be based on a rated capacity of 80% of the manufacturer's recommendation for each type of vibrator. The total consolidating capacity so computed shall be not less than the maximum rate at which CVC is placed in the Works. For every four (4) vibrators in use on the Works, an additional standby vibrator of similar consolidating capacity and in good working order shall be available for use no more than 15 min. from the location of the compaction.
- Green Cutting
  - The Contractor shall remove laitance on concrete surfaces, on which another lift of CVC will be placed, by green cutting with a high velocity water jet or air-water jet.
  - Green cutting shall be performed before CVC has taken its final set so that all laitance will be removed, but that large pieces of aggregate will remain embedded in the matrix.
  - Materials which are loosened or dislodged as a result of green cutting shall be completely removed from the surface of the lift.

22.3.8 Curing and Protection of CVC

- Immediately after placing of CVC for unshuttered parts and immediately after removal of formworks in other cases, CVC shall be protected from the effects of direct sunlight and drying winds and shall be water-cured for a period of fourteen (14) days from the time of placement (or until covered with fresh CVC).
- CVC cured with water shall be kept continuously wet by covering with water saturated material, by a system of perforated pipes, mechanical sprinklers or porous hose, or by any other approved methods, which will keep surfaces continuously wet.

Systems in which the exposed surfaces are intermittently wetted will not be permitted.

- Except for certain surfaces for which membrane curing may be approved, CVC shall be cured by water. Water shall comply with the requirements of Mixing Water specified in Clause 2 "Materials" herein.
- Unformed top surfaces of walls and slabs shall be moistened by covering with water-saturated material or by other effective means as soon as CVC has hardened sufficiently to resist damage by water. Such surfaces shall be kept completely and continuously moist, prior to and during form removal, by water applied thereon and allowed to pass down between the forms and the formed concrete faces. This procedure shall be followed by the specified water curing or membrane curing, if approved.
- At least fourteen (14) days prior to placing CVC in any structure, the Contractor shall submit for approval, details of the equipment and methods he proposes to use for water curing. After the initial placement of CVC in any structure, subsequent placements will not be permitted until equipment for curing has been satisfactorily installed and is operating on all previous placements in the structure.
- Membrane curing, if approved, shall be by application of an approved curing compound on the surface of CVC in compliance with the manufacturer's instructions and as specified below.
  - At least fourteen (14) days prior to the use of curing compound, details of the proposed compound shall be submitted for approval. Such details shall be accompanied by test certificates to show that the compound will give satisfactory results for the proposed application.
  - Curing compound shall be delivered to the Site in suitably labeled containers to enable identification of the batch number and date of manufacture.
  - Curing compound shall be applied to the concrete surfaces by spraying on one coat, or where directed, brushing or rolling on two coats. Coatings shall be such as to ensure a continuous uniform membrane over all areas. The PMC will direct the surface coverage in liter/m² to be used, according to the roughness of the surface to be covered. If necessary to adequately cover the surface, an additional coat of curing compound shall be applied if so directed.
  - When curing compound is approved for use on unformed concrete surfaces, application of the compound shall commence immediately after the finishing operations are completed.
  - When curing compound is approved for use on formed concrete surfaces, the surface shall be moistened with a light spray of water immediately after the forms are removed, and shall be kept wet until the surface will not absorb more moisture. As soon as the surface film of moisture disappears, but while the

surface still has a damp appearance, the curing compound shall be applied. After application of the curing compound has been completed and the coating is dry to touch, any required repair of concrete surfaces shall be performed. After completion of repairs, the surface areas disturbed shall be moistened and coated with curing compound in accordance with the foregoing requirements.

- Traffic and other operations shall be such as to avoid damage to coatings of curing compound for a period of not less than twenty eight (28) days after application. Where such is impossible because of construction requirements, the coated surface may, subject to prior approval, be covered by a 25mm layer of sand when the sealing membrane has completely dried. Approved operations may take place on the sanded surface. Any sealing membrane which is damaged or peels from concrete surfaces within twenty eight (28) days after application, shall be repaired without delay.

22.3.9 Finishing of Non-Shıttered Concrete Surfaces

The Contractor shall be responsible for finishing non-shuttered concrete surfaces as soon as CVC placing has been completed and before hardening.

Surfaces shall be finished using a simple screed, a vibrating screed, a float, etc. or by any other means enabling the required quality to be obtained. Screed guiding devices and supports shall be submitted for the PMC's prior approval.

Surfaces shall be provided with a slope to allow water to drain off, as provided for in the Drawings or as instructed by the PMC.

Classes of unformed surface finishes are specified in Chapter 0410 "Formwork and Surface Finishes".

22.3.10 Joints

Refer to Chapter 0440 "Concrete Structure Joints and Bearings".

22.3.11 Repair of Defective CVC

22.3.11.1 General

- CVC surfaces which do not comply with the requirements of Chapter 0410 "Formwork and Surface Finishes", damaged by improper curing, traffic or any other cause or any CVC which is honeycombed or has interstices or is not homogeneous, shall be repaired as specified herein or as otherwise directed.
- If on stripping any formwork the concrete surface is found to be defective in any way, the Contractor shall make no attempt to remedy such defects prior to the PMC's inspection and the receipt of any instructions which the PMC may give.

- Where the structural integrity of the unit may be impaired by the defective CVC, the PMC shall have the sole right to decide whether or not the unit may be repaired or must be reconstructed. To assist in making this assessment, the PMC may instruct that certain tests be carried out by the Contractor.
- Repair of damaged or defective surfaces shall be performed by skilled workmen only. Repair work shall not commence prior to approval of the surface preparation and repair methods.
- Unless specifically waived on each occasion, repair work shall be performed only in the presence of the PMC.
- Unless otherwise approved, repairs shall be completed within twenty four (24) hours after placement in the case of unformed surfaces and within twenty four (24) hours of form removal for formed surfaces.
- Materials and procedures that may be specified to suit individual types of repair and to reinstate structural capacity of members, include non-ferrous non-shrink grout, epoxy or latex-based bonding agents, epoxy compounds and cementitious grout, mortar and CVC. The Contractor shall, whenever possible, perform repair of defects while the CVC is still green. Curing interruptions shall be limited to the minimum time and area practicable.
- Abrupt or gradual irregularities which lie outside specified tolerances, shall be corrected by rubbing with a carborundum stone or grinding where directed.
- Holes left by removal of pipes, tie-rods or other accessories shall be reamed with suitable toothed reamers before being cleaned and filled with dry-pack as specified below. All bulges and other projections on exposed surfaces shall be chipped and ground until a true smooth surface of matching color and texture is obtained.
- Honeycombed, fractured or otherwise defective CVC, and surfaces which must be built up to correct excessive depressions, shall be excavated to expose sound, undamaged CVC or as otherwise instructed by the PMC, but shall not be less than 100mm or 25mm clear distance behind reinforcement whichever is the greater. The surface shall then be restored to the prescribed lines with dry-pack, mortar or CVC, as specified below.
- On exposed surfaces, the perimeter of the repair shall be neatly defined by disc cuts not less than 25mm deep. The cavity shall have roughened sides at least 75mm in depth for the full perimeter and the sides of the cavity shall be splayed back to form a dovetail.
- Filling of recesses in surfaces designated to receive F1 finish will be required only where recesses are deeper than 30mm in members less than 500mm thick, and will not be required in walls of thickness greater than 500mm. Where bulges and abrupt irregularities protrude outside the limits specified in Chapter 0410 "Formworks and Surface Finishes", the protrusions shall be reduced by bush-hammering and

grinding, so that the surfaces are within the specified limits. After dressing, the irregularities shall not exceed the specified limits.

- Repaired surfaces shall be protected and cured as stipulated in Clause 3.8 "Curing and Protection of CVC" and in accordance with manufacturer's instructions in the case of proprietary products. When cured, the repair and adjacent surfaces shall be sound and free from shrinkage cracks, hollow areas and other imperfections.
- When required by the PMC, the Contractor shall drill and grout in injection pipes for subsequent grouting of any remaining voids.
- 15.Where instructed by the PMC, cracks shall be pressure grouted using appropriate chemical or epoxy grouts applied strictly in accordance with the manufacturer's instructions. Where agreed by the PMC, alternative methods appropriate to the locality and type of structure may be accepted for filling cracks.

22.3.11.2 Dry-Pack

Dry-pack shall be used for filling holes having at least one surface dimension approximately the same size as the hole depth, for narrow slots cut for repair of cracks, for small pipe recesses, and for tie-rod fastener recesses. Dry-pack shall not be used for filling behind reinforcement or for filling holes that extend completely through a concrete section.

Dry-pack shall be composed of a mix of 1 part of cement, by volume, to 2.5 parts, by volume, of fine aggregate passing a 1.2mm square sieve, together with sufficient water to produce a mortar which will just stick together when molded into a ball by light pressure of the hands and will not exude water, but will leave the hands damp.

Dry-pack shall be placed and packed solidly or hard rammed into undercut holes in approximately 10mm thick layers.

22.3.11.3 Mortar Filling

Mortar filling, placed under impact by use of a mortar gun, shall be used for repairing defects which are too wide for dry-pack filling and too shallow for concrete filling. In no case shall mortar filling be used to repair holes which extend beyond the far side of the reinforcement nearest the surface.

22.3.11.4 Concrete Filling

Concrete filling shall be used for holes extending entirely through concrete sections, for holes which are greater in area than 0.1m² and deeper than 100mm, and for holes in reinforced concrete which are greater in area than 0.05m² and which extend beyond the reinforcement nearest the surface, unless otherwise directed by the PMC.

22.3.11.5 Use of Epoxy Resins

Epoxy resin repair cover the use of epoxy resin material, mortar, additive or bounding agent.

22.3.11.5.1Material

Epoxy resin repairs shall be used when the repairs have not been made within seven (7) days after concreting. Materials used for epoxy resin repairs shall be subject to approval and the repairs shall be the following types:

- Epoxy bonded repairs - an unfilled epoxy resin is used as the bonding medium between old concrete and the repair material, which may be dry-pack, mortar filling or concrete;
- Epoxy filled repairs - a previously filled epoxy resin, to which an approved filler is added, forms the repair material. Such method will normally be approved only for filling of small holes to produce a required surface finish.

22.3.11.5.2Repairs

Epoxy resin repairs shall be carried out as follows:

- Imperfections to be repaired with epoxy resin shall be chipped back to sound concrete and the edges of the holes trimmed square for a minimum depth of 3mm;
- Immediately before carrying out a repair, the surface of CVC to be repaired shall be freed of all contaminants by sandblasting or scabbling, and shall present a clean, sound, dry, roughened and dust-free surface with the surface temperature not more than 30ºC;
- After preparation, repairs using epoxy material shall be carried out strictly in accordance with the manufacturer's instructions;
- Unused epoxy resin, either filled or unfilled shall be wasted when it loses its plastic condition. Excess or spilled resin shall be cleaned immediately and while the resin is in a plastic state;
- Should it be necessary to form an epoxy filled repair, the forms shall either be incompatible with the epoxy resin or coated with a special release agent;
- Finished surfaces of the epoxy resin repairs shall conform to the requirements of Clause 3.9 "Finishing of non-shuttered concrete surfaces". Any grinding required on epoxy-filled repairs shall be performed wet using a silicon-carbide or other suitable abrasive.

22.4 SPECIAL CONCRETE

22.4.1 Mortar

This clause covers mortar for use ahead of concrete placing, for bedding under the bases of steel columns and other uses in connection with operations covered by this Specification.

Mortar shall be composed of fine aggregates, ordinary Portland cement and extenders. The mix propositions shall be as stated in the Drawing or elsewhere in this Specification or if not stated shall be 1 part of cement to 2 parts of fine aggregate by weight. The water content of the mortar shall be as low as possible consistent with the use for which it is required but, in any case, the water/cement ratio shall not be more than 0.50.

Unless otherwise directed by the PMC, small quantities of mortar may be hand mixed but for amounts over 0.5m³ a mechanical mixer shall be used.

Mortar which is specified as "dry pack" shall be mixed with sufficient water for the mix to become cohesive but not plastic when squeezed by hand. Dry pack mortar shall be rammed into the cavity it is required to fill, using a hand rammer with sufficient force to ensure full compaction.

22.4.2 Dental / Backfill Concrete

Dental/backfill concrete for placement in cracks, seams, crevices and pockets in rock foundations shall be applied with Concrete Class C20 unless otherwise stipulated in the Construction Drawings, and constituent proportions as required by the PMC to suit each particular foundation condition.

22.4.3 Lean Concrete

The lean concrete is designed to be placed in the structure foundations on common soil; the layer of lean concrete must be impermeable with a minimum thickness of 100mm.

The lean concrete shall be a Concrete Class C15 unless otherwise stipulated in the Construction Drawings. The exact composition shall be proposed by the Contractor.

22.4.4 Econd Stage Concrete of Galleries / Tunnels

- Unless otherwise approved by the PMC, local cavities, depressions, recesses, pits, sumps, turnouts, temporary excavations, deeper than 0.5m behind the B-line indicated in the Drawings, which are caused by the Contractor's operations, shall be filled with concrete class C20 up to the B-line in advance of placing structural concrete thereon as directed by the PMC. Local geological over break approved by the PMC and deeper than 0.5m shall also be filled similarly with concrete C20 up to the B-line. Other depressions less than 0.5m behind the B-line may be cast together with the structural lining concrete.

- The lining concrete of galleries / tunnels shall be cast either full-round or vault and invert in separate operations. The Contractor shall propose the method. The proposed method of concrete placement is subject to the approval of the PMC.
- The Contractor shall satisfy the PMC that the concrete production, transport and placing equipment to be used for concrete pouring has sufficient capacity to produce and handle the amount of concrete necessary for the lining sections. In addition, the Contractor shall provide details of the steps to be taken in the event of an interruption in the concrete supply.
- The number of vertical construction joints shall be reduced to minimum.
- The PMC may modify the extent of the steel reinforcement required in the concrete lining, based on the results of the rock mechanics test.

22.4.5 Backfill Concrete Behind Steel Liners

- The backfill concrete placing shall not be commenced before completion of steel liner test for full circle steel liner.
- The backfill concrete behind the steel liners shall be placed in blocks separated by vertical construction joints. Spacing and location of the joints and concrete placing lift height shall be proposed by the Contractor for approval by the PMC. Formwork F1 used at the approved construction joints will be measured for control and recording. Special care shall be taken to ensure compaction of concrete and complete filling of the space beneath the steel lining, and the filling of the crown.
- Class of the backfill concrete shall be as shown on the Drawings. Other class of concrete may be directed by the PMC so as to minimize void or gap between concrete and steel liner or between rock and concrete. Cavity grouting into crown cavity between rock and concrete shall be made by the Contractor as per the "Drilling and Grouting" specifications. Grout injection piping and vent piping for cavity grouting shall be designed by the Contractor and approved by the PMC.
- All surfaces shall be cleaned with air-water jets or by other satisfactory means. Particular attention shall be given to the drainage of flowing and the removal of standing water where concrete will be placed.

22.4.6 Concrete of Botto Outlet

22.4.6.1 General

- The Contractor shall place all required concrete around the Bottom Outlet on Dam Body and its inlet and outlet sections in accordance with the requirements of these Specifications, as shown in the Drawings or as directed by the PMC.
- Due consideration shall be given to the Hydraulic Steel Structures components during equipment installation and its embedment, including provision of bracing and

ties necessary to maintain all equipment in their correct position during placement of the surrounding concrete.

- The major concrete Bottom Outlet Gates will be divided into following main parts:
  - **First stage concretes**, includes all concrete on upstream and downstream walls and columns up to the top of overhead crane runway girders, all erection bay walls and floor slabs, and trunnion yoke girder.
  - **Second stage concretes** are encasement concrete around steel liner, guard and regulating gates that to be placed after completion of the steel liner and gates installation and piping.

22.4.6.2 Embedment of Equipment

- The manner of placing concrete on or against equipment, including the precautions necessary to ensure sound contact between the concrete and the equipment and to avoid disturbing the position of the equipment, shall be subject to the approval of the PMC.
- The Contractor shall construct concrete erection pedestals for placing and aligning the gate frames, guide rails etc. and provide setting anchors, reinforcing steel, and dowels, as directed by the PMC. The items to be embedded shall be checked for alignment immediately before, during and after concrete placing operations.
- Second stage concrete shall be placed in a continuous monolithic pour in layers not exceeding 0.5m per hour. Concrete vibrators shall not be used within 0.5m.
- Unless otherwise specified or shown in the Construction Drawings, concrete class C25 with the addition of an approved non-shrink agent shall be used for embedding of equipment in second stage concrete. However, the PMC may order certain part of the second stage concrete to be executed as class C20.
- At any point where an inspection (e.g. by sounding) indicates that a cavity exists between steel liners and the surrounding concrete, as determined by the PMC, contact grouting shall be performed after the concrete has cooled and achieved sufficient strength as determined by the PMC. The grout holes will be prepared by the Contractor. The grout mix and grouting pressures shall be as directed by the PMC. After grouting, all grout holes shall be sealed by the Contractor.

22.4.6.3 Concrete in Blockouts for Equipment Embedding

- The Contractor shall form blockouts, place reinforcement and concrete as shown in the Construction Drawings or as directed by the PMC, and in such manner as to ensure good bond with the existing concrete, to secure complete contact with the metalwork to be embedded in the blockout concrete and to avoid displacement of the metalwork.

- Blockout concrete excludes concrete designated in the Construction Drawings or by the PMC as second stage concrete.
- Before placing concrete in blockouts, all parts to be embedded shall be checked jointly to ensure that they are firmly fixed in their required position. The surfaces of blockouts or holes shall be thoroughly cleaned and wetted. Oil or grease shall be removed by brushing and chipping of affected surfaces to a sufficient depth, or by application of approved chemicals and flushed with clear water.
- The parts to be embedded shall be cleaned of rust, mill scale, paint, oil or grease before they are set into place. Where bond between metal parts and concrete or grout is not desired, approved material such as flake graphite or paraffin shall be applied to the metal parts. The metal surfaces shall be wetted before placing the concrete or grout.
- Unless otherwise specified or shown on the Construction Drawings the concrete class C25 containing an approved non-shrink agent shall be used for concrete in blockouts for equipment embedding.

22.4.6.4 Grouting of the Equipment Bearing Plates and Anchors

- Limited spaces and small blockouts where equipment bearing plates, anchors, rails, etc., are placed shall be grouted under pressure.
- The grouting shall be performed using nontrunk cement-based grout or non-shrink epoxy grout as proposed by the Contractor and approved. All mixing and grouting shall be performed in accordance with the manufacturer's recommendations and shall be tested prior to grouting. Technical service by manufacturer shall be organized by the Contractor upon request by the PMC.
- Forms for grouting shall be installed where necessary and care shall be taken that the grout fills all spaces under the plates leaving no voids.

22.4.7 Second Stage Concrete for Embedded Parts of Equipment

- The second stage concrete around the Bottom Outlet and its gates shall refer to the Clause 4.6 above.
- Second stage concrete shall be placed for embedded parts of equipment installed by the Contractor or the other contractor.
- Placing of the second stage concrete shall not proceed until embedded parts have been completely assembled, aligned and secured.
- Constant, caution shall be exercised in placing concrete to avoid distortion and displacement of parts being embedded.
- The workability shall be sufficient to achieve satisfactory pouring in the interstices of first stage concrete.

- A controlled expansive admixture from an approved manufacturer shall be added. The admixture shall be mixed in accordance with the manufacturer's instructions. Prior tests shall be conducted before final approval can be given by the PMC to adjust the amount of admixture to obtain effective non-shrinkage concrete.
- Cast iron powder admixture shall not be used in contact with high-tensile steel nor in direct contact with water.
- Unless otherwise specified or shown on the Construction Drawings the concrete class C25 containing an approved non-shrink epoxy agent shall be used for concrete in blockouts for equipment embedding. For small holes (section less than 1 dm²), mortar shall be used. The mix shall be 450kg/m³ of cement and sand with the addition of an approved controlled expansive admixture.
- Formwork shall be perfectly connected with the first stage concrete; irregularities shall be made good by means of grinding.

22.4.8 Fludified Concrete

22.4.8.1 Materials and mix

- The concrete composition shall be the composition of a pumpable concrete and the amount of material finer than 0.250mm (fine sand and cement) shall be at least 450kg/m³ of concrete. This concrete shall have a consistency measured by the slump test of 6cm with the tolerance specified above, before addition of the fluidizer.
- The fluidizer shall be added to the concrete mixture already transported to the concreting site in a liquid form by means of an automatic control system. The fluidizer addition shall be followed by an additional mixing of the concrete-fluidizer mixture in a special concrete mixer (minimum mixing time: 3 min.) or in the truck mixer itself (minimum mixing time: 5min.).
- The amount of fluidizer added shall be such that the slump of the mixture after the additional mixing is 15cm. However, this amount shall not be less than 0.5% of the cement in weight.
- The setting retarder effect of the fluidizer may be compensated by use of an approved combined setting accelerator if required.
- Suitability Test: Forty days before commencing any concrete works, the Contractor shall perform suitability tests in the PMC's presence, which shall cover, depending on the observed characteristics of the concrete ingredients:
  - Operation of the cement mixers, of the control devices for fluidizer addition, of the additional mixing and of the final transport of fluidified concrete to the site (pipes, channels).
  - The quality of the fluidified concrete:
    i. Consistency measurement (before and after the fluidizer addition).

ii. Simple compressive strength at 1, 3, 7 and 28-day.

iii. The strength shall be at least 90% of the corresponding strength of the same concrete without addition of the fluidizer.

iv. Measurement of air content of fresh concrete after the additional mixing.

v. The compatibility of the fluidizer with any other additive possibly used, as requested above for any additive proposed.

vi. Suitability of the concrete mix as regards to segregation.

vii. Suitability of the concrete mix as regards to pumpability.

viii. Effect of the variations in the quantity of fluidizer added, as described above for the submittal of any additive to the approval of the PMC.

22.4.8.2 Execution

- The fluidized concrete shall not be poured from more than 1.0m in height and where required channels or pipes for the concrete transport shall be used.
- The fluidized concrete shall be poured within the time for which the fluidizer has a real effect. No addition of fluidizer or water or any other additive in order to prolong this effect will be tolerated after the initial addition of the fluidizer.
- Shuttering and forms shall be designed to withstand the full load exerted by the liquid concrete. In addition, they shall be fully watertight in order to prevent any loss of the mix.
- Where required by the PMC, the fluidified concrete will be slightly compacted by use of low frequency vibrators.

22.4.9 Precast Concrete

22.4.9.1 General

The Contractor shall submit clear details of the casting and placing procedures that he intends using as well as his planned arrangements for the precasting yard. Precasting work can start as soon as the PMC has given his approval of the foregoing details and arrangements. No separate measurement will be made for cement either by casting at the Site or by purchasing units from a supplier.

22.4.9.2 Formwork

- Molds shall be so constructed that they do not suffer distortion or dimensional changes during use and are tight against loss of cement or fines from the concrete.
- Molds shall be set up on firm foundations so that no settlement occurs under the weight of the fresh concrete.

- Molds shall be constructed so that units may be removed from them without sustaining any damage.
- Release agents used for demolding shall not stain the concrete or affect its properties in any way.

22.4.9.3 Reinforcement Cages

When performed cages are used the cages shall be made up on jigs to ensure dimensional accuracy and shall be carefully supported within the mold in such a way that they cannot move when concrete is placed.

- Reinforcement shall comply with Chapter 0420 "Reinforcing Steel". ASTM A615 may be tack welded where bars cross to provide rigidity in the cage provided under
- Cover to main reinforcement shall be as shown in the Drawings.
- Bars shall be spaced so that the minimum clear distance between them is the maximum nominal aggregate size plus 5mm but in any case, not less than the diameter of the bars.

22.4.9.4 Casting and Curing of Precast Units

- The area in which units are cast shall be adequately protected from the weather so that the process is not affected by rain, sun or drying winds.
- The Contractor shall ensure that units do not suffer any loss of moisture or sudden changes of temperature for at least four (4) days after casting. If a fog spray is used for curing, the water shall be at a temperature within 5°C of the temperature of the unit being cured.
- If the Contractor proposes curing at elevated temperatures, the method shall be subject to the agreement of the PMC and shall include means whereby units are heated and subsequently cooled evenly without any sudden changes of temperature.

22.4.9.5 Surface Finish and Tolerances

Refer to Chapter 0410 "Formwork and Surface Finishes".

22.4.9.6 F. Handling and Storage of Units

- Precast units shall be handled in a manner which will not cause damage of any kind and shall be stored on a hard, impermeable base. Prestressed units and large precast normally reinforced units shall be handled and stored so that no stresses shall be induced in excess of those which they will incur in their final positions in the Works unless they have been designed to resist such stresses.

- Units shall be provided with adequate lifting holes or loops, placed in the locations shown on the Drawings or agreed by the PMC and when it is not possible to provide holes or loops, suitable sling positions shall be indicated in paint on unexposed faces of the units.
- Units shall be marked indelibly with the reference number and date of casting and shall be stacked on suitable packers which will not damage the concrete or stain the surfaces. Not more than two packers shall be placed under each unit and these shall be located either at the positions of the permanent support points or in positions such that the induced stresses in the unit will be a minimum.

22.4.9.7 Purchased Units

- If the Contractor proposes to purchase precast units from a supplier, he shall ensure that such units comply with the requirements of the Specifications and shall carry out any tests which the PMC may require to check compliance.
- Units shall not be obtained from any supplier who refuses free access by the PMC to the factory to inspect and test materials and workmanship.

22.4.9.8 Testing Units

- Precast units shall be capable of safely sustaining the loads which they have been designed to carry. If instructed by the PMC, the Contractor shall subject units selected by the PMC to load tests simulating the work conditions. Details of such tests shall be agreed between the PMC and the Contractor.
- In the case of units subject to bending loads the test pieces shall be supported at full span and a loading equivalent to 1.25 times the sum of the live and dead loads which were assumed in the design shall be maintained for one hour without the appearance of any signs of distress. The recovery one hour after the removal of load shall be not less than 75% of the full load deflection.
- If the unit fails to meet the above requirements, further tests shall be carried out on two more units. If either of these fails the whole batch of units will be rejected.
- If the PMC so requires, a test to destruction shall also be carried out which on units subject to bending shall be as follows:
  - The unit shall be supported at full span and a load applied in increments instructed by the PMC up to 95% of the designed ultimate load. This load shall be held for fifteen (15) minutes without failure of the unit. The deflection at the end of this period shall be not more than 1/40th of the span. The load shall then be further increased until failure occurs.
  - If the unit fails to sustain the required load for the prescribed period or if the deflection exceeds the specified amount, the PMC may order two further tests,

and if either of these fail, the batch of units which they represent may be rejected.

22.4.10 Concrete Work for Tunnel Plud

22.4.10.1 Concrete Class for Tunnel Plug

Unless otherwise directed by the PMC, Class C20 concrete shall be used for tunnel plug works.

22.4.10.2 Coil Cooling for Concrete Plug

In order to minimize temperature rise of the placed plug concrete and drop the concrete temperature to 25°C or to the degree otherwise directed by the PMC, artificial cooling shall be continued by the Contractor in the plug work during and after placement of the plug concrete by circulating chilled water in the cooling coils embedded at every lift of the concrete.

The cooling to the plug concrete shall be made maintaining the rate of temperature drop of the concrete not exceeding 0.5°C per day.

Plug concrete shall be placed in lifts of maximum thickness of 1.3m unless otherwise approved by the PMC.

Not later than fifty six (56) days before placing each concrete plug, the Contractor shall submit to the PMC for his approval method statement for pacing plug concrete. The statement shall include:

- Method and duration of artificial coil cooling to the plug concrete including concrete lifting schedule, coil arrangement for each lift, method of chilling and capacity of its plant, etc.
- Number of thermometers and embedding location of them.
- Concrete mix design to minimize cement contents and achieve appropriate consistency of the concrete satisfying the requirements specified in these Specifications.
- Cement or pozzolanic materials of low hydration heat.

Unless otherwise directed by the PMC, the Contractor shall measure and record temperatures of the plug concrete, circulating cooling water and air by embedding approved thermometers at the following frequencies.

- Daily for the first eight (8) days after placement,
- at two (2) days intervals up to the next fourteen (14) days, then
- weekly for the period of two months from each start date of the lift cooling.

The Contractor shall submit to the PMC the result of the temperature measurements of the day including the followings:

- Maximum and minimum air temperature
- Placing concrete temperature measured at the point of the placement
- Location of concrete lifts placed and cooled
- Cooling water temperature at entry to and exit from the plug concrete

The Contractor shall submit in written form to the PMC for approval the date and period of disconnecting cooling coils from any lift, and any subsequent reconnection.

Chapter 0431

23 SHOTCRETE

23.1 GENERAL

23.1.1 Scope

This Chapter covers the requirements for furnishing and application of pneumatically applied concrete (shotcrete) and sprayed mortar (gunite) as lining and support of the excavation temporarily or permanently exposed in underground works or surface works, dental shotcrete in dam foundations and in other areas as shown on the Drawings or otherwise directed.

23.1.2 Related Works / Sections

Chapter 0420 Reinforcing Steel

Chapter 0430 Conventional Concrete (CVC)

23.1.3 Definitions

- Gunite: mortar with the maximum aggregate size less than 5.00mm sprayed pneumatically onto a receiving surface.
- Shotcrete: Shotcrete contains aggregate with maximum size of 12.50mm or 25.00mm (By getting approval of the PMC) sprayed pneumatically onto a receiving surface.
- Wet mix Process: All materials and water, but without accelerators, are mixed together to produce mortar or concrete. The mixture is then conveyed by positive displacement or compressed air to a nozzle where air, and possibly accelerator, is injected to increase velocity, and projected without interruption into place.
- Dry mix Process: The cement, aggregates and accelerator batched are thoroughly mixed dry (with enough moisture to prevent dusting) 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 a nozzle in which water as a spray is introduced to hydrate the mix which is projected without interruption into place.
- Overspray: Shotcrete material deposited away from the intended receiving surface.
- Rebound: Shotcrete material which ricochets off the receiving surface and falls to accumulate on the ground or other surface.
- Sloughing (also called sagging): Subsidence of shotcrete, due generally to excessive water in the mix or placing too great a thickness of shotcrete in a single pass.
- Steel Fiber Reinforced Shotcrete (SFRS): Shotcrete mix containing steel fibers

23.1.4 Codes and Standards

The Work included in this Chapter shall comply with the requirements of the following standards and codes, except where this Specification differs from these standards and codes, in which case the requirements of the Specification shall take precedence:

23.1.4.1 American Concrete Institute (ACI)

ACI 506R	Recommended Practice for Shotcreting
ACI 506.2	Materials Proportioning and Application
ACI 506.3R	Guide to Certification of Shotcrete Nozzle men
ACI 544.1R	Report on Fiber Reinforced Concrete

23.1.4.2 American Society for Testing and Materials (ASTM)

ASTM A185	Steel Welded Wire, Fabric, Plain for Concrete Reinforcement
ASTM C33	Specifications for Concrete Aggregates
ASTM C42	Methods of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
ASTM C94	Specification for Ready-Mixed Concrete
ASTM C150	Specification for Portland Cement
ASTM C642	Test Method for Specific Gravity, Absorption, and Voids in Hardened Concrete
ASTM C1550	Flexural Toughness of Fiber Reinforced Concrete (Using Centrally Loaded Round Panel)

23.1.5 Quality Assurance

23.1.5.1 Testing

23.1.5.1.1 General

The Contractor shall provide all material; labor and equipment required for preparation of test panels, the extraction of cores therefrom and from the shotcrete placed in the Work.

23.1.5.1.2 Pre-construction Testing

Pre-construction testing is required to certify the shotcrete nozzle-men to be employed and to assess the ability of the Contractor's crew, equipment, materials, mix proportions and procedures to produce shotcrete of the specified quality.

At least forty two (42) days before commencing any shotcrete works, the Contractor shall perform pre-construction tests on test panels in the presence of the PMC, for each mix design proposed for the works. These tests shall cover, depending on the observed characteristics of the concrete ingredients:

- Operation of the cement-mixers, of the control devices and the sprayed installations, under normal site operating conditions.
- The quality of the shotcrete:
  - simple compressive strength at 8-h, 24-h, 7-day and 28-day,
  - adherence of the shotcrete to the terrain (minimum adherence on the most critical fissures or joints: 50% of the maximum adherence obtained on sound surfaces),
  - continuity of the shotcrete (no voids between the terrain and the shotcrete nor within the shotcrete itself),
  - apparent density of the shotcrete,
  - effective composition of the concrete,
  - consistency measurement (without additives),
  - boiled absorption.

These tests shall be carried out on not less than three (3) tests panels for each mix for testing. Sets of test panels shall comprise one (1) shot downwards onto a horizontal surface, one (1) shot onto a vertical surface and one (1) shot onto an overhead horizontal surface.

Such panels shall be fabricated on smooth wood surfaces. The test panels of shotcrete shall be 750mm x 750mm x 120mm thick and shall be fabricated by application of shotcrete using the same equipment, air pressure, water content and materials as will be employed for the actual work. One (1) test panel for each mix design shall be shot horizontally and the second panel shot vertically overhead. Test panels shall be fabricated by the nozzle-men who will be employed for the actual work.

Each test panel shall be field cured in the same manner as for the work for an initial period of three days prior to delivery to the test laboratory. Panels shall also be protected against being disturbed and from exposure to excessive heat during this period.

To check the quality of the shotcrete, nine (9) 100mm diameter cores shall be cut at right angles to the plane of the panel. The cores shall be cut not less than taken within 125mm from the edges of the panel. The cores shall be stored, cured and tested in accordance with ASTM, three (3) being tested at 3-day, three (3) at 7-day and the other three (3) at 28-day after the panel was sprayed.

Thirty days after the fabrication of test panels, the PMC will either accept the mix designs or request modification of mix proportions.

The PMC may give tentative acceptance for the initial use of a mix or nozzle man and crew on the basis of the 7-day test results if the results appear satisfactory. Such acceptance will be subject to the 28-day test results meeting the specified requirements.

23.1.5.1.3 Construction Testing

For wet mix volumetrically batched shotcrete, the Contractor shall, once per shift or for each 40m³, whichever is more frequent, determine shotcrete mixture proportions at the point of discharge from the mixing equipment, for compliance with the approved mix design.

Construction test panels shall be fabricated from sealed plywood or other suitable forming material and have 45° sloped edge form boards, to prevent entrapment of rebound. Panel dimensions shall be 750mm x 750mm x 120mm deep.

The Contractor shall shoot one test panel for each 40m³ of shotcrete placed, or one per week, whichever is more frequent. For the first 50m³ of shotcrete sprayed in each tunnel heading or surface work location, test panels shall be prepared and tested for each 10m³ applied. Subject to satisfactory performance of the shotcrete, the testing frequency may be reduced at the discretion of the PMC. Orientation of the test panels as shot shall be representative of the production work. Construction test panels shall be shot by the nozzle-man employed on the work.

Test panels shall be field cured in the same manner as the work for two (2) days prior to moving to the Site laboratory.

Nine (9) 100mm diameter cores shall be cut at right angles to the plane of the panel forty eight (48) hours after it has been sprayed. The cores shall be cut not less than taken within 125mm from the edges of the panel. The cores shall be stored, cured and tested in accordance with ASTM, three (3) being tested at 3-day, three (3) at 7-day and the other three (3) at 28-day after the panel was sprayed

Soundness of the sprayed concrete shall be tested by a hammer. Any areas sounding hollow shall be investigated, and where necessary the Contractor shall drill 60mm diameter cores to determine the thickness of sprayed concrete.

When instructed by the PMC, the Contractor shall drill 100mm diameter cores in the sprayed concrete, and these cores shall be tested in a similar manner to those from the test panels. Core holes in the finished works shall be filled to a flush finish by ramming in dry pack concrete of a similar mix to the surrounding concrete.

23.1.5.1.4 The BA and VPV Tests

The ASTM C642-06 standard test method for Specific Gravity, Absorption, and Voids in Hardened Concrete, is referred to in this Chapter as the boiled absorption (BA) and volume of permeable voids (VPV) test.

The BA and VPV test procedure is to be adopted as a quality control measure for shotcrete and are considered as a useful indicator of potential long-term durability using the limits and categories in the following table:

Volume of Permeable voids, %	Boiled Absorption, %	Suggested Quality Indicator
< 14	< 6	Excellent
14 - 17	6 - 8	Good

17 - 19	8 - 9	Fair
> 19	> 9	Marginal

The following limits are to be considered for all final shotcrete:

- BA < 8 AND VPV < 17 for non-accelerated shotcrete,
- BA < 9 and VPV < 19 for accelerated shotcrete.

23.1.5.2 Acceptance Criteria

23.1.5.2.1 Strength Acceptance

Compressive strength acceptance or rejection will be based on concrete cores extracted from construction test panels and/or from the in place shotcrete. Core holes in place shotcrete shall be carefully filled with approved mortar.

The average compressive strength of any three cores taken from the structure, or a test panel representing one shift or 40m³, of shotcrete shall comply with ACI 506.

23.1.5.2.2 Shotcrete Quality

In place shotcrete shall be of uniform quality and free of defects such as segregation, honeycombing, sand pockets, dry patches, laminations, overspray, rebound, single voids with dimensions in excess of 15 mm in any direction, or excessive cracking.

Delamination either within shotcrete or at substrate/shotcrete interface will constitute cause for shotcrete rejection. Extent of delamination will be evaluated by sounding with a blunt metal instrument and, where necessary, verified by coring.

23.1.5.3 Tolerances on finished surfaces

In order to control the thickness of the sprayed concrete, the Contractor shall place reference pegs in the foundation material (see Clause 3.3.5).

In addition to the steel pins installed as specified above, the thickness of the shotcrete shall also be verified by core holes drilled for sampling purposes.

23.1.6 Submittals and Approvals

- Not less than thirty (30) days prior to commencing pre-construction tests, the Contractor shall submit the following for review and approval:
  - test plan, showing test methods and location, source and proof of conformance to project specifications of: Portland cement, aggregates, mix water, accelerator, steel fiber, proposed admixtures and curing compound;
  - details of proposed mix design for shotcrete with and without steel fiber mix;

- qualifications, experience and work function of personnel assigned to shotcreting;
- details of all equipment to be used for batching, mixing, conveying, applying and curing.

- Not less than forty two (42) days prior to commencing any shotcrete works, the Contractor shall perform pre-construction tests in the PMC's presence and shall submit the results of the related tests for approval of the mix and process.
- The Contractor shall submit certification showing that each nozzle man has passed the ACI Nozzle man's Qualification Test in conformance with ACI 506.3R. Testing shall be performed on Site in the presence of the PMC.
- Results of the periodical Construction Testing during the work shall be submitted in an approved form to the PMC as soon as the laboratory test results are available.
- Submittals for Alkali Aggregate Reaction tests and execution described in the Chapter 0430 "Conventional Concrete (CVC)".

23.2 MATERIALS

23.2.1 Cement and Extenders

Cement and extenders shall conform to the requirements of the Chapter 0430 "Conventional Concrete (CVC)".

23.2.2 Water

Water used in shotcrete production shall be clean and free of injurious quantities of substances known to be harmful to Portland cement such as sulphates, chlorides, fluorides and nitrates.

23.2.3 Aggregates

- Aggregates shall conform to the requirements of ASTM C33. Gradation limits for coarse and fine aggregate fractions of shotcrete shall be as shown in the table below.

Material	Aggregate Size	Fraction	Aggregate
Gunite	0.00-5.00mm	100%	fine aggregate
Shotcrete	0.00-5.00mm	30 - 50%	fine aggregate
	5.00-12.50mm	20 - 30%	course aggregate (a)
	12.50-25.00mm	30 - 40%	course aggregate (b)

- No more than 2% of the aggregate, by weight, shall pass the U.S. Standard Sieve No.200 (0.075 mm).

- Coarse aggregate and fine aggregate fractions shall be stockpiled separately and separately batched during mixing.
- Should the nature of the aggregates used during the course of the work change (e.g. source, rock type, shape) from that used in the trial mix tests, the Contractor shall produce new trial mixes, using the new aggregates.

23.2.4 Admixtures

- Use of any admixture shall be subject to the PMC's approval.
- A shotcrete accelerator, Sigunite or approved equivalent, shall be used in all underground applications. The use of an accelerator for above-ground work shall be at the Contractor's option and be subject to the PMC's approval.
- Other admixtures meeting the requirements of Chapter 0430 "Conventional Concrete (CVC)". Clause 2.5 may be used. Such admixtures shall not contain water-soluble chlorides or materials corrosive to steel, and shall not induce other detrimental effects such as cracking or spalling. The admixture used shall have a demonstrable, acceptable service history of at least five years in similar applications.

23.2.5 Welded Wire Mesh

Refer to Chapter 0420 "Reinforcing Bars".

23.2.6 Steel Fibers

As an alternative to the wire mesh, the Contractor may use steel fiber-reinforced shotcrete (SFRS), containing artificial steel fibers of size and concentration determined by trial mixing and spraying tests to be performed by the Contractor at the pre-construction test.

Steel fibers shall be commercially produced fibers with diameter of 0.25-0.50mm and length of 25- 60mm. Both ends of fiber may have hook. The length of fiber shall be at least two times the maximum size of aggregate in the shotcrete mix. The mixing proportion of steel fibers to be used as reinforcement of shotcrete shall be between 20-60 kg per m^3 of shotcrete mix. Recommendations of ACI Committee 544 "State of the Art Report on Fiber Reinforced Concrete (ACI 544.IR-96) shall be applied for the use of the steel fiber reinforced concrete.

23.3 EXECUTION

23.3.1 Mix Design

- The Contractor shall be responsible for the design of the shotcrete mix. The Contractor shall provide shotcrete mixes, as approved by the PMC, capable of being

placed without excessive rebound or segregation, and capable of developing the required strength.

- The proportioning of shotcrete mixes shall be such that the compressive strength requirements are met with the lowest practicable water cement ratio. Minimum compressive strength of shotcrete and gunite shall be 25MPa.
- Shotcrete trial mixes shall contain, as a minimum, 350kg/m³ of Portland cement, in addition to aggregate and water.
- The amount of accelerator shall not exceed 3% by weight of cement.
- Proportion of fines by weight shall not be less than 17%.
- Wet mix shotcrete shall have a slump of 40mm to 80mm.
- Approval of trial mix proportions does not relieve the Contractor of his responsibility of complying with and meeting all the requirements of the Specifications.
- The compressive strength of shotcrete, determined from cores with a length to width ratio of approximately 2, shall meet the following minimum requirements when tested in accordance with ASTM C42:

4 MPa	at 8 hours
15 MPa	at 72 hours
25 MPa	at 28 days

23.3.2 Equipment

- Shotcrete equipment shall be subject to approval before being used in the Work and shall be in good working condition. Equipment shall have an acceptable performance record in applying shotcrete as specified herein and shall be operated and maintained in accordance with the manufacturer's instructions. The delivery machine shall be capable of ejecting material from the nozzle at velocities that will allow adherence of material to the surface to be treated with minimum rebound and maximum adherence and density. Sufficient standby equipment shall be available on Site to ensure that production is not delayed by malfunction of any item of equipment.
- The batching plant and proportioning devices shall conform to the applicable provision of ASTM C94 and shall be capable of providing the exact required ingredients in the approved proportions.
- Wet mix shotcrete equipment shall include a mixing chamber and pump which are adequate to ensure a steady delivery of well mixed shotcrete ingredients to the nozzle. The shotcrete material shall leave the nozzle with sufficient velocity to ensure that the in place material is of uniform consistency and hardens to the specified strength at all times.

- Dry mix shotcrete equipment shall consist of a spray nozzle providing for ejection of dry materials and water in an intimate mixture, separate hoses to deliver dry materials and water to nozzle, a suitable machine to introduce the dry materials to the delivery hose under air pressure, and air and water supply system. The water supply system shall consist of a local reservoir and a positive displacement pump capable of supplying water through a regulating valve, easily and accurately controllable by a nozzle-man, in sufficient amount and at pressure slightly above the operating air pressure recommended by the manufacturer of the delivery machine.
- No supply system shall be used that delivers air contaminated by oil, or that is incapable of maintaining a constant pressure.
- If the dry mix system is adopted, the entire system shall be arranged so that the nozzle man may use air and water in any combination to prepare surfaces on which shotcrete will be applied.
- The accelerating admixture shall be added immediately prior to depositing the materials in the placing equipment, or if in liquid form, may be accurately proportioned into the water supply at the application nozzle. Dry admixture shall be accurately proportioned and thoroughly mixed with the other ingredients.

23.3.3 Shotcrete Placement

23.3.3.1 General

- Work of this Chapter shall conform to the requirements of ACI 506R and ACI 506.2.
- Only nozzle-men and crew experienced in the application of shotcrete shall be used and nozzle men and crew shall not be used on permanent work unless their pre-construction test panels have been accepted by the PMC.
- Prior to placing shotcrete, surfaces shall be thoroughly cleaned of all loose material and any deleterious substances, by air and water jetting and the surfaces shall be clean, sound, damp and free of ponded water. Where necessary, such surfaces shall be saturated and/or drained. Where shotcrete is to be applied to a previously applied layer of shotcrete, the previously applied layer of shotcrete shall be completely free of laitance, rebound and overspray and shall be thoroughly cleaned with air or air and water or by sand blasting if necessary.
- Surfaces other than rock shall be compact, trimmed and graded as required and damp. They shall be sufficiently cohesive to avoid erosion by the spraying operation, otherwise pretreatment may be necessary.
- Concrete, brickwork and masonry shall be clean and damp without any loose material. When a second layer is being applied to freshly sprayed concrete, the application shall be deferred until the first layer is hard enough to avoid erosion and creep.

- Surfaces to which shotcrete is to be applied shall be prepared so that there are no abrupt changes in the thickness of the applied layer. Water shall be diverted away from surfaces to be sprayed by drilled drains or surface pipes so that there is no possibility of any leaching of cement or other deterioration of the shotcrete.
- In so far as is possible and after scaling and cleaning, walls shall be wetted before placing shotcrete. The same precautions shall be taken in the case of shotcrete placed in several layers.
- Entry of shotcrete or other foreign materials in drain holes or pipes shall be prevented by caulking the collars of holes and the exposed ends of the pipes with oakum or other approved caulking to the satisfaction of the PMC. In the event that piping or drain holes become plugged they shall be cleaned out or replaced entirely by the Contractor. Caulking shall be removed upon completion of the shotcreting operation, where necessary for the free draining of the pipe or hole.
- Placement of shotcrete shall be performed only in the presence of the PMC, who shall be given adequate notice as to when and where shotcrete is to be placed.
- Shotcrete shall be built up to the thickness required in such number of layers as the Contractor shall deem advisable providing that no sloughing of freshly placed material occurs. Each layer shall be placed in one continuous operation. The average thickness of the layers shall be the specified thickness. In general, the rock shall have a cover of at least 50mm of shotcrete. Formwork or guides shall be fixed rigidly. Reinforcement shall also be fixed rigidly so that no movement occurs during spraying. During starting or stopping the spraying operation, or when the delivery from the nozzle is irregular, the nozzle shall be directed away from the Works.
- Rebound material shall not be worked into the construction or re-used in the Works. The lighting intensity in the spraying area shall be adequate at all times. Freshly sprayed shotcrete shall be completely protected from rapid drying out for a minimum period of three (3) days after spraying.
- Rebound and overspray shall be kept to a minimum. Where possible, overspray and rebound shall be removed prior to hardening. Hardened overspray and rebound shall not be incorporated into the shotcrete work.
- Sequence and details of shotcrete and support placement shall be subject to approval.

23.3.3.2 Shotcrete as Temporary Support

- Contractor shall propose the shotcreting procedure to be used (number of layers, steel reinforcement, fastening method, etc. for approval of the PMC.
- Contractor shall inform the PMC before placing any shotcrete or in the shortest possible time in view of the urgency of temporary support work.

- The firmly placed shotcrete and wire mesh are allowed to project inside the "A-line" as defined in the sections for "Underground Excavations". However, where the projected temporary shotcrete interfere with the permanent traffic, projection of the shotcrete shall not be allowed.

23.3.3.3 Welded Wire Mesh Installation

Refer to Chapter 0420 "Reinforcing Steel", Clause 3.3

23.3.3.4 Control of Water

The Contractor shall provide for all inflowing water to be collected and diverted through weep holes drilled 0.3m into rock, relief PVC pipes or other methods of controlling flows in order to prevent the shotcrete from being washed out and uplift pressures from forming on the treated surfaces. Plastic pipes or tubes may be left in holes drilled into rock and embedded in concrete.

23.3.3.5 Thickness

- In order to control the thickness of the shotcrete, the Contractor shall insert steel pins firmly in the foundation material at high points of the surface to be treated. The length of protrusion of the pins beyond the surface shall be equal to the minimum thickness of shotcrete to be placed or otherwise directed. Shotcreting shall continue until no part of any pin is visible. Where shotcrete is built up to a specified position or shape, the tolerance shall be as for a U1 finish. If the sprayed shotcrete is following a natural surface, the thickness shall be within +15 mm of that required but shall not be thinner than required.
- The shotcrete covering on the reinforcement shall be of 20 mm minimum thickness.
- All surface finishes are to be reasonably uniform in texture and free from blemishes. If any surface shows a lack of compaction or bond, dry patches, voids, sand pockets, sags or slumps, the material shall be removed immediately over an area not less than 300mm square and resprayed at once.

23.3.3.6 Construction Joints

Locations of construction joints and method of forming shall be subject to the approval of the PMC. Joints shall be formed at right angles to the face for at least half the depth of the layer being placed.

23.3.3.7 Curing

Shotcrete surfaces shall be cured in accordance with the requirements for curing of concrete as specified in Chapter 0430 "Conventional Concrete (CVC)".

23.3.3.8 Safety Measures

- Adequate safety measures shall be taken to protect shotcrete crew and all personnel from rebound materials and alkalis in Portland cement and admixtures.
- Shotcrete crews shall wear appropriate hard hats, masks, gloves, eye protection and protective clothing. Eyebaths shall be readily available in the immediate vicinity of the shotcrete application.
- Adequate scaffolding and other safety devices appropriate to the job and location shall be provided for operating personnel.

23.3.3.9 Remedial Shotcrete Work

- The Contractor shall replace shotcrete that does not meet the requirements of the Specifications, unless alternative remedial methods are accepted.
- Where shotcrete repair is necessary, the underlying surface shall be prepared to the satisfaction of the PMC and the bonding surface shall be treated in compliance with either of the following two alternative procedures:
  - Where the shotcrete has not attained its initial set, defective shotcrete shall be cut out and laitance or other deleterious matter shall be removed by careful light brooming.
  - Where the shotcrete has attained its final set, loose rebound shall be brushed off, rebound pockets and other defective shotcrete shall be cut out and laitance removed by sandblasting or water jetting.

Chapter 0433

24 ROLLER-COMPACTED CONCRETE (RCC)

24.1 GENERAL

24.1.1 Scope

This Chapter covers the work associated with the furnishing of all plant, labor, materials and equipment and performing all operations required for the manufacture, transportation, placing, compaction and curing of the roller-compacted concrete (RCC) in the main dam of the PSKEM Hydropower Project.

Also included in this Chapter are the following:

- Preparation works for placing RCC (Dental concrete and leveling concrete);
- Construction of the faces of the dam;
- Construction of joints in the dam body and faces;
- Construction of galleries inside the RCC structure.

All materials and operations associated with the manufacture, transportation, placing, forming, reinforcing and curing of the immersion-vibrated concrete works, others than those indicated above, are covered by the specifications and detailed requirements of Chapter 0430 "Conventional Concrete (CVC)".

The intent of this Specification is to provide suitable direction to construct a final product in accordance with the design and assumptions thereof. As such, the Specification may be modified, from time to time, to suit actual field conditions and design requirements.

24.1.2 Related Works / Sections

Chapter 0220	Surface excavation
Chapter 0240	Drilling and grouting
Chapter 0410	Formworks
Chapter 0420	Reinforcement
Chapter 0430	Conventional Concrete (CVC)
Chapter 0431	Shotcrete
Chapter 0440	Concrete structure joints and bearings
Chapter 0510	Miscellaneous Structural steel Works and metalwork

24.1.3 Definitions

Refer to Sub-Clause 1.3 of Chapter 0430 "Conventional Concrete (CVC)".

24.1.4 Codes and Standards

Refer to Sub-Clause 1.4 of Chapter 0430 "Conventional Concrete (CVC)".

24.1.5 Classes of RCC

The classes of RCC to be used in the works are defined in the following table:

Class	Use	Max. size of aggregate (mm)	Specified strength, f'c (MPa)	Age of strength test (days)
RCC1	High strength	50	25	365
RCC2	Middle strength	50	20	365
RCC3	Low strength	50	15	365

24.1.6 RCC Works Quality Control

24.1.6.1 Quality-Control Measures

The Contractor shall be responsible for providing quality-control measures to ensure compliance of the concrete and RCC with the specified requirements.

The Contractor's shall conduct a concrete quality control programme incorporating as a minimum the tests specified below, to be performed in the a laboratory and with sampling and testing equipment provided by the Contractor. As a part of his concrete quality-control programme, the Contractor shall conduct tests to the extent and frequency necessary to ascertain that the concrete constituents, as well as the fresh and hardened concrete, meet the specified quality.

The RCC quality control program of the Contractor shall be described in the method statements included in his Bid.

Not later than fifty six (56) days after Commencement Date, the Contractor shall submit to the PMC the complete RCC quality control program he proposes to apply, detailing proposed types of tests, tests facilities and sampling equipment provided, frequency of tests, handling of tests results, actions foreseen in case the specified requirements are not met, and any other pertinent aspect. The quality control program shall be subject to the approval of the PMC, who reserves the right to request modifications / improvements to the program as deemed necessary to assure that specifications requirements will be met.

The PMC reserves the right to monitor the tests being carried out by the Contractor and to conduct his own concrete Quality-Control programme and can carry out himself or instruct tests to be carried out by the Contractor to the extent and frequency necessary to ascertain that the concrete constituents, as well as the fresh and hardened concrete, meet the specified quality.

24.1.6.2 Tests

The Contractor shall obtain samples and conduct tests in accordance with the test methods listed below:

No.	Procedures	Standard
1	Testing of pozzolanic material	ASTM C311
2	Testing of Portland cement	ASTM C114, 109, 204
3	Sampling aggregates	ASTM D75
4	Testing aggregate for Los Angeles test on aggregate	ASTM C131
5	Testing aggregate for Soundness	ASTM C88
6	Testing aggregate for Flakiness and Elongation Indices	BS812 (Part 105)
7	Sampling fresh concrete	ASTM C172
8	Concrete uniformity	ASTM C94
9	Density (unit weight) and yield	ASTM C133
10	Air content	ASTM C231
11	Initial and Final setting times	ASTM C403
12	Slump	ASTM C143
13	Temperature at point of placement	insert thermometer in RCC
14	Making and curing concrete cylinder specimens	ASTM C31
15	Capping cylindrical concrete specimens	ASTM C617
16	Compressive testing of concrete cylinders	ASTM C39
17	Direct tensile testing of concrete cylinder	-
18	Compressive strength of concrete cube tests specimens	BS1881 - 116
19	Compressive testing of concrete cores	ASTM C42
20	Direct tensile testing of concrete cores	-
21	VeBe method of measuring concrete consistency	-

24.1.6.3 Test Facilities and Sampling Equipment

The Contractor shall provide the following sampling equipment and testing facilities at the RCC concrete plant:

- An building of not less than 40m² adjacent to the batching and mixing plants, free from plant vibration and excessive plant noises, and furnished with all necessary utilities including lights, compressed air, water, room temperature control, electrical power and the following equipment:

No.	Equipment	Quantity
1	Sample tins, scoops, shovels etc	Supply
2	Riffle box	1 No
3-1	Sets of test sieve (100 - 5mm)	3 sets
3-2	Sets of test sieve (5 - 0mm)	3 sets
4-1	Sieve shaker (large)	2 No
4-2	Sieve shaker (small)	2 No

5	250 ml silt measuring cylinders	3 No
6	Drying trays	Supply
7	Drying oven (500L)	2 No
8	Gas rings (with supply of gas)	2 No
9	Sets of cylindrical metal measures for bulk density	2 sets
10	Tamping rod	2 No
11	Digital balance to weigh up to 100kg with accuracy of 0.1%	2 No
12	Flakiness and elongation gauges	2 sets
13	Digital balance to weigh up to 10kg with accuracy of 0.05%	2 No
14	Distilled water	Supply
15	Thermometers-range -10 to 35 ºc in heavy duty case	10 No
16	Steel or cast iron 150-mm cylinder moulds	100 No
17	Galvanized hand scoops, trowels, steel floats	Supply
18	Mould oil	Supply
19	Maximum and minimum thermometers	2 No
20	Slump cone with tamping rod	3 No
21	Modified vebe consistometer	2 N.
22	Pan mixer with a capacity of 100 liters	1 No
23	Heavy-vibrating table (with facility for varying the frequency of vibration) capable of compacting 6Nº 150-mm cubes at the same time.	2 No
24	200-ton power-operated hydraulic cylinder-testing machine with plates suitable for 150-mm cylinders in compression and 150-mm cylinders in direct tension	2 No
25	Galvanized curing tanks fitted with thermostatically controlled heating/ cooling arrangements and means for circulating the water capable of storing 3,000 pieces of 150-mm cylinder specimens	supply

- Mechanical sampling devices for safely procuring and handling representative test samples of aggregates and other concrete materials during batching and for obtaining representative concrete samples from a point in the discharge stream as the concrete is discharged from the mixers.
- Ample and protected working space near the placement site and a means for safely procuring and handling representative concrete samples.
- After the tests are completed, the test facilities shall remain the property of the Contractor and shall be removed from the Site.
- The Contractor shall submit drawings and data showing locations and descriptions of the test facilities and sampling equipment to be provided. The drawings and data shall provide a description in sufficient detail for an adequate review of the facilities and equipment to be made by the PMC.

24.1.6.4 Tolerances for Concrete Construction

Refer to Chapter 0410 "Formworks and Surface Finishes".

24.1.7 Submittals and Approvals

24.1.7.1 General

The Contractor shall advise the PMC not later than fifty six (56) days after the Commencement Date, by means of a detailed submission, of the arrangements he proposes to adopt for all the construction Plants and Equipment, materials and construction procedures for the production, placing, consolidating, curing and finishing of concrete.

Specific requirements for certification, source and site testing and approvals of materials used in the production and for quality control of concrete, shall be as specified in Clause 2 "Materials" and Clause 3 "Execution" below.

24.1.7.2 Contractor's Plant, Equipment and Construction Procedures

The Contractor shall submit with his Bid a detailed proposal for the construction of the RCC dam, including the type of plant to be used for the manufacture, transportation, placing, compaction, and curing of RCC. The plant shall be located in the Contractor's work areas as shown in the Drawings.

The proposals shall include:

- A description of the transportation, storage and handling arrangements for the cementitious materials (cement and natural pozzolan/rock flour), including transportation from the production/manufacturing areas to the dam Site;
- A description and a plan of the methods of crushing, handling, storing and transporting the aggregates from the proposed and selected quarry;
- A location plan and schematic drawings of the concrete plant, along with a description giving its peak capacity and normal anticipated production rate, together with a plan of the facilities for sampling of concrete and concrete materials at the plant;
- A schedule showing the type and number of pieces of equipment for transporting, placing, spreading and compacting RCC;
- A description and a plan of the arrangements for maintenance of the plants and equipment;
- A schedule of the dam construction stages month by month and method statement for the RCC dam construction, detailed to the extent necessary for a full appraisal of the construction methods proposed.

The Contractor's plant and operations shall be in accordance with the detailed proposals submitted with his Bid and in accordance with any modifications that may be approved or required by the PMC to achieve the desired result.

24.1.7.3 Concrete Placement Programme

Not later than hundred eighty (180) days before the planned starting of RCC placement in the dam, the Contractor shall submit to the PMC a complete detailed cast-in-place concrete placement programme showing his plans for placement of all the individual features, units, or other elements of the integrated RCC cofferdam and the RCC main dam. The concrete placement programme shall be consistent with the schedule and with the overall planning of the river handling during construction submitted in the proposal, and shall be prepared in such form and details as it is necessary to show the location of the placements each month for each item.

24.1.7.4 Test Facilities and Equipment

Not less than sixty (60) days after submission of Quality Control program requested in Sub-Clause 1.6.1 above, the Contractor shall submit the drawings and the data to the PMC for approval, showing locations and descriptions of the test facilities and sampling equipment to be provided. The drawings and data shall provide a description in sufficient detail for an adequate review of the facilities and equipment the Contractor proposes to provide for use in the concrete quality-control programme. The test facilities shall be installed prior to the commencement of the processing of the aggregates.

Test facilities and sampling equipment to be provided for other concrete materials shall comply with Sub-Clause 1.6.3 herein above.

24.2 MATERIALS

24.2.1 General

RCC shall be composed of fine and coarse aggregates, cementitious materials, water and admixtures as specified by the PMC, well mixed and brought to the proper consistency.

24.2.2 Mixture Proportions

RCC Mix proportioning and trials shall be performed by the Contractor. To initiate the RCC mix proportioning and trials, the following three (3) different strengths and other requirements are given as reference:

Items	Unit	Mix Proportion		
		RCC1	RCC2	RCC3
Nominal Max. aggregate size	mm	50	50	50
Portland cement	kg/m³	80 - 120	80 - 120	80 - 120
Pozzolanic Material	kg/m³	120 - 80	90 - 50	60 – 20

The mix shall also need to include a retarder admixture to retain the workability of RCC (i.e. hold the VeBe time) constant during the interval between mixing and completing compaction, especially at hotter times of the day. The main function of this admixture will be the set retardation of the concrete mix up to the times defined in Sub-Clause 2.5 "Admixture" herein below.

The proportions of various ingredients shall be determined by the Contractor first undertaking trial mixes using the actual materials from the site (see Sub-Clause 2.3 "Consistency of RCC" herein below) and second during the trial placement (see Sub-Clause 3.5.2 "Trial placement of RCC" herein below) and during the progress of the work. The Contractor shall make adjustments as directed to obtain RCC having a suitable workability, consistency, impermeability, density, strength and durability.

During the work progress, the PMC may require new mix proportioning tests whenever cements of different characteristics are proposed, and/or whenever the physical or chemical properties of natural pozzolan appear materially different from the samples already tested.

The PMC will take into account the results of these tests, together with the test certificates/test results provided by the Contractor according to Sub-Clause 1.6 "RCC works quality control" above, in requiring the Contractor to store in separate silos the various deliveries of natural pozzolan.

Suitable strength for RCC will be that which ensures that 80% of all test cylinders exceed a 15MPa compressive strength at an age of 28-day.

The PMC may adjust the mixture proportions during the progress of the work whenever the need for such adjustment is indicated by results of testing of the aggregates, cementitious materials and/or RCC.

24.2.3 Consistency of RCC

The consistency of RCC shall be determined by a loaded VeBe apparatus. The apparatus used in this test shall be the standard VeBe equipment as described in BS1881: Part 104: 1983.

The consistency of workable RCC mixtures is dependent upon the energy imparted into the mass during compaction. The allowable range in consistency shall be determined by the PMC based on experience with construction of the trial placement section (see Sub-Clause 3.5.2 "Trial placement of RCC" herein below) and later, the dam itself. RCC outside this range at the time of compaction shall be removed by and at the expense of the Contractor. Preliminary testing indicates optimum compaction results when the loaded VeBe time at time of compaction of RCC is between 14 and 18 seconds. Nevertheless the range may be adjusted at any time by the PMC.

The use of equipment that will not properly handle and place RCC of the specified consistency shall not be permitted.

Uniformity of the RCC consistency from batch to batch shall be required. To maintain RCC at the proper consistency the amount of water and fine aggregate batched for RCC shall be adjusted to compensate for variations in the moisture content and/or grading of the aggregates as they enter the mixer. Addition of water to compensate for stiffening of RCC after mixing shall not be permitted.

24.2.4 Cementitious Materials

24.2.4.1 General

The cementitious materials shall be supplied by the Contractor. For the purpose of this Specification, cementitious materials shall be interpreted to be Ordinary Portland Cement (OPC) plus a pozzolanic material such as a natural pozzolan or rock flour as defined respectively in Sub-Clauses 2.4.2 and 2.4.3.

Transportation from the place of manufacture/production to the batch plant shall be by means that shall protect the cementitious materials completely from exposure to moisture. Immediately upon receipt at the Site, the cementitious materials shall be stored in dry, weather tight, properly ventilated silos until the cementitious materials are batched. The silos shall be emptied and cleaned by the Contractor when so directed by the PMC; however, the intervals between required cleaning shall normally be not less than six (6) months.

Transportation and handling procedures for the cementitious materials shall be submitted with the Contractor's Bid (see Sub-Clause 1.7.2 "Contractor's plant, equipment and construction procedure" herein above).

All storage facilities shall be subject to approval by the PMC and shall be constructed to permit easy access for inspection.

The Contractor shall notify the PMC prior to any changes in source or handling of either of the cementitious materials.

24.2.4.2 Cement

The cement to be used for RCC shall conform to the requirements of Sub-Clause 2.3 "Cement" of Chapter 0430 "Conventional Concrete" and the conditions below:

- The same cement producer shall supply all the cement used for the RCC Works unless otherwise approved by the PMC.
- The cement to be used in the concrete shall be delivered to the storage at the Site in bulk or in bulk bags. Paper bags shall not be used. The transportation shall be furnished with adequate weighing devices and all the necessary facilities to ensure the good condition of the cement and to permit a correct weighing as the shipment arrives at the Contractor's storage silos.

- Sufficient quantities of cement shall be stored at Site to ensure that no delay is caused due to shortage of cement. During the pouring RCC for Permanent Works the reserve storage shallnot be less than the quantity for ten (10) days of scheduled concrete production.

24.2.4.3 Pozzolan Material including Rock Flour

24.2.4.3.1 Standard

The natural pozzolan to be used in RCC shall conform to the requirements of 2.4 "Pozzolan" of Chapter 0430 "Conventional Concrete (CVC)". The natural pozzolan to be used in the Works shall be the one gained at the designated locations or the proposed locations approved by the PMC. It shall meet the requirements of ASTM C618 - Class N.

24.2.4.3.2 Form of Delivery and Transportation of Natural Pozzolan

The natural pozzolan to be used in the concrete shall be delivered in bulk or in bulk bags. Paper bags shall not be used. The transportation shall be furnished with adequate weighing devices and all the necessary facilities to ensure the good condition of the natural pozzolan and to permit a correct weighing as the shipment arrives at the Contractor's storage silos.

All natural pozzolan deliveries shall be accompanied by the following:

- A certificate that the natural pozzolan conforms to the requirements of these Technical Specifications,
- The source of the natural pozzolan
- The date of manufacturing; and
- The quantity of natural pozzolan delivered.

If the natural pozzolan is damaged during transportation, handling, or storage it shall be removed immediately from the Site at the Contractor's expense.

- Storage of Natural Pozzolan

Transportation, handling and storage procedures of the natural pozzolan are subjected to the same requirements as specified in Sub-Clause 3.2 "Transportation" herein above.

Sufficient quantities of natural pozzolan shall be stored at the dam site to ensure that no delay is caused due to shortage of natural pozzolan. During the pouring RCC for Permanent Works the reserve storage shall not be less than the quantity for ten (10) days of scheduled concrete production.

The Contractor shall be responsible for delays that can occur due to insufficient storage.

24.2.4.3.3 Test Requirements of Natural Pozzolan

Sixty (60) days before using any natural pozzolan in any concrete, the Contractor shall submit Certified Test Reports of an independent laboratory in accordance with the applicable ASTM Standards defining the control tests and frequency that will be performed by the Contractor, including the testing of the physical and chemical properties of the natural pozzolan.

In case of pozzolan, unless otherwise authorized in writing by the PMC, as a minimum tests on the milled tuff shall be performed every 10,000ton of milled material obtained. The results of the tests shall be submitted to the PMC for approval not later than twenty eight (28) days before the material will be used.

The PMC reserves the right to order taking samples and performing tests of the natural pozzolan that the Contractor intends to use. No natural pozzolan shall be used until the PMC indicates that the test is satisfactory. If the tests demonstrate that the natural pozzolan that have been delivered are not satisfactory, it shall be replaced at the expense of the Contractor.

24.2.4.3.4 Temperature of Natural Pozzolan

The maximum temperature of the natural pozzolan delivered to the mixers shall not exceed 45°C, unless otherwise approved by the PMC.

24.2.5 Admixtures

The Contractor shall notify the PMC, in writing, of the manufacturers and specific brand names of admixtures that he may propose for use in RCC or leveling or Dental concrete or grout for use in Grout Enriched Vibratable RCC (GEVR). Such admixtures shall meet the requirements of Sub-Clause 2.5 "Admixture" of Chapter 0430 "Conventional concrete (CVC)". This notification should be accompanied by:

- The name of admixture;
- The admixture type;
- The ASTM Standard under which the admixture is formulated;
- The manufacturer's product description, instructions, recommended dosage, chloride content, and precautions to be considered when using the admixture;
- Independent laboratory test data, confirming that the requirements of the applicable ASTM Standard have been met; and

One (1) sample containing approximately one liter of the admixture.

Written notification of products to be used shall be furnished far enough in advance of planned use, so that samples, if required, can be made available to the PMC for a testing period of sixty (60) days after receipt of the samples. The Contractor will be advised within twenty (20) days after receipt of notification if the admixtures are to be tested and examined by the PMC.

The Contractor shall not be entitled to any reimbursement for delays incurred due to testing of admixtures by the PMC nor for delays caused by rejection of the proposed admixtures. Acceptance by the PMC will not be made until the admixture has been satisfactorily tested by the Contractor in the laboratory and during trials in the field.

The proportions and types of retarding admixtures to be proposed shall be such that brings the initial set of the RCC mix up to 12±3 hours and final set at less than 24 hours, measured according to the test described in standard ASTM C403. The Contractor shall carry out the tests outdoors at a temperature between 20ºC and 35ºC. The test sample shall be the material passing through the sieve #4 (4.76 mm) of the RCC mix determined by the PMC and that conforms to these Specifications.

Set retarding agents, which results in a decrease of RCC strength by more than 10% at twenty eight (28) days or that has a negative impact at long term on any mechanical property of the mix without admixture shall not be allowed.

24.2.6 Water

The water used in making and curing concrete shall be free from objectionable quantities of silt, organic matter, salts, and other impurities and shall conform to BS3148 and shall not contain more than 3,000 mg/l dissolved sulphates and shall be between 5.8 and 8.6 based on JSCE-B101.

The water shall conform to the requirements of Sub-Clause 2.6 of Chapter 0430 "Conventional Concrete (CVC)".

24.2.7 Aggregates

24.2.7.1 Aggregate Materials

Aggregates for RCC shall consist of hard, dense, durable, un-coated rock particles and shall be free from organic matter and injurious amounts of dust, clay lumps, soft or flaky particles, or other deleterious substances.

Material for aggregates for RCC may be obtained by crushing the rock extracted from the quarry in the Project Area. However, choice of rock material sources is the Contractor's discretion. The Contractor shall confirm the quality and quality of materials for himself and propose such materials and sources to the PMC for approval.

The RCC trial mix program shall then be carried out with aggregates from the approved quarry.

At least one (1) month before delivering any aggregate to the stockpiles, the Contractor shall supply and install at the crushing plant facilities satisfactory to the PMC for procuring representative test samples, shall obtain such representative samples of the proposed aggregates and shall test the aggregates under the instruction and witnessed by the PMC.

The overall gradation of the aggregate of the RCC shall meet the following requirements based on ASTM E11:

Sieve designation (mm)	Passing by weight (%)
50.8 mm	90 - 100
38.1 mm	80 - 93
19.1 mm	58 - 75
9.53 mm	41 - 57
4.76 mm	28 - 40
2.38 mm	19 - 32
1.19 mm	13 - 24
0.60 mm	8 -18
0.30 mm	6 - 14
0.15 mm	4 - 11
0.075 mm	3 - 9

The above gradation shall be obtained by suitably mixing the fine aggregate and the three (3) coarse aggregates size groups specified in the table below. Separate processing of the aggregates for the conventional concrete and for RCC shall not be required.

The requirements of aggregates quality before mixing for concrete are referred to Sub-Clause 2.7 of Chapter 0430 "Conventional Concrete (CVC).

The gradation limits for the individual sizes of coarse aggregate shall be in line with the criteria defined in Sub-Clause 2.1 of Chapter 0430 Conventional concrete (CVC) and suggested stock piles are as follow:.

Sieve Size (mm) /US Standard Sieve Designation	Per cent passing by weight		
	G3:5/12.5 mm	G2:12.5/25 mm	G1: 25/50 mm
76.2 mm (3 inches)	-	-	100
50.8 mm (2 inches)	-	-	90-100
38.1 mm (1 1/2 inch)	-	100	35-65
25.4 mm (1 inch)	-	90-100	3-10
19.1 mm (3/4 inch)	100	35-65	0-3
12.7 mm (1/2 inch)	90-100	3-10	-
9.53 mm (3/8 inch)	35-65	0-3	-
4.76 mm (No.4)	3-10	-	-
2.38 mm \ (No.8)	0-3	-	-

24.2.7.2 Production of Aggregate

The Contractor shall submit details of the sources of aggregates he proposes to use for the Works with together with representative 30-kg samples of fine aggregate and of each

size of coarse aggregate proposed for use in the Works, for testing at least two (2) months before the materials are required for use or delivery.

Before excavating materials for the production of concrete aggregates, the Contractor shall clear trees, roots, brush, sods, clay, unsuitable sand and gravel, weathered and unsound rock and other objectionable matter from all of those portions of the surface deposits from which aggregates are to be produced. Materials, including stripping, removed from the deposits and not used in carrying out the Works shall be disposed of as specified in these Technical Specifications or as directed by the PMC.

Processing of the raw materials includes crushing, screening and washing, milling and blending, to produce fine and coarse aggregates meeting the requirements of Sub-Clause 2.7.1 and shall be done at a site and in a manner approved by the PMC. Water for washing aggregate shall be free from objectionable quantities of suspended material, organic matter, alkali, salts and other impurities. After washing, fine aggregate shall be stored in stockpiles with a free draining base for at least seventy two (72) hours and shall be subsequently handled so that the fine aggregate delivered to the batching plant has a uniform and a stable moisture content. Where the surface of stockpiles from which fine aggregate is being delivered directly to the batching plant is substantially drier or wetter than the bulk of fine aggregate in the pile, handling shall be such as to exclude this surface material from the batching plant.

The Contractor shall care in loading and handling material from stockpiles so segregation and breakage will be minimized and so that the aggregates will not become contaminated with soil or other foreign material.

The Contractor shall conduct his loading operations to ensure that the stockpiles will be maintained in a safe condition and so that wastage of materials will be kept to a minimum.

The aggregate shall have a limited number of flaky or elongated particles such that the sum of the Flakiness and Elongation Indices of each size of coarse aggregate shall be less than 25% when tested in accordance with BS812 Part: 105.

The Contractor shall sample and test both the fine and coarse aggregate in accordance with ASTM (or BS) Standard. All test samples shall be taken in sufficient time to permit adequate testing and examination of results before used in RCC.

24.2.7.3 Aggregate Stockpiles

The Contractor shall submit to the PMC for review and approval the proposed stockplie arrangements.

Sampling and testing of both fine and coarse aggregate shall be performed by the Contractor under the supervision of the PMC and in accordance with this Specification and the ASTM Standard where applicable or as directed by the PMC. All test samples shall be taken in sufficient time, in the presence of the representative of the PMC, to

permit adequate testing, as directed by the PMC, and examination of results before used in RCC.

24.3 EXECUTION

24.3.1 Batching and Mixing

24.3.1.1 General

The Contractor shall notify the PMC before batching concrete. Unless inspection is waived in each case, batching shall be performed only in the presence of the PMC. Neither bagged Portland cement nor bagged natural pozzolan shall be used for RCC batching.

RCC shall be produced by the concrete plant sufficient to meet the placement program to be proposed by the Contractor. .

24.3.1.2 Batching Equipment

The concrete plant for the RCC shall be dedicated to that purpose only. The plant shall be stationary and shall generally conform to the requirements of ASTM C94.

The Contractor shall provide equipment and shall maintain and operate the equipment as required to accurately determine and control the prescribed amounts of the various materials entering the concrete mixers. The amounts of cement, natural pozzolan and each size of aggregate entering each batch of concrete shall be determined by individual weighing. The fine and coarse aggregate may be weighed with separate scales and hoppers or cumulatively with one scale and hopper. If the batch plant is equipped with automatic interlocking sequential batching controls, the cement and natural pozzolan may be weighed separately with individual scales and hoppers. Water and admixtures shall be measured by weight or by volume.

The batch plants shall be computerized and shall be equipped with printers which list the quantities of individual materials measured for each batch and a summary of materials batched at the end of each shift or day in English. The Contractor shall provide the PMC with a continuous record of these measured batch quantities in electronic files. The computer shall have the capability ofstoring each concrete mix to be used and of adjusting each mix for moisture control without interfering with the batching operation. It shall be capable of storing a minimum of twenty (20) mixes.

All weighing equipment shall be accurate to 0.40% over the working range. The Contractor shall programme and perform monthly tests to ensure that the operating performance of each scale and measuring device is within the 0.40% accuracy and shall provide standard test weights and any other equipment necessary to conduct these tests. The tests shall be made in the presence of the PMC and shall be subject to his approval. In addition to monthly tests, the Contractor shall perform additional tests when requested

by the PMC. The Contractor shall make such adjustments, repairs, or replacements as may be necessary to meet the specified requirements for accuracy of measurement.

Each weighing unit shall be spring-less and shall visibly register the actual weights during the weighing operation and not just indicate when a prescribed weight has been obtained. The digital readouts shall have increments no greater than 1.0kg for water and cementitious materials, and no more than 5.0kg for the aggregates for each m³ normally batched. Each batch weight digital readout and volumetric dispenser shall be in full view of the plant operator. Batching controls shall be interlocked so that a new batch cannot be started until the weighing hoppers have been completely emptied of the last batch and the scales register zero weight.

The equipment shall be capable of controlling the delivery of materials so that the combined inaccuracies in feeding and measuring during normal operation will not exceed by individual weight:

- 1% for water;
- 1% for cementitious materials;
- 2% for each nominal size of aggregate; and
- 3% for admixtures.

The weighing hoppers shall be constructed so as to permit the convenient removal of materials batched in excess of the prescribed mix design and the above tolerances.

Measuring devices for admixtures shall have sufficient capacity to measure at one time the full quantity of the properly-diluted solution required for each batch, and shall be maintained in a clean and freely operating condition. If admixtures are measured by a method other than direct weighing, equipment shall be designed for confirmation of the accuracy of each batch quantity by use of visual-mechanical gauges readily visible from the plant operator's station. Admixture batching equipment shall be so constructed that the required batch quantity can only be added once to each batch, and so that each admixture is discharged separately into the batched mixing water as it is being discharged into the mixer.

Equipment for conveying batched materials from weighing hoppers into the mixer shall be constructed, maintained, and operated so as to prevent spillage of the batched materials and overlap of batches.

Equipment for handling cementitious materials in the batching plant shall be constructed and operated so as to prevent noticeable dust during the measuring and discharging of each batch of material.

Aggregate bins shall be so constructed as to be self-cleaning during drawdown.

Coarse aggregate shall be deposited in the aggregate bins directly over the discharge gates. Aggregate larger than 20-mm nominal size shall be deposited in the aggregate

bins through effective rock ladders, unless the Contractor can prove to the PMC's satisfaction that the aggregate will not be subject to breakage and degradation.

Convenient facilities shall be provided for readily and safely obtaining representative samples of cementitious materials, admixtures and each size of aggregate from the discharge stream between batch bins and the weighing hoppers or between the batch hopper and the mixer.

The water-batching device shall be constructed so that the water will be discharged quickly and freely into the mixer without objectionable dribble from the end of the discharge pipe, and shall be such that leakage will not occur when the valves are closed. In addition, equipment shall be capable of adjusting batch water by as little as 2.0kg/m³ and there shall be a means for accurately introducing small increments of water into each mixer after batching for occasional final adjustments of the workability of the concrete.

The equipment shall be capable of adjustment to compensate for the varying moisture contents of the aggregates and to adjust the mixture proportions as needed.

The Contractor shall inform the PMC prior to and after changes and adjustments in batching equipment and control instrumentation.

24.3.1.3 Mixing Equipment

24.3.1.3.1 General

The concrete ingredients shall be thoroughly mixed in forced-action mixers designed to ensure uniform distribution of all the component materials throughout the concrete at the end of the mixing period.

The concrete, as discharged from the mixer, shall be uniform in composition and consistency from batch to batch. Mixers shall be examined regularly by the PMC for changes in condition due to accumulation of hardened concrete or mortar or to wear of blades. The adequacy of the mixing shall be determined by the PMC in accordance with the concrete uniformity requirements of ASTM C94. Samples of concrete for such tests shall be taken from any size batch which is commonly mixed during concrete production. For testing purposes, the Contractor shall mix, in the mixers to be tested, the size of batch directed by the PMC, and shall assist in the collection of the required samples from that batch.

Any mixer that at any time produces unsatisfactory results shall not be used until repaired. If repair attempts are unsuccessful, a defective mixer shall be replaced.

Batch sizes shall be at least 25% of, but not in excess of, the rated capacity of the mixer.

24.3.1.3.2 Central Plant

The concrete plant for RCC shall be a plant for which it can be demonstrated through use on other similar projects with similar mixes and with similar production rates to be

suitable for production of RCC as described in these Specifications. The plant shall be stationary and generally conform to the requirements of ASTM C94.

Water shall be admitted prior to and during charging of the mixer with all other concrete ingredients. After all materials are in the mixer, each batch shall be mixed for not less than the time recommended by the manufacturer. Minimum mixing times are to be approved by the PMC and shall be adjusted as required following results of the concrete uniformity tests. Excessive over-mixing which requires additions of water to maintain the required concrete consistency shall not be permitted.

The mixing equipment shall conform to the following additional requirements:

- The plant configuration shall be such that the mixing action of each mixer can be observed from a safe location that can be easily reached from the control station. Provisions shall also be made so that the plant operator can observe the concrete in the receiving hopper as it is being dumped from the mixers;
- Each mixer shall be controlled with a timing device which shall indicate the mixing period and ensure completion of the required mixing period; and
- The batch plant shall be equipped with an interlocking mechanism which shall prevent concrete batches from entering mixers that are not empty.

24.3.1.3.3 Truck Mixers

Truck mixers shall not be used to mix nor transport RCC. Truck mixers, if used for any other purpose, shall conform to the requirements of the PMC.

24.3.2 Transportation

All RCC shall be transported to the dam surface by an effective and efficient transportation system. The Contractor shall demonstrate the transportation system with such a manner that it is capable of transporting the required amount of RCC to the dam surface per month as scheduled. A surge hopper with a capacity of not less than 24m³ may be located at the beginning of the transportation system close to the concrete plant.

The Contractor is free to use the transportation method he deems most suitable, provided the following requirements are met:

- No vehicles shall be allowed to travel on the surface of the RCC placement unless they are free of deleterious substances, which may contaminate the lift surface. This may require:
  - The undercarriage and tires or tracks of the vehicles to be cleaned of all such substances,
  - The addition of trays below each vehicle to catch oil, grease and other deleterious materials;

- The transportation of RCC to the dam shall be separate from that on the dam; no vehicles transporting RCC shall travel from off the dam on to the working surface of the dam. Maintenance or servicing of equipment will not be permitted on RCC;
- All tired vehicles travelling on the RCC surface shall have tread-less tires in order to minimize damage to the surface of RCC and all transportation equipment shall be designed so that segregation of the coarse aggregate from the mortar is minimized. The transportation shall be as rapid as practicable by methods which will ensure that at the point of deposition it is of the correct quality and consistency and deposited close to the final compaction location;
- During loading, trucks and dumpers shall be moved forwards, or backwards, to prevent a single heap of material building up in the body which might initiate segregation of RCC;
- All vehicles used to transport RCC on the dam surface shall be operated in such a way as to avoid sharp turns or abrupt stops. As far as is possible, trucks shall travel in a straight line from the point of discharge of the conveyor to the point of placement and in a straight line back to the point of discharge.

24.3.3 Concrete Temperature at Point of Placement of RCC

The temperature of all classes of RCC shall not be more than 22°C although it may be adjusted through the results of the trial mix program. After placing and prior to compaction, the temperature shall be confirmed by using thermometers in the RCC at the placement site. The temperature of the RCC at the mixing plant shall be adjusted to ensure that the specified RCC temperature is attained at the point of placement.

When the RCC is placed in air low temperatures, the temperature of the RCC at the point of placement shall be more than 5°C and the insitu temperature of the RCC shall be maintained at not less than 5°C. This may require the whole of the horizontal surface of RCC (and some of the upstream and downstream faces) being covered in insulation. The Contractor shall submit his proposals for maintaining the temperature of the RCC within the specified limits for approval of the PMC.

When RCC is placed under such the weather that the placing temperature of RCC would exceed the maximum placing temperature specified, the Contractor shall employ effective means such as:

- Pre-cooling the aggregates by cool air-blast, immersion in cold water, vacuum processing or other suitable means;
- Refrigerating the mixing water;
- Adding flake ice to the mixing water, provided that the flake ice has melted prior to completion of the mixing of RCC;
- Cooling the cement and natural pozzolan.

or a combination of these or other approved methods, as necessary to maintain the maximum placing temperature of RCC below the final maximum placing temperature specified. The Contractor shall be entitled to no additional compensation due to the foregoing requirements.

24.3.4 Forming Faces of RCC Structures

24.3.4.1 Methodology

The upstream and downstream faces of the RCC dam shall be formed of Grout-enriched Vibratable RCC (GEVR) against formwork.

Suitable temporary barriers should be erected and maintained by the Contractor along the upstream and downstream faces at all times at the level of the placement area for the safety of workmen and other personnel on the structures under construction.

24.3.4.2 Formwork

The formwork for the faces shall conform to Chapter 0410 "Formworks and Surface Finishes"; shall be designed and constructed by the Contractor; shall have sufficient strength to withstand the pressure resulting from placement, compaction and vibration of RCC and GEVR; and shall be maintained rigidly in position. The formwork shall be sufficiently tight to prevent loss of mortar from the concrete. The formwork joints shall be covered on the internal surface with an approved tape to prevent the loss of mortar through the joints.

The PMC shall be informed before the Contractor strips any formwork. The Contractor shall remain fully responsible for the safety of the structure from which he removes the formwork.

Embedded ties for holding formwork shall remain embedded not less than two diameters or twice the minimum dimension of the tie or 10mm, whichever is the greater, in from the formed face of the concrete. The ties shall be constructed so that the ends, or end fasteners, can be removed without causing appreciable spoiling at the faces of the concrete. Recesses resulting from removal of form ties shall be repaired as instructed by the PMC.

Patching of tie holes shall be accomplished by:

- Removal of any form tie accessories from the embedded tie;
- Cleaning of the recess to be patched with a steel wire brush;
- Coating the surface with a suitable bonding agent;
- "Dry packing" the hole with a suitable mixture of sand/cement/water;
- Curing the patch with a membrane curing compound.

24.3.4.3 GEVR against Formwork

Grout-Enriched Vibratable RCC (GEVR) shall be placed against the formwork on the upstream and downstream faces of the integrated RCC cofferdam and the main RCC dam.

The procedures for forming the upstream and downstream faces of the RCC dam with GEVR shall be as described herein under, except that the placement shall be against formwork rather than a steep face. The cement grout around the waterstop shall have a water/cement ratio in the range 0.50 to 0.60, by weight, or as directed by the PMC.

Transverse joints shall be formed in the GEVR by casting joint-inducer plates into the concrete. The plates shall be 300mm high and penetrate the full GEVR layer height. On the upstream face where there are waterstops and drain holes, care shall be taken to ensure the joint-inducer plates are firmly in contact with the waterstop and the formed drain hole and that they are positioned on the centre of the waterstop and drain hole with an accuracy ±3 mm. To achieve this, the edges of the plates adjoining the edges of the waterstop and the 50-mm timber quadrant nailed to the upstream form, or similar, shall be splayed to form a Y and the edge adjoining the drain former shall end in a 60° circular arc of similar radius to the drain-former. The Contractor shall manufacture suitably robust framework to hold the waterstop, the drain hole former and the joint-inducer plates firmly in their vertical position during encasement in the GEVR surround. Where the plate is not aligned vertically or within the specified tolerance (see Sub-Clause 3.4.5), with the waterstop, the inducer shall be repositioned or the GEVR and the waterstop shall be removed, the area fully cleaned and replaced to the approval of the PMC.

24.3.4.4 Waterstops

- General

  The Contractor shall furnish the waterstops and all materials and equipment for splicing waterstops, for fastening waterstops to the forms, for any supporting structure and for completing the installation of the waterstops. The Contractor shall also furnish all materials for splices and all field-splicing moulds, and electrical energy for heating the moulds. The Contractor shall provide suitable support and protection for the waterstops during the progress of the work and shall repair or replace, at his expense, any damaged waterstop, which, in the

  opinion of the PMC, has been damaged to such an extent as to affect the serviceability of the waterstops. All waterstops shall be protected from oil, grease, and curing compound.

- Material

  The waterstops shall be extruded from an elastomeric plastic compound, the basic resin of which shall be polyvinylchloride (PVC). The compound shall contain any

additional resins, plasticizers, stabilizers, or other materials needed to ensure that, when the material is compounded, it is durable and resistant to any decomposition.

PVC waterstops shall be dense, homogeneous, and free from holes, scratches and other imperfections and shall meet the following requirements:

Requirements	**Method of Test**
Tensile strength using die "C" not less than 150kg/cm²	ASTM D 412
Ultimate elongation using die "C": not less than 330%	ASTM D 412
Stiffness in flexure, 6 mm span not less than 28kg/cm²	ASTM D 747
Tear resistance: not less than 30kg/cm²	ASTM D 624
Specific gravity: 1.3 ± 0.15 at 23°C	ASTM D 792
Shore durometer "A" hardness: between 65 and 75	ASTM D 676

Unless otherwise shown in the Drawings, PVC waterstops to be used for the sealing of the transverse joints at the upstream and downstream faces shall be in accordance with the following type:

Type	**Requirements**	
Type 400	Width	: 400mm minimum
	Thickness	: 6 mm minimum
	Shape	: Central expansion bulb or omega as required by the PMC

- Tests

The manufacturer shall furnish material for tests and all tests shall be made at the place of the manufacturer. The PMC may request the Contractor to carry out additional tests. The Contractor, at his own expense, shall supply specimens from the same materials to be used on the Works for tests at an independent laboratory.

Initial Test

For initial testing, the Contractor shall supply the PMC the manufacturer's affidavit showing that the material to be supplied meets the specified requirements.

The Contractor shall provide sufficient samples for testing the material in official laboratories approved by the PMC. The results of such tests shall be delivered to the PMC before placing the supply order of the waterstops for Permanent Works.

Tests during the progress of the Works

During work progress, test specimens used for tests shall be of the shape and dimensions required in the individual test method.

For each lot that is transported to the Site, the Contractor shall supply the PMC with the manufacturer's affidavit showing that the material supplied meets the requirements specified.

If required by the PMC, the Contractor shall provide sufficient samples and shall perform tests on the material in official approved laboratories. The results of such

tests shall be delivered to the PMC before installing the material in Permanent Works.

- Installation

  The waterstop connection with the foundation shall consist of a hole excavated into sound rock of minimum 500mm sides and depth into which the waterstop shall continue and around which a pourable-grade epoxy grout (with a 2:1 ratio of quartzite aggregate to epoxy by weight) shall be placed to completely seal the waterstop to the rock. At least fifty six (56) days prior to the first installation of waterstops, the Contractor shall provide to the PMC his proposals for forming and installing the waterstops and details and the name of his proposed supplier for the grout. The excavation centre line shall be within ±20mm of specified line of joint.

  The waterstops shall be installed and carefully positioned so as to form a continuous watertight diaphragm at all points. Arrangements shall be made to support and fully protect waterstops in their correct position during the execution of the Works, and special attention shall be given to protecting them when formwork is removed.

  The Contractor shall repair or replace at his own expense any torn, punctured or otherwise damaged waterstops before the final acceptance of the Works.

  Sufficient protection shall be provided to prevent mechanical damage to the exposed and projecting edges and ends of partially-embedded waterstops when concreting has stopped. Waterstops shall then be wound onto a drum so as not to lie on the ground.

  All connections shall be made correctly, with both parts of the joints correctly aligned.

24.3.4.5 Tolerances for the Faces

Tolerances are defined as allowable variations from specified lines and levels and are listed for the faces of the dam and of the upstream and downstream longitudinal walls here below. The PMC reserves the right to reduce the tolerances if such tolerances impair the structural action or operation function of the structures.

Variations from Specified Line and Level of the Faces

- Variations from the theoretical surfaces specified in plan for GEVR on the upstream face of the integrated cofferdam and the main dam:
  - Within a 10 m length of the upstream face: ±15mm (horizontally)
  - For overall length of the upstream face: +60/-20mm (horizontally)
- Variations from the theoretical surfaces specified in plan for GEVR on the stepped upstream and downstream faces of the upstream cofferdam and the main dam:
  - Within a 10-m length of downstream face:

Top surface: ±20mm (vertically)

Outside surface: ±15mm (horizontally)

- For overall length of the downstream face:

Top surface: ±30mm (vertically)

Outside surface: +60/-20mm (horizontally)

The Contractor shall be responsible for finishing RCC to ensure that the completed work shall be within the tolerances specified. Hardened GEVR shall be checked by the Contractor and shall be subject to such inspection and measurement as needed to determine that the lines and levels are within the specified tolerances.

Hardened GEVR that is not within specified tolerances shall be repaired to bring it within those tolerances at the Contractor's expenses. Such repair shall be accomplished in a manner approved by the PMC.

24.3.5 Preparation for RCC Placing

24.3.5.1 General requirements

The RCC Works shall be constructed to the specified lines, levels and dimensions. The sequence of construction shall be subject to the approval of the PMC. The dimensions of the Works as shown in the Drawings will be subject to such modifications as may be found necessary by the PMC to adapt the structure to the conditions disclosed by the excavation or to meet other conditions.

RCC shall be placed on a twenty (20) to twenty four (24) hour a day, seven (7) days a week basis.

Joints shall be constructed as shown in the Drawings. The relocation, addition, or elimination of any construction or contraction joint shall be subject to the written approval of the PMC.

No concrete shall be placed until all parts to be embedded, the preparation of surfaces and the methods and equipment for handling, placing and finishing the concrete are ready and have been approved by the PMC.

No concrete shall be placed in running water nor be subject to the action of running water until the concrete has hardened. All surfaces and embedded materials that have become encrusted with dried mortar or grout from concrete previously placed shall be cleaned of all such mortar or grout before the surrounding or adjacent RCC is placed.

No blasting will be performed within 50m of any placement younger than seven (7) days. For placements older than seven (7) days, blasting may be closer if the peak particle velocity (PPV) is less than 10mm/s.

24.3.5.2 Trial Placement of RCC

At least one hundred twenty (90) days prior to placing RCC in the dam the Contractor shall place RCC at a location approved by the PMC to demonstrate the batching and

mixing capability, to select the most suitable construction methods and to approve the type of equipment for transporting, placing and compacting RCC.

The Contractor shall place the RCC in 300mm thick layers, 10m wide and 40m long to the satisfaction of the PMC. The trial placement will be a minimum of sixteen (12) layers high, nevertheless the Contractor shall continue until RCC is satisfactorily placed in accordance with these Technical Specifications for three consecutive layers. The first RCC layer shall be placed on rock, or a minimum thickness of 500mm of RCC. All aspects of the placement shall be tried, including placing the upstream and downstream faces, joint preparation between layers, contraction joint construction and curing of the concretes.

The PMC will require one hundred (60) days after placement to evaluate the test results before the trial placement is accepted. The Contractor shall assist in this evaluation as directed by the PMC. The evaluation procedure will include the coring of the trial placement to ascertain the density and strength of the concrete, the permeability and the performance of the joints etc. In addition, the trial placement can be used as a datum for the nuclear densometers that shall be used to measure the fresh density of RCC in the dam (see Sub-Clause 3.7 "Compaction" herein below).

Only equipment and operators used and approved during the trial placement shall be used during the initial placement of RCC in the dam. The Contractor may build additional trial placements for the purpose of approving additional equipment and operators.

24.3.5.3 Preparing Foundation

Upon conclusion of the excavations in any given section of the foundations and before any further foundation preparation works are carried out, the Contractor shall perform the consolidation grouting shown in the drawings or required by the PMC, as specified in Chapter 0240 "Drilling and Grouting", unless the PMC requires that such consolidation grouting be carried out after placement of the first layers of RCC.

Smoothing of unevenness and filling of minor cracks may be undertaken by use of cement grout and/or sealed with cement mortar specified in Chapter 0430 "Conventional concrete (CVC)". The quantity of water shall be as necessary to obtain a satisfactory workability for the specific use.

Cement grout shall be placed in local areas where there are concentrations of fissures with a manner specified in Chapter 240 "Drilling and Grouting". Such grout shall be covered with either dental or leveling concrete or RCC immediately after placement.

Immediately before placing Dental concrete, leveling concrete, GEVR or RCC, all surfaces of the foundation upon, or against which the concrete is to be placed shall be free from standing water, mud, debris, oil, objectionable coatings and loose, semi-detached or unsound fragments to the approval of the PMC.

Refer to Sub-Clause 3.5.7 "Compaction of RCC against Abrupt Surfaces" herein below for specific preparation works for steep foundation surfaces.

24.3.5.4 Dental Concrete

The Contractor shall place dental concrete in exposed areas of broken, fractured, or sheared portions of the foundation surface and at other locations as directed by the PMC. Dental concrete shall be used in areas too small to be satisfactorily filled with foundation leveling concrete as determined by the PMC.

Dental concrete shall be lean concrete conforming to the applicable provisions of Sub-Clause 4.2 "Dental concrete" of Clause for "Conventional Concrete (CVC)", and shall have the same properties to that of RCC.

Placement of the Dental concrete may require the use of formwork. Formwork shall be used at locations specified by the PMC.

Designated voids shall be properly excavated and cleaned of all loose materials as approved by the PMC. Open joints, shear zones, and fractured areas shall be cleaned to a depth of at least two (2) times their width. Dental concrete shall be placed as required to form a tight, un-fractured foundation surface against which the dam or concrete structure may be placed.

24.3.5.5 Leveling Concrete

Relatively large area of leveling concrete shall be placed prior to the start of the placement of RCC in any section of the Works. The mixture proportions of the leveling concrete shall be the same as RCC specified in Sub-Clause 2.2 above.

The foundation leveling concrete will be designed by the Contractor to have similar hardened properties to those of the RCC. The gradation of the aggregates will be the same as the RCC (see Sub-Clause 2.7.1). The slump at the point of placement shall be 40±20mm.

The maximum temperature of the leveling concrete at the point of placement shall be the same specified for RCC itself.

Requirements for mixing, transportation, placement and vibration of the leveling concrete are those specified in the pertinent Chapter 0430 "Conventional Concrete (CVC)".

24.3.5.6 Preparing Previously Placed Leveling Concrete and Concrete Surfaces

In the initial stage of setting, but before the final setting of the concrete, the surface of the joint may be washed with water and compressed air jets. The washing shall have the purpose of eliminating the mortar from the surface, removing semi-detached parts, and laying bare the large aggregates, without however removing them.

Hard concrete surfaces, upon or against which RCC is to be placed, shall be cleaned by wet sandblasting to remove all laitance, loose or defective concrete coatings, sand, curing compound if used, and other foreign material to the approval of the PMC. High-pressure water blasting (pressure about 40MPa) may be used in lieu of wet sand-blasting for preparing the surface, if it is demonstrated to the satisfaction of the PMC that the equipment proposed for use will produce results equivalent to those obtainable by wet sand-blasting.

In the process of surface preparation by wet sandblasting or water blasting, care shall be taken to prevent undercutting of the aggregate in the concrete. High-pressure water-blasting equipment, if used, shall be equipped with a suitable pressure regulator and a shut-off switch at the nozzle that will automatically shut of pressure if the nozzle is dropped. After preparation of the joint, it shall be washed clean. Drying of the surface may be accomplished by forced-air jet and/or vacuuming and shall be performed at the last opportunity prior to placing of RCC. The surfaces of construction joints shall be clean and damp when covered with concrete.

24.3.5.7 Compaction of RCC against Abrupt Surfaces

The Contractor shall use Grout Enriched Vibratable RCC (GEVR), when RCC is to be placed and compacted against a sloped rock surface steeper that 0.5H:1.0V, and where typically no leveling concrete has been used. If the rock surface against which RCC is to be placed is flatter than 0.5H:1.0V, the normal foundation preparation specified in Sub-Clause 3.5.3 "Preparing foundation", herein above shall be carried out.

GEVR is a method of modifying the workability of RCC such that it can be consolidated with immersion vibrators. The procedure shall be as follows:

- Prior to the spreading of RCC against the abrupt surface, a small bund of uncompacted RCC shall be spread 500mm from the abrupt surface and parallel to that surface;
- Just prior to the spreading of the new RCC layer against the steep face, grout shall be spread between the abrupt surface and the RCC bunds and also on the face of the abrupt face itself, if the latter is sloping;
- RCC shall be spread perpendicular to the abutment in an even layer against the steep face;
- GEVR shall be consolidated with immersion vibrators until the concrete has completely settled and no air bubbles are present. At this moment, the grout must show on the surface of the concrete;
- RCC shall be compacted with as large a vibratory roller as possible (see, Sub-Clause 3.7.3);
- The junction between GEVR and RCC shall be compacted with the small vibratory roller (see, Sub-Clause 3.7.4); and

- If required to obtain a smooth finish of the consolidated GEVR, the final consolidation of GEVR shall be undertaken with a plate compactor (see, Sub-Clause 3.7.5).

The grout used for this purpose shall consist of a mixture of water and cement in an approximate proportion of 0.50:1 to 0.60:1 by weight. The exact mixture proportions will be determined during the trial placement. The estimated quantity of grout that will be used will be used will be between eight (8) and fifteen (15) liters per linear meter of face, depending upon the slope of the face.

The grout shall be mixed on the Site in external grout mixers and the grout shall be pumped through a network of pipes laid at the faces of the dam. Alternatively the grout mixers could be mounted on mobile platforms driving onto RCC. Trafficking shall be kept to a minimum in the area where the grout has been spread before it has been covered.

GEVR shall be compacted within thirty (30) minutes after the spreading of the grout unless a suitable retarder is added to the grout.

On sloping rock surfaces or other surfaces against which GEVR is placed, any feather edge of GEVR that appears above the consolidated concrete shall be removed. The adjacent rock or sloping surface above the finished GEVR shall be thoroughly cleaned before the placing of the next layer.

If, in the opinion of the PMC, the Contractor allows GEVR to become too stiff before it can be properly consolidated by immersion vibrators or in any way uses procedures which prevents GEVR achieving an intimate bond to the adjoining RCC, GEVR shall be removed, the surface against which it has been placed shall be cleaned to an appropriate standard and GEVR replaced.

24.3.6 Placing

24.3.6.1 General

The Contractor shall provide all equipment required for the placing, compacting, finishing and all other associated works for the completion of RCC.

The Contractor shall notify the PMC before batching begins for placement of RCC. Unless inspection is waived for that specific placement, placing shall be performed only in the presence of the PMC. Placement shall not begin until after all preparations are complete and the PMC has approved completion of all preparations for that placement.

The entire RCC mass shall be placed in sufficient continuity so that it hardens and acts as one monolithic block without discontinuous horizontal joints or potential planes of separation. All joint surfaces of the RCC parts shall be kept clean, uncontaminated, free from earth particles or pounded water and continuously moist until placement of the succeeding RCC or other concrete.

24.3.6.2 Preparation for Placement

Prior to beginning the RCC placement, the Contractor shall have a sufficient number of properly operating trucks, dozers, vibratory rollers and other equipment together with approved operators ready for operation to achieve not only average capacity but also a peak placement capacity. Moreover, the Contractor shall have available, at all times, one additional item of each plant that shall be used during the placement to replace any equipment should they become defective during the progress of the placement. The PMC at the placement location may require the Contractor to delay the start of the RCC placement or to adjust the placement rate until the required numbers of properly operating equipment is available.

24.3.6.3 Joint Preparation

No RCC shall be placed until previously placed RCC has been thoroughly compacted and the surfaces to receive fresh RCC have been approved. Before RCC is placed, surfaces shall be free from any deleterious substances. Deleterious substances include un-compacted, loose, deteriorated, or improperly cured RCC material, laitance or any material other than RCC including but not limited to dirt, petroleum products, curing compound, free surface water from any source, remaining concrete materials from removed RCC or concrete lifts, or sandblast sand.

Before concrete spreading, the surfaces of the underlying RCC layer shall be treated as specified herein below for each type of joint. When necessary, all required joint treatments mentioned below shall be made by the Contractor.

No RCC shall be placed until the previously-placed RCC has been thoroughly compacted and the surfaces of the underlying layer have been treated as specified. The tentative 'exposure times' (i.e. the time gap between the layers) defining the different types of joints will be available when the trial tests currently under execution by the PMC are completed. The definitive figures shall be confirmed after testing of the trial placement Sub-Clause. All joint preparations shall be carried out in a manner that will not cause deterioration to the RCC surface.

24.3.6.3.1 Hot Joints

Joint surfaces for which the total exposure time is less than the initial setting time for a particular work month will be classified as "hot" joints and shall be prepared as follows:

The surface of all hot joints shall be thoroughly cleaned prior to the placement of the next layer to remove all loose materials, pools of water or other foreign matter to the approval of the PMC. The method to be used shall be to the approval of the PMC and may include blowing off carefully with compressed air, compressed air /water and/or the use of a vacuum truck. Cleaning shall be carried out in a manner that will not cause deterioration to the RCC surface. The vacuum truck shall have a vacuum capable of pumping greater than $2m^3/s$ of air and greater than 150L/s of water through a 200mm diameter opening.

The vacuum truck should be maintained in good operating condition and shall not drip oil, grease or other deleterious materials onto the RCC. The gutter brushes shall be removed from the vacuum truck.

No bedding mortar or grout is required.

24.3.6.3.2 Warm Joints

Lift surfaces requiring cleaning that have been exposed more than a hot joint but less than the maturity defining a cold joint will be classified as a "warm" joint and shall be prepared as follows:

The surfaces of all warm joints shall be scarified with a roller brush having bristle (or polypropylene) or bristle and steel or steel tines to produce a rough surface. The different types of tines will be used for different exposure times (i.e. the time between the placement of the successive layers of RCC) and the precise time ranges will be defined during the trial placement.

After treatment, the joints shall be cleaned as for a hot joint. Cleaning operations shall be performed at the last opportunity prior to placing of RCC on the layer surfaces.

No bedding mortar or grout is required.

24.3.6.3.3 Cold Joints

All joint surfaces formed when the RCC layer has set and being placed by the next RCC layer will be classified as "cold" joints and shall be prepared as follows:

In the initial stage of setting, but before the final setting of the concrete, the surface of the joint shall be washed with water and compressed air jets. The washing shall have the purpose of eliminating the mortar from the surface, removing semidetached parts, and laying bare the large aggregates, without however removing them.

The surfaces of all cold joints shall be prepared using high-pressure water blasting (maximum water pressure of not less than 40MPa). In the process of joint preparation care shall be taken to prevent undercutting of the aggregate in the RCC. The high-pressure water-blasting equipment shall be equipped with a suitable pressure regulator and a shut-off switch at the nozzle that will automatically shut off pressure if the nozzle is dropped. Care should be taken to prevent removal of the aggregate particles from the surface of joint.

After treatment, the joints shall be cleaned as for a hot joint. Cleaning operations shall be performed at the last opportunity prior to placing of RCC on the layer surfaces.

24.3.6.3.4 Super-cold joints

The surfaces of all super-cold joints shall be prepared using high-pressure water blasting in accordance with Sub-Clause 3.6.3. After treatment to produce an approved joint, grout

shall be applied. The grout shall have a target water/cement ratio of 0.55, by weight, and an optimum range between 0.50 and 0.60.

The grout shall be applied in a uniform operation with a thickness between 5mm and 10mm bedding grout immediately before placement of the new RCC layer. The vacuuming and grouting operations shall be performed at the last opportunity prior to placing grout on the layer surfaces. The grout shall not be spread more than 10m in front of the leading edge of the lane being placed. The RCC shall be spread over the grout and compacted within seventy five (75) minutes of the time the grout was mixed, prior to the time that it begins to set or dry from exposure, and within thirty (30) minutes of when the grout was first deposited on the joint.

24.3.6.3.5 Damaged Joints

All joint surfaces that have been, as determined by the PMC, damaged such that more extensive clean-up is required, shall be classified as a "damaged" joint and shall be prepared in the same fashion as a "cold" joint.

24.3.6.3.6 Contaminated Joints

If material deleterious to the bonding of layers is spilled on joint surfaces (including but not limited to oil, motor fuel, curing compound and paint), the contaminated RCC shall be removed down to the next layer and replaced with fresh RCC at the Contractor's expense. The replacement RCC shall be thoroughly compacted prior to the placement of the next RCC layer.

24.3.6.4 Placing, Depositing and Spreading

The integrated RCC cofferdam and the main RCC dam shall be raised at essentially the same level across the entire area of the section under construction. A layer shall consist of adjacent longitudinally-deposited widths. The leading edge of a deposited width shall be no more than 50m ahead of the leading edge of the adjacent deposited width. In the dam, widths shall not be placed in an upstream/ downstream direction.

Depositing and spreading of RCC shall be by methods which prevent segregation, contamination or drying of RCC and prevent contamination or deterioration of the previously-placed RCC.

Except at the start of a new layer, RCC shall always be dumped on top of freshly-spread RCC, not on the previously-roller-compacted layer surface. It shall then be spread by bulldozer over the previous layer.

End dumping in piles shall not be permitted. The thickness of the loose RCC as it is deposited on the RCC shall not exceed 750mm. RCC shall be spread into an even layer that will, after compaction, be 300±20mm thick.

The transporting, depositing and spreading of RCC shall be completed within seventy five (75) minutes after the mix water combines with the cementitious materials. This time shall be confirmed after testing in the trial placement.

Spreading shall not be permitted with rubber tire equipment. During and after depositing and before compaction is completed, care should be taken not to drive on the un-compacted RCC with equipment other than that required for spreading and compacting the particular area of RCC.

Lift lines shall be marked out with thin intermittent paint lines on the prepared rock foundation and formwork and the layer thickness shall be controlled using a laser system that automatically adjusts the blade of the spreading bulldozer. The bulldozer shall be fitted with low-pressure road tracks or, alternatively, the grousers on the low-pressure tracks should be cut down to the lowest possible profile in order to minimize damage to the RCC layer surface. The operator shall be capable of skewing and tilting the blade of the bulldozer.

All equipment shall be maintained in good operating condition so that it does not leak nor drip oil, grease, nor other visible contamination on to RCC.

The Contractor shall continuously observe and monitor the dumping and spreading operations to ensure that they are done in a manner that minimizes segregation and the amount of spreading after dumping. Each layer of RCC shall be routinely checked in its spread un-compacted condition for evenness and correct thickness that will result in a smooth, even, compacted layer within the thickness tolerance specified and having an average thickness as required. The depth of each layer shall be measured at two (2) locations for every 500m² placed using the same criteria as the density determinations (see Sub-Clause 3.7.6 "Density control", herein below).

RCC shall not be placed when rollers cause depressions greater than 50mm in the compacted RCC. Causes of this include improper mixture proportions and excessive water due to curing or heavy rain.

Light rain is defined as that with intensity less than 2.5mm per hour. If rain occurs that is heavier than light rain, placing operations shall be suspended; however, RCC that has been deposited and spread can be compacted before operations are suspended, provided grout is not worked up to the surface. After the rain has stopped, all un-compacted RCC shall be removed and if grout had been worked up to the surface by compaction, all RCC with surface grout shall also be removed. The surface of the previous layer shall then be prepared as specified in Sub-Clause 3.6.3.

24.3.7 Compaction of RCC

24.3.7.1 General

Each layer of RCC shall be compacted to a density as defined in Sub-Clause 3.7.6 "Density control", herein below within thirty (30) minutes after spreading. The vibratory

rollers shall conform to Sub-Clause 3.7.3 "Self-propelled vibratory rollers", herein below for the large self-propelled vibratory rollers and to Sub-Clause 3.7.4 "Small vibratory rollers", herein below for the small vibratory rollers. The small vibratory rollers shall provide the equivalent compaction to that of the large vibratory rollers.

One pass of the roller is defined as the required number of roller trips which, by means of sufficient overlap, will ensure complete coverage by the roller of the entire surface to be compacted. Unless otherwise directed by the PMC, the first pass of the vibratory roller shall be in the static mode; second and subsequent passes of the roller shall not be made until each previous pass has been completed. When any compaction operations are interrupted prior to completion of compaction so that RCC is left un-worked for more than thirty (30) minutes for any reason, or when RCC is drenched by rain or dried, the entire area of the layer affected shall be removed and shall be replaced in accordance with these Technical Specifications at the expense of the Contractor. RCC shall be compacted uniformly throughout the entire layer. The surface of the compacted RCC shall be dense and sealed with exposed aggregate held firmly in place by paste. The compacted surface shall be free of major undulations, tracks or roller marks greater than 50mm in depth.

In the dam, compaction shall not be done in an upstream-downstream direction except along the abutments or when specifically approved by the PMC.

The largest equipment specified below capable of physical and practical operation in the area to be compacted shall be used. In general, large-width, self-propelled steel-drum vibratory rollers shall be used in the open areas; small vibratory rollers shall be used in areas inaccessible to the large rollers; and GEVR shall be used in area that cannot be reached by either of the rollers. Plate compactors shall be used to level off and complete the placement at the abutment slopes, along formwork and in and around other confined areas.

24.3.7.2 Pre-qualification of Self-propelled Vibratory Rollers

All vibratory rollers shall be approved by the PMC prior to use on the RCC dam. This approval may be withdrawn at any time if the performance of any roller is not satisfactory. If a roller in good condition is found not to be satisfactory it shall immediately be replaced.

The number of passes required for complete compaction initially shall be determined at the trial placement of RCC. The number of passes required for complete compaction shall be determined through in-place density testing of RCC immediately following each of a succession of roller passes until the required density is achieved in accordance with Sub-Clause 3.7.6; Density control, herein below. In addition, compaction shall be further evaluated by inspection of hardened concrete from the trial placement for voids which may result from incomplete compaction. All vibratory rollers shall be pre-qualified by the PMC to determine the number of passes required for complete compaction. In addition, vibratory rollers shall be checked at regular intervals as determined by the PMC to ensure that complete compaction is being maintained.

All vibratory rollers shall be properly maintained to ensure the maximum compactive effort of each roller is being achieved. All vibratory rollers operating on each layer of RCC shall be of the same make and model number.

24.3.7.3 Self-propelled Vibratory Rollers

The self-propelled dual-drive single-drum vibratory rollers shall transmit a dynamic impact to the surface through a smooth steel drum by means of revolving weights, eccentric shafts, or other equivalent methods. The roller shall have a gross weight of not less than 10,000kg and shall produce a minimum dynamic linear load of 30kg/cm of drum width. The roller shall have variable amplitude and a minimum vibrating frequency of at least 25Hz. The roller drum shall have a minimum diameter of 1.4m.

The engine driving the eccentric mass shall have a rating of not less than 70kW. The roller shall be operated at speeds not exceeding 2km/hr. Within the range of the operational capability of the equipment, the PMC may direct or allow variations to the frequency and speed of operation which result in maximum density at the fastest production rate. At least four (4) operating (and one (1) standby, see Sub-Clause 3.6.2 "Preparation for placement", herein above) self-propelled vibratory rollers in good operating condition and meeting these requirements shall be maintained on the placement area at all times.

Each large, self-propelled vibratory roller shall be equipped with a compaction meter having a digital readout within the plant operator's view. The compaction meter shall not be used as a control for determining how many passes of rolling are necessary for compaction. It shall be used as an indicator to the operator to remind him if he has not provided the required number of passes necessary to obtain the desired compaction. The numerical value indicated by the readout box shall increase as the degree of compaction beneath the roller increases and shall instantaneously show the relative compaction beneath the roller at all times.

The rollers shall not remain stationary on RCC with the vibratory mechanism operating.

24.3.7.4 Small Vibratory Rollers

Small vibratory rollers, which are capable of operating adjacent to a near-vertical face, shall be used to compact RCC at areas where the larger vibratory rollers as specified in Sub-Clause 3.7.3 cannot maneuver. The self-propelled double-drum vibratory rollers shall have a gross weight of not less than 2,000kg and shall produce a minimum static load of 10kg/cm of drum width. The engine driving the eccentric masses shall have a rating of not less than 20kW. At least three (3) operating and one (1) standby small vibratory rollers in good operating condition and meeting these requirements shall be maintained on the placement area at all times.

The number of passes and layer thickness required shall be whatever is necessary for the particular equipment to provide the same degree of compaction as would be attained with the large self-propelled vibratory roller specified in Sub-Clause 3.7.3.

24.3.7.5 Plate Compactors

Reversible vibratory plate compactors shall be used along the abutment slopes, along the upstream and downstream formwork, and other areas where the vibratory rollers specified above cannot maneuver. The plate compactors shall have an operating weight between 60kg and 150kg, a dynamic force between 1,000kg and 3,000kg, and a minimum vibrating frequency of 10 Hz. A sufficient number of fully operable plate compactors shall be on the placement area at all times during the RCC placement. If multiple plate compactors are used, they shall all be the same make, model and size, and they shall all be operated in the same manner.

24.3.7.6 Density Control

A laboratory density shall be defined by the PMC that will be the density of cubes compacted to refusal in the laboratory. This density may vary from time to time as the mixture proportions and materials change throughout the placement.

Control of the compacted RCC shall be such that the density of the compacted RCC shall conform to the following limits:

- Compacted RCC having an in-place wet density less than 97% of the Laboratory density will be rejected. Such rejected material may be re-rolled to within 98% of the Laboratory density if compaction can be achieved within forty five (45) minutes after spreading. If this cannot be achieved, the rejected RCC shall be removed at the Contractor's expense;
- Within the above limit and based on a continuous record of tests on previously-placed and accepted RCC, the uniformity of the in-place wet density shall be such that:
  - No more than five percent of RCC represented by samples tested shall have in-place wet densities less than 98.5% of the Laboratory density,
  - The average in-place wet density of all accepted RCC shall be not less than 99% of the Laboratory density;
  - No more than one test in any ten (10) consecutive tests shall be less than 98.5% of the Laboratory density.

The Contractor shall maintain at least four (2) nuclear-densometer gauges on the Site in good working condition. The PMC shall have access to the gauges at all times. The PMC's staff shall be listed on the certificate of use for the gauges. The Contractor shall provide on-site training for both his staff and that of the PMC. The training classes shall

be conducted prior to the commencement of the trial placement. A factory representative especially trained in the use of nuclear-densometer gauges shall conduct the classes.

Density readings shall be taken at two (2) locations for every 500m² placed. A pattern of grid sections shall be established delineating each 500m² of surface area from which tests are to be made. At each location within each grid section nuclear density determination shall be made at two (2) depths, at 150mm and 300mm. At each depth three (3) readings shall be taken at 120° to each other. The density readings obtained by use of the nuclear-densometer gauges shall be calibrated against cores taken from both the trial placement and from the RCC structures themselves when under construction.

When placement of RCC is near or exceeds the limits of uniformity specified above, the Contractor shall immediately make adjustment to procedures as necessary to maintain the placement density within the specified limits.

24.3.7.7 3.7.7 Moisture Content

During the compaction of RCC, the in-place moisture content shall be maintained so that the Cw (water/ cementitious ratio, by weight) is within 0.02 of its design Cw.

The Contractor shall not supply any additional moisture to RCC after the completion of mixing. The moisture content of RCC prior to and during compaction shall be distributed uniformly throughout each layer of RCC. To check that the moisture content of RCC is acceptable, relative to the design optimum moisture content, field and laboratory tests shall be made at frequent intervals on samples taken at locations determined by the PMC.

The necessary adjustments made by the Contractor to maintain the correct moisture content include, but are not limited to, the following:

- Discontinuance of placing RCC;
- Covering the un-compacted RCC and RCC in hauling vehicles;
- Compacting RCC immediately after spreading; and
- Making necessary adjustments in the stockpiling, handling, batching and mixing operations of RCC.

The Contractor shall be entitled to no additional allowance above the stipulated unit prices by reason of any work required to achieve the correct placement moisture content.

24.3.8 Curing of RCC

24.3.8.1 General

RCC shall be continuously cured, and curing shall begin immediately after compaction. The RCC surfaces shall be treated as specified to prevent loss of moisture from RCC for

sixty (30) days, or until immediately prior to placement of other concrete, other RCC or backfill against those surfaces. Only sufficient time to prepare construction joint surfaces or lift surfaces and to bring them to a moist, clean condition shall be allowed between discontinuance of curing and placement of adjacent RCC or concrete. Improperly-cured RCC shall be considered defective and shall be removed at the Contractor's expense. The PMC reserves the right to delay RCC placements until the Contractor implements proper curing procedures which are approved by the PMC.

The outside surface of the upstream face and the exposed surfaces of the downstream face shall be cured by both water curing and by the use of wax-based or water-emulsified resin-based reflective curing compound on the vertical faces. The curing compound shall be applied by rollers or by spraying, provided that shields are used to protect all surfaces not required to receive curing compound. The curing compound shall be white or silver in color.

All concrete surfaces shall be treated as specified to prevent loss of moisture from the concrete until the required curing period has elapsed or until immediately prior to placement of other concrete or backfill against those surfaces. Only sufficient time to prepare construction joint surfaces and to bring them to a surface dry condition shall be allowed between discontinuances of curing and placement of adjacent concrete.

24.3.8.2 Water and Membrane Curing

- General

  Materials used for curing shall meet the following requirements:

  - Water used for curing shall meet the requirements of Sub-Clause 2.6 herein above for water used in mixing concrete;
  - Wax-based and water-emulsified, resin-based curing compounds shall conform to the requirements of ASTM C309. Curing compounds shall be of uniform consistency and quality within each container and from shipment to shipment.

- Sampling, testing and certification

  The PMC will test or require approved manufacturer's certification of all curing compounds prior to use. However, acceptance will not be made until the material has been satisfactorily applied at the Site.

  The Contractor shall give copies of all purchase orders for curing compounds to the PMC. Copies of the purchase orders shall be made available far enough in advance of planned use so that the samples, if required, will be available to the PMC to allow a testing period of at least forty five (30) days. The Contractor shall then be informed in writing, whether the materials covered by each purchase order will be tested or whether the manufacturer's certification will be sufficient. The PMC shall act on any required certification as to conformance with these Technical Specifications within

twenty (15) days after receipt of certification by the PMC, and shall notify the Contractor.

Manufacturer's certification, if required, shall be furnished to the PMC. The manufacturer shall certify that the material is within one percent (by weight of each individual constituent) of the same composition as material which previously has been found to comply with the Specification when completely tested.

Samples of curing compound, if required, shall be one liter in size and included with each sample shall be a certification that the sample is from the actual batch from which shipments are to be furnished.

The Contractor shall be responsible for the accuracy of all certifications submitted and data contained therein whether submitted by him, a manufacturer, or a subcontractor. The costs and delays that result from rejection of materials or inadequate certifications shall be the responsibility of the Contractor.

- Water curing

  Concrete cured with water shall be kept wet for at least sixty (30) days from the time the concrete has attained sufficient set to prevent detrimental effects to the concrete surfaces. The concrete surfaces to be cured shall be kept wet by:

  - Covering them with water-saturated material;
  - By using a system of perforated pipes, mechanical sprinklers, or porous hoses.

  or by other methods which will keep all surfaces continuously (not periodically) wet. All curing methods are subject to approval by the PMC.

- Curing with wax-based or water-emulsified, resin-based compound

  Curing by curing compound shall be by application to designated concrete surfaces to provide a water-retaining film. The curing compound shall be reapplied as necessary to maintain a continuous, water-retaining film on the surfaces for at least sixty (60) days. The curing compound shall be mixed thoroughly and spray (or roller) applied to the concrete surfaces in one coat to provide a continuous, uniform film over the concrete. Equipment for applying curing compound, the method of application and the coverage shall be in accordance with the manufacturer's recommendations. On rough surfaces, the coverage shall be increased as necessary to obtain the required continuous film. Special care shall be taken to ensure ample coverage with the compound at edges, corners and rough surfaces.

  Where curing compound is to be applied, formed concrete surfaces shall be kept continuously moist by repeated light spraying with water until immediately prior to application of curing compound. Curing compound shall be applied as soon as the surface film of moisture has disappeared but while the concrete still has a damp appearance.

  After application of the curing compound has been completed and the coating is dry to touch, all remaining required concrete repairs shall be performed without delay.

Completed repairs shall be moistened and coated with curing compound in accordance with the foregoing requirements.

- Protection of curing membranes

  Curing compound membranes shall be maintained to provide a moisture-proof membrane for curing concrete for the minimum period specified. Curing compound that is damaged, or that peels from concrete surfaces within sixty (30) days after application, shall be repaired without delay by moistening the concrete and applying additional compound in a manner satisfactory to the PMC.

  Where foot traffic or other construction activity is necessary on concrete being cured by curing compound, the curing membrane shall be protected by covering with sand or earth not less than 20mm thick, with plywood, or by other effective means approved by the PMC. Protective covering shall not be placed on curing compound until the compound is dry. The Contractor shall remove protective coverings before final acceptance of the work.

24.3.8.3 Thermal Insulation

The Contractor shall fix a thermal blanket having the same thermal properties as the 300mm of dry fine aggregate on all exposed faces of contraction joints (if any) and on the upstream and downstream faces of the integrated RCC cofferdam and the main RCC dam. This can comprise a minimum of:

- 150mm of polystyrene slabs;
- 25mm of expanded polystyrene slabs;
- 10mm of mineral wool suitably protected from rain by encapsulation between protective layers, or
- A combination of the above.

In addition, all galleries and shafts shall be closed off using temporary partitions to prevent the free circulation of air. The partitions shall be provided with temporary doors that will allow easy access for personnel and equipment. The doors shall be kept closed at all times other than at the instant when access is required. Two sets of partitions shall be provided to each opening with a space in between and the inner door shall not be opened till the outer door is closed

24.3.9 Protection of RCC

24.3.9.1 General

The Contractor shall protect RCC against damage until the issue of the Taking Over Certificate. In addition, compacted lift surfaces shall be protected until the lift surface is covered by the subsequent lift placement. Equipment and vehicles shall be operated in

a manner which precludes tight turns, sudden stops, spinning wheels, or other procedures that could damage previously placed RCC.

Concrete curing membranes shall be kept intact and other curing materials and processes shall be maintained as necessary to ensure continuous curing for the minimum specified curing time of 30 days.

Fresh concrete shall be protected from rain. The Contractor shall provide such protection to prevent erosion of fresh concrete whenever such precipitation, either periodic or sustaining, is imminent or occurring. All fresh concrete surfaces shall be protected from contamination and from foot traffic until the concrete has hardened. Methods of protection shall be subject to approval by the PMC.

24.3.9.2 Protection against inclement Weather

The Contractor shall provide a recording thermometer to provide hourly temperature readings for determining the mean hourly temperature.

Un-compacted RCC and fresh RCC shall be protected from rain. The Contractor shall provide such protection to prevent erosion of RCC whenever such precipitation, either periodic or sustaining, is imminent or occurring.

When precipitation appears imminent, the Contractor shall immediately make ready at the placement site all materials which may be required for protection of RCC. The PMC may delay placement of RCC until adequate provisions for protection against weather are made.

24.3.9.3 Stoppages of RCC

When an RCC placement is halted for more than ten days, for whatever reason, the top surface of the finished layer of RCC (i.e. after compaction and joint preparation for restarting the placement of the RCC) shall be covered with a minimum of 300mm thickness of dry fine aggregate to provide not only protection of that surface but also insulation of the RCC. If the RCC is expected to be overtopped, the Contractor shall make proposals of how the surface will be protected and insulated.

The Contractor shall prepare the surface of the layer before covering the surface with the fine aggregate protection.

The Contractor shall cover the top of the fine aggregate with a waterproof material to prevent the fine aggregate being carried away by wind and to keep the material dry. A similar waterproof material shall be placed on the finished surface of the RCC below the fine aggregate to act as a curing membrane.

Immediately before starting to prepare the surface for the placement of the next layer the Contractor shall remove the fine aggregate and carry out any additional surface preparation and cleaning works that may be necessary.

24.3.10 Contraction Joints in RCC Structures Body

Contraction joints in the body of the RCC structures shall be located and constructed as shown in the Drawings, or as directed by the PMC.

The joints in the body of the dam shall be formed by the insertion of joint inducers into RCC after compaction, except where formed contraction joints are required according to the approved concrete placement programme.

Gaps between joint inducers (approx. 2m long) shall be no more than 200mm long and shall not exceed 10% of the total length of RCC across the structure. Joint inducers shall be placed laterally to within ± 50mm of the specified line.

The Contractor may propose other methods for installing the contraction joints in the RCC structures body, subject to the approval of the PMC

The seal arrangements of the contraction joints at the dam faces shall be formed in GEVR against the formwork by casting waterstops, the formed drain holes and joint-inducer plates into the concrete as shown in the Drawings. Care shall be taken to ensure the joint-inducer plates are firmly in contact with the waterstop and the formed drain holes and that they are positioned on the centre of the waterstop and drain hole with an accuracy ±3 mm. The plates shall penetrate the full GEVR layer height. Suitably robust framework shall be manufactured to hold the waterstop, drain-hole former and joint-inducer plates firmly in their position during encasement in GEVR surround. Where the plate is not aligned vertically or within the specified tolerance with the waterstop, the inducer shall be repositioned or GEVR and the waterstop shall be removed, the area fully cleaned and replaced to the approval of the PMC.

The Contractor shall give in his Bid all necessary details of the materials and procedures he intends to use for installing the contraction joints and joint seal arrangements in the RCC dam body.

The waterstops shall conform to the requirements of Sub-Clause 3.4.4 herein above.

24.3.11 Disposal of Waste RCC

Rejected RCC, or waste materials from lift surface preparation, shall be removed by the Contractor to a spoil dump area approved by the PMC.

24.3.12 Galleries and Shafts inside RCC Structures

24.3.12.1 Methodology

The Contractor shall submit to the PMCPMC's approval full details of the methods he proposes to use for building the various galleries, encasement of steel liner for the Bottom Outlet and shafts inside the RCC structures, and for minimizing hindrances due to the presence of such galleries and shafts on the RCC placement and compaction.

It is anticipated that:

- Galleries walls will be formed using GEVR against steel form and/or pre-cast concrete walls;
- Gallery roofs will be made of steel form and/ or pre-cast concrete slabs;
- Steel pipes may be used for small diameter ventilation shafts and for the pendulums to beinstalled in the dam body.

In general, it is expected that GEVR will be placed and compacted directly against formwork, except where high initial strengths are required because of the construction methods used, such as the edges supporting the pre-cast elements for the sidewall and roof of the galleries. In such cases, steel reinforcement shall be embedded in GEVR.

24.3.12.2 Formwork

Formwork used shall conform as applicable to Sub-Clause 3.5 of Chapter 0430 "Conventional Concrete (CVC)" shall be designed and constructed by the Contractor; shall have sufficient strength to withstand the pressure resulting from placement, compaction and vibration of RCC and GEVR; and shall be maintained rigidly in position. The formwork shall be sufficiently tight to prevent loss of mortar from the concrete. The formwork joints shall be covered on the internal surface with an approved tape to prevent the loss of mortar through the joints.

The PMC shall be informed before the Contractor strips any formwork. The Contractor shall remain fully responsible for the safety of the structure from which he removes the formwork.

Embedded ties for holding formwork shall remain embedded not less than two diameters or twice the minimum dimension of the tie or 10mm, whichever is the greater, in from the formed face of the concrete. The ties shall be constructed so that the ends, or end fasteners, can be removed without causing appreciable spoiling at the faces of the concrete. Recesses resulting from removal of form ties do not need to be repaired or plugged.

24.3.12.3 Tolerances

Allowable variations from specified lines and levels for the galleries and shafts will be in line with those specified for the faces of the dam (see Sub-Clause 3.4.5 "Tolerances for faces", herein above). The PMC reserves the right to reduce the tolerances if such tolerances impair the structural action or operation function of the galleries.

The Contractor shall be responsible for finishing the concrete to ensure that the completed work shall be within the tolerances specified. Hardened RCC or GEVR shall be checked by the Contractor and shall be subject to such inspection and measurement as needed to determine that the lines and levels are within the specified tolerances.

Hardened RCC or GEVR that is not within specified tolerances shall be repaired to bring it within those tolerances at the Contractor's expenses. Such repair shall be accomplished in a manner approved by the PMC.

Chapter 0440

25 CONCRETE STRUCTURE JOINTS AND BEARINGS

25.1 GENERAL

25.1.1 Scope

This Chapter covers the requirements in connection with the concrete joint treatment and supply and installation of waterstop, joint sealants and fillers to be used in construction joints, contraction joints and expansion joints as shown in the Drawings or as directed. The elastic bearing pads are included as materials related to the concrete structures.

25.1.2 Related Works & Sect'ons

Chapter 410 Formworks and Surface Finishes

Chapter 430 Conventional Concrete (CVC)

25.1.3 Definitions

- Construction joints are defined as concrete surfaces on or against which concrete is to be placed and to which new concrete is to adhere, and which have become so rigid that the new concrete cannot be incorporated integrally with that previously placed. Concrete surfaces against which mortar and second stage concrete is to be placed shall be considered construction joints.
- Contraction joint
  - It is a contact between two (2) elements generally without continuity of reinforcement.
  - Such joints will enable concrete cracks to be localized and construction phases to be localized.
  - They shall have no filler material (concrete cast against concrete).
- Expansion joint
  - An expansion joint is formed by creating complete discontinuity with clear gap between two (2) elements.
  - The purpose of expansion joints is to prevent structural disruptions as a result of temperature variations or differential movements.
  - The joints shall be filled with a preformed joint filler.
- Waterstop (Sealing strip)
  - Watertight sealing is achieved by PVC strip held in the two parts of structures in contact, unless other materials are specified in the Drawings.
  - Strips are generally fitted to contraction and expansion joints but also to construction joints.
- Sealing compound

Joints may be sealed with an elastomer joint-sealing compound.

- Bridge joints

  The purpose of bridge joints is to absorb bridge deck (aqueduct) movements with respect to their supports or foundations as well as to maintain continuity of level and watertightness.

- Elastomeric bearings

  Elastomeric bearings shall include plain bearings (consisting of elastomer only) and laminated bearings (consisting of layers of elastomer restrained at their interfaces by bonded laminates.

25.1.4 Codes and Standards

The Work included in this Chapter shall comply with the requirements of the following standards and codes, except where this Specification differs from these standards and codes, in which case the requirements of the Specification shall take precedence:

ASTM D-412	Test Methods for Rubber Properties in Tension
ASTM D-624	Test Method for Rubber Property - Tear Resistance
ASTM D-747	Test Method for Apparent Bending Modulus of Plastics
ASTM D-792	Test Methods for Specific Gravity and Density of Plastics
ASTM D-1751	Specification for Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction

25.1.5 Quality Assurance

25.1.5.1 Tolerances

- Waterstops

  Before pouring of concrete: 5 mm in all directions

  Final faces of the structure after pouring of concrete: 20mm in all directions.

- Joint sealing

  After making the joint, the surface of the facing shall be continuous and smooth and shall not have any local irregularity greater than 5mm.

- Elastomeric bearings

  Laminations of elastomer shall be 12mm + 3mm thickness. Variation in thickness of an individual elastomer lamination shall not exceed 3mm within the width or length of a pad and the variation in thickness of all elastomer laminations within a pad shall be such that each metal or fabric lamination will not vary by more than 3 mm from a plane parallel to the top or bottom surface of the pad. The total thickness of a pad

shall not be less than the thickness shown on the plan nor more than 6mm greater than that thickness. Variation of total thickness within an individual pad shall not exceed 3mm.

25.1.6 Submittals and Approvals

Samples of materials for waterstops, joint fillers and joint sealants, and bearings shall be submitted at least twenty eight (28) days before use in the Works.

When submitting samples, manufacturer's literature showing the properties of materials, results of quality control tests and Manufacturer's instructions for the storage and use of products shall be provided, as well as a written guarantee by the supplier confirming compliance of materials with the Specifications.

25.2 MATERIALS

25.2.1 Waterstops

All waterstops shall be PVC made unless otherwise directed by the PMC. The PVC waterstop shall be extruded from a high grade PVC compound. The material shall be homogeneous and free from porosity or other imperfections. The PVC waterstop shall be manufactured from virgin polyvinyl chloride, containing no reclaimed or scrap material. The PVC waterstop shall be obtained from internationally reputed manufacturer as approved by the PMC.

The PVC waterstop shall be of center bulb type with width varying from B=200 mm to 400 mm as indicated on the Drawings.

Jointing of waterstop shall be by welding. Manufacturer's technical documents detailing the jointing method and equipment for all joints, such as flat joint, T-edge joints, mitre joints, etc. as well as test method of the weld joints shall be submitted for consent of the PMC. Method of installation and fixing during concrete pouring shall follow the manufacturer's instruction manual.

Waterstops shall be tested by the following test standards:

Requirements	Method of Test
Tensile strength	ASTM D 412
Ultimate elongation	ASTM D 412
Stiffness in flexure	ASTM D 747
Tear resistance	ASTM D 624
Specific gravity:	ASTM D 792

The PVC material, when tested in accordance with the relevant Standards, shall have the physical properties mentioned hereunder.

Items	Requirements
Durability	unchanged by oil, river water, and solar radiation; impermeable, free of pores and cracks
Tensile strength	12 N/mm² minimum
Elongation at fracture	285% minimum
Hardness degree (Shore)	42-52 ShA tolerance
Water absorption; total immersion in distilled water for 48 hours at 50°C (in% by weight)	0.6%
Cold crack temperature	not higher than -25°C
Density	1.30 g/cm³ or more
Accelerated Aging Test: Retention of initial tensile strength	85% (minimum)
Retention of initial elongation at fracture	85% (minimum)
Stability in Alkali Tests: Weight gain after 7 days Weight gain after 30 days	0.25% (maximum) 0.40% (maximum)

* Tests on properties shall be carried out at 25°C, except for cold crack temperature and water adsorption.

The waterstops shall be of sufficient stiffness so that they remain in their correct position during concreting. The type chosen shall suit the particular location in the structure in which the waterstop is to be placed and the pattern shall be such that concrete can be placed entirely around it with

complete consolidation and no voids or crevices. Waterstops used in each location shall include at least one nailing strip so located that the efficiency of the waterstop is not impaired.

25.2.2 Preformed Joint Filler

Unless otherwise indicated on the Drawings or described herein, preformed joint filler material shall consist of 12mm or 18mm thick bituminous fibre sheet complying with ASTM D 1751.

25.2.3 Elastic Joint Sealant

25.2.3.1 Joint Sealant for Contraction and Expansion Joints

Elastic joint sealant to cover contraction and expansion joints shall be a thixotropic single component joint sealant with a polyurethane base that, after curing, forms a flexible, elastic and adhesive material capable of sealing joints in concrete effectively against the infiltration of moisture throughout repeated cycles of expansion and contraction.

The product shall not have any chemical action on the materials with which it will come into contact (concrete, preformed joint filler).

25.2.4 Bridge Joints

They shall be formed by steel and approved rubber. They shall be of the medium-heavy type capable of accommodating movements of 20-30mm.

25.2.5 Elastomeric Bearings

The elastomer shall conform to the following:

Items	Requirements
Tensile strength (refer to D412 in ASTM)	160 kg/cm² minimum
Elongation at fracture (D412)	350% minimum
Compression set, 22 hrs at 67 degree C (D395)	25% maximum
Tear strength (D624)	13 kg/cm² minimum
Hardness degree (Points) (D2240)	60+5

The Contractor shall furnish to the PMC a certification by the manufacturer, for approval, that the elastomer and fabric of used, in the elastomeric bearing pads to be furnished conforms to all of the above requirements. The certification shall be supported by a certified copy of the results of test performed by the manufacturer upon samples of the elastomer and fabric to be used in the pads.

25.3 EXECUTION

25.3.1 Construction Joints

Construction joints shall be located in the position shown in the Drawings, as specified herein or as directed by the PMC. Forming of additional joints or deviations from the joints indicated in the Drawings will not be permitted without approval by the PMC. Joints at exposed surfaces of concrete shall be straight and continuous, as shown in the Drawings, or as otherwise directed.

In the initial stage of setting, but before final setting, the surface of the joint shall be washed with water and compressed air jets, with the purpose of cleaning mortar from the surface, removing loose material and exposing large aggregate, without however removing particles thereof.

If the lift surface is congested with reinforcement and is relatively inaccessible, or for any other reason, it is considered undesirable to disturb the surface of a lift before it is hardened, surface cutting by means of air-water jets will not be permitted and the use of wet sand blasting will be required and shall be performed immediately before placing the following lift.

Green-cutting or sand-blasting shall continue until all unsatisfactory concrete, laitance, coatings, stains, debris and other foreign materials are removed.

Immediately before placing is resumed, air and water jet cleaning will be repeated, until the washing water remains clear. Water employed in washing surfaces shall be carefully removed from the placing zone, leaving the surface wet, but without puddles.

The air pressure used in the jet shall be not less than 600KPa and the water pressure shall be just sufficient to bring the water into effective influence of the air pressure.

All construction joints of the below ground level or against which water may stand shall be water tightened with plain web waterstops or sealing profiles, as shown in the Drawings or as directed. After green-cutting and sand-blasting and before casting the side concrete lifts, sealing joints will be fixed in the middle of the construction joints of the external walls in contact with ground water.

25.3.2 Contraction and Expansion Joints

Contraction joints shall be located and constructed as shown in the Drawings. The joints shall be made by forming the concrete on one side of the joint and allowing it to set before the concrete is placed on the other side thereof. The joint surface of the concrete placed first, shall be coated with a sealing compound of an approved type and grade, to prevent bond with the newly-placed concrete.

An expansion joint shall be separated by an approved preformed joint filler as shown in the Drawings and sealed as specified herein.

In no case shall any fixed metal, embedded in the concrete, be continuous through a contraction or expansion joint, except as shown on the Drawings or directed.

25.3.3 Waterstop Installations

Waterstops shall be stored so as to permit free circulation of air around it and shall not be exposed to the direct rays of the sun nor to any other source of heat. It shall be protected at all times from contamination by oil, grease or other deleterious substance. Prior to installation in the Works, waterstop shall be thoroughly cleaned of all foreign matter. Waterstops shall be stored and installed in strict accordance with the Manufacturer's instructions.

The type of waterstop selected shall suit the particular location in the structure, and the pattern shall be such that concrete can be placed around it with complete consolidation and without voids or crevices.

The Contractor shall take adequate precautions and shall supply the means for the support and protection of waterstop material during the progress of the Works and shall repair or replace damaged waterstop as instructed.

Particular care shall be taken in positioning and supporting waterstop to ensure that the centre of the waterstop coincides with the joint opening and that the waterstop are

perpendicular to the plane of the joint. Concrete shall be carefully placed and vibrated around waterstop to ensure complete filling of the forms in the areas around the waterstop and the development of a complete bond between the concrete and embedded areas of the waterstop.

Sealing strips as well as special intersection or connection parts, shall be fastened to the formwork or the reinforcement so as to keep them in the correct position as defined on the Drawings during concreting operation.

Under no circumstances shall sealing strips fastening devices compromise watertightness (nailing for example).

Waterstops as well as special intersection or connection parts shall be interconnected in order to guarantee total continuous sealing. The method of connection shall be of an approved type such

as hot-vulcanized connection using an electric vulcanizer, or cold connection using a preformed rubber sleeve, and special solvent, as specified by the Manufacturer.

Whenever waterstop projects from completed sections and its complete embedment is to be delayed to the extent that, in the opinion of the PMC, there is a danger of damage, such waterstop shall be adequately protected by timber enclosures or by other approved means.

Restarting parts of sealing strips or special parts shall be protected from the risk of mechanical accidents and, if necessary, from the effects of solar radiation if the exposure time were to exceed one month.

25.3.4 Jıint Fillers

Joint fillers shall be stored, placed and installed in strict accordance with the manufacturer's instructions, in the locations shown in the Drawings or as otherwise directed by the PMC.

Particular attention shall be paid to cleaning and priming the concrete joint faces.

25.3.5 Joint Sealants

Joint sealants shall be stored, placed and installed in strict accordance with the manufacturer's instructions.

The edges of joints shall not show any signs of spalling or beading. Any repairs that may be required on the joint lips shall be carried out using epoxy resins approved by the PMC.

Before filling with the joint sealing compound, the joint faces shall be trimmed straight and cleaned of any loose laitance by sand-blasting or grinding or brushing.

Unless otherwise approved by the PMC, width of rectangular joint groove to be prepared for sealant filling shall be at least 15 mm at contraction joints and 30 mm at expansion joints. Depth of the groove shall be at least 15 mm.

25.3.6 Bridge Joints

Anchor bars of bridge joint shall be welded to the reinforcement bars.Bridge joints shall be placed and installed in strict accordance with the manufacturer's instructions, in the locations shown in the Drawings or as otherwise directed by the PMC.

25.3.7 Elastomeric Bearings

When elastomeric bearing pads are shown on the Drawings, the concrete surfaces on which pads or packing are to be placed shall be wood float furnished to a level plane which shall not vary more than 1.5mm from a straightedge placed in any direction across the area. The finished plane shall not vary more than 3mm from the elevation shown on the Drawings to that required by the PMC.

Chapter 0510

26 MISCELLANEOUS STRUCTURAL STEEL WORK AND METALWORK

26.1 GENERAL

26.1.1 Scope

The work described in this Chapter includes the supply of all labor, plant and materials to complete the design and detailing, supply, fabrication, painting or galvanizing, and installation of the miscellaneous structural steel work and miscellaneous embedded and non-embedded metalwork as shown in the Drawings or required to complete the Work as directed by the PMC, including:

- Structural steel framing of the Dam control house, the Power distribution house, the Guard house, Bottom Outlet gate chamber and flushing gate chamber,
- Structural beams supporting the overhead travelling crane of the Bottom Outlet gate chamber and the flushing gate chamber,
- Miscellaneous metalwork
  - Embedded metalwork including steel drain pipes, floor opening frames, anchor pads, anchor bars/bolts, concrete anchor (expansion type, drilled hole anchors), surge chamber orifice port liner, etc.
  - Non-embedded metalwork including steel drain pipes, plate cover or grating cover for floor openings, steel stairs, ladders and steps, support brackets, galvanized steel or stainless steel pipe handrail, chain handrails, floor drains, etc.
  - Non-embedded metalwork including tunnel doors, bolted fire door, guard rail, wire fence with gates, entrance gates, cast iron manhole covers, etc.
  - Water level staff gauges

The locations, materials and nominal sizes of the miscellaneous metalwork will be indicated in the Construction Drawings. Shop fabrication drawings shall be prepared by the Contractor and submitted to the PMC for approval.

This Chapter excludes the requirements for the Part B Hydraulic Steel Structures that shall comply with the provisions contained in Hydraulic Steel Structures Technical Specifications.

26.1.2 Related Works / Sections

Chapter 0430 Conventional Concrete (CVC)

26.1.3 Definitions

The metalwork parts to be supplied, placed and embedded in the concrete by the Contractor consist of two (2) types which will be shown in the Drawings:

- Pre-embedded metal parts which will be used by the other contractor for setting, adjusting and erecting their own mechanical parts without transmission of operating loads,

- Metalwork parts which will be used for setting, erecting and fixing any part supplied under the Contract, with or without loads.

Equipment and structures will be attached by the other contractor to the pre-embedded parts by adjustment rods under his responsibility. Concreting around these parts with second stage concrete or mortar is included in the Contract and is defined in the Chapter 0430.

26.1.4 Codes and Standards

26.1.4.1 General

The work included in this Chapter shall comply with the requirements of the following codes, standards and specifications. In case of conflict between these codes (or standards or specifications) and the requirements specified in this specification, the latter shall govern to the extent of such difference.

26.1.4.2 American Institute of Steel Construction (AISC)

- Specification for Structural Steel Buildings - Allowable Stress Design and Plastic Design.
- Specification for the Design of Cold-formed Steel Structural Members.

26.1.4.3 American Society for Testing and Materials (ASTM)

A 6/A 6M	Specification for General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Uses
A 36/A 36M	Specification for Structural Steel
A 48	Specification for Grey Iron Castings
A 53	Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless
A 108	Specification for Steel Bars, Carbon Steel, Cold-Finished, Standard Quality
A 123	Standard Specification for Zinc (Hot Dip Galvanized) Coatings on Iron and Steel Products
A 193	Specification for Alloy-Steel and Stainless Steel Bolting Materials for HighTemperature Service
A 307	Specification for Carbon Steel Bolts and Studs 60,000 p.s.i. Tensile
A 325M	Specification for High-Strength Bolts for Structural Steel Joints [Metric]
A 394	Specification for Zinc-coated Steel Transmission Tower Bolts
A 446	Specification for Steel Sheet, Zinc Coated (Galvanized) by the Hot-Dip Process, Structural (Physical Quality)
A 467	Specification for Machine and Coil Chain

A 490M	Specification for High-Strength Steel Bolts, Classes 10.9 and 10.9.3, for Structural Steel Joints [Metric]
A 500	Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
A 501	Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing
A 525	Specification for General Requirements for Steel Sheet, Zinc Coated (Galvanized) by the Hot-Dip Process
F 436M	Specification for Hardened Steel Washers

26.1.4.4 Steel Structures Painting Council (SSPC)

- Paint Application:

  SSPC-PA 1 Shop, Field and Maintenance Painting

  SSPC-PA 2 Measurement of Dry Paint Thickness with Magnetic Gages

- Preparation Methods:

  SSPC SP 1 Solvent Cleaning

  SSPC SP 3 Power Tool Cleaning

  SSPC SP 6 Commercial Blast Cleaning

  SSPC SP 10 Near White Blast Cleaning

26.1.4.5 American Welding Society (AWS)

AWS D1.1 Structural Welding Code - Steel

26.1.4.6 Uniform Building Code (UBC of USA) AWS A56

26.1.5 Quality Assurance

26.1.5.1 Inspection

- All materials supplied and all work performed off the Site under this Chapter will be subject to inspection by the PMC at the point of manufacture and/or fabrication. Unless inspection is waived by the PMC, no material shall be shipped until after such inspection and receipt by the Contractor of authorization from the PMC to deliver the material to the Site. Where directed by the PMC, certified mill or shop test reports shall be furnished to the PMC by the Contractor in lieu of inspection at the mill. Acceptance of material or the waving of inspection thereof shall in no way relieve the Contractor of the responsibility of furnishing materials and workmanship conforming to the Specifications in all respects.
- At least 70% of all structural welds shall be 100% tested by non destructive methods, as directed by the PMC. Fillet welds shall be tested by magnetic particle or liquid penetration inspection. Groove welds shall use radiographic (RT) and/or ultrasonic

(UT) testing. This concerns particularly the steel beam supporting overhead travelling cranes.

- At least 15% of all welds in non-structural steel or structural steel subject to climatic loads only (roofs) and in miscellaneous metalwork shall be tested by magnetic particle or liquid penetration methods, as directed by the PMC.
- The Contractor shall provide all materials, equipment and qualified personnel to carry out radiographic, ultrasonic and/or magnetic particle inspection of shop welds and spot inspection of field welds at locations selected by the PMC.
- Data and records of all testing shall be properly referenced and kept in an orderly manner by the Contractor during the Work and shall be made available to the PMC upon request and then turned over to the PMC upon completion of the Work.
- All materials and workmanship inspected in the shop or at point of manufacture will also be subject to inspection at the Site and, if found faulty, will be rejected and shall be rectified by the Contractor.
- The PMC reserves the right to inspect the paint application facilities in the Contractor's and/or his subcontractor's workshops and to ensure that they comply with the prescribed standards and painting procedure.
- The number of coats of paint and the total thickness of the coating will be checked and the PMC reserves the right to have the thickness of individual coats checked in his presence. On a protected surface, a test area and a number of test points shall be defined by the PMC. The minimum measured thickness shall not be below 90% of the guaranteed thickness and the average of all measurements shall not be below the guarantee. The Contractor shall supply the measuring apparatus, which shall be of the electronic detection type), giving readings accurate to within 1 micrometer. One measurement shall be taken every 0.5m² or every 0.5 linear meters.
- Adhesion tests shall be performed on submerged and partially submerged equipment, in accordance with standard ASTM. The instruments required, in accordance with the same standard, shall be supplied by the Contractor.

26.1.6 Submittals and Approvals

- The Contractor shall submit copies of certified manufacturer's tests.
- The structural steel work and miscellaneous metalwork shall conform to the details and data shown on the Drawings and design criteria supplied by the PMC, and to the actual dimensions of the structures and items already built. The Contractor shall prepare complete design drawings of structural steel work and shop and erection drawings of all structural steel work and miscellaneous metalwork to be supplied by him, showing in detail the sizes of each component part, type and grade of metal, connections and welding details, method of assembly, hardware anchorages or connection with other work and the areas and type of painting or corrosion protection. Such drawings shall be submitted to the PMC for approval to proceed

with the work at least sixty three (63) days prior to fabrication or ordering of any item shown thereon.

- The Contractor shall also prepare and submit to the PMC for approval, at least sixty three (63) days prior to fabrication, bills of material listing complete details of the component parts of all items to be supplied by him as required to complete the installation shown on the Drawings.
- The Contractor shall submit welding procedures and certificates of qualifications of welders for approval which shall be in accordance with the AWS D1.1.
- For each type of corrosion protection system by painting, and at least twenty eight (28) days prior to ordering of paint materials, the Contractor shall submit the following for PMC's approval:
  - Description of each paint system including preparation of surfaces, products applied, thickness,
  - A list of all paint products proposed for use, including the name of the manufacturer, product characteristics, and characteristics of the dry coating,
  - Copies of the manufacturer's specifications and application instructions,
  - Place of application (workshop, site),
  - Summary table dealing with all the equipment and the required protection, including the nature of the products, thicknesses, color of each of the coats, and surface to be protected.
- For each type of protection system by galvanizing, the Contractor shall submit the following for PMC's approval:
  - Galvanizer's references to comply with the present Specification.
  - Test certificate for factory galvanized products or attestation of conformity with Specifications.
  - Identification of the factory producing the galvanized products.
  - Identification marks for galvanized parts checked at the factory.
- The Contractor shall give the PMC notice at least twenty eight (28) days before the scheduled date of inspection of the various items of structural steel.
- The Contractor shall not proceed with painting of any of the equipment subject to workshop inspections and tests without the prior written approval of the PMC.
- The Contractor shall submit the painting application report defined as follows:
  - Daily report of the maximum and minimum ambient temperature and list of parts to be painted.
  - Daily report of the maximum and minimum humidity level in the paint application room.
  - Other pertinent information.

26.2 MATERIALS

26.2.1 General

- All materials supplied by the Contractor shall be new and shall be subject to approval by the PMC. Except as otherwise specified or shown in the Drawings or otherwise approved by the PMC, materials shall conform to the following specifications.

Structural steel shapes, bars, plates	ASTM A36/A36M
Floor plates	ASTM A36/A36M
Cast iron	ASTM A 48 Class 25
Steel pipe for handrails	ASTM A 53
-Standard	Schedule 40
- Extra strong	Schedule 80
Chains	ASTM A 467
Welding materials	AWS A5.1 or A5.5
Bolts, nuts and washers	
- High strength	ASTM A 325M or ASTM A 490M
- Stainless steel	ASTM A 193
- Standard strength	ASTM A 307 Grade A or B
- Threads	Coarse thread series
- Washers, hardened	ASTM F436M
- Washers, standard strength	Standard commercial quality
- Bevel washers	Malleable iron or steel
- Shear connectors (studs)	ASTM A108 Grades 1010 through 1020

- Unless otherwise specified herein or shown in the Drawings, all exposed fastenings shall be of the same material, color and finish as the metal to which they are attached.

- Grout for base plates and bearing plates shall be dry-pack mortar as specified in Chapter 0430.
- Non-shrink cementitious grout or approved equivalent to be used as structural grouting under column base plates.

26.2.2 Paint Materials

26.2.2.1 Materials

Unless specified otherwise herein or in the Drawings, weldable zinc primer used for steel and metalwork shall be subject to prior approval of the PMC.

After-weld primer shall be epoxy zinc rich primer approved by the PMC.

Finish coat shall be of high build epoxy mastic approved by the PMC.

26.2.2.2 Storage of Paint Materials

The storage conditions of painting products shall comply with the recommendations indicated on the supplier's technical data sheets. Failure to comply with any of these conditions may give rise to rejection of the product. In particular, the Contractor is deemed to be fully acquainted with the climatic conditions prevailing on site and shall be required to take such conditions into account.

The stores used for the storage of paints and associated thinners shall be closed and covered, thereby enabling the temperature and degree of humidity to be maintained at a level consistent with the Specifications indicated on the Instructions for use of the products.

26.2.3 Galvanizing

Zinc for galvanizing shall comply with ASTM A123.

26.3 EXECUTION

26.3.1 Fabrication

- The design, fabrication and erection of structural metalwork and associated bracing, base plates, connections splices, fittings, ties, hangers, bearings, brackets, anchors and associated metalwork, and miscellaneous metalwork shall be in accordance with the requirements of AISC Allowable Stress Design except as otherwise specified herein or shown in the Drawings.
- Individual component members or parts of an item of structural or miscellaneous metalwork shall not be spliced, except where shown in the Drawings or approved by the PMC.
- Connections shall be designed by the Contractor and submitted to the PMC for authorization to proceed with the Work. Shop connections shall be welded. Field

connections shall be either welded or bolted for structural members that are painted, and bolted for members that are required to be galvanized. Except as otherwise specified or shown in the Drawings, high strength friction type bolts shall be used for bolted connections.

- Spliced structural members to be connected in the field shall be assembled completely and match marked in the shop, and each connecting member shall be clearly marked to correspond with the erection marks shown on the erection drawings.
- Welding shall be undertaken in a shop fully approved by the PMC. Such shop may be that of the Contractor, of a Sub-contractor or of a fabricator. All welding shall meet the requirements of AWS D1.1.
- Members to be joined by welding shall be cut accurately to size, with edges sheared, flamecut, or machined to suit the required type of welding and to allow thorough penetration. The surfaces of plates to be welded shall be free from rust, grease, and other foreign matter along the edges prepared for welding. The cut surfaces shall be free of all injurious defects.
- All welding shall be continuous along the entire line of contact, except where tack welding is permitted. All exposed welds shall be ground smooth.
- Exposed welds shall be ground smooth and flush with the adjacent metal on all angles, frames, ladders, handholds and upper rails of handrails, on bearing surfaces where weld projections would prevent proper seating or bearing of contacting members, and on the surfaces of runways and guides for moving parts.
- Welding of galvanized steel will not be permitted except where shown in the Drawings or directed by the PMC.
- The joints shall be filled, milled or machined as may be necessary to secure close and perfect connections. All frames shall be provided with suitable bracing connections. All frames shall be provided with suitable bracing to maintain alignment during transport.
- Structural and miscellaneous metalwork shall be handled carefully at all times to ensure that no permanent deformation or other damage results to the Work and to minimize paint damage.
- Members shall not be overstressed during the construction and hammering will not be permitted.
- Stud anchors shall be welded to metalwork as shown in the Drawings or as required by the PMC and in accordance with the stud manufacturer's instructions.
- Manufacture Tolerances:
  - Dimensions without direct influence on the assembly of the element: 0.2%.
  - Main dimensions: 0.1%.
  - Local (area 200 x 200mm): 0.5/400 cm².

- Flatness: 1mm.
- Main parallelism, main squaring: 1mm/m.
- Straightness, alignment: 2mm.

26.3.2 Painting

26.3.2.1 General

- The Contractor shall not proceed with painting of any of the equipment subject to workshop inspections and tests without the prior written approval of the PMC. The Contractor shall take all reasonable precautions to ensure that the protective coatings are not damaged during handling in the factory, during transport or during erection. In particular, he shall ensure that no damage is caused through the use of inappropriate packing systems and handling means. In the event of damage, the Contractor shall make good the existing protective coatings using the same products and under the same conditions of application. For all the equipment included in the supply, a single make of paint approved by the PMC and identical products for identical operating conditions shall be chosen except for standardized equipment. Regardless of where the corrosion protection coating is applied, the cost of all the necessary installations shall be borne by the Contractor.
- Except as otherwise specified herein, shown in the Drawings or required by the PMC, all metal surfaces of structural and miscellaneous metalwork shall be prime and finish painted in the shop prior to shipment to the Site.
- Unless otherwise shown in the Drawings or specified herein, surfaces which are galvanized, exposed aluminum surfaces, and surfaces which will be in contact with concrete, mortar or grout shall not be shop painted.
- All metal parts not protected by a metal layer or surface treatment process shall receive marine type corrosion protection, based on the application of paint.
  - Parts embedded in concrete

    Immediately prior to the application of the protective coating, all traces of calamine, rust and paint shall be removed by abrasive jet cleaning.

    The protective system for submerged parts or parts exposed to air, as applicable, shall be applied over a length of 100mm measured from the line of penetration in the concrete for parts with surfaces not embedded in the concrete.
  - Machined surfaces

    A protective varnish shall be applied to the dried and cleaned surfaces using either a brush or with a spray gun. This varnish must be capable of being easily removed by the application of petrol or trichloroethylene.
  - Internal surfaces of tanks

The internal surfaces of tanks designed to contain oil shall be sand blasted and immediately protected with two coats of oil-proof enamel paint.

- Insides of box girders

  The insides of box girders not accessible for painting after erection shall be subjected to a watertightness test using compressed air, unless otherwise specified.

  The compressed air pressure will be 0.15 bars for the test.

  On completion of this test, a desiccating powder shall be blown into the box girders in order to dry the air. The opening shall then be carefully sealed by means of a welded plate.

- Access ways, platforms, handrails, ladders, covers, lampposts

  All these items shall be protected with paintwork system meeting the same requirements as for equipment exposed to the atmosphere or with galvanization. Any access way and platform plating shall be coated with non-slip, temperature-resistant paint with additional UV radiation protection for equipment located outdoors.

  Surfaces inaccessible after assembly and/or erection of the equipment shall be prepared and protected using the complete system selected for the whole of the equipment before such erection and assembly are carried out.

  In the event of assembly without a sufficient gap being available, a flexible seal will be installed between the various parts, after assembly.

- Pipework

  The internal and external surfaces of air and water pipework shall be protected by hot galvanizing. Small diameter pipes shall be weldless assembled to avoid the risk of deterioration of the corrosion protection. Large diameter pipes may be weld assembled if the welds are accessible for making good the internal and external corrosion protection. Galvanization is not required for oil piping. The external surface of the oil pipes shall be protected by painting according to the SSPC standard, in relation to their position.

- Colors

  The colors proposed shall be submitted to the PMC for approval.

- Standardized equipment

  The corrosion protection of standardized equipment, usually carried out in the supplier's workshop, shall be submitted to the PMC for approval.

- All safety components and accessories which, in contact with water, might be subject to serious corrosion or scaling, liable to cause operating faults, shall be protected from corrosion and, wherever possible, from scaling by the use of materials whose mechanical and physical qualities must meet the conditions of use imposed on the components.

26.3.2.2 Coating Application Requirement

- The general procedure to remove oil and grease shall be by solvent cleaner approved by the PMC. After solvent cleaning, all metal for fabrication shall be sandblast cleaned. The abrasive use shall be a 20-50 mesh clean dry white silica sand and shall produce an anchor pattern of 30 to 35 μm.
- For prepainted substrates and surface preparation between each coat, the surface preparation will be defined in relation to the primer applied in the workshop and to the requirements for the correct adhesion of the other coats, which will be defined by the paint supplier (surface, roughness, possible removal of zinc, salts, etc.).
- After blasting is complete the surfaces shall be vacuumed or blown with dry compressed air to remove dust and any foreign particles. Immediately thereafter, the metal shall be coated with pre-construction primer to a dry film thickness of 15 to 20 μm. If, in the opinion of the PMC, any rust bloom has formed after blast cleaning, the surface shall be re-blast cleaned before painting. No priming shall be done when the metal temperature is less than 7°C or when ambient atmospheric conditions are not in accordance with the instruction for use of the products or with good painting practice.
- After fabrication, all weld spatter, rough welds, or sharp protrusions shall be removed by chipping and grinding. All welds shall then be sandblast cleaned.
- Unless specified otherwise herein or shown on the Drawings, the surfaces to be painted shall then be prime coated with one coat of after-weld epoxy rich primer applied to yield a dry film thickness of 50 μm.
- Unless specified otherwise herein or shown in the Drawings, the surfaces to be painted shall then receive two finish coats of high build epoxy mastic each coat having a dry film thickness of 125 μm for a total of 250 μm.
- Contact surface within slip-critical (friction type) high-strength bolted connections shall be free of oil, paint, lacquer or other coatings.
- Blast cleaning and painting work shall be carried out only when the ambient air temperature and degree of humidity are within the requirements of the instructions for use of the products.
- Generally, all such work shall be suspended as soon as the degree of humidity exceeds 75% and the ambient temperature exceeds 40°C or drops below 5°C. The substrate temperature shall always be at least 3°C higher than the dew point.
- The Contractor shall bear the cost of equipping each work station with sufficiently accurate measuring instruments. Temperature and humidity shall be recorded during paint application.
- The choice of place(s) for the application of the final coats shall be made in relation to the following:
  - Type of product.

- Programme and procedure of manufacture and erection.
- Climatic conditions.
- Mode of application of the paint.
- Equipment, materials and personnel available.
- Other factors may be taken into account.

26.3.2.3 Touch-up Painting

- Touch-up painting is the painting of items at the Site, after installation, that have previously been painted or galvanized and require repair due to damage caused during transit, storing, testing or installation, or painting of welded or bolted field connections, where the paint has been left off or has been applied thinner than on the adjacent surface.
- The Contractor shall supply and apply touch-up to all shop painted and galvanized surfaces which, in the opinion of the PMC, require touch-up.
- Surface preparation for touch-up shall conform to the applicable standards for removal of oil and grease and for removal of dirt, loose rust and loose paint. Surface preparation of field welds, where applicable, shall be by sandblast cleaning.
- All sandblasted, ground or wire brushed surfaces shall be primed as soon as possible after such treatment, but in any case the maximum time before priming shall be 8 hours.

26.3.3 Galvanizing

- Galvanizing and testing shall conform to the requirements of ASTM A123.
- Before galvanizing is started, the Contractor, if required by the PMC, shall furnish the PMC with a detailed description of his galvanizing works and an analysis of the spelter he proposes to use. During galvanizing, the PMC will carry out such tests on the coating and analysis of the spelter as he considers necessary. All facilities, material and labor required for this testing shall be furnished by the Contractor at no additional cost to the Employer/PMC.
- Material shall be galvanized after all fabrication, machining and shop work is completed, except as otherwise specified herein.
- Before galvanizing, all weld spatter, rough welds, or sharp protrusions shall be removed by chipping and grinding. All welds shall then be sandblast cleaned. The remaining surfaces shall be thoroughly cleaned of all loose mill scale, rust, oil, grease and weld flux deposits. After cleaning, welds shall have a continuous, regular surface free from any porosity and perfectly watertight. All these works shall conform to the applicable standards approved by the PMC.
- All components of any assembly to be bolted or riveted shall be delivered to the galvanizer unassembled for separate treatment. Holes for bolts, rivets or pins shall

be carefully bored before galvanizing to a diameter that takes into account the thickness of the deposit, as no retouching work may be carried out after treatment.

- The coating shall be clean, smooth, homogeneous and free from defects. Bare spots, loosely attached spelter, unevenness of coating and globules which may be broken in handling, will be cause for rejection by the PMC. If more than 5% of material is rejected, manufacture shall be stopped and the process altered so that satisfactory work will be produced.
- The galvanizing of bolts, nuts and washers shall be in accordance with ASTM A394. Nuts shall be tapped after being galvanized and the threads of nuts left bare in accordance with ASTM A394.
- It shall be the Contractor's responsibility to take whatever measures are necessary to ensure that frames or similar items of metalwork are not distorted during the galvanizing process. In this regard if the Contractor proposes to additionally reinforce, brace, or otherwise stiffen metalwork, he shall submit details of the proposed measures to the PMC for his approval prior to proceeding with the relevant work. The properties, shapes and characteristics of the material shall not be affected by galvanizing.
- The weight of zinc deposited shall be on average 7 g per dm² and at least 5 g per dm², with a minimum thickness of 70 µm In the case of tubes, hollow parts and assembled parts, these values apply to both faces.

26.3.4 Erection

- The Contractor shall exercise care in storing, handling and erecting all structural and miscellaneous metalwork delivered to the Site and shall properly support it at all times so that no piece will be bent or twisted or stored in contact with the ground or in such a manner as to hold water, or be otherwise damaged.
- Any metalwork damaged during transport or erection shall be replaced or repaired by the Contractor to the satisfaction of the PMC, at no extra cost to the Employer.
- Before commencing erection, the Contractor shall take such measurements as are necessary to verify the location of all adjacent work and structures which might affect installation of the structural and miscellaneous metalwork. If the measurements indicate that irregularities are present in the work, the Contractor shall submit to the PMC for approval proposals to rectify the irregularities prior to any adjustments being made to the structural or miscellaneous metalwork or adjacent work or structures.
- Adequate provision shall be made for erection stresses and temporary bracing shall be provided where necessary to keep the structural and miscellaneous metalwork plumb and in true alignment during construction. Bracing members, if shown on the Drawings, are required for the finished structures and it shall not be assumed that they are adequate for erection purposes. It shall be the responsibility of the Contractor to make proper and adequate provisions for erection stresses.

- Every failure of the fabricated material to fit together properly shall be reported to the PMC before any corrective measures are taken.
- Enlarging or relocating bolt holes on bolted connections shall be done by drilling. Flame cutting of bolt holes will not be permitted.
- Base plates and bearing plate, to be grouted shall be shimmed and leveled with steel shims or leveling nuts and washers.
- Before installation, embedded items shall be thoroughly cleaned of loose rust, grease, paint, concrete spatter or other coatings that will reduce the bond.
- Embedded metalwork shall be accurately set in place, inspected and approved by the PMC before the concrete is placed. Subject to the approval of the PMC, formed recesses may be left in the concrete and the metalwork placed, anchored and grouted in place at a later time.
- Where it is impractical in the opinion of the PMC to place anchors or anchor bolts by either of the foregoing methods, holes shall be drilled in the concrete and concrete anchors shall be installed by the Contractor as directed by the PMC.
- Anchor bolts and anchor pads shall be installed within the following tolerances unless otherwise shown in the Drawings:

Variation from alignment	± 4 mm
Variation from bolt projection	± 7 mm

- The Contractor shall, at no additional cost to the Employer, provide and use templates for setting anchor bolts, in order to meet the tolerances specified or shown in the Drawings.
- Grout, where required, shall consist of epoxy cement or of aggregate, sand, cement and water in the proportions proposed by the Contractor and approved by the PMC. Forms for grouting shall be installed where necessary. Grout shall fill all space of recesses, with no voids. After grout has hardened, any visible wedges shall be removed, and exposed joints neatly finished to a smooth dense surface. 15.Erection tolerances:
  - Dimension without influence on the operation of the element: ± 0.2%.
  - Main dimensions: ± 0.1%.
  - Local (area 200 x 200mm): 0.5/400 cm².
  - Flatness: ± 1 mm.
  - Straightness, alignment: ± 2 mm.
  - Verticality: ± 2 mm.
  - Horizontality: ± 2 mm.

  If the installed embedded metalwork is not correct in position, the Contractor shall renew the metalwork or replace with other at his cost as approved by the PMC.

- All tolerances shall allow proper operation of the equipment.

26.3.5 Miscellanous Metalwork

26.3.5.1 General

The following Sub-clauses describe certain of the major types of miscellaneous metalwork which come under the scope of this Chapter. Miscellaneous metalwork not specifically described herein but necessary for the Work shall be provided by the Contractor.

26.3.5.2 Embedded Miscellaneous Metalwork

Embedded miscellaneous metalwork to be supplied and installed by the Contractor shall include the following:

- Pre-embedded parts to be used for setting and adjusting mechanical equipment by others will be shown in the Construction Drawings.
- Steel pipes for draining or other purpose shall be as shown in the Drawings.
- Anchor Bolts, Anchor Pad Assemblies, Concrete Anchor (Expansion Anchor) and Adhesive Anchors (except anchors for equipment supplied under other contract)

  The details and locations of embedded anchor bolts complete with anchor bolt sleeves, where required, anchor pad assemblies, hold down anchors, lifting hooks, pulling eyes and concrete anchors are as indicated in the Drawings.

  Concrete anchors (expansion anchors or wedge anchors) shall be expansion or sleeve anchors, self or non-self drilling of the type approved by the PMC. Adhesive anchors shall be of the type approved by the PMC. Installation of concrete and adhesive anchors shall be in accordance with the manufacturers' recommendations and as approved by the PMC.
- Slotted Steel Inserts and Threaded Concrete Inserts

  Slotted steel inserts, also referred to or shown in the Drawings as concrete inserts shall be hotdip galvanized and installed complete with all necessary closure strips, anchors and end caps. Slotted steel inserts need not be grounded directly and will be considered satisfactorily grounded if equipment attached to the inserts is grounded.

  Threaded concrete inserts shall be of the types and sizes shown in the Drawings as or required by the PMC. Threaded concrete inserts shall be supplied with ferrules to suit National Coarse Thread as shown.

  Concrete stud anchors shall be deemed to be an integral part of the metalwork to which they are welded.
- Frames and Protection Angles

Steel frames and corner protection angles for floor and wall openings, shall be as shown in the Drawings or as directed by the PMC.

Where frames are too large to ship in one piece they shall be fabricated in convenient sections and fitted with self-aligning bolted splices. Welds for such frames and angles shall be continuous. Exposed welds shall be ground smooth and flush with adjacent metal. Holes for cover plates and other attachments shall be drilled and tapped as shown in the Drawings or as directed by the PMC. Concrete stud anchors for embedded frames, protection angles, corner guards and other purposes shall be Nelson Type H4L (as or approved equal) and shall be of the sizes shown in the Drawings.

26.3.5.3 Non-embedded Miscellaneous Metalwork

Non-embedded miscellaneous metalwork to be supplied and installed by the Contractor shall include the following:

- Cover Plate or Cover Grating for Hatch, Channel, Sump, Manhole, Floor Opening

  Hatch covers and cover plates for manholes and sumps as shown in the Drawings shall be supplied in sections convenient to handle, complete with floor curb frame having steel anchors, gaskets, plastic caps and fittings where required. The sections shall be cut to dimension for close fitting joints, have finished edges, and be fitted with lifting holes or slots. Such plates shall be of galvanized checkered plate and shall be carefully flattened to prevent movement or rocking under traffic. Plates shall be attached to frames with flat head brass screws in countersunk holes unless otherwise noted and shall be flush with the tops of the embedded frames. Floor plates for hatch covers and cover plates shall have a raised pattern. Eye bolts for lifting a cover panel shall be provided at least one full set per two (2) panels.

  Steel frame for concrete-filled hatch covers shall be of welded steel construction made of rolled steel profiles and plates as shown in the Construction Drawings. The steel cover frame and floor curb frame shall be fully galvanized before concrete filling. Concrete filling work for this hatch cover shall follow the specifications of Chapter 0430. Eye bolts for lifting a cover panel shall be provided at least one full set per two (2) panels.

  Steel grating cover for floor opening shall be of galvanized steel construction with floor curb frame having steel anchor bars as shown in the Construction Drawings.

  Stainless steel grating for floor channel or gutter shall be as shown in the Drawings.

- Spiral Stairs, Step Ladders, Rung Ladders and Climbing Iron Steps

  Spiral stairs, step ladders, rung ladders with or without safety cages and climbing iron step bars, including all necessary supports, brackets, anchors, and fittings, shall be as shown in the Drawings. All exposed steel members shall be of galvanized steel construction.

- Pipe Handrails, Conductor Railings, Guard Posts, Safety Chains, Guard Rails and other Safety Accessories

Pipe handrails, guard posts, post sleeves or sockets, safety chains, snap hooks, shackles and other safety accessories, including all necessary supports, anchors, sleeves, and fittings, shall be as shown in the Drawings. Safety chain shall be stainless steel chain to be hooked on stainless steel pipe posts to be installed when necessary.

- Tunnel Doors, Grills, Bolted Fire Door

  Steel plate doors or grilled doors in tunnels and fire doors bolted to each transformer cell wall including door hinges, door anchors, boor bolts, door handles, locks, man-door fixed to main door shall be provided and installed as shown on the Drawings.

- Entrance Gates

  Steel fabricated sliding type door shall be provided at entrances of the switchyard compound and the main access tunnel as shown in the Drawings. Runway rails, moving rollers and door lock shall be included. Runway foundation and side post concrete shall be constructed to follow the specification in Chapter 0430. The runway rails shall be accurately installed and firmly fixed to the foundation concrete.

- Cast Iron Covers

  Cast iron cover for manhole in outdoor or indoor drainage pits shall be complete with cover, floor frame, anchors, embedding mortar or concrete, chain link of cover, cover lifting device as shown in the Drawings and as shown on the manufacturer's drawings. The cover shall comply with the Uzbekistan standards for heavy duty covers.

- Cast Iron Grating

  Cast iron grating to cover drain ditches in transformer quenching pits and other drain ditches shall be as follows:

Type A for 300 mm wide ditch:	25 mm thick grating panels with width of 350 mm and length of 500 mm to 450 mm.
Type B for 500 mm wide ditch:	30 mm thick grating panels with width of 570 mm and length of 500 mm

  Grate shall have parallel openings with width of 15 mm ±1mm. Each grating panel installed on ditch shall withstand 2-ton tire load. Edge of the panel shall be ground smooth. Design of the grating shall be submitted to the PMC for approval.

- Bridge Steel Forms

  Bridges Steel Forms for the bridge shall be galvanized steel form type HB308 INV-1.52 mm or equal.

26.3.5.4 Wire Fence

26.3.5.4.1 Wire Net Fences

1. 2m high security fencing shall be fitted with 50mm galvanized wire mesh and topped by three (3) nos.-single strand fully galvanized barbed wire 2.6 x 2mm, with a design to be submitted to the PMC's approval.

2. 2m high gates (standard W-pattern) shall suit width of access either single or double leaf as agreed with the PMC, and shall be of fitted with the galvanized pipe frames of the agreed diameters plus durable brass security lock on galvanized chain with a key.

26.3.5.4.2 Barbed Wire Fence

2 m high security fencing will be fitted with 8 equally spaced double strand high tensile fully galvanized strands 250mm apart with 76mm pitch 2mm diameter barbed wires, with a design to be submitted to the PMC's approval.

Chapter 0610

27 MASONRY WORKS

27.1 GENERAL

27.1.1 Scope

This Chapter covers the requirements for masonry works including brick masonry, concrete hollow block masonry, stones paving and wet rubble masonry wall as shown in the Drawings.

27.1.2 Related Works / Sections

Chapter 0430	Conventional Concrete (CVC)
Chapter 0420	Reinforcing steel
Chapter 0510	Miscellaneous Structural Steel Works and Metalwork
Chapter 0640	Doors and Windows

27.1.3 Codes and Standards

American Society for Testing and Materials (ASTM)

ASTM C-140	Sampling and Testing Concrete Masonry Units
ASTM 476	Specification for Grout for Reinforced and Non-reinforced Masonry

27.1.4 Quality assurance

27.1.4.1 Tests and Controls

Finished surfaces shall be free of waves or distortions, square with adjoining work, flush with casings, and free of any defect detrimental to appearance or performance.

27.1.4.2 Tolerances

- Finished rendered work shall be true, plumb, or level and straight to a maximum tolerance of 3mm in 1 m.
- Finished unrendered work shall be within the following tolerance:
  - Variation from plumb, level and straight: 3mm in 1m.
  - Alignment with columns: maximum 6mm from true line.
  - Variation from unit to adjacent unit: 1.5mm maximum.
  - Variation of joint thickness: 3mm in 1m with a maximum of ± 20% the specified thickness.
- The flatness of the stone masonry will be such that irregularities will be less than 5 cm.

27.1.5 Submittals and Approvals

- The method of connection between the masonry works and the reinforced concrete structure shall be submitted to the PMC for approval.
- The quality of the rock stones to be used for stone masonry shall be submitted to the PMC for approval prior placing.
- The grout mix design shall be submitted to the PMC for approval prior to commencement of the Works.
- Samples of concrete hollow blocks (hereinafter call as CHB) shall be submitted to the PMC for approval. One sample of CHB wall conforming to the requirement of this Chapter shall be constructed by the Contractor in the place directed at Site. The size shall be approximately 2000mm long and 800mm high and shall be properly maintained during the construction period. The certificate of test result for proposed CHB shall be submitted to the PMC for approval. Otherwise the Contractor shall carry out testing for CHB at an authorized laboratory approved and submit the results to the PMC for his approval.

27.2 MATERIALS

27.2.1 Bricks

Bricks shall be of 60 x 120 x 240 mm in size unless otherwise approved by the PMC. The bricks shall be uniform in size and shape and shall be deep red in color and sufficiently well burnt. Bricks shall be wholly clean and free from flaws, cracks or under-burnt lumps of any kind. Bricks shall have sharp edges and angles and even surfaces. The Contractor shall submit to the PMC sample bricks for his approval.

27.2.2 Concrete Hollow Blocks

Concrete hollow blocks shall be of hollow core load-bearing concrete blocks and hard, even in shape, square with true arises, well matured and dense, well consolidated mixture having external dimensions of 390mm x 190mm. The thickness of the block shall be 190mm as shown and directed by the PMC. The concrete hollow block shall have a compressive strength of not less than 4 MPa and apparent specific gravity, air dried of not less than 1.7 conforming to ASTM C90-66T or equivalent approved by the PMC.

All units shall be sound and free of cracks or other defects, and shall have uniform color, texture and appearance.

27.2.3 Stones for Paving and Rubble masonry

Stones shall be made of sound rock selected from quarry site approved by the PMC.

Stones shall be sound, free from seams, weathered parts, dirt and earth which may prevent the proper adhesion of the mortar, and will be brushed and cleaned if necessary.

The size of the stones shall be of 20 cm to 30 cm diameter in stone paving and 20cm to 50cm in wet rubble masonry wall, with the exception that smaller stones may be used for pinning and for filling the interstices.

The stones shall be roughly squared where required. All shaping or dressing or stone shall be done before the stone is laid in the masonry work.

27.2.4 Concrete Lintels

Lintels for doors, windows and other openings left in the concrete block walls and partitions shall be reinforced concrete designed according to the span of the opening, but not less than 10 x 15 cm. Each lintel shall be reinforced with a minimum of four 10 mm dia. bars.

27.2.5 Mortar For Placing Concrete Blocks or Bricks

General requirements for sand used in concrete (Chapter 0430) applies except that the sand for mortar shall contain no particle greater than 2 mm. The mix shall be 400 kg cement per m³ of sand. The mortar is to be mixed dry in a mechanically operated drum type mixer and water shall be added after the constituents have been thoroughly mixed. Mortar which has begun to set or which has been mixed for more than 30 minutes shall not be used or remixed.

The mixer shall be operated at the speed recommended by the manufacturer and the total quantity of materials mixed in each batch shall not exceed the rated capacity of the mixer. The entire content of the drum shall be discharged before a new cycle of batching is started and at all times the inside of the drum shall be kept free from a build-up of materials. The mixer drum shall be thoroughly cleaned prior to change of mix or on cessation of mixing.

27.3 EXECUTION

Preparation:

- All surfaces designated to receive brick or concrete blocks shall be clean and level to the lines and grades shown on the Drawings or as directed.
- Laying of bricks or blocks shall not proceed until the PMC has inspected and approved the prepared surfaces.
- The surface to receive stone masonry shall be cleaned and all geological overbreaks shall be filled with stone and mortar or with concrete.
- Water shall be diverted away from surfaces by drains or surface pipes

27.3.1 Blockwork

- Blockwork (brick and concrete hollow block) shall be built without recesses or projections unless otherwise shown on the Drawings. Blocks or bricks shall be soaked in water before use. The tops of walls left off shall be wetted before work is recommenced. Blocks and brick shall be well buttered with mortar before being laid and all joints shall be thoroughly flushed up, raked or pointed as the work proceeds. Except where otherwise specified vertical and horizontal joints are not to exceed 10mm in thickness
- Blockwork shall be carried out in a uniform manner such that no portion shall be more than 1m above another. Blockwork shall be kept true and square and all units properly bonded together. Particular attention shall be paid to ensure strict verticality of blockwork.
- Half block walls and inner and outer skins of double-skin walls and casings shall be built in stretcher bond.
- The brick work, unless otherwise specified, shall be built in English bond with no joint wider than 10mm. Except where indicated to be fair face, all joint shall be thoroughly raked out as the work proceeds. For fair face brick work, after the joint mortar has begun to stiffen, joints shall be squarely raked to a depth of 6mm and clean. Then the joint shall be finished with cement mortar of 1:1 ratio. Expansion joints shall be provided in external blockwork at approximately 12m centers, or as shown on the Drawings or directed by the PMC. The joint shall be formed with "Flexcell" or other approved expansion strip and sealed with "Seaastic" or other approved joint sealer. Care shall be taken to ensure that the wall is properly bonded or tied at each side of the expansion joint to prevent any loss of stability.
- The concrete hollow block to receive cement mortar finish shall be laid in stack bond masonry with joints approximately 10mm thick of which mortar shall have one part of cement and three part of sand (1:3). All horizontal and vertical joints shall be struck off flush with the wall as each block is laid. The concrete hollow block with pointing finish shall be laid in the same manner as above. After mortar has begun to stiffen joints shall be finished to face work by square raking to a depth of 6mm and clean. The joints shall then be finished with cement mortar 1:1 ratio. The hollow of the block through which the reinforcement bars runs shall be thoroughly filled with 1:3 cement mortar.
- The concrete hollow block walls shall be reinforced with reinforcing bars D13 at every 800mm for vertical and the distribution bars D10 shall be provided at every 600mm in horizontal. The reinforcing bars shall be anchored into the adjacent structure with the length of 40 times of bar diameter for vertical bars and 25 times of bar diameter for horizontal bars. The dowel bars shall be preinstalled into the adjacent structures at an interval and location to connect with the vertical and horizontal bars. Splice length shall be 40 times of the bar diameters.

- When required, galvanized steel ties, meshes or cramps shall be carefully embedded in the mortar.
- All blockwork shall be cleaned down on completion to remove mortar dropping, runs or stains and again before rendering to remove any efflorescence.

27.3.2 Bonding of Blocks / Bricks to Concrete Works

Where blockwork abuts concrete columns, walls or beams, there shall be adequate bonding between the two materials by means of wire ties or approved wire mesh which shall be recessed 40mm from the face of the brickwork or blockwork at such intervals as approved by the PMC.

27.3.3 Lintels and Caulking

- Where required to install doors, windows and any other openings in the brick or concrete hollow block wall, reinforced lintels shall be provided over all openings. The lintels shall rest on both sides of adjacent block walls for more than 200mm long. The lintels shall have 200mm high by thickness of concrete block walls with two or four 10mm dia. reinforcing bars and 6mm dia. stirrups at 150mm maximum spacing. All free end of the top of concrete hollow block walls shall be provided with concrete lintels having minimum 150mm depth by thickness of walls. The Contractor shall design the lintels and obtain PMCs approval.
- The spaces around the door frames and built-in items shall be solidly fixed with mortar.
- Spaces around the door and window hold fasts shall be filled with concrete

27.3.4 Rendering

- Blocks/bricks which are to receive rendering or plastering shall have a surface which will ensure good adhesion of the applied finish.
- Projecting burs of grout shall be removed and the surface shall be wire brushed and cleaned with scrubbers. If the surface is smooth it shall be prepared by roughening with a pointed tool to form pocks, not less than 3mm deep, spaced not more than 50mm apart. Surface shall be cleaned and wetted before plaster is applied.
- Outside rendering shall be of uniform thickness applied in one coat of 15mm minimum.
- Inside plastering shall be 20mm thick made of two layers: 15mm under coat and 5mm finished coat.
- Following completion of rendering all surfaces shall be thoroughly cleaned. Any unsatisfactory work shall be removed and the rendering shall be re-applied.

27.3.5 Stone Paving and Wet Rubble Masonry Facing Wall

- Stone paving shall not commence until the wall foundation has been approved by the PMC.
- Stone paving shall be built without recesses unless shown in the Drawings.
- Stones shall be soaked before placing and shall be laid in full mortar beds. Stones will not be considered properly bedded until mortar exudes from the underside of the bedded stones.
- Stones shall be well buttered with mortar before being laid and all joints shall be thoroughly flushed up, raked as the work proceeds. Except where otherwise specified, joints are to be 10 to 30mm in thickness. The stones shall be arranged so as to be aesthetically pleasing.
- Weepholes (50mm dia.) shall be constructed as shown in the Drawings or as directed by the PMC.
- Within twenty four (24) hours of construction, the joints on all exposed faces shall be raked clear of loose mortar and pointed with mortar so that the joints are recessed approximately 6 mm. The wall shall be kept wet while pointing is being done.
- After pointing is completed and mortar set, projecting burs of grout and mortar shall be removed from the stone surface which shall be wire brushed and cleaned with scrubbers. Masonry shall be protected from sun and kept moist for at least three days after pointing.
- For wet rubble masonry facing wall, stones shall be moistened and hand-placed with uncoursed close joints onto a bedding of 20cm thick drainage and 15cm thick filter layers. Spaces between stones shall be filled with mortar. Surface joints shall be finished struck. Mortar for wet rubble masonry walls shall comprise 3 parts of clean fine aggregate to one part of cement by volume. Fine aggregate and cement shall comply with the requirements specified in the Chapter 0430. The upper surface of the walls shall be finished smooth with trowelled layer of 10cm thick capping concrete.

27.3.6 Wet Rubble Masonry Gravity Wall

- For wet rubble masonry gravity wall, stones shall be moistened and hand-placed on mortar bed to make gravity wall shape as shown in the Drawings. Spaces between stones shall be filled with mortar. Surface joints shall be finished struck. Mortar for wet rubble masonry walls shall comprise 3 parts of clean fine aggregate to one part of cement by volume. Fine aggregate and cement shall comply with the requirements specified in the Chapter 0430. Weepholes (50mm dia.) shall be constructed as shown in the Drawings or as directed by the PMC.

- Sand and gravel layer will be placed behind wall for drainage purpose under the Chapter 0320.

Chapter 0710

28 MONITORING INSTRUMENTATION

28.1 GENERAL

28.1.1 Scope

This Chapter deals with the requirements governing the supply, storage, installation, and commissioning of the instrumentation to be installed in and around the RCC dam, and the readings to be taken during construction period for the monitoring of its structural behavior, as shown in the Drawings and/or required by the PMC.

28.1.1.1 Work Included

The Contractor shall be responsible for design, configuration and commissioning of the of the Dam Instrumentation and Monitoring Sytem, and the timely procurement of all instrumentation components, allowing all instruments at least two (2) months on site to acclimatize to local conditions. The dam monitoring instruments and equipment to be placed and installed shall be the latest model and type at the date of placement and installation. Before placing any purchase orders, the Contractor shall request PMC's approval of his proposed instrumentation selection.The Contractor shall store, test and calibrate as required, transport, install, complete commissioning and maintain all the procured instrumentation (including all cabling, power supplies, auxiliaries, readout units, etc). 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 protection facilities.

All electronic instrumentation installed shall be integrated into an Automated Data Acquisition Systems (ADAS). The contractor shall be responsible for the design, configuration and commissioning of the ADAS system.

The Contractor shall further construct the defined instrumentation shafts in the RCC and provide the necessary cable racks for power supply and connection of instrumentation to the designated monitoring stations

Installation procedures shall be planned well in advance of scheduled installation dates. The Contractor shall issue method statements (step-by-step procedures) to the PMC for the drilling methodologies, installation of the individual instruments, cabling and protection, making use of the instrumentation manufacturers' instruction manuals and state-of-the-art knowledge. This shall include a detailed cabling routing plan and instrumentation numbering system.

Installation of all instrumentation shall only be undertaken by experienced Contractor's personnel, whose qualifications shall be proven to the PMC. The personnel involved in the testing, calibration, installation, commissioning, monitoring and maintenance of the instrumentation system shall be suitably qualified and experienced in this field. Specialists from the relevant instrumentation suppliers shall visit the site to train the Contractor personnel as required.

Factory calibration shall be undertaken by the relevant manufacturers and individual calibration certificates for each instrument shall be submitted to the PMC prior to installation.

Pre-installation acceptance tests (and calibration as required) shall be performed by the Contractor, in the presence of the PMC, immediately prior to installation of the instruments. The Contractor shall provide detailed records of the pre-installation acceptance tests and calibration as well as of the installation of the instruments.

Initial readings, including calibration and commissioning of the installed instruments, shall be carried out in the presence of the PMC to prove the proper installation and function of the instruments.

The Contractor shall submit an instrumentation installation schedule for each instrument and location for approval by the PMC. The instrumentation schedule shall be consistent with the issued construction schedule and shall be submitted to the PMC prior to installation of the first instruments.

All instruments in the RCC dam shall be installed in sequence with the progress of the Works, and in particular with the progress of the RCC and the construction of the galleries. The Contractor shall be responsible for the protection of the instruments, cables and readout units at all times during construction.

It is a requirement of this contract that all the instrumentation, inclusive of the ADAS shall be fully operational and approved by the PMC before reservoir impoundment commences.

The Contractor shall be prepared to accept changes in the instrumentation layout or additional installations of instruments, if required by the PMC, and shall also be prepared to receive installation instructions for changed site conditions. The Contractor shall provide access to all instrumentation locations at all times during construction.

A meteorological station shall be purchased by the Contractor at the earliest possible date. A compatible data management and presentation for this instrumentation tool shall be available before the start of dam construction.

28.1.1.2 Instrumentation Monitoring

The Contractor shall be responsible for all instrumentation readings for the duration of the Construction and Defects Notification Periods, and for the sensible and sustainable recording of all instrumentation data and its management.

Accordingly, it will be in the interest of the contractor to have the ADAS system operational as soon as practically possible. Until such time that the ADAS is operational, the Contractor shall download all data to the designated laptop computer. The intervals for recording data for each instrument and the requirements in respect of reporting instrument data to the PMC are defined in Clause 3.1 of this Chapter.

Measurement reports including graphic presentation of the readings shall be prepared by the Contractor and submitted to the PMC on a weekly basis for the readings to be taken as indicated in Clause 3.1.6 below.

The interpretation of the measurements will be undertaken by the PMC.

28.1.2 Related Works / Sections

Chapter 0220 Surface Excavation

Chapter 0240 Drilling and Grouting

Chapter 0430 Conventional Concrete (CVC)

Chapter 0433 Roller-Compacted Concrete (RCC)

28.1.3 Definitions

ADAS	: Automated Data Acquisition Systems
RMU	: Remote Monitoring Unit
RCC F.S	: Roller Compacted Concrete: Full Scale

28.1.4 Codes and Standards

All instrumentation shall operate on 230V single phase 50Hz power supply. The Contractor shall be responsible for all transformers and associated cabling to instruments operated on low voltage systems (e.g. 12V)

28.1.5 Quality Assurance

28.1.5.1 General

Instruments shall be installed only in the presence of the PMC.

Instrumentation installation shall be supervised by personnel with a minimum of ten (10) years' experience in this specialized line of work.

The PMC may direct that instruments be installed only during daylight hours. If installation needs to proceed at night, suitable lighting shall be supplied.

All instruments and cables are to be regularly checked and tested for functionality during installation.

The Contractor shall operate the relevant readout boxes for taking regular readings and to calculate the data and present the results to the PMC.

28.1.5.2 Acceptance Criteria

Acceptance of installations will be determined by the PMC, based upon readings taken immediately after installation and readings taken during the on-going construction activities. Instruments which fail for whatever reason shall be replaced forthwith.

28.1.5.3 Installation

Where possible and appropriate to the relevant installation, calibration shall be done by the manufacturer in his factory.

Where the site configuration requires on-site calibration, this shall be undertaken by suitably qualified personnel (See Clause 1.6) to fully compensate for the site installation's unique elevation, orientation, environmental conditions, etc.

Tolerances

Instruments shall be installed within 100 mm of the locations shown in the Drawings or directed.

28.1.5.4 Protection of Instruments during Construction

The Contractor shall be responsible for protection of all instruments against damage or displacement by construction plant, lightning and/or blast damage. Suitable construction procedures shall be developed, which will be for the cost of the Contractor, which neither compromise the effectiveness of the instrumentation, nor the integrity of the RCC. Any instrument damaged by the Contractor's plant shall be replaced at the Contractor's own expense.

28.1.5.5 Sequencing - Scheduling

The scheduling of the procurement, supply and installation of all instrumentation shall be built into the Work Execution Programme, with specific line items being provided for each instrument.

The Contractor shall make due allowance in his construction programme for any delays due to the installation of the instruments and associated readout devices, cables and accessories. Notwithstanding, the Contractor shall design his instrumentation installation to minimize, or eliminate any impact on the progress of RCC placement.

28.1.5.6 Changes

Should any instruments or monitoring equipment become faulty or damaged, the Contractor shall immediately submit to the PMC a detailed memorandum summarizing the problems experienced. The faulty or damaged equipment shall then be replaced as soon as possible. The instrument supplier's instructions for replacement shall be followed to ensure best use of devices and equipment.

Monitoring equipment shall be re-calibrated at the intervals as defined by the supplier, at the expense of the contractor, during his period of responsibility.

28.1.5.7 Monitoring

The Contractor shall take readings from the instruments during execution of the Works. The PMC will confirm the initial readings immediately following approval of their installation.

The Contractor may be required to delay placement of fill or concrete over any instrument, ducts, cables or leads, and splices or couplings, until after the initial readings of the instrument have been taken. The Contractor shall maintain access and lighting to all instrument/readout locations for the taking readings for the full contract period.

All instrumentation read-out data shall be backed up to a separate off-site location

Any monitoring undertaken by the PMC shall not relieve the Contractor of his responsibility for the proper execution of the Works as regards his own monitoring obligations.

As part of the monitoring regime, any other observations made which may relate to accuracy of readings shall be noted and reported to the PMC.

Only monitoring equipment with valid calibration certification shall be used, including leveling equipment for precise leveling.

28.1.6 Submittals and Approvals

- Within ninety (90) days of the Commencement Date, the Contractor shall submit for PMC's approval the schedule of delivery and installation for all instrument types in relation with the Construction program;
- At least two (2) months before ordering the supply of any instrument, data loggers and/or acquisition systems, the Contractor shall submit for PMC's approval:
  - Each instrument's supplier details
  - The installation subcontractor details and Curricula Vitae (CV) of the personnel in charge of the supervision.
  - The proposed instrument referencing system (See Clause 3.3)
  - The specifications, model and size of each instrument and associated readout devices, cables and accessories. The submittal shall include all details related to the proposed instruments and the manufacturer's installation specifications,
  - Detailed specifications and drawings defining the proposed cabling routing.
  - Details of the ADAS system, including, but not limited to the database and presentation software to be used, the planned customization and graphical presentation configurations, the groups of instruments to be graphed, etc.

- At least twenty eight (28) days prior to the scheduled date of installation, the Contractor shall submit for PMC's approval:
  - Proposed procedures for installation, backfilling and testing, if different from those specified;
  - Proposed methods of access to instrumentation and temporary readout panels, and protection during construction;
- No later than fifty six (56) days prior to the commencement of classroom training, the Curricula Vitae (CV) of the personnel proposed for operational and maintenance training shall be submitted to the PMC for approval
- 5. After the installation of the first instruments, the Contractor shall submit an updated instrument reading listing of all installed instruments to the PMC in electronic format on a weekly basis. These submittals shall continue until the expiry of the Defects Notification Period.
- No later than two (2) months after initiation of impoundment, as-built drawings of the installed instrumentation and associated readout devices, cables and accessories.
- No later than two (2) months after initiation of impoundment, the operational manuals for the ADAS system.

28.2 MATERIALS

28.2.1 General

Instruments for RCC dam monitoring shall include:

- Survey prism targets and survey monuments;
- Geodetic survey instruments;
- Pendulums, both hanging and inverted;
- Inclinometers;
- Multiple points borehole extensometers (rock meters);
- Electrical piezometers;
- Water temperature meters;
- Air temperature meters;
- Distributed fiber optic temperature measurement system ;
- Thermocouples;
- Effective concrete stress meters;
- Long-base-strain-gauge-temperature-meters;
- Strain gauges;

- Flow measuring weirs;
- Strong motion accelerometers;
- Water level staff gauges;
- Water level transducers;
- Data loggers, etc;
- ADAS system.

The Contractor shall procure, install and commission the different instruments suitable for the site conditions (RCC dam, mountainous with hot summers and cold winters), complete with accessories, installation devices and manuals after the approval of the proposed instrumentation details by the PMC. The dam monitoring instruments and equipment to be placed and installed shall be the latest model and type at the date of placement and installation.

All instruments and their associated cabling, read-out units, installation consumables, appurtenances, etc. shall be procured from manufacturers having a worldwide reputation and proven track-record in the field of geotechnical or seismic instrumentation. Specifications and technical data of the instruments proposed by the Contractor shall be submitted to the PMC for approval before placing the purchasing orders.

Installation shall be carried out where shown in the drawings and/or instructed by the PMC, as soon as the progress of the construction allows. Reading of the instruments shall be commenced as soon as the progress of the construction allows.

The Contractor shall submit detailed step-by-step procedures (method statements) on the complete installation procedures for each instrumentation type to the PMC for approval. Drilling of boreholes, logging of cores, flushing of holes and checking that holes are entirely free of any debris and drill mud will fall under the responsibility of the Contractor.

It is the Contractor's responsibility to procure the different instruments and set up the instrumentation installation works in accordance with the dam construction schedule. The installation of dam instruments shall not interfere with the continuous process of RCC placement.

28.2.2 Cabling and Transient Protection

All cabling shall be multi-cored, purpose designed instrumentation cable of a type approved by the manufacturer of the instrument whose signal is to be carried. Individual insulated conductors shall be twisted into pairs inside a conductive insulating material in the cables. The cables shall be of the heavy duty insulated type of robust construction and suitably durable and reliable for RCC dam construction. All cable must include all requirements for waterproof splicing, waterproof connection to instruments and appropriate end connections and identification markings at readout points. All related

and necessary sundry and miscellaneous items shall be deemed to be included with the supply of the cables.

All instruments shall require earthing and lightning protection of adequate capacity to eliminate related damage to the instrument, or cabling during a lightning strike.

Cables shall be suitably protected against possible damage during RCC and concrete placement and general construction activity. Any installation damaged during RCC and/or concrete placement shall be replaced by the Contractor at his own cost. This may include full replacement of the installation in higher RCC layers.

28.2.3 Installation in the RCC

The drawings indicate the general locations of the instrumentation and anticipated cable routes. Generally, cabling shall be directed horizontally in the RCC towards the galleries or instrumentation shafts/pendulum shafts. Cabling directed to a particular gallery level shall continue to the associated RMU Station at that gallery level. Cabling directed to the top gallery level shall remain on the same half of the dam as the instruments in its route to the RMU Station.

The contractor shall plan his operations around the locations of the instruments and cable routes.

Instruments designated to be embedded in RCC shall be installed within the monolithic body of the RCC and within the uninterrupted course of RCC placement. It is more important to install instruments in the ongoing placement than to place all instruments in the same RCC layer. It is considered significantly preferable to install all instruments required at one "elevation" over a maximum of three progressive placement layers, than to install all instruments in the same layer with the consequence that a warm, or even, a cold joint is required between the applicable and the successive layers.

The Contractor shall design and arrange all of his activities and procedures to minimize the risk of damage to installed instruments and instrumentation cables. Until second set of the RCC, all instruments shall be read hourly to ensure correct function. Should any malfunction be detected, the instrument will be excavated and replaced. During the first two days after instrument installation, the alignment of the cabling and the instrument locations will be marked with flags in the surface of the RCC placement area and the passage of any heavy traffic over these areas shall be kept to a minimum.

28.2.4 Operational Conditions

Unless otherwise stated, all instrumentation installed in/on the dam shall be suitable for use under the following conditions:

- Operation temperature range: -15°C to +70°C
- Operation humidity range: 5% to 100%.

28.2.5 Survey Prism Targets and Survey Monuments

The Contractor shall procure and install built-in Survey Targets Receptacles and removable Survey Prism Targets (stationary geodetic light reflectors) on the downstream crest of the dam for monitoring the displacements of the dam by geodetic precision survey.

The receptacles shall be grouted into the concrete of the dam wall crest, approximately 100mm from the downstream edge, to form a permanent reference point. Each receptacle shall be provided with an alignment and mounting frame and a lockable, hinged protection cover. The protection cover shall be of a strong and durable construction to allow the protection of the survey target receptacle from all potential vehicle and other hazards on the crest of the wall and will seal against the mounting frame to ensure weather-proofing when the cover is closed. The alignment frame must be adequate to ensure the absolute vertical alignment and strong anchorage of the receptacle. All components shall be manufactured in heavily proportioned brass. The receptacles shall have a 5/8 inch Wild bayonet fit to receive and ensure the accurate location of the prism target. The prism target receptacle shall allow the repeated absolute accurate location of the prism to within 0.1mm.

The prism targets shall allow accurate targeting from a distance of 2,500m, be visible by at least three survey targets on the abutments and have a vertical target range of 45°. The Installation location of the reflectors shall be such that a clear sight is provided between the relevant survey monuments and the reflectors. The targets shall be of a robust, high quality construction, shall be individually numbered for identification and shall be provided with a robust, weather-proof case for protection during storage. A very high level of machining accuracy must be applied for the prism manufacture (<1mm accuracy), and a positioning tolerance of 0.1mm shall be maintained at all targets.

Survey monuments shall be as per the details on the Drawings. These shall be constructed at suitable locations on sound, stable rock, approved by the PMC. The mounting brackets shall be manufactured of brass and compatible with the Geodetic Survey Instruments as per Clause 2.6 below.

The locations of the prism targets and monuments shall be as provisionally shown in the Bid Drawings. The final layout will be confirmed by the PMC once the survey triangulation system is finally set up.

The Contractor shall be responsible for protecting the survey monuments and the instruments from any damage or displacement and for the maintenance of the same at his own cost during the execution of the works.

28.2.6 Geodetic Survey Instruments

The Contractor shall procure a tachymeter (laser total station) and an electro-optical level including a 2m and 5m leveling staff gauge for alignment, leveling and triangulation as indicated below. The Contractor shall furnish a high quality tripod with each instrument.

Tachymeter specification:

- Measurement distances 1.5m to 2.5km (Strong haze, 5km visibility, or strong sunlight, severe heat shimmer)
- Precision of distances <1mm ±1ppm (Ditto)
- Precision of angles <±0.5'' (0.15mgon) (ISO 17123)
- Distance resolution ±0.01mm
- Angle resolution ±0.1''
- Magnification 30x
- Shortest focusing distance 1.7m
- Automatic target recognition for standard reflector prisms

Leveling specification:

- Measurement distances 1.5m to 2.5km (Strong haze, 5km visibility, or strong sunlight, severe heat shimmer)
- Accuracy <0.1mm/km (Ditto)
- Resolution <±0.1''
- Magnification 32x
- Shortest focusing distance <1.6m
- Insensitive to direct solar radiation

All necessary accessories for the operation of the instruments shall be included, including accessories required such as, but not limited to, a device for data transfer to a PC, software for data transfer and evaluation on a PC, operation manuals, batteries, spare batteries and battery chargers, etc.

28.2.7 Pendulums and Reading Stations

The Contractor shall procure, install and commission complete pendulums and reading stations to monitor deflections of the dam structure as shown in the Drawings and/or instructed by the PMC.

Specified lines of pendulums at critical sections will be installed between gallery levels. The top pendulum on the specified flanks shall be installed from special chambers in the crest of RCC dam, while the lower pendulums will extend from the lowest gallery at the specified depth into the foundation, as indicated on the Drawings.

28.2.7.1 General

All pendulum components shall be of a robust construction and shall be suitably protected against corrosion for reliable long-term use in a damp and humid environment. All the necessary associated nuts, bolts, washers, installation cord and clamps to allow successful installation and operation shall be included.

Suitable, strong support frames and measurement tables, manufactured in robust, corrosion protected materials, shall be provided. The support frames must finally be bolted firmly into position.

Pendulum wires shall be of the non-twisting type, manufactured from Invar steel, 1.5mm in diameter and the ends shall be fitted with a suitable stainless steel eyelet for connection to the respective anchor system.

300mm Diameter epoxy-painted conical aluminum shields, complete with locating bushes and nylon locking screws to allow attachment to the pendulum wire, shall be provided on all pendulum wires to prevent water from interfering with observations.

Manual reading stations for coordiscope measurement and automatic reading units are to be installed in the pendulum chambers off the galleries, as shown on the drawings and/or instructed by the PMC.

The manual measuring unit shall comprise an epoxy-painted steel measuring plate with a central 150mm dia. hole, to accommodate the pendulum wire, and with four fixing bolts for location on the support frame. Two travelling vernier microscopes (per readout table) shall be mounted on the plate in such a manner as to sight the wire in orthogonal directions. Each microscope shall be fitted with a scale magnifier and a cross-hair eyepiece.

The automatic reading unit shall permit either local readings by portable PC or remote operation. The measuring unit shall consist of a half bridge differential AC excitation and shall be supplied with a calibration device and appropriate read-out devices. The measuring units shall be mounted on an appropriate epoxy-painted steel frame.

The measuring units shall be insensitive to temperature and moisture changes. Reading accuracy in both transversal (upstream-downstream) and longitudinal directions shall be:

- Optical reading ± 0.1mm
- Automatic reading ± 0.1mm

The range of reading shall be

- Upstream-downstream direction 0 to 100mm
- Dam axis direction 0 to 50mm
- Vertically 0 to 50mm

28.2.7.2 Hanging Pendulums

The hanging pendulums shall include:

- Pendulum wire, deflectors, reading stations, instrumentation cabling to the RMU station, mounting frames, nuts, bolts, etc
- The upper suspension point shall be accessible from the dam crest or the upper gallery to details shown on the Drawings. The upper anchor system shall include a galvanized steel frame fixed to the structure on which a stainless steel rail shall be mounted with a sliding block bringing a tail sheave and the locking nut for the wire. The sliding block shall allow the positioning of the wire and of the tensioning weight inside the lower tank while the locking nut shall allow adjustment of the wire length.
- Pendulum shaft furnished by the Contractor and built by encasing a precast concrete pipe with an inner diameter of not less than 0.6m into the RCC during the dam construction. Alternatively, the use of slip forms is allowed. Deviations from vertical alignment in both cases shall be:
  - Within a 10 m length: ±20mm
  - For overall length ±50mm
- It shall be taken into consideration that, due to the relatively weak foundation and height of the dam, a deformation between the lowest foundation and dam crest of up to 210mm towards downstream is expected during construction and first filling of the reservoir.
- Anchor unit: The anchor unit for the hanging pendulum shall comprise a threaded 16mm stainless steel bolt, fitted with a cadmium-plated steel pivot pin to connect with the stainless steel eyelet on the pendulum wire. A 400mm long cross beam and two suitably sized centralizing washers, complete with rubber seals to allow grouting, shall be provided.
- Tensioning weight: The weight shall comprise a solid stainless steel cylinder of at least 10kg mass. Paddles shall be welded to the cylindrical weight in order to damp any rotational movement in the oil damping tank. One end of the cylinder weight shall be fitted with appropriate eye-bolt fittings to carry the pendulum wire and the installation chord.
- Damping tank for hanging pendulum: The tank for damping the movement of a hanging pendulum shall be cylindrical, manufactured in PVC and of adequate dimensions to accommodate the applicable pendulum weight. Appropriate quantities of suitable mineral oil for the damping tanks shall be furnished.

28.2.7.3 Inverted Pendulums

The inverted pendulums shall include:

- Pendulum wire, deflectors, reading stations, instrumentation cabling to the RMU station, mounting frames, nuts, bolts, etc
- Anchor pendulum shaft, constructed by drilling a vertical borehole of 300mm inner diameter from the gallery into the dam foundation. Deviations from vertical alignment shall be maximum 50mm along the entire borehole.

  Inverted pendulum wires are to be secured at their bottom end, within the borehole, using an appropriate proven grouted, concrete anchor system. The anchor system is to be secured into the bottom of the borehole with high strength cement mortar placed through a tremmie pipe. The pendulum wire shall be bolted to the anchor system, with a stainless steel bolt passing through a stainless steel eyelet on the end of the wire, to ensure precise central fixing. A suitable adjusting rod shall be provided to tension the wire, once installed.
- Floating body, damping vessel, set plates for three (3) directions. The float shall consist of a rigid PVC annular chamber of approximately 600mm O.D., 300mm I.D. and 250mm high, filled with foamed polystyrene. Cross beams with a central adjustable tie bar and pulley shall connect the float with the pendulum wire; 200mm of adjustment shall be available to take up slack and to tension the wire. The float tank and lid shall be constructed in rigid PVC with a glass fiber reinforcing skin. The tank shall have a +150mm I.D. central riser pipe to take the pendulum wire and to locate the float.

28.2.8 Multiple Points Borehole Ectensometers for Dam Foundation

Multipoint borehole rod extensometers (Rock Meters) for dam foundation monitoring shall be installed in boreholes with the required diameter. Each borehole shall be equipped with five (5) single extensometer rods, anchored at depths of -80, -60, -40, -20 and -10m below the dam–rock interface.

The proposed extensometers shall be specifically designed for the measurement of rock deformations and shall essentially be composed of five (5) single gliding rods of stainless steel, inplace rod anchors, protective tubes, the measurement head and the readout deflectometer. The measurement heads shall be grouted into the upper borehole opening. The in-place grouted bottom anchors at one end of the rods and the head of the extensometer shall be the fixed points between the sections.

The multipoint extensometers shall generally be installed in vertical boreholes, but which may be up to an inclination of 20° from vertical.

The borehole shall be 1 m longer than the longest rod. (i.e. 81m long) The top 0.5m of the borehole shall be enlarged to not less than 120mm to house the measurement head. After complete installation, the space between the protective tube and the borehole wall shall be filled with grout.

Each multipoint extensometer shall be equipped with thermometers corresponding to requirements of the thermistor type instruments described in Clause 2.12 herein below, at mid distance between the rods fixed points.

Each anchor of the extensometers shall be provided a special bayonet modification which will allow the measurement rod to be disengaged from the anchor to facilitate the checking of the correct functioning of the instrument.

The extensometers shall be of waterproof design and shall comply with the following requirements:

- Deflection measurement range 200mm
- Accuracy/resolution ±0.2mm

In accordance with the cable and RMU-station layouts (See Clause 2.3), suitable numbers of automatic readout units, data loggers (multi-channel for connection of more sensors on one logger) and backup power supplies, all of a type recommended by the instrument manufacturer shall be provided with these instruments.

A compatible portable read-out unit shall be supplied with the instruments for the interim period until the ADAS is up and running. Where the latter unit can be used on more than one vibrating wire type instrument, only suitable numbers to meet with the monitoring requirements need be procured.

The diameter of the holes, the permissible deviation from the design alignment and the installation procedures shall be as recommended by the manufacturer of the instrument.

The head shall be protected with a strong steel cap suitable to preserve the head from any damage that can occur during construction.

28.2.9 Inclinometers

The Contractor shall procure, install and commission inclinometers for the monitoring of the behavior of the upstream portion of the dam under loading where shown in the Drawings or instructed by the PMC.

The inclinometers shall be specifically designed for the measurement of structural deformation. These shall essentially be composed of inclinometer probes and grooved inclinometer casings installed vertically on the sides of the pendulum shafts as these are constructed, and shall at all times be protected from damage, blockage, etc. The attachment to the shafts shall be in accordance with the manufacturer's recommendations. The grooves shall be orientated for measurement parallel and perpendicular to the dam axis. The casings shall be manufactured from pultruded fiberglass.

Two inclinometer probes, complete with cable, accessories and readout equipment shall also be provided, suitable for use with all casings installed. Manual measurement of deformation shall be undertaken using the supplied probes at the frequency described

in Clause 3.1.6. The Inclinometer sensors shall be of the Micro-Electro-Mechanical (MEMS) type. The stability of the Micro-ElectroMechanical sensor output shall be unaffected by changes in cable resistance caused by water penetration, temperature variations and contact resistance.

A portable readout unit integral to the cable roll, of a type recommended by the instrument manufacturer shall be provided with each instrument. Provision to link this into a suitable receiver at the RMU-Station shall be provided such that, once the portable readout unit is docked with this receiver, new data will be automatically read by the ADAS system.

The inclinometers shall be of waterproof design and shall comply with the following requirements:

- Casing individual lengths — Minimum 3m unit lengths to a maximum of 45m between gallery levels
- Casing inside diameter — > 70mm
- Casing spiral — < 0.005 Rad per 3m
- Casing deformation range — Maximum 25mm per 5m
- System accuracy — 0.1mm per m
- Probe resolution — ±0.025mm per 500mm
- Probe wheelbase — 1.0m

28.2.10 Electrical Piezometers

The Contractor shall procure, install and commission electrical vibrating wire piezometers for the monitoring of the temperature and uplift pressure in the rock of the dam foundation where shown in the Drawings or instructed by the PMC.

The electrical piezometers shall essentially consist of a diaphragm and vibrating wire pressure sensor, housed in a stainless steel sealed body with a porous filter tip, the connecting cables and the read out unit, suitable both for local reading and for automatic remote reading.

In accordance with the cable and RMU-station layouts (See Clause 2.3), suitable numbers of automatic readout units, data loggers (multi-channel for connection of more sensors on one logger) and backup power supplies, all of a type recommended by the instrument manufacturer shall be provided with these instruments.

A compatible portable read-out unit shall be supplied with the instruments for the interim period until the ADAS is up and running. Where the latter unit can be used on more than one vibrating wire type instrument, only suitable numbers to meet with the monitoring requirements need be procured.

Electrical piezometers shall comply with the following requirements:

- Measuring range up to 3.0MPa
- Accuracy <0.1% F.S.
- Resolution <0.025% F.S.
- Thermal sensitivity shift <0.05% F.S / °C

Vertical boreholes shall be drilled by percussion or rotary equipment at Contractor's convenience to reach at a depth of -4m below the monolith base. The final depth of installation will be dependent on the geological conditions identified when the foundations are fully opened and will be instructed by the PMC at the time. The specified piezometers shall be installed near the bottom of the boreholes as shown on the related Drawings. The diameter of the boreholes and the instrumentation installation procedures shall be as recommended by the manufacturer of the instrument.

The piezometer unit shall contain a built-in thermistor, conforming requirements of the thermistor type instruments described in Clause 2.12 herein below.

The transducer shall be manufactured entirely in stainless steel components and hermetically sealed, forming a vacuum chamber for the vibrating wire element. The ends of the vibrating wire shall be clamped, using a swaging technique that ensures high stability, while allowing miniaturization of the components. The piezometer shall use electromagnetic coils to both pluck the wire and to convert the vibration generated into an electrical output current, whose frequency is identical to the natural resonant frequency of the wire, across the full range of applicable wire tensions. The piezometers shall be fitted with 59 micron sintered stainless steel filters (suitable for low air entry).

The stability of the vibrating wire output shall be unaffected by changes in cable resistance caused by water penetration, temperature variations and contact resistance.

The piezometers shall be inserted into the completed and stable borehole at the required depths. The piezometers shall be surrounded by a sand filter 300mm either side of the transducer which shall be completely sealed by bentonite plugs at its bottom and top part. The borehole shall be filled with grout between two piezometer locations.

Instrumentation cables shall lead to the data logger installed in the closest RMU-Station of the lowest gallery in the respective dam block.

The head of the installation shall be protected with a strong steel cap suitable to preserve the head from any damage that can occur during construction.

28.2.11 Water Temperature Meters

The Contractor shall procure, install and commission vibrating wire type thermometers for the long term monitoring of the impounded water temperature, and surface temperature of the dam during construction, where shown in the Drawings or instructed by the PMC.

The temperature sensor shall comprise a stainless steel transducer body, to which a vibrating wire element is attached. The gauge shall be protected with robust stainless steel housing. The installation will include all cabling routed in the RCC to the nearest dam gallery and in the gallery to the RMU station, and the read out unit.

The stability of the vibrating wire output shall be unaffected by changes in cable resistance caused by water penetration, temperature variations and contact resistance.

The temperature sensors are to be housed in concrete box-outs in the upstream face of the dam, the external faces of which will be protected with stainless steel gratings (to be supplied under this specification). In this environment, the temperature sensor shall be robust, water-proof, durable and suitable for reliable underwater operation over an extended period.

In accordance with the cable and RMU-station layouts (See Clause 2.3), suitable numbers of automatic readout units, data loggers (multi-channel for connection of more sensors on one logger) and backup power supplies, all of a type recommended by the instrument manufacturer shall be provided with these instruments.

A compatible portable read-out unit shall be supplied with the instruments for the interim period until the ADAS is up and running. Where the latter unit can be used on more than one vibrating wire type instrument, only suitable numbers to meet with the monitoring requirements need be procured.

The water temperature meters shall comply with the following requirements:

- Measuring range -20°C to 80°C
- Accuracy ±0.2 °C
- Resolution 0.1 °C
- Response time 2.5 minutes
- Thermal equilibrium 15 minutes

The Contractor shall install the thermometers, cables, etc in accordance with the recommendations of the manufacturer.

28.2.12 Air Temperature Meters

The Contractor shall procure, install and commission electrical resistance type thermometers (thermistors) for the short and long term monitoring of the air temperature at the downstream side of the dam, where shown in the Drawings or instructed by the PMC.

Each thermometer installation shall essentially consist of an electrical resistance type thermometer housed in a shock resistant robust stainless steel body, of the required cabling, routed in the RCC to the nearest dam gallery and in the gallery to the RMU station, and of the read out unit.

The temperature sensors are to be housed in concrete box-outs on the steps on the downstream face of the dam, the external faces of which will be protected with stainless steel gratings (to be supplied under this specification). In this environment, the temperature sensor shall be robust, weather-proof, durable and suitable for reliable operation over an extended period.

In accordance with the cable and RMU-station layouts (See Clause 2.3), suitable numbers of automatic readout units, data loggers (multi-channel for connection of more sensors on one logger) and backup power supplies, all of a type recommended by the instrument manufacturer shall be provided with these instruments.

A compatible portable read-out unit shall be supplied with the instruments for the interim period until the ADAS is up and running.

Electrical thermometers shall comply with the following requirements:

- Measuring range -20°C to 80°C
- Accuracy ±0.2 °C
- Resolution 0.1 °C
- Variation in resistance >110 ohm/ °C (including cable)

The Contractor shall install the thermometers, cables, etc in accordance with the recommendations of the manufacturer.

28.2.13 Distributed Fibre Optic Temperature Measurement System

The Contractor shall procure, install and commission a distributed fiber optical cable temperature measurement system (DFTM) for the recording of the evolution of temperature in the RCC as it hydrates as well as the long term monitoring of the temperature of the dam, where shown in the Drawings or instructed by the PMC.

Essentially, the DFTM cables shall be laid in the RCC between the upstream and downstream formwork, and raised at alternating sides of the dam to return to the other at 5m vertical intervals, at two specific sections in the dam. Each loop shall commence at the specified flank instrumentation shaft chamber in the upper level gallery, and extend through the galleries and instrumentation shafts to the relevant section, then loop through the RCC and return back through the galleries and instrumentation shafts, to the instrumentation shaft chamber. Each loop shall be measured on a double-ended system.

The optical fiber itself shall consist of a core and a cladding layer, selected for total internal reflection due to the difference in the refractive index between the two. This coating shall protect the fiber but shall not contribute to its optical waveguide properties. Measurement shall be by fiber optic thermometers providing information about temperature along the cable with a very high longitudinal resolution of 0.5m. Temperature records shall consequently be surveyed in steps of at least 1.0m from one

end of the fiber to the other. The optical fibers shall be included in a seven (7) core armored cable to the details shown on the drawings.

An automatic multi-channel readout unit, laser transmitter, data logger and backup power supply shall be installed at the instrumentation shaft chamber. Suitable software for the collection, storage and evaluation of data from the cables shall be provided, both on the local read-out unit, as well as the ADAS computer.

The Fiber Optic Temperature Measurement System shall comply with the following requirements:

- Accuracy ±0.2 °C
- Sensitivity 0.1 °C
- Spatial resolution 1.0m
- Sampling resolution 0.5m
- Fiber 50/125 µm graded index, communications grade, multimode.
- Fiber attenuation <0.6 dB/km @ 1300 nm, < 2.4 dB/km @ 850 nm
- Fiber bandwidth >600 Mhz.km @ 850 nm and 1300 nm

The Contractor shall install the fiber optic cables in accordance with the recommendations of the manufacturer. Joints/splices shall be kept to an absolute minimum. Before installation, a predetermined length of fiber optic cable shall be prepared for installation in the RCC and connected to the data logger in the instrumentation shaft chamber when the first length of cable is laid, so that measurements can take place immediately. The fiber optic cable shall be kept rolled up, and protected from the elements, construction activity, etc. at either end of the dam section as the installation progresses.

28.2.14 Thermocouples

The Contractor shall procure, install and commission thermocouples with complete set of wires, junctions, connectors and readout units for the monitoring of the temperature of the dam RCC during and after the construction period of dam, where shown in the Drawings or instructed by the PMC.

Thermocouples shall comply with the following requirements:

- ANSI type Copper-Constantan (Type T) thermocouple wire;
- Accuracy: < 0.5°C; in according to ASTM E-230(1993) & ANSI MC96.1 (1998).
- Miniature type connector.
- Insulation resistance at room temperature shall be according to ASTM E-585 (table 2).

- The formability shall be according to ASTM E-585 (Can be formed around a mandrel equal twice the outside diameter without sheath rupture or loss of IR.)
- Twisted/shielded thermocouple wire to reduce electrical noise.
- The sheath outside diameter and wall thickness shall be according to ASTM E-585 and the sheath material shall be stainless steel grade 304SS.
- The wire type and diameter shall be sized for the lengths of installation anticipated.
- The cable shall be either welded, brazed or soldered without changing IR.

In accordance with the cable and RMU-station layouts (See Clause 2.3), suitable numbers of automatic readout units, data loggers (multi-channel for connection of more sensors on one logger) and backup power supplies, all of a type recommended by the instrument manufacturer shall be provided with these instruments. The Readout unit shall comply with the following requirements:

- Compatible with Thermocouple Type T;
- Applicable for ambient temperatures of 0 to 50°C and maximum relative humidity of 90%;
- Accuracy < 0.2°C;
- Resolution 0.1°C;
- Dual input (Temperature 1, Temperature 2, Difference T1-T2).

The Contractor shall install the thermocouples in accordance with the recommendations of the manufacturer.

28.2.15 Effective Concrete Stressmeters

The Contractor shall procure, install and commission Effective Concrete Stressmeters (hereinafter called Stressmeters) for measuring the stress evolution within the RCC dam body, where shown in the Drawings or instructed by the PMC. These shall be installed in standardized configurations as well as in tandem with strain gauges at various locations throughout the dam structure. The instruments will include an internal thermistor to measure the associated temperature of the surrounding RCC.

Stressmeters shall comply with the following requirements:

- Stress measurement -3 MPa(Tension) to +25MPa (compression)
- Accuracy and Sensitivity ±0.2°C and ±0.08MPa
- Resolution 0.01°C and 0.04MPa
- The outside circumference of the entire stressmeter, excluding the anchor plate, shall be coated with a suitable de-bonding coating.

In accordance with the cable and RMU-station layouts (See Clause 2.3), suitable numbers of automatic readout units, data loggers (multi-channel for connection of more

sensors on one logger) and backup power supplies, all of a type recommended by the instrument manufacturer shall be provided with these instruments.

A compatible portable read-out unit shall be supplied with the instruments for the interim period until the ADAS is up and running. Where the latter unit can be used on more than one vibrating wire type instrument, only suitable numbers to meet with the monitoring requirements need be procured.

Specific procedures for the installation of the instruments are required and the Contractor shall implement these in accordance with the Manufacturer's recommendations. The RCC to be installed in the Stressmeters at installation shall be compacted through vibration and the action of a Kangohammer to the same density as the in-situ, roller compacted RCC. Similar cylinders of RCC shall be made in the laboratory for comparative density, shrinkage and strength testing. The aggregate skeletal structure of samples manufactured in this manner will also be compared with cores recovered from the dam body RCC.

28.2.16 Long BaseStarin Gauge with Temperature Meters

The Contractor shall procure, install and commission Long-base strain gauges, with integral temperature meters, for measuring the strain evolution within the RCC dam body. The Long base Strain gauge-Temperature-Meters shall be of the vibrating wire type and capable of measuring horizontal strain over joints, with a frequency output suitable for transmission over long cables.

Long base strain gauge temperature meters shall comply with the following requirements:

- The instruments shall be of a strong and durable construction suitable for installation in RCC.
- The vibrating wire sensor shall be housed in a protective PVC pipe. A second protective PVC pipe of smaller dimensions shall telescope inside the housing and the sliding joint shall be sealed with "O"-rings. One end of the vibrating wire sensor shall be connected to one flange and the other end shall be connected to the other flange by means of a stainless steel rod inside the protective PVC coating.
- Strain range 3000 με
- Active gauge length >600 mm <1000mm
- Accuracy ±0.1% F.S, ±0.1mm
- Resolution 0.4 με
- Nonlinearity <0.5% F.S.
- Flange diameter >75mm, <100mm, stainless steel
- Inner PVC pipe diameter 50mm

- Outer PVC pipe diameter 60mm
- Total crack width measurement range 10mm

The meters are to allow installation with an offset of 2mm to measure closure.

The temperature sensor component of the meter shall be a thermistor, conforming requirements of the thermistor type instruments described in Clause 2.12 herein.

In accordance with the cable and RMU-station layouts (See Clause 2.3), suitable numbers of automatic readout units, data loggers (multi-channel for connection of more sensors on one logger) and backup power supplies, all of a type recommended by the instrument manufacturer shall be provided with these instruments.

A compatible portable read-out unit shall be supplied with the instruments for the interim period until the ADAS is up and running. Where the latter unit can be used on more than one vibrating wire type instrument, only suitable numbers to meet with the monitoring requirements need be procured.

28.2.17 Strain Gauges

The Contractor shall procure, install and commission strain gauges, with integral temperature meters, in the RCC of the dam wall to measure horizontal strains in both the upstream-downstream direction as well as parallel to the dam axis, where shown in the Drawings or instructed by the PMC.

The strain gauges shall be of a strong and durable construction, suitable for installation in RCC, and the vibrating wire sensor shall be housed in a protective stainless steel pipe. The instruments shall have frequency output suitable for transmission over long cables.

The strain gauges shall comply with the following requirements:

- Strain range 3000 με
- Active gauge length 250mm
- Accuracy ±0.1% F.S.
- Resolution 0.4 με
- Nonlinearity < 0.5% F.S.
- Flange diameter > 50mm, < 75mm, stainless steel

The integral temperature sensor component of the gauge shall be a thermistor, conforming requirements of the thermistor type instruments described in Clause 2.17 herein above.

In accordance with the cable and RMU-station layouts (See Clause 2.3), suitable numbers of automatic readout units, data loggers (multi-channel for connection of more sensors on one logger) and backup power supplies, all of a type recommended by the instrument manufacturer shall be provided with these instruments.

A compatible portable read-out unit shall be supplied with the instruments for the interim period until the ADAS is up and running. Where the latter unit can be used on more than one vibrating wire type instrument, only suitable numbers to meet with the monitoring requirements need be procured.

28.2.17.1 Flow Measuring Weirs

The Contractor shall construct flow measuring weirs in the dam galleries and elsewhere as shown in the Drawings or instructed by the PMC. He shall procure, install and calibrate the necessary ancillary weir plates and measuring equipment to enable flow rates to be accurately measured and recorded.

The flow measuring weirs shall consist of a flume and stilling-well constructed in RCC as detailed on the drawings, of a stainless steel V-notch weir, of a water level recording instrument to be integrated into the ADAS and of a staff gauge for manual water level reading. Generally two separate measuring weirs are provided at each measuring location, facilitating measurement of flow from both sides.

The water level recording instrument shall consist of a housed cylindrical weight suspended from a vibrating wire force transducer. The transducer shall be vented to the atmosphere to compensate for atmospheric variations. The instrument shall comply with the following requirements:

- Min Measuring range 350mm
- Accuracy ±0.1% F.S.
- Resolution ±0.025% F.S.

The flow measuring weirs shall be calibrated by approved methods after installation. This shall include the controlled discharge of accurately known flow rates of water though the system.

In accordance with the cable and RMU-station layouts (See Clause 2.3), suitable numbers of automatic readout units, data loggers (multi-channel for connection of more sensors on one logger) and backup power supplies, all of a type recommended by the instrument manufacturer shall be provided with these instruments.

A compatible portable read-out unit shall be supplied with the instruments for the interim period until the ADAS is up and running. Where the latter unit can be used on more than one vibrating wire type instrument, only suitable numbers to meet with the monitoring requirements need be procured.

28.2.18 Seismic Monitoring Installation

The Contractor shall procure, install and commission a complete seismic monitoring installation at the dam.

28.2.18.1 Strong Motion on Dam

The strong motion accelerometer installation shall include:

- Tri-axial force-feedback accelerometers with a large dynamic range suitable for measuring strong ground motions at dam sites.

  Three strong motion accelerometers shall be provided for independent, isolated operation in the pendulum chambers leading off the top, middle and bottom galleries, approximately at the highest section of the dam wall. Additionally separate accelerometers shall be provided at both extremities of the topmost gallery level, specified depth into the foundation, as shown on the drawings.

  Accelerometer shall be mounted directly to the RCC of the dam body or, onto a massive concrete monument in the abutment gallery and be protected against possible seepage water. They shall be shall be housed in a corrosion resistant watertight enclosures and be provided with a precise leveling system to ensure accurate alignment.

- Sufficient multiple channel data loggers with acquisition modules to read the signals from the accelerometers (Typically three (3) channels per instrument) These shall be time synchronized to absolute UTC (Universal Time coordinated) utilizing suitable systems (e.g. Global Positioning Systems: GPS), so that the structural instruments can be synchronized with the remotely located accelerometer/seismometer data logger.

  The digitizers shall store at least one month's continuous recorded data from all channels at the minimum sample rate specified below, and 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 to be produced on a PC.

- Suitable cabling to power, communicate and time-synchronize all accelerometers.

The strong motion accelerometer shall comply with the following requirements:

- High shock and vibration survival
- Acceleration Measurement: Triaxial, ±4g full scale in vertical and horizontal
- Sampling Rate: > 400 sps (samples per second, digitizer)
- Accuracy: Non-linearity ≤0.2% F.S.
- Frequency Response: 0 to 150Hz (±1%)
- Dynamic Range: >120dB (down from full scale at > 400sps)
- Processor clock accuracy: within 250 micro-seconds of GPS at all times
- No hysteresis, low noise, temperature compensated (bipolar)

28.2.18.2 Regional Seismicity Monitoring

A separate system, a minimum of 500m away from the dam and power facilities, shall be installed to link into the surrounding local seismic monitoring system. This shall consist of an accelerometer/ seismometer combination, timing synchronization, cabling and digitizers, as above.

The Seismometer shall comply with the following requirements:

- High shock and vibration survival
- Velocity Output Bandwidth: 1 s – 100 Hz
- Velocity Output Type: Triaxial, differential
- Velocity Sensitivity: 2000 V/m/s with a full scale of ±10V or equivalent"
- Dynamic Range: 140dB or greater at 100Hz
- No hysteresis, low noise, temperature compensated (bipolar)

The accelerometer shall comply with the same specification as the dam accelerometers, except that the dynamic range may be >100dB

Both units shall be mounted onto a massive concrete monument or 2.5m x 2.5m x 1.5m and provided with a weather-, rodent- tamper- and theft proof housing.

The installation will be considered an additional RMU-Station and a communication system, as per Clause 3.1.5 shall be supplied.

28.2.19 Water Level Staff Gauges

The Contractor shall procure, install and commission calibrated metal staff gauges for the visual control of reservoir level during flood events and for the calibration of the automated water level pressure transducers.

The Staff Gauges shall be finished with a special porcelain enamel to ensure easy reading and to resist rust or discoloration. Each gauge or gauge section shall be 1m in length and accurately graduated in into centimeters divisions, with each decimeter numbered using the International Epattern available in white on black. Specific one meter elevation demarcation shall be indicated with separate compatible number plates securely attached to the gauge plates.

The gauge plates shall be 100-150 mm wide with a minimum of six grommeted holes for fastening with stainless steel round-head bolts to mounting posts. The mounting posts shall consist of 100x100x10mm stainless steel Gr 304 angles, of length between 1.6m and 2.5m. The lower 0.5m of the post shall be vertically and securely concreted in 600mm diameter holes in the abutment rock. Alternatively, at the discretion of the PMC, 1m long posts shall be mounted to the inclined upstream face of the dam body with suitable stainless steel Gr 304 adjustment adaptors. All bolts, nuts and washers shall be compatible stainless steel.

Successive staff gauge units should be correctly leveled to within 0.1mm to allow accurate water level readings without gaps or overlaps.

28.2.20 Water Level Transducers

The Contractor shall procure, install and commission vibrating wire type water level pressure transducers for the accurate measuring of impounded and tailwater levels. They shall be installed in conduits provided in the upstream and downstream faces of the dam and connected to the impounded water, as shown in the Drawings or instructed by the PMC. The instruments shall be accessible from the top of the conduit at the crest and face of the dam for removal and inspection.

The water level transducers system shall essentially consist of a diaphragm and vibrating wire pressure sensor, housed in a stainless steel sealed body with a porous filter tip, the connecting cables and the read out unit, suitable both for local reading and for automatic remote reading.

The transducers shall comply with the following requirements:

- Measuring range up to 1400 kPa
- Accuracy: <0.1% F.S.
- Resolution: <0.025% F.S.
- Thermal sensitivity shift: <0.05% F.S / °C

The transducer shall be manufactured entirely in stainless steel components and hermetically sealed, forming a vacuum chamber for the vibrating wire element. The ends of the vibrating wire shall be clamped, using a swaging technique that ensures high stability, while allowing miniaturization of the components. The transducers shall use electromagnetic coils to both pluck the wire and to convert the vibration generated into an electrical output current, whose frequency is identical to the natural resonant frequency of the wire, across the full range of applicable wire tensions. The piezometers shall be fitted with 59 micron sintered stainless steel filters (suitable for low air entry).

The stability of the vibrating wire output shall be unaffected by changes in cable resistance caused by water penetration, temperature variations and contact resistance.

Upstream instrumentation cables shall lead to the data logger installed in the highest gallery via cable trenches in the crest of the dam, the nearby pendulum shafts and galleries. Downstream instrumentation cables shall lead to the data logger installed in the second gallery level via cable a cable duct through the RCC and the gallery itself. In both cases, the cables and attachment to the transducers shall be suitable for extracting the transducer for inspection and/or maintenance, with an accurate means of confirming the actual level of the instrument itself.

In accordance with the cable and RMU-station layouts (See Clause 2.3), suitable numbers of automatic readout units, data loggers (multi-channel for connection of more

sensors on one logger) and backup power supplies, all of a type recommended by the instrument manufacturer shall be provided with these instruments.

28.2.21 Meteorological Station

The meteorological station shall be located close to the construction site, but outside the range of disturbing site traffic and dust. The meteorological station is a permanent station and it shall monitor the environmental conditions during the project's life time. Autonomous power supply shall be provided by the Contractor for the station.

The Contractor shall procure, install and commission all required instruments of the meteorological station, which shall record continuously the environmental conditions at the dam site.

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 requirements:

- Temperature measurement: Range -30°C to +70°C
  Accuracy ±0.5°C
- Relative humidity: Range up to 100%
  Accuracy ±2.5%
- Global solar radiation: Range 0 to 1400 W/m²
  Accuracy <5% of measured value
- Wind speed: Range up to 30 m/s
  Sensibility <1m/s
- Wind direction: Range 360°
  Accuracy 1°
- Barometric Pressure: Accuracy: ±0.3 mb at +20°C±0.6 mb between 0° to 40°C;
  Accuracy ±0.25 mb
- Automatic precipitation meter with compensator:
  Cross area: 200 cm
  Resolution: 0.2mm precipitation
- Autonomous p ower supply through solar panel and battery capable of powering the system for forty eight (48) hours without solar input.
- A suitable automatic data logger, readout unit and backup power supply, all of a type recommended by the instrument manufacturer, shall be provided with the

instruments. The logger shall be interface directly with the PC for the ADAS system and suitable software incorporating the weather data into the ADAS system shall be developed. Suitable communication systems shall be included between the meteorological station and the Dam Monitoring House containing the ADAS system.

The meteorological station's instruments shall be procured from manufacturers having a worldwide reputation in the field. Specifications and technical data of the instruments proposed by the Contractor shall be submitted to the PMC for approval before placing the purchasing orders.

Installation details shall be according to the manufacturer's recommendations and the PMC's instructions, and shall include all bases, masts, cabling, housing, cabinets, etc.

28.3 EXECUTION

28.3.1 Data Collection & Reporting

28.3.1.1 Principles

All instrumentation data will be interrogated stored and processed using the ADAS and it is intended that this system be implemented as early as possible. Until the time that the ADAS system has been installed and its reliability proved to the satisfaction of the PMC, all instrument data shall be measured and recorded manually by the Contractor, at the intervals stated below.

All instrument data will be collected and stored from the time of first installation. The readings at installation will be recorded, with the instrument installed in fresh RCC, together with an exact record of the progress of the successive RCC layers above and the actual first and final set times for the RCC. The atmospheric conditions on installation shall be recorded and the data from the instrument shall be read hourly thereafter until final set of the RCC.

28.3.1.2 Remote Measuring Unit Stations

Eight (8) Remote Measurement Unit Stations (RMU-Stations) will be constructed off the galleries in the dam as shown on the drawings. These will be 3.5m x 3.5m in plan dimension and will be separated from the galley by a lockable steel door. An RMU–Station will be constructed on specified flank of the upper gallery levels.

Instrumentation cabling will be routed through the RMC, galleries and instrumentation shafts as described in Clauses 2.2 and 2.3, up to the RMU–Stations where the data loggers shall be installed in suitable instrumentation cabinets.

All instrumentation cabinets shall be manufactured in approved materials. All cabinets and boxes shall be provided with weatherproof seals on all cable/conduit entry points and doors. Doors shall be so sized and hinged that all instrument terminals are easily

accessible and the door shall be lockable from the outside. All instrument terminals shall be clearly and permanently marked.

The Contractor shall also procure and install all required power cables, connection cables, cable trays, auxiliaries, etc. needed to power the RMU-Station. Until such time that the permanent power is supplied for the dam, the Contractor shall be responsible for all temporary power to the RMU– Stations.

A back-up power supply shall be provided at each RMU station to provide forty eight (48) hour uninterrupted power supply. All equipment shall be provided with adequate transient protection.

28.3.1.3 Data Loggers

The Contractor shall procure, install and commission data loggers for each instrumented section of the dam for the following instruments, including all necessary auxiliaries:

- Pendulums, both hanging and inverted;
- Inclinometers;
- Multiple points borehole extensometers;
- Electrical piezometers;
- Water temperature meters;
- Air temperature meters;
- Distributed fiber optic temperature measurement system;
- Thermocouples;
- Effective concrete stress meters;
- Long-base-strain-gauge-temperature-meters;
- Strain gauges;
- Water level recorder for the flow measuring weirs;
- Strong motion accelerometers and seismometers, etc;
- Water level transducers;
- Meteorological station

The data loggers shall be multi-channel devices to collect readings from multiple instruments where appropriate. Multiple vibrating wire instruments shall be linked through terminal/switching boxes to the data loggers to minimize the number of vibrating wire data loggers required. Each data logger shall be compatible with, and supplied by the same manufacturer as the instrument it receives data from.

Portable read-out units shall be supplied with each type of instrument (or sensor as the case may be) for the interim period until the ADAS is up and running.

The terminal/switching boxes and data loggers shall be installed and commissioned in time to start reading of the above instruments as soon as they are installed. Where instrumentation installation precedes the construction of the RMU-Stations, the contractor shall be responsible for the temporary arrangements to ensure that the instruments are read as required.

28.3.1.4 Automated Data Acquisition System

The Contractor shall design, procure, install and commission a centralized ADAS to interrogate, collect, store, manage and processed all instrumentation data. The main control computer for the ADAS shall be installed in the Dam Monitoring House.

The Dam Monitoring House shall be provided with air conditioning to maintain a constant temperature of 22˚C and ventilation to maintain humidity at below 25%. It shall be the Contractor's responsibility to make all necessary provisions to ensure the facility is dust and damp-free and adequately secured against theft and vandalism until the end of the Defects Notification Period.

The ADAS shall be capable of:

- Performing automatic remote reading at specified programmable time intervals for all electronic instruments;
- Performing automatic remote reading of the inclinometer probes when plugged into any of the receivers at the RMU.
- Manually downloading geodetic survey data from the designated instruments;
- Storing the data obtained from the data loggers; and manual input, and downloading from all instruments.
- Elaborating the data of individual instruments, or of instrument groups, in graphic and numeric form;
- Summarizing data of individual instruments, or of instrument groups, in long-term graphs and numeric tables;
- Automatically displaying alarms when reading of selected instruments reaches specified values.
- Transmitting data and alarm signals via a modem link to the WAPDA central control.
- Raising an alarm message at the scheme central control and at the WAPDA central control should failure of the system, or a failure in its power supply, occur.

The Contractor shall provide licensed computer software for the required data recording, management and presentation. This shall include all database management tools required (Preferably SQL). The software shall be customized to suite the configuration of the instrumentation in the dam, facilitating rapid and easy interpretation of readings. The system shall be able to present data on each instrument, or any group of instruments

for any selected or pre-programmed time intervals. Presentation shall be clear, concise and easily referenced.

The Contractor shall also procure and install all required power cables, connection cables, communication cables, cable trays, auxiliaries, etc. needed to link the data loggers with the ADAS, as well as a modem link through the telecommunications systems of the colony.

The minimum hardware specification for the ADAS computer shall comply with the following requirements:

- Intel® Core™ i7-2600 Processor (8M Cache, 3.40GHz),
- 8GB (1x8GB) DDR3-1333 nECC RAM,
- 2 x 3TB SATA 6Gb/s 7200RPM HDD,
- SuperMulti DVD,
- Windows 8 Professional 64-bit,
- Standard keyboard
- Optical Mouse
- 24 inch LED full HD monitor
- 10/100/1000 NIC
- Modem link

The minimum hardware specification for the laptop computer shall comply with the following requirements:

- Robust, dustproof construction suitable for a construction site,
- Intel® Core™ i7 3610QM Processor HM76 Chipset,
- 8GB DDR3 1600 MHz SDRAM
- 1TB 2.5" SATA 5400RPM HDD,
- SuperMulti DVD,
- Windows 8 Professional 64-bit,
- Standard keyboard
- Optical Mouse
- 15.6" Full HD Screen
- 10/100/1000 NIC
- 4 x USB 3.0 ports
- RS232 interface (USB adaptor)

The minimum hardware specification for the printer shall comply with the following requirements:

- A4 Color laserjet
- 600 x 600 dpi
- 30ppm print speed.
- Monthly print volume: 2500 to 10,000 pages
- Input tray: 500 pages.

28.3.1.5 Communication between RMU's and ADAS

The Contractor shall design, procure, install and commission a fiber-optical communication systemnetwork between the RMU stations in the dam and the Dam Monitoring House.

Individual fiber-optical cables will be laid on cable racks in the galleries to a common point outside the dam where after the cables will be laid in a common trench to the Dam Monitoring House. It is to be noted that the cables from the lowest gallery must be routed through the instrumentation shafts between upper gallery levels to the exit.

Communication from the isolated seismic installation and meteorological station shall be provided as part of this system.

The system shall include the necessary switches, optical fiber junction boxes, power supplies, transceivers, cabling, trenching, cable mounts, etc. Equipment selection shall be based on the cable lengths involved and the requirement for Ethernet 1000BASE-LX networking for transmission up to 2.5km.

The fiber optic communication cable shall comply with the following requirements:

- Fiber: 9.3/125 µm cabled step index, communications grade, single mode.
- Fiber attenuation: <0.35 dB/km @1310 nm, < 0.25 dB/km @1550 nm.

The Contractor shall install the cables in accordance with NECA/FOA 301 Standard for Installing and Testing Fiber Optics.

28.3.1.6 Instruments Reading During Construction

The Contractor shall start reading of the different instruments as soon as they are installed, and shall continue reading during the construction period with the frequency indicated below, unless different instructions are given from time to time by the PMC:

Required Frequency of Reading for Instruments Installed in RCC

Frequency of Instrument Reading During Indicated Period				
Until Final Set	1st Week	1st Month	Months 2 - 6	After Month 6
Hourly	Twice Daily	Daily	Weekly	Monthly

Required Frequency of Reading for Other Instruments

Instrument	Frequency of Reading During Indicated Period		
	Construction	First Filling	To End of Defects Notification
Inclinometers	Weekly	Twice Weekly	Monthly
Piezometers	Monthly	Twice Weekly	Monthly
Pendulums	-	Twice Weekly	Monthly
Leakage Weirs	-	Twice Weekly	Weekly
Seismometers	-	Permanent	Permanent
Surface Temperatures	Twice Daily	Twice Daily	Daily

Survey results and Instrument readings shall be submitted to the PMC in approved forms within twenty four (24) hours of the observation. Plotted results shall be submitted within forty eight (48) hours from the observation.

28.3.2 Maintenance and Operation & Maintenance Training

28.3.2.1 Maintenance

The Contractor shall be fully responsible for the maintenance of all instruments installed until expiry of the Defects Notification Period. The operation after Taking Over shall be carried out by the Employer.

The Manufacturer's recommendations for all necessary transportation and storage care and protection, preparation, handling care, testing and maintenance shall be followed by the Contractor on all instruments and instrument cabling until the end of the Defects Notification Period.

Where physically possible, instruments damaged by the construction activities or malfunctioning for any reason before the expiry of the Defects Notification Period shall be replaced by the Contractor at his own cost.

In case of damaged or malfunctioning instruments, if possible shall be replaced the Contractor. Alternatively, if considered possible, the PMC reserves the right to instruct the installation by the Contractor at his own cost of other monitoring instruments which could provide equivalent information.

28.3.2.2 Operation and Maintenance Training

The Contractor shall provide complete operation and maintenance manuals and a comprehensive training to the Employer's personnel on the operation, maintenance and reading of all instruments installed, and on the operation and maintenance of data loggers and of the ADAS system.

Training shall be provided by suitably qualified specialists from the instrumentation manufacturers, whose curricula vitae shall be submitted to the PMC for approval.

The Employer will nominate eight (8) of his personnel for training in the operation of the instrumentation at the dam. They shall become available on a part time basis for training two months before the designated first impoundment date.

The Contractor shall propose a suitable training schedule for the approval of the Employer.

28.3.3 Instrumentation Referencing and As-Built Information

It will be the responsibility of the Contractor to develop a meaningful and accurate reference system to plan the installation and record the exact location of each instrument and its associated cabling. The referencing system shall identify each instrument installed by:

- Instrument type
- Elevation
- Sectional location (e.g. chaninage)
- Position (e.g. distance from the dam axis)
- RCC placement layer No. and depth of instrument from surface at installation.

Each instrument shall be numbered with the appropriate identifier and all readings logged against this number.

At the time of installation, each instrument and its associated cabling shall be surveyed for its exact position in the structure to the nearest 50mm. This shall be recorded on suitable as-built drawings and tabulated in an Excel spread sheet for submission to the PMC. Photographic records of the installation (open and closed) and a detailed record of the ambient atmospheric conditions during installation shall be kept with the location reference information.

All instruments shall be interrogated immediately on installation and all instruments installed in fresh RCC shall be interrogated hourly thereafter until final RCC set. Data records for all instruments shall a history of placement of the successive fifteen (15) RCC layers above, accurate to the nearest hour.

As-built drawings shall be prepared in the latest version of AutoCAD in an approved layout system

Chapter 0810
29 ROADS AND PLATFORMS

29.1 GENERAL

29.1.1 Work Included

This Chapter covers the construction of permanent access roads, associated culverts and site drainage works, as well as platforms to be established in the vicinity of the various structures of the Project as shown on the Drawings or directed by the PMC, together with the maintenance of the same during the Works.

Road work shall include excavation, support of excavated surfaces, the construction of embankments and placement, grading and compaction of sub-base and base course material and sealing the surface with a bitumen seal. It shall also include the revegetation of cut and fill slopes, except for construction roads.

Site drainage work shall include supply and construction of drainage cutting/ embankments and associated lined or unlined catch drains to divert flow away from the Works, lined and unlined catch drains parallel to roads to be constructed, and other work required to ensure satisfactory drainage of surface runoff away from the areas occupied by the Works.

The Contractor shall construct and maintain the permanent and temporary access roads shown in the drawings. The Contractor shall be responsible for maintenance of the roads at the Construction Site.

29.1.2 Related Works / Sections

Chapter 0210	Site Preparation
Chapter 0211	Diversion, Dewatering and Care of Water
Chapter 0220	Surface Excavation
Chapter 0260	Drainage of Structures
Chapter 0330	Rock Protection
Chapter 0410	Formwork & Surface Finishes
Chapter 0420	Reinforcement Steel
Chapter 0430	Conventional Concrete (CVC)
Chapter 0440	Concrete Structure Joints and Bearings

29.1.3 Definitions

- Permanent access roads shall mean the permanent road in the construction site and their connection roads to the existing highway.
- Temporary access roads shall mean roads constructed the Contractor for his own purposes of project construction. These roads, to be built by the Contractor, shall be designed by the Contractor and reinstated at the final stage of construction.

- Platforms shall mean the accessible surfaced areas to be established in the vicinity of the various structures to be built under the Contract.
- Sub-base shall mean the layer of compacted material placed above the bottoms of excavated cuts or on top of embankments.
- Base course shall mean the layer of compacted material placed above the sub-base.
- Subgrade shall mean the grade elevation to which excavations and embankments are constructed, upon which the sub-base course will be placed.
- Limit lines define the physical and theoretical lines within which the volume of excavation, embankment fills and surfacing materials will be measured. Limit lines comprise lines defined by approved field survey records of earthwork surfaces and lines of excavation, embankment fills of surfacing materials, as shown on the Drawings or as directed by the PMC.
- Cutback asphalt shall mean penetration grade asphalt cement which has been blended with light petroleum solvent or oils of low volatility. The viscosity is controlled by the amount of solvent and is generally kerosene type for Medium Curing (MC) products.

29.1.4 CODES AND STANDARDS

The Work included in this Chapter shall comply with the requirements of the following codes and standards, except where this Specification differs from these codes and standards, in which case the requirements of the Specification shall take precedence:

- American Society for Testing and Material (ASTM)

ASTM A762	Specification for Corrugated Steel Pipe, Polymer Precoated for Sewers and Drains.
ASTM C76M	Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe.
ASTM D422	Method for Particle Size Analysis of Soils
ASTM D1557	Test Methods for Moisture-Density Relations of Soils and Soil Aggregate Mixtures using 10 - lb (4.54 kg) Rammer and 18 - in. (457 mm) Drop
ASTM D2167	Test Method for Density and Unit Weight of Soil In Place by the Rubber Balloon Method.
ASTM D2922	Standard Test Methods for Density of Soil and Soil Aggregate in Place by Nuclear Methods (Shallow Depth).
ASTM D3017	Standard Test Method for Moisture Content of Soil and Soil Aggregate in Place by Nuclear Methods (Shallow Depth)
ASTM D4318	Standard Test Method for Liquid Limit, Plastic Limit and Plasticity Index for Soils.
ASTM D 1883	Test Method for CBR (California Bearing Ratio) of Laboratory - Compacted Soils.

ASTM C 131	Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.
ASTM C 535	Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.
ASTM D 979	Methods of Sampling Bituminous Pouring Mixtures.
ASTM D 1074	Test Methods for Compressive Strength of Bituminous Mixtures.
ASTM D 1241	Specification for Materials for Soil-Aggregate Sub-base, Base and Surface Courses.
ASTM D 1559	Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus.
ASTM D 1664	Test Method for Coating and Stripping of Bitumen-Aggregate Mixtures.
ASTM D 1751	Specification for Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction.
ASTM D 2726	Test Method for Bulk Specific Gravity of Computed Bituminous Mixtures Using Saturated Surface - Dry Specimens
ASTM D 3282	Recommended Practice for classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes.
ASTM D 4254	Test Methods for Minimum Index Density of Soils and Calculations of Relative Density.
ASTM D 4318	Test Method for Liquid Limit Plastic Limit, and Plasticity Index of Soils.
ASTM D 4429	Test Method for Bearing Ratio of Soils in Place.
ASTM D 4791	Test Method for Flat or Elongated Particles in Coarse Aggregates.
ASTM D5 ASTM D95	Test Method for Penetration of Bituminous Materials.Test Method for Water in Petroleum Products and Bituminous Material by Distillation.
ASTM D113	Test Method for Ductility of Bituminous Materials.
ASTM D140	Methods for Sampling Bituminous Materials.
ASTM D402	Test Method for Distillation of Cutback Asphaltic (Bituminous) Materials.
ASTM D2042	Test Method for Solubility of Asphalt Materials in Trichlorethylene.
ASTM D2170	Test Method for Kinematic Viscosity of Asphalts (Bitumens).
ASTM D3143	Test Method for Flash Point of Cutback Asphalt with Tag Open Cup Apparatus

- American Association of State Highway and Transportation Officials (AASHTO)
- British Standard (BS)
- Asphalt Institute Manual: "Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types": Manual Series No.2.

29.1.5 QUALITY ASSURANCE

- The Contractor shall be responsible for the control of the quality of fill materials, and shall perform tests in the field and laboratory on samples of uncompacted and

compacted fill to determine if such materials and their compaction meet requirements of this Specification. The PMC will notify the Contractor of any deficiencies in materials or construction when the results of the test are known. Deficiencies shall be remedied by such measures as the PMC may approve, including additional measures to increase density, lower or raise moisture content, and complete removal of portions of embankment which fail to meet the requirements of this Specification.

- Control tests on uncompacted material shall be carried out by the Contractor according to the frequency given in the following table to determine whether all fill material, as produced by the method employed, satisfies the requirements of this Specification.

Test (1 test each)	Materials (m³)			
	General fill	Sub-base	Base course	Stone Aggregates
Grading analysis	4000	500	500	50
Atterberg limit	4000	500	500	
Natural moisture content	4000	500	500	
Standard ASTM D61557 density test	5000	3000	3000	
Organic matter content			1000	
Los Angeles abrasion		1000	1000	
Californian bearing ratio (Lab)			1000	50
Flakiness index			1000	50

- The frequency of the tests may be amended as required by the PMC according to the results of previous tests, material variations and weather conditions.
- The following controls shall be made on materials either placed or in situ:

Test	Sub-grade	Sub-base	Base
Californian bearing ratio (in situ)	1 per 100m	1 per 100m	1 per 100m
Density of soil in place	-	1 per 200m³	1 per 200m³

The frequency and nature of the tests may be amended as required by the PMC depending on the results of previous tests, material variations or climatic conditions.

- Bulk density will be determined in field in accordance with ASTM D1557 with dimensions and apparatus modified to suit the soil tested, or with ASTM D2167, whichever is most suitable in the opinion of the PMC, to obtain representative density of fill tested. Particle size distribution will be performed in accordance with ASTM D422 modified as required to suit the material tested.

- The Contractor may use a nuclear apparatus to determine density and moisture content in accordance with ASTM D2922 and ASTM D3017, if materials of consistent gradation are being placed.
- Final acceptance of earthworks will be made after materials have been dumped, spread and compacted if required. Rejection by the PMC may be made at the source, on transporting vehicles, or in place.
- Cutback Asphalt shall be subject to testing in accordance with the ASTM standards designated for each requirement in Clause 2.6. Samples shall be provided in accordance with ASTM D140, and in such reasonable quantities as may be required for independent testing purpose.

29.1.6 SUBMITTALS AND APPROVALS

Regarding the temporary access roads / construction roads, not less than thirty (30) days prior to commencement of road construction, the Contractor shall submit for approval his detailed plans for excavation, embankment construction, drainage and road surfacing, including complete details of his proposed construction equipment and methods.

29.2 MATERIALS

29.2.1 General

Materials shall be obtained from excavation, borrow areas or other sources approved by the PMC. The Contractor shall explore for suitable borrow location and perform necessary tests in advance of material exploitation. Location of borrow areas and selection of materials therefrom shall be subject to the approval of the PMC.

29.2.2 Common Fill

Common fill, to be used for drainage berms and road embankments, shall be selected from excavation for the Works, excavation from borrow areas or other approved alternative sources.

The material shall comply with following requirements:

- Organic matter content : ≤ 0.1%,
- Maximum rock dimension : 150 mm
- Plasticity Index : ≤ 15
- Fraction passing 0.074 sieve (US) : ≤ 15%

29.2.3 Sub-Base Course

The material shall be selected from selected excavation for the Works and from borrow areas, and shall consist of approved granular fill, free of rock and stones larger than 75 mm.

- The gradation of the material shall conform to the following table. If the below gradation envelope cannot be obtained from selective excavation material for the Works or borrow areas, the material shall be processed.

No.	US Standard Sieve Size (mm)	Percent Passing by Weight (%)
1	75	100
2	50	95 to 100
3	19.1	50 to 100
4	9.5	20 to 80
5	1.2	0 to 30
6	0.074	0 to 12

- The material shall also comply with following requirements:
  - organic matter content: ≤ 0.1%,
  - Plasticity Index: ≤ 6
  - Californian Bearing Ratio ≥ 50% at 95% of ASTM D1557 maximum dry optimum density.
  - Material retained on Sieve No. 4 shall have a percentage of wear by Los Angles Abrasion of not more than 50%.

29.2.4 Base Course

The base course shall be processed material of hard, durable particles of fine and coarse fragments of crushed gravel in a binding matrix of plastic soil. The plasticity index shall be between 10 and 15.

The gradation of the material shall conform to the following:

No.	US Standard Sieve Size (mm)	Percent Passing by Weight (%)
1	19.1	100
2	9.5	60 to 80
3	4.8 (No.4)	45 to 75
4	2.4 (No.8)	30 to 70
5	0.42 (No.40)	20 to 45
6	0.074 (No.200)	12 to 30

In addition, the material shall meet the following test requirements:

- Dry density: ≥ 17.5 kN/m³.
- Plasticity: 6 ≤ IP ≤ 15.
- California Bearing Ratio ≥ 80% at 95% of ASTM D1557 maximum dry density.
- Los Angeles: ≤ 40.
- Organic matter content: < 0.1%.
- The percentage of wear by the Los Angles Abrasion test shall not be more than forty (40).

  Where graded crushed stones are used, the following requirements shall be added:

  Flattening coefficient (NF P 18-561) ≤ 30.

29.2.5 Natural Ccementitious Material

If the base course material does not contain a sufficient quantity of natural cementitious material to bond readily under the action of traffic, a binder, consisting of laterite, rock screenings, or other cementitious material obtained from approved sources shall be added to, and incorporated in it.

After the binder has been added, the combined grading of the mixture shall be within the limits specified above. The binder may be incorporated in the material at the point where the material is produced, or may be incorporated during the progress of the work by blading with a grader so that a uniform blend of material size is achieved before compaction.

29.2.6 Prime Coat

Bitumen for prime coat shall be cutback asphalt consisting essentially of petroleum derivatives and shall be substantially free from water and other impurities. The asphalt shall not foam when heated to the application temperature.

Cutback asphalt shall be medium curing type, of grade MC-30 or MC-250, meeting the requirements described in the following Table:

Cutback Asphalt

No.	REQUIREMENTS	GRADE				Test Method ASTM
		MC-30		MC-250		
		Min.	Max .	Min.	Max .	
1	Flash Point°C	38	-	65	-	D3143
2	Kinematics Viscosity at 60°C, mm²/s	30	60	250	500	D2170
3	Distillation Test, % of Total Distillate to 360°C: to 225°C	-	25	-	10	D402

4	Distillation Test, % of Total Distillate to 360°C: to 260°C	40	70	15	55	
5	Distillation Test, % of Total Distillate to 360°C: to 315°C	75	93	60	87	
6	Residue from Distillation to 360°C, volume % by difference	50	-	67	-	
7	Asphalt term per temperature for spraying, °C	30	45	75	90	
PROPERTIES OF RESIDUE FROM DISTILLATION:						
8	Penetration at 25°C, 100g, 5s, 0.1 mm	120	250	120	250	D5
9	Ductility at 25°C, cm*	100	-	100	-	D113
10	Solubility in Trichloroethylene	99	-	99	-	D2042
11	Water, %	-	0.2	-	0.2	D95

* If the ductility at 25°C is less than 100, the material will be accepted if its ductility at 15°C is more than 100.

29.2.7 Surface Course

29.2.7.1 Composition

Asphalt concrete for the surface course shall consist of crushed aggregate, mineral filler and asphalt. The quality of aggregate shall conform to the requirements for concrete aggregate. Mineral filler shall consist of limestone dust, dolomite dust, or similar rock dust, Portland cement, hydrated line or other non-plastic mineral matter approved by the PMC. It shall be thoroughly dry and free from lumps. Asphalt cement shall conform to the requirements of Standard Specification for asphalt cement, ASSHTO M20-63, and its penetration value shall be 60-70. No additives shall be included in the asphalt. The shoulder having a 1m width is formed by double surface treatment (DST) along both sides of carriageway.

29.2.7.2 Design of asphalt concrete mixes

The design of asphalt concrete mixtures shall be undertaken by the Contractor. The design of the asphalt concrete mixtures shall be undertaken on the basis of trial mix prepared and tested according to standard Marshall methods in the material testing laboratory approved by the PMC

The selection of mix design shall be based on the following limitation: Gradation of Aggregate and Filler

US Standard Sieve Size (mm)	Percentage Passing by Weight
19.1	100
9.5	60-80

4.8 (No.4)	40-65
2.4 (No.8)	30-50
1.2 (No.16)	20-40
0.60 (No.30)	15-35
0.30 (No.50)	10-25
0.15 (No.100)	7-17
0.074 (No.200)	5-9

Asphalt cement content by total weight of the mixture shall be in the range of 5.0-7.0 %. The asphalt concrete shall have the following characteristics:

- Marshall Stability not less than 1,000kg.
- Marshall Flow (0.01 inch) not less than 8 nor more than 14.
- Marshall Stability (above) / Marshall Flow (above) < 125
- Air voids in Mix: 4-8 %
- Voids filled with Asphalt: 75-80 %
- Voids in Mineral Aggregate; 15-20 %"

In case of shoulder materials, the portion of aggregates retained on the 9.5mm sieve shall not contain more than 15% of particles by weight.

29.2.8 DRAINAGE WORKS

29.2.8.1 Concrete Pipes, Box Culverts and Causeways

Precast concrete drain pipe, box culvert and causeway shall be used for water crossing. The Work is defined in Chapter 0260 - Drainage of Structures, and shown in the Drawings.

29.2.8.2 Headwalls, Wingwalls and Aprons

Headwalls and wingwalls, where required for the connection and construction of road works, shall be of concrete bag construction unless otherwise specified or shown in the Drawings. The bags shall be of woven jute or approved equivalent containing sand and cement in proportions as described in the Drawings.

29.2.8.3 Bedding and Backfill Materials

Bedding and backfill material for placement around culvert and drain pipes shall be of sub-base course specified in Clause 2.3 unless otherwise designated in the Drawings.

29.2.9 ROADSIDE BARRIERS

Roadside barriers shall be guard posts constructed as shown in the Drawings.

29.3 EXECUTION

29.3.1 Roadworks - General

- Clearing and grubbing shall be carried out in accordance with Chapter 0210.
- Diversion, dewatering and care of water shall be in accordance with Chapter 0211.
- Excavation and disposal of excavated materials, shall be in accordance with Chapter 0220.
- The profile of all roads shall follow the natural topography so as to minimize cut and fill operations.
- Before placing sub-base course material, the subgrade shall be free of holes and waves, and shall be uniformly graded. The sub-base and base courses shall be placed to the lines and grades shown in the Drawings, and as otherwise directed by the PMC;
- The Contractor shall not excavate beyond the specified limit lines of excavation without prior written approval from the PMC. Excavations beyond the limit lines of excavation will only bepermitted within reasonable limits, to facilitate the Contractors construction operations.
- The Contractor shall be responsible for safety, maintenance, support and protection of all excavated surfaces.
- During the process of excavation, the surfaces of excavations shall be maintained in a welldrained condition at all times and temporary drains or drainage ditches shall be constructed where necessary to intercept and divert surface water which may otherwise affect the performance or condition of the Work.
- The Contractor shall strip top soil and other organic materials from areas where excavation and/or embankment construction is to take place. All top soil resulting from stripping shall be stockpiled separately in temporary stockpile areas to be approved by the PMC.
- Locations of permanent stockpiles shall be as shown on the Drawings or as otherwise approved.
- Materials from the excavations which meet, or can be processed to meet, the requirements for the construction materials specified herein, shall be either stockpiled for later use, or used directly for construction of the Work.
- The fill materials shall be placed in such a manner as to ensure that they can be satisfactorily compacted without damage to adjacent structures.

- 13.Unless otherwise directed by the PMC, backfill material shall not be placed and compaction shall not be permitted adjacent to concrete for fourteen (14) days after the placing of concrete, and compaction of backfill material placed above buried concrete shall not be permitted to be carried out with vibrating rollers within 500 mm vertically of the surface of the concrete.
- A special care shall be given to compaction along concrete structures and at all locations where easy access is not possible. At these locations all the required criteria for each type of fill shall be fulfilled.
- Moisture content of materials may have to be adapted by drying or moistening operations as described in Chapter 0320, Fill, Backfill and Embankment Construction, in order to fulfill the requirements of the Specifications.

29.3.2 Inspection

No excavation and fill shall start without prior agreement of the PMC.

Prior to commencement of any excavations for the construction of the roads, a survey shall be performed as required in the Specifications for purpose of recording.

29.3.3 Investigations

Prior to opening any excavation in a borrow area, the Contractor shall perform a detailed investigation which shall include one exploratory pit per 3,000 m² of borrow area in order to investigate the available volume.

Depth of the pit shall be so as to investigate the full height of suitable material. Samples shall be taken every 1.5 m and subjected to the following laboratory tests to be carried out in the site laboratory:

- Natural moisture content,
- Atterberg limits,
- Grading and hydrometer,
- Standard Proctor test,
- CBR.

The pits shall be logged by the Contractor's geologist in accordance with ASTM D 2488.

On completion of each pit, pit logs shall be submitted by the Contractor. They shall contain the following information on a form submitted to the approval of the PMC:

- Contract title.
- Contractor's name.
- Pit coordinates.
- Date of beginning and completion.

- Method of digging.
- Depth to each change of stratum.
- Records of ground water including level of standing water.
- Description of each stratum in strict accordance with ASTM D 2488.
- Soil classification according to USCS.
- The depths at which samples were taken.
- The results of laboratory tests performed on the samples.
- The reason for stoppage (rock, water ingress, order...).

29.3.4 Road Embankment Foundation and Sub-Grade Preparation

29.3.4.1 Foundation

- Excavation shall be carried out so as to expose an acceptable foundation surface. An acceptable foundation surface is a surface below which, after compaction, the material has density similar to that of the compacted fill material to be placed thereon. Preparation of such a surface may include drying, compaction, scarifying or other measures.
- The PMC will determine the requirements for removal of additional material, if any, in order to establish an acceptable surface for foundations. Filling operations shall not be started on any part of the foundation, until the PMC has inspected and approved it.
- Unless otherwise approved, the foundation surfaces shall be compacted such that the density of the foundation material at a depth of 0.3 m below the surface is not less than the specified density of the fill to be compacted thereon.

29.3.4.2 Sub-grade Preparation

- The areas to be covered with sub-base or base course shall be carefully cleaned so that no objectionable material can be incorporated in the future courses.
- Fissures, cavities, pockets, hollows and depressions in surfaces which will be in contact with the sub-base or base courses shall be filled. Soil drains shall be installed in saturated areas of the sub-grade, or as directed by the PMC.
- The sub-grade shall conform to lines and grades shown on the Drawings. The materials shall be spread to a depth of 300 mm at the maximum and compacted to the density specified, so that sub-base material, when placed, will not mix with the sub-grade material.
- Compaction shall be achieved by means of a smooth drum vibrating roller with the following minimum characteristics:

- Minimum static weight 8 t
- Drum diameter: not less than 1,500 mm
- Minimum static weight per meter of drum 3.5 t
- The number of passes shall be adapted to the material.

- All soft areas shall be cut out and filled with approved material brought to the correct level after compaction.
- If any area previously accepted should become softened and/or rutted as a result of erosion due to surface runoff or contaminated with objectionable materials, the soft or contaminating materials shall be removed, ruts shall be filled and the foundation prepared again, to the satisfaction of the PMC and at no additional cost to the Employer.

29.3.5 Placement and Compaction of Materials

- Common fill, sub-base, base courses shall not be placed until all required excavation has been completed and approval has been given for placement to commence by the PMC.
- The Contractor shall dump, spread and level materials in such a manner as to avoid segregation and to obtain a reasonably well graded mass
- The Contractor shall provide sufficient, suitable, approved compaction equipment as is necessary for compaction of the various fill materials to the specified densities.
- Common fill and sub-base and base course materials shall be placed in continuous horizontal layers of uniform thickness. Each layer shall, after placing and spreading, be leveled with a road grader prior to compaction.
- Wherever the use of rollers is not practical, the Contractor shall compact fill materials using hand operated power tampers or other approved compaction equipment, provided layer thickness is adjusted to provide the specified relative compaction.
- If required by the PMC, the Contractor shall moisten the fill materials by sprinkling with water, to obtain the specified moisture content. Sprinkling shall be performed with tank trucks equipped with spray bars and suitable apparatus. Any placed material which does not meet the specified requirements shall be removed and disposed of or reworked by the Contractor to produce a material which does satisfy the specified requirements, at no additional cost to the Employer.
- The Contractor shall place compacted sub-base course and base course materials to the thickness indicated in the Drawings. No reduction in specified thickness at either sub-base course or base course shall be permitted.

29.3.5.1 General Fill

Placing and compaction shall be adapted to the material used according to its grading and plasticity in order to achieve a CBR value in situ more than or equal to 25%.

29.3.5.1.1 Placing and compaction for earthfill materials

- Unless otherwise specified, thickness of common fill and sub-base layers before compaction shall not exceed 300 mm for fill to be compacted by approved vibrating roller or 100 mm for fill to be compacted by approved hand-operated power tampers, but shall not be less than 1.5 times Dmaximum.
- Each layer shall be compacted by means of a vibrating smooth drum roller so as to achieve a dry density at least equal to 95% of the maximum dry density as determined by ASTM D698. Each layer of material spread shall be compacted by not less than four complete passes by approved compacting equipment. Layers shall be compacted in strips, with adjacent strips, overlapping not less than 600 mm. Compaction units shall not travel at speeds in excess of 5 km/h.
- Placement moisture content of the material shall be so that:

  $-3 \leq w-w_{opt} \leq +3$ with:

  - w : placement moisture content measured on the compacted layer;
  - w_{opt} : optimum moisture content of the standard Proctor compaction test.

29.3.5.1.2 Placing and compaction of rockfill materials

- The maximum lift thickness shall be 300 mm and at least 1.5 times of Dmaximum.
- Each layer shall be compacted by means of a vibrating smooth drum roller, so as to achieve a relative density in the range of 60 to 70%.
- The relative density shall be determined by the USBR Method Designation E12.
- If necessary to achieve the compaction requirements the material shall be wetted.

29.3.5.2 Sub-base Course

- In-situ CBR tests shall be made as required in Clause 1.5.1 "Control tests" or as directed by the PMC to determine the necessity for a sub-base layer either on natural ground or embankments.
- If CBR $\geq$ 25%: no sub-base required.

  If 25 > CBR $\geq$ 10%: sub-base 200 mm minimum thickness.

  If CBR < 10%: sub-base 300 mm minimum thickness.
- The sub-base course material shall be spread longitudinally in uniform layers not exceeding 150 mm loose thickness.

- The compaction shall not be at less than 98% of the maximum dry density.

29.3.5.3 Base Course

- The Contractor may propose to add cement to the base course material as described in Clause 2.5 in order to reduce moisture content of the material and improve the characteristics of the base course and thus diminish the quantities used and/or diminish the maintenance.
- The base course and base course material shall be spread longitudinally in uniform layers not exceeding 200 mm loose thickness. The final profile of the surface shall be to the dimensions and elevations shown on the Drawings or as directed by the PMC.
- Each layer shall be compacted by means of a vibrating smooth drum roller so as to achieve a dry density at least equal to 95% of the maximum dry density as determined by ASTM D698.
- Placement moisture content of the material shall be so that:

  $-2 \leq W_{opt} \leq +2$ with:

  - W: placement moisture content measured on the compacted layer;
  - Wopt: optimum moisture content of the standard Proctor compaction test.

  A CBR higher than 80% shall be achieved.

29.3.6 Construction of Surface Course

29.3.7 Prime Coat Application on Base Course

- The bituminous prime coat shall be a medium curing bitumen cutback, MC-30, as per Clause 2.6, applied at a rate of 1.5 liter/m² to the surface of the base course for the road carriageway width. The rate of application of prime coat shall be subject to approval or modification by the PMC based on the results of trial sections to be prepared by the Contractor prior to the commencement of surfacing works.
- Heat asphalt to required temperatures given in Table Clause 2.6 shall be in accordance with the Manufacturer's directions.
- Immediately before the application of the prime coat, the surface of the base course material shall be swept clean of all loose material to the satisfaction of the PMC using soft-haired brushes and the material brought to a damp condition by a light sprinkling of water as necessary.
- The prepared base course shall be primed and asphalt concrete shall not be applied until the prime coat has been left to for a period sufficient to allow it to dry thoroughly but in any event not less than twenty four (24) hours after the application of the prime coat.

- If prime coat fails to penetrate within twenty four (24) hours, spread sand blotter material in amounts required to absorb material, sweep and remove excess blotter material.
- Traffic shall not be permitted to use the primed surface unless the surface is adequately protected to the approval of the PMC. Notwithstanding such protection, traffic shall not run over a primed base during its period of curing.
- Before the application of the asphalt concrete, the primed surfaced shall be thoroughly examined and any weak or damaged areas shall be made good by cutting out the unsatisfactory material and replacing it and re-priming the affected area to the approval of the PMC.
- Repaired areas shall be at least equal in standard to and integral with the rest of the primed surface.
- Immediately before application of the asphalt concrete, the primed surface shall be brushed and thoroughly cleaned to the approval of the PMC. The rate of application of bitumen shall be as directed by the PMC and shall be within ± 10% of the specified rate as measured by the Road Tray Test.

29.3.7.1 Placing and Compacting Surface Course

- Asphalt concrete surfacing having a maximum aggregate size of 20 mm shall be placed to a compacted thickness of 70 mm.
- The delivery temperature of the mixture shall be within the absolute limits of 140°C and 163°C. Breakdown compaction of the mat shall commence as soon as working clearance exists behind the paver for the breakdown roller. Materials deposited on the road behind the paver and not in the course of being compacted by the roller, may be rejected should its temperature be less than 120°C.
- Asphalt concrete surfacing shall be placed using self-propelled tamper/spreader paving machines, approved by the PMC. Each paving machine used shall work in conjunction with two road rollers, a steel drummed roller for breakdown rolling and a multi tired roller for finish rolling. The steel drummed roller shall have a mass of at least eight (8) tons. The multi tired roller shall have a mass of at least ten (10) tons and shall have at least nine (9) tires each capable of inflation to a pressure of 830 kPa (8.0 kg/cm²). Each roller shall incorporate a means of keeping the drums (tires) wet during operation to prevent picking up of the asphalt concrete mat. Only experienced operators shall be used on the rollers. Sharp turns and sudden reversals of travelling direction will not be permitted on the asphalt concrete surface.
- Placement of asphalt concrete shall be continuous. In the event of an interruption of placement due to the weather or plant failure or any other cause, the PMC may direct the formation of a construction joint in the mat before placement resumes.

- The PMC may direct control testing to be undertaken by the Contractor on days when asphalt concrete is being placed. The PMC will direct the frequency of control testing on the basis of the daily production volume. All control testing shall be in accordance with current ASTM procedures.

29.3.7.2 Application

- The rates of application of prime and seal coats are as specified below, subject to approval or modification by the PMC based on the results of trial sections to be prepared by the Contractor prior to the commencement of surfacing works. Such rates and order application shall be:
  - The bituminous prime coat shall be a medium curing bitumen cutback, MC-30, as per Clause 2.6, applied at a rate of 1.9 liter/m² to the surface of the base course for the road carriageway width.
  - The first seal coat, a binder coat, shall be medium bitumen MC-250 as per Clause 2.6, applied at a rate of 1.9 liter/m² and covered with 20mm stone aggregate (type B) at a rate of 24 kg/m².
  - The second seal coat shall be medium curing bitumen 80/100 MC-250 as per Clause 2.6, applied at a rate of 1.19 liter/m² and covered with 10mm stone aggregate (type A) at a rate of 12.5 kg/m².
- Heat asphalt to required temperatures given in Table Clause 2.6, in accordance with the Manufacturer's directions.
- Immediately before the application of the prime coat, the surface of the base course material shall be swept clean of all loose material to the satisfaction of the PMC using soft-haired brushes and the material brought to a damp condition by a light sprinkling of water as necessary.
- The prepared base course shall be primed and the first seal coat shall not be applied until the prime coat has been left to for a period sufficient to allow it to dry thoroughly but in any event not less than twenty four (24) hours after the application of the prime coat.
- If prime coat fails to penetrate within twenty four (24) hours, spread sand blotter material in amounts required to absorb material, sweep and remove excess blotter material.
- Traffic shall not be permitted to use the primed surface unless the surface is adequately protected to the approval of the PMC. Notwithstanding such protection, traffic shall not run over a primed base during its period of curing.
- Before the application of the first seal coat the primed surfaced shall be thoroughly examined and any weak or damaged areas shall be made good by cutting out the unsatisfactory material and replacing it and re-priming the affected area to the approval of the PMC.

- Repaired areas shall be at least equal in standard to and integral with the rest of the primed surface.
- Immediately before application of the first seal coat, the primed surface shall be brushed and thoroughly cleaned to the approval of the PMC. The rate of application of bitumen shall be as directed by the PMC and shall be within ± 10% of the specified rate as measured by the Road Tray Test.
- The Contractor shall ensure that the coverage of the bitumen is even and complete, that the joints between spraying strips are straight and that no bitumen is sprayed on adjacent complete surfacing. There shall be no areas of the binder coat with an excess or deficiency of bitumen. Any sections with a deficiency shall be resprayed, and in sections with an excess of binder the material shall be removed by burning off and the section resprayed all to the approval of the PMC.
- Prior to the commencement of spraying of surface, a strip of paper 2 m wide or similar protection shall be laid over the previous section and the bitumen sprayer shall commence spraying from over this strip. Protection shall also be laid on the shoulders to ensure that the surface dressing terminates at the edge of the carriageway and forms a neat line.
- Rolling shall commence at the edge of the carriageway and proceed in a longitudinal direction. Immediately following the application of the binder coat of bitumen the surface shall be covered with approved stone aggregate. The rate and method of spreading the stone aggregate shall be such that a finished appearance of a closely-knit mosaic of stone particles firmly adhering to the bitumen shall be achieved, with individual aggregate grains in contact with their adjacent grains.
- The surface shall be rolled with an approved pneumatic tired roller immediately after the application of the stone aggregate. Overlap on successive passes shall be at least half the width of the roller.
- The completed bitumen surfacing layer shall be evenly textured and graded, show no lean or fat areas and shall not have any areas which will allow the accumulation of water.
- Bitumen surfacing shall not be carried out when the road temperature is below 20°C.
- All stone aggregate shall be dry and free from deleterious matter. Where stone aggregate has become dusty in transit or in the stockpile, they shall be cleaned to the PMC's satisfaction.
- Quantities of materials for DST are as follows:
  - First treatment: 24.0 kg/m² for aggregates and 2.14 liters/m² for bituminous material
  - Second treatment: 12.5 kg/m² for aggregates and 1.63 liters/m² for bituminous material

- Asphalt cement, liquid asphalt and emulsified asphalt shall be applied by means of pressure distributor manual or automatic at the temperature specified for the type and grade of asphalt being used. The spread of bituminous materials shall be at least 10cm more than the width to be covered by the aggregates from the spreading device.
- Immediately after applying the asphalt material, dry aggregates shall be uniformly and evenly distributed over he treated surface from an approved mechanical aggregates spreader or any other means approved by the PMC. No portion of the binder shall remain uncovered for a period of excess of 20 minutes after spraying. Immediately after spreading of aggregates, the treated surface shall be rolled with a self-propelled pneumatic tire roller having a minimum contact pressure of 2.8kg/cm2. A steel wheeled roller weighting between 6 to 8 tons may be used as a second roller.

29.3.8 Drainage Works

29.3.8.1 Unlined Surface Drains

Unlined side drains and turn-out drains shall be constructed at the locations and to the lines, grades and dimensions shown in the Drawings or as directed by the PMC. This work shall also include inlets and outlets to culverts. The PMC may direct these drains to be lined in accordance with Clause 3.7.2 below.

29.3.8.2 Lining of Surface Drains

Lining of surface drains shall be required in high velocity flow areas or as directed by the PMC and shall be constructed of precast concrete, cast-in-place concrete or masonry placed in trenches which have been excavated to conform with the shape and dimensions of the lining so that its lower surface is in complete and continuous contact with the underlying material. Where neat trimming of the trench to the required shape is not practicable, selected impervious backfill or mortar, as directed by the PMC, shall be placed under and about the lining and thoroughly tamped to provide a firm, uniform bedding.

Joints between precast concrete linings which are not bedded on concrete or mortar and joints between lining material and other structures shall be filled completely and neatly with an approved resilient type mastic filler.

29.3.8.3 Drainage Embankments

- Drainage embankments shall be constructed at the locations designated by the PMC to divert overland runoff away from other structures and into existing watercourses or drains.

- Material for drainage embankments shall consist of approved material excavated from the associated lined or unlined surface drains or other approved common fill material obtained from the Works or designated borrow areas.
- Construction of drainage embankments shall be in accordance with the requirements of Clauses 3.4, and 3.5.

29.3.8.4 Soil Drains

Soil drains shall be coarse aggregate with sand or geotextile filters, constructed to lines and grades as to lead water from the subgrade to the side drain or down-slope side of the road, at the locations and in accordance with the details defined by the PMC.

29.3.8.5 Installation of Concrete Pipe Drains

- Concrete pipe drains shall be constructed at the locations and to the lines, grades and dimensions shown in the Drawings or as directed by the PMC.
- Pipe shall be laid in trenches, excavated to the depth and grade, and at the locations shown on the Drawings. Compressible and other unsuitable material on the bottom of the trenches shall be removed as directed and backfilled to grade with granular sub-base course material and thoroughly tamped or otherwise compacted to ensure a firm uniform foundation.
- The pipes shall be laid on the concrete foundation and properly jointed using concrete collars with mortar caulking as shown in the Drawings.
- After the pipes have been bedded, laid and jointed, backfill material shall be placed simultaneously on both sides of the pipes and compacted by tamping or other approved methods, for a height of at least 400mm above the top of the pipes unless otherwise shown in the Drawings or as directed by the PMC. Backfill material placed within 30cm around any pipe shall not contain stone or rock fragments having a maximum dimension greater than 25mm. The remainder of the trench shall be filled with material having a maximum dimension of 75mm. Insofar as is practicable, backfill material shall be obtained from trench excavation for laying of the pipe being backfilled and additional material which may be required shall be obtained from sources approved by the PMC.
- Concrete bag headwalls and riprap placement shall be constructed to the lines, grades and dimensions shown in the Drawings or directed by the PMC. Pipe ends shall be field cut to match the profile of the headwall.
- A full trench condition shall be provided wherever possible, but in no case shall the trench be of lesser depth than 50% of the diameter of the pipe.

29.3.8.6 Installation of Corrugated Steel Culverts

- Corrugated steel culverts may be used for the permanent and temporary access roads.
- Culverts shall be laid in trenches excavated. A full trench condition shall be provided wherever possible, but in no case shall the trench be of lesser depth than 50% of the diameter of the culvert.
- If the material in the bottom of the trench excavation is of such a character as to cause unequal settlement along the length of the culvert, the trench shall be excavated below the grade to such depth as directed by the PMC and backfilled with sub-base material and thoroughly tamped or otherwise compacted to ensure a firm and uniform foundation.
- Where rock occurs in the bottom of the trench, the rock shall be excavated below grade and backfilled with sand or fine gravel so that there will be at least 150mm cushion between the rock and all portions of the culvert.
- Culverts shall be erected on a bedding consisting of well-compacted approved granular fill. The bedding thickness shall be 150mm unless otherwise directed by the PMC. Backfill material shall be placed about the culverts and compacted by tamping or other methods, to a height of at least 600 mm above the top of the culvert. The bedding and backfill shall contain stone or rock fragments with maximum dimension not exceeding 75 mm and with no more than 10% passing 0.074 mm (US No.200) sieve size. Erection shall proceed in accordance with the pipe manufacturer's detailed instructions.
- Approved granular material shall be placed and compacted around the pipe in accordance with the recommendations of the pipe manufacturer.
- Concrete bag headwalls and riprap placement shall be constructed to the approved lines, grades and dimensions. Pipe ends shall be field cut to match the profile of the headwall.
- Care shall be used to give the culvert a firm and uniform bearing. Any culvert which has settled after it is laid or which is not in true alignment shall be taken up and re-laid by the Contractor without any additional cost to the Employer.

29.3.9 Steel Guard Rails, Guard Posts and Sign Plate

Where necessary for safety, mainly where steep slopes occur in natural ground, and in road bend extrados agreed by the PMC or shown in the Drawings, steel guard rails shall be installed as directed by the PMC.

The sign plate shall be of a steel sign plate with various road signs written as directed on the white-paint board which is fitted on a reinforced concrete post of 10cm x 10cm square approved by the PMC.

29.3.10 Maintenance

The Contractor shall maintain the roads as specified in Clause 1.1 during the Contract Work.

The roads include the permanent and temporary access roads in the Projet Area, where of the section handed over from the Employer to the Contractor, together with associated drainage, stream crossings, road markers, lighting, guard posts and rails and any other measures required for roads servicing the construction camps, structures, storage, stockpile, borrow and disposal areas.

Maintenance work shall include:

- Keep road structures, culverts, drains and other waterways clear of any debris and in good working order at all times;
- Patch potholes with approved materials, keep the road surface in good repair and perform any grading, rolling, spraying for dust control and necessary resurfacing;
- Maintain fence posts, guide posts, guard posts, fencing, signs, signposts and other roadside structures;
- Keep the road surface and shoulders free from rocks, fallen timber, branches, limbs, leaves, garbage and other debris and materials removed from drains and drainage structures;
- Maintain barriers; and
- Maintain adequate side windrows on fill batters and natural slopes adjacent to the roads to prevent drainage from passing down fill slopes, except in drains properly constructed with masonry paving, pipes or half-round lining.

29.3.11 Rehabilitation

All rehabilitation of the cut and fill slopes shall be carried out in accordance with Section 0820 - Site Reinstatement.

29.3.12 Stone Masonry Dressed Coursed With Mortar

This item shall consist of dressed coursed stone masonry with mortar of ratio 1:3.

The individual stones shall be large and well proportioned. They shall not be less than 20cm nor more than 50cm in thickness. The stone shall be dressed to exact size and shapes before being laid and shall be cut to lie on their natural beds with top and bottom truly parallel. The bottom shall be the full size of the stone and no stone shall have an overhanging top. Beds of face stone shall be fine-finished for a depth of not less 30cm.

Vertical joints of face stone shall be fine finished and full to the square for a depth of not less than 15 cm.

29.3.12.1 Stretches

Stretches shall have a width bed of not less than one and half (1.5) times their thickness. They shall have a length of bed not less than twice nor more than three and half (3.5) times their thickness, and not less than 90cm.

29.3.12.2 Headers

Headers shall be placed in each course and shall have a width of not less than one and half (1.5) times their thickness. The header shall extend entirely through the wall. Headers shall hold in the heart of the wall the same size shown in the face and shall be spaced not further apart than 2.5m centre to centre. There shall be at least on header to every two stretchers.

29.3.13 Stone Masonry Dressed Un-Coursed Dry

The item shall consist of Dressed Un-coursed stone masonry without mortar.

Stones shall be dressed to exact sizes and shapes and cut to lay on beds with top and bottom truly parallel. Hollow beds shall not be permitted. Beds of face stone shall be fine finished for a depth of not less than 30cm. vertical joints of face stone shall be fine finished and full to the square for a depth of not less than 25cm.

29.3.13.1 Stretches

Stretches shall have a width of bed not less than one and half (1.5) times their thickness and length of bed not less than twice not more than three and half (3.5) times their thickness but in no case less than ninety centimeters.

29.3.13.2 Headers

Headers, placed in each course, shall have width not less than one and a half (1.5) times their thickness. The header shall extend entirely through the wall. Header shall hold in the heart of the wall spaced not further apart than 2.5m centre to centre. There shall be at least on header to every two stretchers.

The quantity of stone masonry to be paid shall be the number of cubic meters in the completed work.

HYDROMECHANICAL WORKS SPECIFICATIONS

Chapter 0910

30 HYDROMECHANICAL SPECIAL TECHNICAL SPECIFICATIONS (STS)

30.1 GENERAL REQUIREMENTS

30.1.1 SCOPE

The present Specifications cover the technical requirements and limits of supply for Hydro-mechanical and accessories to be installed in PSKEM Dam Project.

The supply shall include the design, manufacture, shop testing and painting, delivery to the site, installation, Site Testing, commissioning, acceptance testing and placing into successful operation of all equipment hereinafter outlined.

The supply shall conform to the General Technical Specifications and to the Drawings, unless otherwise specified.

The description of the items of the supply in the following paragraphs does not limit the responsibility of the Contractor to perform all works and to supply all accessories, within the contractual limits, in order for the same to be complete and ready for operation.

30.1.2 OBJECT AND LIMITS OF SUPPLY

The Supply shall include design, calculation, manufacture, painting and shop testing, delivery to site, field erection and testing of the following equipment:

Bottom Outlet:

a) One (1) set of fixed-wheel gate as Maintenance Intake gate for Bottom outlet, comprising structural steel sections complete with seals, electromechanical hoist (Winch), electrical and control systems, by-pass system, lifting and dogging attachments, all embedded parts including bearing, seal paths, railway and embedded parts, all as detailed in Chapter 2 of this Specification;
b) Two (2) sets of Bottom Outlet slide gates, comprising two high pressures, enclosed, guided, vertical slide gate with gate leaf, gate bonnet enclosures, by-pass systems, hydraulic hoists, electrical and control systems, fittings and connections necessary for operation of gates, all as detailed in Chapter 3 of this Specification.
c) One (1) set of steel lining and appurtenances for bottom outlet including, bell-mouths, boxes and boxes reduction, all as detailed in Chapter 4 of this Specification.
d) One (1) set of overhead traveling crane for bottom outlet gates chamber, comprising, main hoist, electrical and control systems, safety devices, lights, fittings and connections, all as detailed in Chapter 5.

The Supply shall be complete with all parts to be embedded in the first and second stage concrete such as anchor bolts, base plates, pipes, etc.

The Tenderer shall clearly show in the illustrative drawings annexed to his proposal:

- The number of pieces in which the fixed and movable parts of the equipment will be divided.
- The type of connections: flanged or welded.
- The number of pieces in which the equipment will be divided shall be limited to the minimum allowed by the transport limitations.

30.2 OUTLET MAINTENANCE INTAKE GATE

30.2.1 GENERAL

This chapter covers the Special Technical Specification for:

- Supply of One (1) set of fixed-wheel gate as Maintenance Intake gate for Bottom outlet, comprising structural steel sections complete with seals, electromechanical hoist (winch), electrical and control systems, by-pass system, lifting and dogging attachments, all embedded parts including bearing, seal paths, railway and embedded parts.

30.2.2 DESIGN DATE

Bottom Outlet	Intake maintenance gate
- Type	Fixed-wheel gate
- Number	One set
- Number of panels	Two
- Dimension of opening	4.00 x 5.00 m (w x h)
- Sill elevation	1035.50 m.a.s.l
- Elevation of operation platform	1100.00 m.a.s.l
- Normal Elevation	1096.00 m.a.s.l
- Max. elevation (flood 10000 years)	1098,0 m.a.s.l
- Operating system	Electrical wire-rope hoist
- Operating condition	No flow
- Pressure balancing	Build in by-pass
- Inclination angle	App. 72.0°
- Corrosion allowance	2 mm
- Allowable stresses	Acc. to DIN19704
- Earthquake loading	OBE

30.2.3 DESIGN CRITERIA

The Maintenance intake gate shall be of the fixed-wheel type and will be used for maintenance of downstream equipment such as steel lining and gates.

The gate shall only operate in balanced pressure and will be located in completely open or completely closed position. The pressure balancing shall be attained by means of a by-pass valve in the gate leaf. By-pass valve shall be operated by first motion of hoist.

The gate will be operated on railway with 72 degree inclination angle from dam crest at elevation 1100.00 m.a.s.l.

The gate and casing shall be designed to withstand the maximum static pressure. The effect of earthquake force shall be considered with normal static pressure in calculation of the gate.

The load cases for gates shall be determined as describe here under:

- NB case: Acc. to normal water level;
- BB case: Acc. to maximum water level (Flood 10,000 Y);
- In AL case: dynamic head (as per Clause 3.2.1.7 of GTS) shall be added to NB case.

The closing forces shall prevail over the resisting forces with a safety factor of 1.5.

30.2.4 STRUCTURAL DETAILS

30.2.4.1 Gate Leaf

The gate shall be manufactured of welded steel sections consisting of horizontal beams and vertical stiffeners that shall support a continuous watertight surface (skin plate). The skin plate shall be on downstream side.

The gate structure shall be calculated in accordance with DIN 19704 standard. The resulting thickness shall be increased by 2 mm to allow for corrosion. The minimum skin plate thickness shall not be less than 15 mm, including 2 mm for corrosion.

30.2.4.2 Gate Wheels

Four wheels for each panel shall be used. The wheels shall be of forged steel (such as ASTM 668 or 35Mn2) and shall run on stainless steel (such as X20Cr13) rails with hardness higher than wheels (Min. 30 HB).

The wheels axles shall be made of stainless steel (such as X20Cr13), designed to bear unexpected or irregular loads.

The wheels bearings shall be of the self-lubricating types.

The wheels shall be hardened by heat treating, oil quenching and tempering. After heat-treating and machining, the finished-wheels shall be free from cracks as determined by magnetic particles; fluorescent or dye penetrates inspection tests.

To provide adjustment for the wheels, the end supports of the wheels axels shall be eccentric with respect to the centerline (at least 3 mm), so that after final assembly, all the wheels will bear uniformly on the track.

The adequate edge on the surface of wheels shall be provided to limit lateral displacement and to prevent vibrations during operation.

30.2.4.3 Gate Seals

The gate shall be sealed by contact of the bottom wedge type elastomeric seal and the bottom edge with the sill beam or the top plate of the segment below. The top and the side seals shall be of the double-stem type. The bottom seal shall be of the wedge-type. The bottom edge of the skin plate shall be machined to make a near-watertight contact with the sill beam.

The seals shall be positive in action so there is no leakage when the gate set is in position. The seals shall also not unduly interfere with the placing and removal of the gate. The seals shall be in continuous lengths and all corners shall be separate moldings. Where joints are necessary, these shall be oblique rather than perpendicular to the line of contact and a minimum of 300 mm from a corner. All joints shall be hot vulcanized or joined by an appropriate compound such that have a tensile strength of not less than 80% of the tensile strength of the un-spliced material.

All seals shall be secured to the gate with stainless steel bolts to facilitate their replacement. Bolt spacing shall not exceed 100 mm. The seals shall be guarded in order to protect them from possible damage due to timber or other objects becoming jammed between the seals and the embedded parts.

When the gate is in the position, the seals compressing shall be at least 3 mm for 'j' seals and 5 mm for flat seal.

Holes for seal bolts in the gate leaf and seal clamp bars shall be drilled in the workshop.

After inspection, the seals shall be match-marked with the gate element and when the gate is prepared for shipment, the seals shall be removed and packed separately.

Contractor shall not apply rubber cement to the joint in the shop but shall provide sufficient cement in suitable airtight containers for application by others during Site assembly

30.2.4.4 Rails and Sealing Surfaces

The rails and sealing surfaces shall be smooth, true to form and free from twists, warps and kinks. All surfaces which are in contact with the rubber seals and the wheels shall be lined with stainless steel (such as X20Cr13) sheets.

The rails shall be supplied complete with anchor plates and bolts and other accessories including the welding plates to be embedded in the first stage concrete. Stud bolts to be welded to the welding pads during erection shall be provided with double nuts and washers for precise alignment of the rails. The welding plates shall be provided with two drilled holes to facilitate nailing to formworks.

30.2.4.5 Anchor Rods & Plates

The Contractor shall supply all necessary anchor rods and plates to be embedded in the first stage concrete.

The supply shall include all distribution plates having a thickness of not less than 15 mm.

The dimensions of the plates shall be such that stresses in the concrete will be less than 60 kg/cm^2.

30.2.5 OPERATING SYSTEM

30.2.5.1 General

The maintenance intake gate shall be operated by an electromechanical wire-rope hoist (winch). The hoist capacity shall be determined by safety factor 1.5.

The hoist shall be located on a steel base (pedestal) at elevation 1100.00 m.a.s.l. in the dam crest. For supporting the rope, on the operation path, adequate rollers shall be provided.

The hoist shall be calculated accordance to CMAA, FEM or other related standards which are acceptable for consultant.

Contractor shall supply all of the embedded parts, anchor plates and bolts which will be installed in first and second stage concrete.

30.2.5.2 Design

a) Wire Rope

The rope shall be made from galvanized or stainless wire steel. The breaking strength of the wire shall be in accordance with DIN 3088 or equivalent standard approved by the PMC. The minimum safety factor based on breaking strength of wire rope shall be selected as 6. The ends of rope shall be casted in tapered rope sleeves.

b) Rope Drums, Pulleys and Compensating Rollers

The drum shall be of such size that there will be no more than one layer of rope on it. The length of drum shall be such that each end of rope has minimum two full turns on it when the gate is at its lowest position and one spare groove for each end of drum when the gate is at its highest position. The drums shall be machine grooved and contour at the bottom of grooves shall be circular over an angle of at least 120°.

The radius of grooves shall be 0.53 times of rope diameter. The depth of grooves shall not be less than 0.35 times of rope diameter.

The minimum pitch diameter of drums, pulleys and sheaves shall be in accordance to DIN 19704.

Sheaves and pulleys shall be machine grooved to a depth of not less than 1.5 times of rope diameter.

c) Gear Box

Gearbox shall be of rigid construction with inspection covers and lifting handles where necessary. The gearboxes shall be so designed that the gears can be easily removed or replaced and shall be such that the gears are suitably lubricated.

Facilities for oil filling and draining, connection for oil level indicating and adequate breathing shall be provided where necessary. The boxes shall be mounted on a leveled surface. Material for gearboxes shall be cast steel.

d) Brake

One automatic spring set, electric release shoe type (or disk type for electro-motors with rated power below 5KW) holding brakes shall be arranged to operate when current is cut off or fails.

The brake shall prevent acceleration of the load, when lowering, and shall sustain the load in any desired position when motors are not operating. Breaking capacity, in both directions shall be at least 150 percent of maximum driving torque.

e) Motor

Motor shall be totally enclosed, self-cooled, polyphase induction type, designed for hoists. Windings shall be suitable for tropical climate with Class F insulation. Ratings shall be suitable for Class B temperature rise. The motor shall be designed for continuous service, with above 20 starts per hour. Motors shall be equipped with anti-friction bearings and enclosed terminal boxes. The Motor of same characteristics shall be interchangeable and shall be mounted in such a manner that they can be removed while the load is being held by the hoist brake. The Motor shall be supplied with anti-condensation heater.

30.2.6 ELECTRICAL EQUIPMENT

Complete operating electrical system for the gate hoist, shall be provided.

All electrical equipment shall be suited for outdoor operation. All live elements shall be totally insulated or protected in order to prevent any accidental contacts.

The electro-motors and all devices required AC supply shall be provided through local control panel which is fed from main distribution board.

The power and control panel shall comply with the requirements given in the General Technical Specification.

30.2.7 CONTROLS

The gate shall be operated from the local control panel by motor driven wire-rope hoist. The hoisting equipment shall be capable of raising, lowering and sustaining the gate in any position under the conditions and operating requirements specified.

One control panel for intake gate shall be provided.

The control panel shall have all the necessary alarms and signals and the necessary contacts to send signals to the Dam Control Board.

The control of the gate shall be done by means of push buttons. The control panel shall be provided with the following controls:

- One selector switch for "off", "Normal" and "Maintenance";
- One "opening", one "stop" and one "closing" push buttons;
- One selector switches for lamps "on ", "off ";

A mechanical gate position indicator located beside the hoist shall be provided for gate.

The supply shall include slack rope protection and automatic load limiter devices (load cell), which shall prevent lifting of loads greater than the preset maximum ones.

The limiter shall be adjustable between 80 percent and 110 percent of the rated load.

30.2.8 OPERATING SEQUENCE

The gate shall be operated under balanced pressure (no flow) conditions, and shall be either fully open or fully closed. Controls shall be from a local control panel and shall include momentary contact-type open, close and stop push-buttons for hoist motion control. Over hoist, slack rope, by-pass valve open, gate closed, gate at top of the tunnel and gate at parking limit switches shall also be provided for control and protection of each system.

In opening condition, after opening the by-pass valve, the relevant limit switch shall stop the motor. When the pressure of both side of the gate is balanced and tunnel filled, a water level switch, included in the supply, shall give the consent for further opening. With another "open" command the gate shall be raised up to the top of the intake level and stopped. For further rising in maintenance conditions, another "open" command is required.

In closing sequence, the gate shall be stopped in top of the opening level. For more lowering, another "close" command is required. These sequences have to be shown in the Logic Diagrams.

30.2.9 FITTINGS AND ACCESSORIES

30.2.9.1 By-Pass

On upper segment of maintenance intake gate, a by-pass valve shall be incorporated for the filling of the conduit. The by-pass valves shall be operated by the wire-rope hoist.

The sealing shall be made of bronze stainless steel contact, the bronze side being on the gate and the stainless steel on the valve. The spring and rode of by-pass valve shall be made of stainless steel.

Particular care shall be taken in the design of the by-pass so that there will be no risk that the by-pass valve remains opened when the gate is completely lowered.

30.2.9.2 Air Pipes

In each intake, three air galvanized pipes (ϕ=300 mm) shall be installed to release the air during filling of the conduit.

The end of each pipe shall be raised up to operation platform.

30.2.9.3 Supporting Rollers

On the operation path of the gate, sufficient quantity of supporting rollers shall be considered to support the rope during operating.

30.2.9.4 Dogging Device and Support

A pair of suitable dogging devices shall be designed to keeping the gate in inclined position. The dogging device shall be designed with impact factor 2. In this case, the allowable stresses are the permissible stresses in normal case load.

30.2.10 TOLERANCES

The dimensions of the gate shall not differ by more than ±0.1% from the design data. The possible parallelism error between lower and upper sides, as well as between side edges, shall be fully compensated by the deformation of the rubber sealing.

The sealing surfaces of the side and top seals, when assembled on the finished gate element shall not depart from a true plane surface by more than 1 mm.

All points on the sill sealing face shall lie between two planes parallel to the horizontal plane at the theoretical sill elevation with ±1 mm.

The maximum admissible water leakage shall be less than 1.0 l/min/m.

30.2.11 TESTS

30.2.11.1 Shop Tests

During fabrication and installation, the Contractor shall perform all routine and special tests in accordance with the applicable standards and the relevant articles of the present General and Special Technical Specifications.

a) Mechanical Tests

The gates shall be shop assembled for inspection and tests.

The assembly shall be checked or tested for dimensional accuracy, tolerance, operation, travel and to control that the requirements of these Specifications are met. Any error or omission discovered shall be corrected.

The operation of by-pass valves shall be checked.

Wire-rope hoists shall be shop assembled for inspection and test. A complete running test and load test shall be performed.

After shop assembly, the electromechanical hoists with the required match-marks shall be disassembled into major units. Control panels shall be shipped completely assembled except for those fragile components that will require separate packing.

b) Tests on Electrical Equipment

Motors and panels, completely assembled, shall be tested according to Standards. For electric motors, the torque values as well as the starting current values shall be measured.

c) Test on Welding

All main welds shall be examined according to the procedure indicated in the General Technical Specifications.

All main welds shall be ultrasonically tested. At least 20% of welds and 100% T-joints shall be radio graphically examined according to the procedures indicated in the General Technical Specifications.

In any case, all butt welds of plates shall be 100% ultrasonic tested.

Dye Penetrate Tests on the sliding surfaces shall be carried out in workshop.

No cross-joint welds shall be allowed at all cases.

30.2.11.2 Site Tests

Before any mechanical test runs are made, a throughout inspection shall be made of all mechanical and structural connections. The tests shall include but not necessarily is limited to those described below.

The gate, after being installed, shall be inspected and operated to check clearances and accuracy of alignment and smoothness of operation.

All motions of the completely assembled gate shall be thoroughly and completely observed for freedom of operation and from internal mechanical interference, proper alignment of all running parts and freedom from vibration.

Tests to be performed shall include but shall not be limited to:

- Test of the by-pass valves.
- Water leakage tests (the maximum admissible water leakage shall be less than 1 l/min/m;
- Wire-rope hoist operation tests.

30.2.12 PROTECTIVE COATINGS

Surface preparation and protective coatings shall be in accordance with General Technical Specification.

30.2.13 SPARE PARTS AND SPECIAL TOOLS

30.2.13.1 Spare Parts

All spare parts shall be interchangeable and of the same material and workmanship and shall meet the same requirements as the corresponding original parts.

The Contractor shall supply for the each gate the spare parts listed hereunder, which are to be considered as a minimum requirement:

- One (1) complete series of seals;
- Ten percent (10%) of the bolts and nuts used;
- One (1) complete set of wheel bearing;
- One (1) set of all indicating lamps and fuses;
- Twenty percent (20%) of Contactor, circuit breaker, switches and relay of each type (minimum one);
- Two (2) limit switches of each type;
- One (1) level switches of each type;
- Twenty percent (20%) of each type of electronic cards with a minimum of one;

The Contractor shall provide any other spare parts he may consider necessary for five years operation of the gates.

30.2.13.2 Special Tools

The Supply shall include one complete set of special tools required for the erection and maintenance of the gate. All special tools shall be permanently identified as to their specific use and shall be located in a lockable portable metallic tool cabinet.

a. Eyebolts, lifting lugs, shackles, slings and any other special equipment required for handling during shipment to Site or during erection of the gate shall be furnished.

30.3 BOTTOM OUTLET SLIDE GATES

30.3.1 GENERAL

This chapter covers the Special Technical Specifications for one (1) set of Bottom Outlet gates, comprising two high-pressure, enclosed, guided, vertical slide gate tandems with gate leaf, gate bonnet enclosures, by-pass system, hydraulic hoists, controls, fittings and connections necessary for operation of gates, as shown in the drawings.

30.3.2 DESIGN DATA

- Type			High pressure enclosed and guided slide gate
- Number			Two, one as service and one as emergency
- Dimension of opening			
For service gate			2.50 x 3.12 m (w x h)
For emergency gate			2.50 x 3.37 m (w x h)
- Sill elevation (app.)			1030.00 m.a.s.l.
- Operation level			1096.00 m.a.s.l.
- Max. discharge in Normal Head			220 m^3/sec
- Normal Elevation			1096.00 m.a.s.l
- Max. elevation (flood 10000 years)			1098,0 m.a.s.l
- Hoist type			Electro-hydraulic hoist
- Number of hydraulic Power unit			1 set
- Operating speed			0.3 m/min (app.)
- Operating condition			
For service gate			Under full flow
For emergency gate			Emergency closing under full flow and normal closing and opening under equal pressure
- Sealing type			Bronze on ST. ST at top and lateral, ST-ST on ST-ST at bottom
- Corrosion allowance			2 mm
- Allowable stresses			Acc. to DIN 19704
- Earthquake Load	Service Gate	Gate	MCE
		Casing	MCE
	Emergency Gate	Gate	DBE
		Casing	MCE

30.3.3 DESIGN CRITERIA

These slide gates shall be placed in tandem. The upstream gate shall operate as the emergency gate, and the downstream one as the service gate. The gates shall be installed in the gates chamber located at the bottom outlet tunnel.

The emergency gate shall only operate completely open or completely closed. However, the service gate shall be capable of partial operation. The gates shall be designed to operate against the maximum flow under the maximum static head, and shall close the bottom outlet without leaks.

In normal operation, the upstream gate will be operated under balanced condition, for the maintenance of the downstream gate. However, in case of emergency, the upstream gate shall be capable of closure under the maximum flow condition.

The pressure balancing shall be attained by means of an external by-pass provided with two hand-operated valves. When the pressure on both sides of the upstream gate is balanced, a differential pressure switch included in the Supply shall give the consent for further opening.

The gates shall be of sturdy construction and in every partial opening, shall not induce any cavitations, vertices, vibration and instability. To ensure cavitations and vibration free operation of the gates and determination of opening and closing forces, and aeration pipe, necessary Hydraulic Model Study report should be performed by the Contractor, at his own expense according to below section.

The gates shall be kept in the open position by servomotors without the use of any mechanical devices, and the pump shall automatically compensate any small oil leakage that might occur. The piping and connections shall be fabricated in such a way that the pump will come into operation not more than once a week.

Each gate shall be completely manufactured and assembled in the workshop. No major welding connection shall be allowed at Site except the welding between the gate body and the steel lining of Bottom Outlet conduit.

The gates shall be designed according to DIN 19704 Standards. Butt weld joints shall be designed for a weld efficiency of 0.9.

The load cases for gate shall be determined as describe here under:

- NB case: Acc. to normal water level;
- BB case: Acc. to maximum water level (Flood 10,000 Y);
- In AL case: The earthquake dynamic pressure acting on the gates that shall be added to NB case.
- Thermal effects ($\Delta t = \pm$ 10 °C)

The load cases for gate casing shall be determined as describe here under:

- NB case: Acc. to normal water level;
- BB case: Acc. to maximum water level (Flood 10,000 Y);
- In AL case: The earthquake dynamic pressure acting on the casing that shall be added to NB case.
- External pressure due to cement grouting at 3 kg/cm2;
- Thermal effects ($\Delta t = \pm$ 10 °C)

The opening and closing forces shall prevail over the resisting forces with a safety factor of 1.5.

30.3.4 HYDRAULIC MODEL STUDY REPORT

The model study shall be conducted over the full range of hydraulic operating heads and discharges through the 0, 2, 5, 10, and 20 to 100% of gates opening. The study shall be used to determine:

- Cavitations in gates, slots in maximum reservoir level and different opening;
- Discharge curves as a function of the gate opening in reservoir levels;
- Jet flow underneath the gate and in the side slots and gate downstream;
- Gate vibration and absence of detrimental resonance frequencies;
- Gate loads, vertical down pull and uplift forces acting on the gate;
- Horizontal components of hydraulic forces acting on the gate leaf;
- Air vents capacity and sizes for aeration of the space between the emergency and service gates;
- Air demand in cooperation of service and emergency gates.

After studying has been completed, Contractor shall provide Employer's Representative with copies of a report describing the complete hydraulic model study program which shall include details of the hydraulic model study, dimensions of the component parts, a description of the study program, sample calculations, detailed listings and plotted graphs of the results.

30.3.5 STRUCTURAL DETAILS

30.3.5.1 Gate Leaf

The gates shall be manufactured of welded steel sections consisting of horizontal beams and vertical stiffeners that shall support a continuous watertight surface (skin plate). The skin plate will be on upstream side and seals shall be on downstream side.

The gate structure shall be calculated in accordance with DIN 19704 standards. The gate shall be calculated taking into account horizontal earthquake acceleration without suffering from permanent deformation that will jeopardize the operations. The resulting thickness shall be increased by 2 mm for emergency gates and service gates to allow for corrosion. The minimum skin plate thickness for gate, casing and cover shall not be less than 15 mm. The following design measure to consider to reduce cavitation and vibration;

- The gate bottom edge shall be designed in such manner as to avoid any kind of vibration, resulting in resonance of the gate structure. The gate lip shall have an angle of min. 30° to the horizontal, final design subject to model studies results.
- In order to keep the lateral gate slots as small as possible, a single cantilever type vertical end plate (perpendicular to flow direction) shall transmit the forces caused by the hydraulic thrust into the tracks of the casing. All guiding and bearing plates shall be mounted on this vertical end plate

30.3.5.2 Gate Casing

The gates casing to be embedded in the concrete except for the cover, shall be of the totally enclosed watertight box type, made of steel plates and shapes and shall accommodate the gate leaf guides and sealing surfaces.

The casing shall be flanged at the groove and at the sill to permit accurate machining and assembly of the components.

The casing shall be made of welded and/or bolted parts; except watertight welds in any case no Site welds shall be allowed and the design shall be such as to guarantee that all the body connections are perfectly watertight.

The parts of the gate casing to be welded to steel lining shall have edge preparation in conformity with the steel-lining edge preparation.

The resulting skin plate thickness shall be increased by 2 mm for casings and cover to allow for corrosion. The minimum skin plate thickness shall not be less than 20 mm.

Continuous hardened stainless steel strips shall be provided within the gate grooves extending from the sill to the top cover to provide a track for the anti-friction bearing and guide strips attached to the gate leaf.

Service gate shall be watertight on top and lateral seal in partial operations and the seal top plate of downstream bonnet surface shall be made of stainless steel plate or clad.

The seal between the body and the cover shall be ensured by synthetic rubber gaskets.

30.3.5.3 Seals

The gates shall be provided with metallic seals at the upper & lateral side, and the chemical composition of seals shall be different with the seats.

The seal material shall be slightly softer than that of the seats to avoid seizing of the mating surfaces under load. So, the sealing shall be made of bronze-stainless steel contact, the bronze being on the gates and the stainless steel on the sealing surface.

The bronze machined bars shall be attached to the downstream skin plate face. For bottom sealing, stainless steel seal shall be selected and the connection with metal seal shall be suitably watertight.

All seals shall be secured to the gate with stainless steel bolts to facilitate their replacement. Bolt spacing shall not exceed 100 mm. The seals shall be guarded in order to protect them from possible damage due to timber or other objects becoming jammed between the seals and the embedded parts.

When the gates are prepared for shipment, the seals shall be removed and packed separately.

No leakage shall be admitted.

30.3.6 OPERATING SYSTEM

30.3.6.1 Hydraulic Servomotors

Each gate shall be operated by one double acting hydraulic servomotor. Connection shall allow easy disassembly for maintenance. Minimum reserve stork shall be considered as 50 mm (both side of piston).

The calculation of the cylinder barrel shall be based on DIN 2413-1. When carrying out a stress proof for static stress in operational case, the safety factor "S" according to DIN 2413-1: 1993-10, table 3, scope I, shall be increased by 40%.

The cylinder shall be made from standard seamless barrels accordance with DIN 1630 or DIN EN 10297-1. The cylinder internal surface shall be bored to a uniform concentric finish having a surface roughness not exceeding 0.4 micron.

Connection between cylinder and cylinder heads shall not be welded.

All connections for pressure oil piping and oil drain piping to and from the cylinder shall be welded as far as possible and shall be made of stainless steel. Necessary vents and drains shall be provided. The cylinder shall be thoroughly inspected visually.

The cylinder shall be provided with the necessary devices to actuate the open position indication transducer and fully open/closed signalling and limit switches.

The piston and piston rod assemblies shall consist of a one-piece rod, a piston, piston rings and oil seals. The piston shall be of cast steel and shall be rigidly connected to the piston rod. The connection shall be designed for easy disassembly for maintenance purposes. The piston rod shall be made of stainless steel with a weight proportion of chromium of at least 15.5% such as X20CrNi17-2 and hard chromium-plated over its full length not less than 50 µm thickness or unalloyed steel with oxide ceramic coating over its full length not less than 150 µm thickness and a surface hardness of 800 to 1000 HV.

Surfaces of the piston rod should be finished so that the Ra value would be less than 0.3 µm.

The operating pressure in the hydraulic cylinder and hydraulic system shall be computed in accordance with DIN 19704-1: 1998-05, section 8.5.2.

The computed operating pressure in the rest of the system shall not exceed 200 bars. The computed operating pressure in the hydraulic cylinder shall not exceed 180 bars.

The rings and oil seals on the piston shall prevent leakage of oil from one side of the piston to the other side at a differential pressure up to 150% of the computed operating pressure in the rest of the system.

A sufficiently large diameter return line shall be provided from the bottom of the cylinder to the top for circulating oil during closure. The gates shall cover the last part of closure travel at a reduced speed.

The packing gland in the lower cylinder head shall be V-type or similar.

For proper bleeding of the hydraulic cylinder, pressure measurement connections shall be provided at suitable locations.

All bearings for trunnions of hydraulic cylinders shall be self-lubricating. The sliding bearing areas of the bearing pins shall be made from stainless steel.

Air vent holes with plugs shall be drilled through the bottom flange of each cylinder and through each cylinder cover.

30.3.6.2 Hydraulic System

For two tandems operated gates, one complete pumping set shall be provided.

The Contractor shall provide the complete hydraulic system necessary to ensure a complete and efficient installation in accordance with the intent of these Specifications. The components of the hydraulic system shall include all piping, flexible connections, shut-off, throttle and control valves, High and Low pressure switches, pipe and valve hangers and supports, pumping units, oil tank, gauges, instruments and appurtenances and all necessary oil.

Two oil pumps and motors rechargeable, one for normal operation and the other as automatic stand-by for supplying oil to the servomotors, shall be provided.

The automatic stand-by pump shall start in case of failure of the main pump or low pressure in pressure line. Both pumps shall be also push button operated.

The hydraulic system shall be installed inside the Bottom Outlet gate chamber, as shown in the Drawings.

The pumping set shall be designed to operate one gate at a time, using one pump.

A hand-operated pump shall be furnished to be used in case of emergency.

The oil system shall be provided with magnetic filters in discharge and suction line. Clogging of filters shall be indicated.

Adequate throttling shall be provided on the servomotor in order to guarantee that the gate closing speed will not be excessive in case of any pipe failure.

Each pump shall be provided with a check valve. The closing speed of the gate shall be adjustable within ample limits by means of the throttling valve on the discharge line.

An oil tank, made out of steel plates, shall be supplied. The total oil tank storage capacity shall be 150% of the volume of the hydraulic servomotors and all piping. Anchor bolts and provisions for bolting the tank to the concrete shall be supplied. The tank shall be totally closed and fitted with a filter-type air vent and screened filter.

The tank shall be provided with drain cocks, baffle plates and connections for the oil return lines. A sight gauge, to indicate the reservoir oil level, shall be mounted on the outside of the tank and suitably protected to prevent damage to the gauge. Also oil temperature and oil pressure indicators shall be provided.

All pipes shall be stainless steel pipe suitable for an oil pressure of 50% greater than the selected working pressure.

Fittings shall be forged steel-socket welding fittings. Bending of pipes by heating is not allowed.

Each electric motor-driven pump consists of a totally enclosed electric motor, provided with conduit entrance, connected by means of an elastic joint, to a gear pump. Gear teeth shall be hardened to a depth of at least 0.3 mm.

The oil pumps shall be capable of discharging against 150% of rated pressure.

30.3.7 CONTROLS

The gates shall be controlled individually. Contractor shall provide local controls for raising and lowering the gates. In addition, lowering the service gate and emergency lowering of the guard gate shall also be done from the Dam Control Board.

One control panel for both gates shall be provided in the bottom outlet gate chamber.

The control panel shall have all the necessary alarms and signals and the necessary contacts to send signals to the Dam Control Board.

The control of the gates shall be done by means of push buttons. The control panel shall be provided with the following controls:

- One "Selector switch" for "Normal", "Maintenance" and "Off" operation with lock and key;
- One "selector switch" for gate selection;

- One "opening", one "stop" and one "closing" push buttons for each gate;
- One "start" and one "stop" push buttons hydraulic system electro pumps;
- One "emergency closure" push button for emergency gate;
- One "selector" switches for "manual" and "automatic" operation for hydraulic electro pumps;
- One "selector" switch for "pump No. 1", "pump No. 2" for main pump selection;
- One selector switch for lamps "on ", "off ";
- One "lamp test" push button.

The following controls shall be provided on the Dam Control Board:

- One "closing" push button for service gate;
- One "emergency closure" push button for guard gate.

With selector switch set on "maintenance", Normal controls and commands from remote shall be cut-off and Bottom Outlet gates will be operated independently from normal operation condition for maintenance purposes.

With Selector Switch on "Off" all controls shall be cut-off.

With selector switch set on "automatic" operation, if the selected pump is out of service, the stand-by pump shall start and an alarm shall be operated in the local control panel.

The emergency gate shall be provided with open/closed limit switches and limit switches that shall come into operation during its descent at full opening gate position. Starting from full opening, the contacts shall be in the following sequence:

First level contact	Starting of the main pump
Second level contact	Alarm and closing service gate

The above mentioned two level contacts shall operate respectively for a gate lowering of 5 cm, 10 cm below the fully opened position. Each operating level shall be independently adjustable within a range of ±10 cm around the above-prescribed values.

A mechanical gate position indicator located beside the hydraulic cylinder shall be provided for each gate.

An electrical gate position indicator located on local control panel shall be provided for service gate and with transducer to send a remote signal to the Dam Control Board; the signal shall be continuous (4-20 mA) type.

The cut-off system in fully closed position of each gate shall be activated by Hi-Pressure Switches after complete sealing.

30.3.8 OPERATING SEQUENCE

In normal operation, the downstream gate shall act as service gate and shall be capable of opening and closing under the full flow range.

The upstream gate, used as guard gate, shall only close when downstream gate is closed and there is no water flow. However, in case of emergency, the upstream gate shall also be capable of closure under the maximum flow condition.

Two hand operated external by-pass valves, shall balance the pressure on both sides of the upstream gate; on balancing the pressure, a differential pressure switch included in the supply, shall give the consent for further opening. Differential pressure switch shall be equipped with filter and drain.

30.3.9 ELECTRICAL EQUIPMENT

The gates shall be complete with all electrical equipment necessary for operation. All external connections to the pumping unit shall be by standard liquid tight flexible metal conduits.

All electrical equipment and panels shall be of type suited for outdoor operation (IP 54). The control panels shall be located inside the Bottom Outlet Gate Chamber.

The power and control panel shall comply with the requirements given in the General Technical Specifications.

30.3.10 MAINTENANCE

The design of gates and servomotors shall make easy operation and maintenance. An Electrical overhead Traveling Crane is foreseen for maintenance in the gate chamber, as shown in the Drawings.

The crane capacity is indicative. The Contractor shall confirm the value increasing it if necessary.

The Contractor shall also provide all necessary accessories that are needed for the gate disassembling and maintenance at the gate chamber (Without using any devices supplied by others).

30.3.11 FITTINGS AND ACCESSORIES

30.3.11.1 By-Pass and Air Valves

One by-pass system shall be provided to allow the filling of the space between the two gates. The system shall include two hand operated valves (PN16) (main and guard), and all necessary piping (PN16).

Adequate number of aeration disk valves (PN16) between service and emergency gate and one air valve on each cover shall be provided. Size and number of valves shall be

determined by Model Study. The minimum size of aeration disk valves shall be 300 mm. A gate valve (PN16) shall be used under each air valve for maintenance.

30.3.11.2 Supports for Cables and Piping

The supply shall include all necessary supports and fittings for cables and piping.

30.3.11.3 Oil for First Filling

The Contractor shall supply sufficient hydraulic fluid for two times fillings of the system. The hydraulic fluid shall be suitable for the climatic conditions and the use intended. Hydraulic oil shall be supplied in a non-returnable container.

30.3.12 TOLERANCES

In general, the provisions of the General Technical Specification shall govern.

The sealing surface of gate body and of gate casing shall not depart from a true plane surface by more than 0.3 mm. The admitted gate tolerances shall be ±0.2 mm in width and ±1 mm in height.

30.3.13 TESTS

During fabrication and installation, the Contractor shall perform all routine and special tests in accordance with the applicable standards, and the relevant articles of the present General and Special Technical Specifications.

30.3.13.1 Shop Tests

a) Mechanical Tests

The gates, housings, servomotors and hydraulic pumping set with cabinets and such other equipment shall be shop-assembled for inspection and tests by the PMCs.

The servomotor shop assembly shall include the cylinder, heads, piston, piston stem, rings, packing and glands.

Gates movement shall be smooth, free of chatter or binding and with a minimum amount of friction.

The cylinder, with the piston pressed against the upper head or bearing member, shall be subjected for 30 minutes to a pressure of 150% of that required for a gate lifting. During such test, no oil shall leak past the stem packing and only a negligible amount past the piston packing. Operation of the limit switches shall be verified during these tests.

The hydraulic pumping unit shall be included in the test. The system shall be filled with hydraulic oil, thoroughly vented, and tested to full design relief pressure. All fittings, joints, piping and accessories shall remain tight under test.

The hydraulic oil used in the tests shall be similar to the oil, which will be furnished under the Contract.

After shop assembly, the gates and the hydraulic servomotors with the required match marks shall be disassembled into major units. Control panels shall be shipped completely assembled except for those fragile components that will require separate packing.

b) Tests on Hydraulic System

The servomotor shop assembly shall include the cylinder, heads, piston, piston stem, rings, packing and glands.

The cylinder, with the piston pressed against the upper head or bearing member, shall be subjected for 30 minutes to a pressure of 150% of that required for a gate lifting. During such test, no oil shall leak past the stem packing and only a negligible amount past the piston packing. Operation of the limit switches shall be verified during these tests.

The hydraulic pumping units shall be included in the test. The system shall be filled with hydraulic oil, thoroughly vented, and tested to full design relief pressure. All fittings, joints, piping and accessories shall remain tight under test.

The hydraulic oil used in the tests shall be similar to the oil to be furnished under the Contract.

After shop assembly, the gate and the hydraulic servomotor with the required match-marks shall be disassembled into major units. Control panels shall be shipped completely assembled except for those fragile components that will require separate packing.

c) Tests on Electrical Equipment

Motors and panels, completely assembled, shall be tested according to Standards. For electric motors, the torque values as well as the starting current values shall be measured.

The controls of the oil pumping set, completely wired, shall be checked in order to ascertain their correct functioning.

d) Tests on Welding

All main welds shall be examined according to the procedure indicated in the General Technical Specifications.

All main welds shall be ultrasonically tested. At least 20% of welds and 100% T-joints shall be radio graphically examined according to the procedures indicated in the General

Technical Specification. In any case, all butt welds of plates shall be 100% ultrasonic tested.

Dye Penetrate Tests on the sliding surfaces shall be carried out in workshop.

No cross-joint welds shall be allowed at all cases.

30.3.13.2 Site Tests

Before any mechanical test runs are made, all parts shall be properly lubricated and thorough inspection made of all mechanical and structural connections. The tests shall include, but not necessarily be limited to, those described herein.

The gates, after being installed and completely wired, shall be inspected and operated to check clearances and accuracy of alignment and smoothness of operation.

All motions of completely assembled gates shall be thoroughly and completely observed for freedom of operation and from internal mechanical interference, proper alignment of all running parts and freedom from vibration. Electrical continuity of all circuits and servicing of all points requiring lubrication shall be completely inspected.

The tests to be performed shall be the following:

- Verification of closing and opening speeds;
- Pressure test on assembled piping at 150% of the rated pressure;
- Water leakage tests;
- Test of the by-pass valves;
- Operation of all controls and limit switches.

30.3.14 PROTECTIVE COATINGS

Surface preparation and protective coatings shall be in accordance with General Technical Specification.

30.3.15 SPARE PARTS AND SPECIAL TOOLS

30.3.15.1 Spare Parts

All spare parts shall be interchangeable and of the same material and workmanship and shall meet the same requirements as the corresponding original parts.

The Contractor shall supply for each gate the spare parts listed hereunder, which are to be considered as a minimum requirement:

- One (1) complete series of seals;
- One (1) sets of gaskets;
- Ten (10) percent of all nuts and bolts used;

- One (1) Electro-valves for servomotor feeding of each size and type;
- One (1) limit and magnetic switches of each type;
- Twenty percent (20%) of resistors, circuit breakers, contactors, push buttons, selector switches and relays of each type (with a minimum of one);
- Hundred percent (100%) of fuses and lamps;
- One (1) differential pressure switch of each type;
- One (1) temperature and level switch of each type;
- One (1) pressure switch of each type;
- One (1) thermostat;
- One (1) filters of each type;

The Contractor shall provide any other spare parts he may consider necessary for five years operation of the gates.

30.3.15.2 Special Tools

The Contractor shall supply one complete set of special tools required for the erection and maintenance of the gate and accessories. All special tools shall be permanently identified as to their special use and shall be located in lockable metallic tool cabinets.

All special equipment required for handling during shipment to site or during erection of the gates shall be furnished.

30.4 STEEL LININGS

30.4.1 GENERAL

This Chapter covers the Special Technical Specifications for the following equipment and its accessories, spare parts and special tools:

- One (1) set of steel lining and appurtenances for bottom outlet including, bell-mouths, boxes, box reductions;

The above equipment shall be complete with relevant embedded items.

30.4.2 DESIGN DATA

- Normal water level	1096.00 m.a.s.l.
- Maximum water level	1098.0 m.a.s.l.
- Elevation of center line	See Contract Drawings
- Lengths	See Contract Drawings
- Internal dimensions	See Contract Drawings

30.4.3 DESIGN CRITERIA

30.4.3.1 General Characteristics and Provisions

The Contract Drawings are intended to show the general layout and characteristics of linings; the final design shall be carried out by the Manufacturer and shall strictly comply with the Contract Drawings as for layout and dimensions.

The design shall be carried out by the Manufacturer in accordance with the best modern practice and the requirements of these Specifications notwithstanding minor omissions therein.

The design shall be carried out without any effect of concrete.

Manufacturer's calculation shall be performed by generally known and recognized methods, already employed in designing other similar works and shall be submitted to the PMC for approval with a list of plants in which same calculation was applied.

No drainage will be provided to relieve the external water pressure.

Linings shall be self-resistant both to internal and external pressures.

Exceptions to this provision will not be accepted. Linings shall be reinforced on the external side by beams; anchoring claws will not be accepted.

30.4.3.2 Loading Conditions

The linings shall be designed taking into account the most critical combination of the following load conditions:

a) Internal water pressure corresponding to the normal water level in the reservoir, as Normal (permanent) case.

b) Internal water pressure corresponding to the maximum water level in the special case (%0.01) in the reservoir, as Special (Intermittent) case.

c) External pressure due to cement grouting at 3 kg/cm^2;

d) External water pressure due to saturation, infiltration and equal to normal water head.

e) Load due to effect of thrust force.

f) Thermal effects ($\Delta t = \pm 10\ ^\circ C$)

The stress "T" to be compared with the allowable one shall be calculated according to the following formula:

$$T= (T12 + T22 – T1.T2)0.5$$

Where T1 and T2 are the main biaxial stresses.

The T1 and T2 values to be taken into account in the determination of T shall be the most unfavorable conditions.

The comparison stress "T" shall not exceed the allowable values obtained with the following formula:

$$f = c\ k\ F$$

Where "f" is the allowable stress, "F" the lower yield stress point of the material under consideration, "K" is a safety factor according to DIN19704 standard for rectangular steel lining and according to CECT standard for circular steel lining , "Min. K=1.7" is a safety factor according to CECT standard, and "c" is the welding factor equal to 0.9.

The steel lining shall be able to withstand the grouting pressure applied locally or uniformly on the external surface, without concrete co-operation, the Manufacturer shall reinforce the steel lining during grouting with provisional internal structures to be designed, supplied, erected and dismantled by him. The Manufacturer shall be responsible, for all the effects of any deformation of the steel lining due to the above condition.

In design of steel lining for external pressure, the average gap between concrete and steel lining to be considered is 0.001Ri, where Ri is the steel conduit hydraulic radius (Ri = A/2p, with A steel conduit area, 2P steel conduit perimeter) .

Thickness calculated in accordance with the above specified allowable stresses shall be increased by:

- 2 mm, to take into account corrosion;

The minimum thickness for the the bottom outlet steel liner shell shall not be less than 15 mm.

The adopted lining thickness shall, in any case, not be lower than the one determined by the following formula:

$$S_{\min} = \frac{R_i + 1000}{200}$$

Where Smin is the minimum thickness and Ri is the conduit hydraulic radius (all in millimeters).

30.4.3.3 Materials

The proposed type of steel shall be the same as the one already used in similar well-known construction. The Manufacturer shall include in the offer, with the description of the proposed types of steel, all physical- chemical characteristics of the materials.

The linings that will be used in the construction shall be of the fine grain steel, resisting to aging, of impact value not less than 25 J at -20°C (Charpy V), easy to weld.

The ratio between yield and ultimate tensile strength, resulting from technological tests to be carried out on the materials, shall not be more than 0.72.

The flanges shall be of the rolled or forged type, without welding, and shall be connected to the pipe by means of a but-welding-joint vee groove.

30.4.4 STRUCTURAL DETAILS

30.4.4.1 General

The Manufacturer is free to choose the subdivision of Work to be carried out at the workshop and at Site according to his experience.

The linings shall be accurately cut to the required dimensions with the edges prepared in view of the type of welding and thickness of plates so as to form the most convenient joints, in order to ensure a complete penetration of the welding.

Parts shall be match-marked in the shop prior to shipment to Site.

Care shall be made in matching the edges and ends of the adjoining linings, and the thickness of joining linings at welding edges shall not differ by more than 2 mm.

30.4.4.2 Welding

The welding procedures shall be in accordance with the indication of the General Specifications.

In any case the welding procedures shall be qualified and shall be approved by the PMC before the start of the manufacture as well as the heat- treatment on the welded parts, if any. Any heat treatment up to 600 ± 20°C for welds of each section is anyway required for steel lining of over 30 mm thickness and/or over 520 MPa tensile strength.

The heat treatment temperature shall be maintained for two minutes for each millimeter of steel lining thickness; it can be lowered up to 500°C ± 20°C increasing the heat treatment duration according to the following table:

Heat treatment

Heat treatment temperature (°C)	600	550	500
Time required for heat treatment (min/mm)			
(referred to steel plates thickness)	2	6	25

The heat treatment carried out according to the above provisions shall be followed by a slow cooling.

Welding procedures and testing procedures shall be such as to guarantee for all the welded joints carried out outside the tunnels an efficiency factor equal to 1.

All welders and welding operators shall be qualified in accordance with the Standards.

If in the opinion of the PMC the work of any welder at any time appears questionable, such welder shall be required to pass another qualification test.

The test plates from which the specimens are to be prepared for qualification tests of welders or welding procedures shall be of such dimensions that all the specimens required for such test can be obtained within a discard at each end of each test plate of not less than 5 cm. The test plates shall be made of material identical to that used in the fabrication of the steel linings and the technique including the rate, position and welding electrodes used, shall be identical to that actually required for the fabrication.

The PMC shall witness the preparation of all test plates.

All qualification tests of welders or welding procedures, including the physical tests of the specimens welded in the qualification tests shall be made by and at the expense of the

Manufacturer who will furnish the PMC with certified copies of reports of physical tests of specimens welded in the qualification tests.

30.4.4.3 Tolerances

The following tolerance criteria shall be fulfilled:

1. All internal welds (hydraulic surfaces) shall be ground flush with the plate. Weld convexity on the outside shall in any case not exceed 2 mm for plates.
2. All welds shall be ground smooth for UT-testing.
3. No offset of plates in contact with water (hydraulic surfaces) in flow direction; offsets shall be ground flush and smooth.
4. Offsets on the external side of the liner shall be limited to 1.5 mm.

30.4.5 TRANSPORTING AND ERECTION

30.4.5.1 Transporting

Because of the limitations imposed by transportation of the lining parts, these shall be subdivided into sections of adequate weight and dimensions to be welded on Site.

These sections shall be provided with facilities for their handling during the loading and unloading operations and during erection.

To avoid deformation during transportation they shall be duly reinforced as needed.

The Manufacturer is assumed to know perfectly the conditions of the ways of communications between his workshops and the port of disembarkation.

30.4.5.2 Grouting Holes

The irrigation and Bottom outlet steel lining shall be provided with holes for cement grouting all along the linings (if it is necessary).

The grouting holes complete with plugs, shall be 50 mm threaded and shall be spaced in the following way:

1 hole each 6 m^2.

The Contractor shall supply all the necessary screw plugs, to be welded in place and ground to a smooth surface and flushed with the lining.

30.4.5.3 Miscellaneous

In addition to the above specified, the Manufacturer shall supply all steel accessories for the steel linings, such as lining initial joints and all accessories (even if embedded into the concrete) necessary for the erection.

30.4.6 PAINTING

Surface preparation and protective coatings shall be in accordance with General Technical Specification.

30.4.7 TESTS

30.4.7.1 Mechanical Tests

Each rolled plate shall be subject to the following tests at the steel mill:

- Tension test
- Bend test
- V-notch Charpy impact test
- Ultrasonic test (at steel mill or at the workshop). Each plate shall be ultrasonically tested all along the edges (at least 20 cm). Plate thickness 25 mm or more, shall be ultrasonically tested on the whole surface with a scanning 10 x 10 cm.
- Dye Penetrate or magnetic particle inspection on edges after preparation for welds.

30.4.7.2 Examination of Welds

All main welds shall be tested radio graphically (20%) and ultrasonically (100%) 100 % off T-joint welds shall be radio-graphed. No cross-joint welds shall be allowed at all cases.

The finishing of the welded surfaces shall be adequate for such test and therefore, where necessary, the welds shall be grinded.

The ultrasonic examination shall be carried out after a careful calibration of the testing equipment, carried out according to the Standards.

The tester shall stamp each weld examined and found satisfactory by this method at both ends with his own punch. Welds found out without or with unreasonable stamps shall be re-examined.

Should the ultrasonic examination reveal some defects, the relevant weld shall be radio-graphed.

The radiographic evaluation of the defects shall prevail over the ultrasonic evaluation.

The Manufacturer shall supply the PMC with a full written record covering all radiographs and describing all defects.

All the surface of the welds carried out manually shall be checked by dye-penetrant or magnetic particles.

Defects shall be removed by grinding and the surface shall be rechecked.

30.4.7.3 Checking of Painting

The checking of the painting shall be carried out in the workshop and at site in compliance with the following provisions:

a) Check of the materials adopted;

b) Check of the sandblasted pipe surfaces;

c) Measurement of the thickness of the various paint coats and of the total paint coat, by means of a suitable meter.

The Manufacturer shall supply all the equipment for the paint checking.

30.4.8 SPECIAL TOOLS

The Manufacturer shall supply one complete set of special tools required for the erection and maintenance of the linings accessories.

All special tools shall be permanently identified as to their specific use and shall be located in lockable, metallic tool cabinet.

Eyebolts, lifting lugs, shackles, slings and any other special equipment required for handling during shipment to Site or during erection of linings shall be furnished.

30.5 CRANE

30.5.1 GENERAL

This Chapter covers the Special Technical Specifications for the following equipment and their accessories, spare parts and special tools:

- One (1) set of Overhead traveling Crane equipment and its accessories, spare parts and special tools located in the bottom outlet gates chamber.

30.5.2 DESIGN DATA

- Location		Bottom outlet gates chamber
- Type		Overhead traveling Crane
- Number		One (1) Set
- Main Capacity (app.)		20 tons
- Auxiliary Capacity (app.)		5 tons
- Span		8.50 m
- Max. lift (app.)		15.0 m
- Hoist speed (two speed)		4.0, 0.5 m/min
- Trolley speed (two speed)		5.0, 1.0 m/min
- Bridge/Gantry speed		5.0 m/min
- Operating		Electromechanical actuator
- Feed		400/230 V AC
- Control		Pendant push button box
- FEM Class	Mechanism	A3
	Structure	M3

30.5.3 DESIGN CRITERIA

a) Rails

All the necessary rails, connecting plates, etc. for the crane rails shall be supplied.

The type of the rail for the bridge traveling shall correspond to the calculated force of the wheels.

The rails shall be leveled and secured to avoid the possibility of side Movement during traveling of the fully loaded crane. The end of crane runway shall be equipped with strong metal buffers.

b) Bridge

- Structure

The bridge structure shall be of structural steel of approved design, having ample stiffness, and shall be capable of carrying the maximum load safely at full traveling speed, the trolley being in any position on the bridge.

The bridge structure shall be of double girder. Trolley shall travel on rails with end buffers provided on top of the girder.

- Traveling

Bridge traveling shall be ensured by two drives, one on each side of bridge. The bridge drive shall be designed to move fully loaded crane with rated speed, and to enable traveling free of vibrations and rocking.

Driving system shall consist of driving wheel suitably coupled, through reduction gear, to an electric motor. Electric brake shall also be provided.

- Bogies

Bogies carry the bridge and house the driving and traveling wheels. Two double-flanged wheels shall be placed in crane bogie, one for driving. Bogies shall be equipped with wheel break supports, preventing the falling down of the bridge in case of wheel or wheel axle breaking.

c) Trolley

- Structure

The trolley structure shall be welded of mild steel sections and plates and so constructed to give ample stiffness. The trolley shall be equipped with one hoist mounted on the trolley framework with equal distribution of the load on all wheels without undue deflection.

- Traveling

Trolley traveling shall be ensured by two drives, one on each side of trolley. The trolley drives shall be designed so that travel under all conditions will be steady and free from vibrations and rocking.

Four wheels for trolley traveling shall be provided two for driving. Driving system shall consist of driving wheel suitably coupled, through reduction gear, to an electric motor. Electric brake shall also be provided.

- Hoist

Hoists shall be of the wire rope, electric motor-driven type with gear reduction unit, electric brake, limit switches, drums and associated components. The hoist motor, brake and gear reducer shall be mounted on a common frame. The drum shall be mounted on frames located directly over the shave block at the lifting bracket. The hoist revving

system shall be such that the load raised and lowered evenly, vertically and without vibration or bending under all conditions of operation.

For design of the wire rope hoists the provisions of General Technical Specifications shall be considered.

The lifting and lowering of the hook shall be perfectly vertical, without swing of the load. Hoist shall be equipped with following:

- **Brakes**

Automatic spring set, electric release shoe type (or disk type for electro-motors with rated power below 5 KW) holding brakes shall be arranged to operate when current is cut off or fails.

The brake shall prevent acceleration of the load, when lowering, and shall sustain the load in any desired position when motors are not operating. Breaking capacity, in both directions shall be at least 150 percent of maximum driving torque.

- **Rope Drums**

The drums shall be driven by electric motors through reduction gears. One hand operated reduction gear shall be provided for load lowering in case of power failure. The drums shall be of ample diameter and sufficient length to take the full amount of ropes without overlapping when the hook is in the highest position. The rope attachment to the drum shall be such that in case of a rope unwinding completely, there shall be no danger of its becoming free from the drum.

- **Ropes**

The ropes shall be of flexible steel and shall be of galvanized wire, lubricant impregnated during manufacture. They shall be designed so that the maximum working load does not exceed one-fifth of the breaking strength of the rope.

- **Hooks**

Hooks of forged steel, single type shall be equipped with thrust bearing. The bearing shall be totally enclosed and constructed to prevent grease leakage.

The hooks shall rotate freely and provided with safety latch.

30.5.4 ELECTRICAL EQUIPMENT

30.5.4.1 General

The crane shall be supplied complete with all electrical equipment necessary for its operation.

All elements shall be totally insulated or protected in order to prevent any accidental contact.

Feeding shall be through a main feed line disconnecting switch installed in the wall, at proximity of the hoists and a main contactor installed on the crane, equipped, on the three phases, with thermal relays of adequate adjusting range and with high interrupting capacity fuses, current limiting type.

An undervoltage relay shall be also provided on the feeding line preventing energization of the main contactor coil if the undervoltage relay has operated. Also a sequence phase relay shall be supplied on the feeding line.

30.5.4.2 Control

For the Crane, the lifting and travel motions shall be controlled by a push button box hanging from the crane (pendant control). The push button box cable length shall allow easy operation from operating level.

The box shall be provided with a disconnecting switch, key operated, and a "stop" button acting on the main contactor coil.

An independent spring return button “dead man” type shall control each motion.

Overhoist, slack rope, end of motion limit switches and indicating lamps shall be provided for cranes.

30.5.4.3 Feeding System

A four copper strand conductor, synthetic rubber insulated cable shall mainly constitute feeding.

The cables shall be of extra flexible type, 4 kV insulation class, suitable for carrying continuously not less than 125 percent the full load current.

The cable shall be supplied complete with the terminal block.

The cable length shall be sufficient for the complete travel of the crane.

30.5.4.4 Motors

All motors shall be totally enclosed, self-cooled, polyphase induction type, designed for crane. All motors shall be wound rotor types. Windings shall be fully impregnated with an oil and moisture resistant compound, provided with a vermin and fungus proof finish suitable for tropical climate with Class F insulation. Ratings shall be for 30 minutes with a 75 °C temperature rise. All motors shall be designed for intermittent service, with an intermittence ratio of 40 percent referred to 120 maneuvers per hour. Motors shall be equipped with anti-friction bearings and enclosed terminal boxes. Motors of same characteristics shall be interchangeable and shall be mounted in such a manner that they can be removed while the load is being held by the hoist brake. Motors shall be supplied with anti-condensation heaters.

30.5.4.5 Limit Switches

The crane shall be provided with a geared or screw-type limit switches, which will automatically open the power circuit of corresponding motor at the preset positions and block exceeds end limit of travel and hoist.

In addition, a block operated limit switch shall be provided on the crane to prevent the hook block being raised above the highest safe position. This switch shall switch off the power circuit and the rest shall be manual.

30.5.4.6 Wiring

Wiring for power and control circuits shall be flexible, stranded copper conductors, insulated for not less than 600 V. Insulation shall be poly-vinyl-chloride 75 °C. Power wiring shall be sized to accommodate thermal requirements and be such as to limit voltage drop at the minor terminals to no more than five percent of the supply voltage. The termination of all wires and the connections on terminal blocks shall be permanently marked with code numbers assigned on the wiring diagram to be supplied by the Contractor.

A legend, clearly describing the coding used, shall be shown on the diagrams. All wiring shall be pulled and tagged before shipment from the manufacture works.

30.5.4.7 Grounding

All metal parts of the crane and accessories shall be electrically interconnected so that all the equipment can be grounded when installed. Bolted connections with parts in metal to metal contact and moving components with contact surfaces of metal, with no intervening insulating material between the contact surfaces including rails, wheels and bearings may be considered satisfactorily interconnected.

30.5.4.8 Safety Devices

The supply shall include automatic load limiter devices, which shall prevent lifting of loads greater than the preset maximum ones.

The limiter shall be adjustable between 80 percent and 110 percent of the rated load. The limiter actuation shall not prevent the operator from lowering the load, which he attempted to raise.

30.5.5 FITTINGS AND ACCESSORIES

The crane shall be equipped with all accessories, even if not particularly mentioned, necessary to ensure a complete, safe and reliable operation.

30.5.6 TESTS

30.5.6.1 Shop Assembly

All equipment shall be fully assembled in contractor's shop for inspection by and at Employer representative option. All necessary adjustments shall be made in the shop to achieve the specified tolerance.

Without limiting the foregoing, shop assembly of complete crane shall be carried out, including:

- Bridge beams and gantry structure with rail trucks and drives
- Bridge beam tie bars
- Trolley hoists on bridge beams
- Complete hoists with motors, brakes, gearboxes, controls, etc
- Complete bridge and trolley drives
- Complete hook and sheave assemblies
- Electrical control panels, starter, contactors, position indicators, limit switches, etc.

If any of the above assemblies reveal inaccuracies or other faults, these shall be corrected prior to shipment.

Prior to dismantling, 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. In particular, there shall be minimum disconnection of electrical wiring.

All hoist, bridge, gantry or trolley drives shall be assembled and tested in the shop, as specified herein. Operational tests shall be made in the shop on controls and instruments to demonstrate that the specification requirements have been met.

Contractor shall complete the application of protective coating in its shop as specified.

Employer representative will, at its own option, inspect all equipment during fabrication and before shipment and witness the shop tests after final assembly.

The shop tests shall include, but not be limited to, the following.

a) Running Test

The crane shall be operated by power, and tests shall be carried out to prove the following:

- All clearances and alignments are in order, lubrication has been applied, brakes are adjusted, and all gearboxes and gear trains operate without excessive noise

- Operation of each control and vibration switch, contactor relay and other control device is satisfactory, and that all limit switches are adjusted and functioning correctly under all operating conditions
- All circuits, interlocks and sequences of operation are correct
- All protective devices operate satisfactorily
- All crane motions operate correctly.

b) Load Test

The crane shall have each motion tested with the main hook carrying

- Rated load, at 110 percent rated load by operating the hoist at rated speed. During these tests the specified speeds are to be attained, provided that the current supply to the crane is correctly maintained.
- Overload (125% of the rated load). During these tests, the specified speeds need not be attained, but the crane itself shall be capable of accommodating the condition without difficulty.

c) Deflection Test

During this test, it is to be established that the specified maximum deflection is not exceeded. The tests shall be carried out with the rated load at rest and the trolley in the central position. The deflection measurement shall be taken only after the load has been applied several times.

d) Brake Tests

All brakes shall be tested under full-load conditions, from maximum speed to rest, three times in quick succession without overheating.

30.5.6.2 Site Performance Tests

Contractor shall carry out complete performance tests on every element of the work. The tests shall demonstrate that all guarantees have been met and the entire equipment meets the contract requirements in that it is properly installed and adjusted to operate correctly and safely. Any defects, which become evident during testing, shall be immediately corrected and the tests continued until the installation as a whole is proved to be in satisfactory working order.

The site tests shall be done as same as shop tests but with the load of the heaviest part which actually will be moved by the crane.

30.5.7 PROTECTIVE COATINGS

In general, the provisions of the General Technical Specifications shall govern.

30.5.8 SPARE PARTS AND SPECIAL TOOLS

30.5.8.1 Spare Parts

All spare parts shall be interchangeable and of the same material and workmanship and shall meet the same requirements as the corresponding original parts.

The Contractor shall also supply the spare parts listed hereunder, which are to be considered as a minimum requirement for each crane:

- One (1) bearing for each type used.
- One (1) gasket for each type used.
- One (1) limit switch of each type and size;
- Twenty percent (20%) of contacts, push buttons, circuit breakers, relays, switches and contractors of each type used, with minimum of one;
- Hundred percent (100%) of fuses and lamps;
- Twenty percent (20%) of each type of electronic cards with a minimum of one;
- Ten percent (10%) of auxiliary equipment with a minimum of one piece for each type;
- One (1) push button box (pendant control).

30.5.8.2 Special Tools

The Contactor shall supply one complete set of special tools required for the erection and maintenance of the crane, tackles and accessories.

All special tools shall be permanently identified as to their specific use and shall be delivered in lockable, portable metallic tool cabinets.

30.6 GROUNDING SYSTEM

30.6.1 GENERAL

This Section covers the requirements for the grounding system.

30.6.2 CHARACTERISTICS OF THE L.V. NETWORK

- System according to IEC 60364: TN.
- Neutral conductor: grounded but separated from the protective conductor "PE".
- Protective conductor "PE": shall be included in power and feeding cables.
- Protection against electric shock in case of a fault: by automatic disconnection of supply with over current devices.

Fault loop impedance determining the current for automatic operation of the protective device shall be:

Where: $Zs \leq Vo/Ia$

V_O = voltage between phase and neutral;

I_a = current determining the operation of the over current device within 5 s.

30.6.3 PROJECT CRITERIA

Generally, the feeding cables of the electric devices shall include also the protective conductor "PE" dimensioned to assure the over current device intervention within the time fixed by the standard.

The grounding system shall be realized to connect all the electric devices; also those already connected by means of their own conductor "PE", the mechanical apparatus and all the metal structures.

The grounding electrode shall be realized either by the group of conductors placed deliberately into contact to earth or by those metallic shells that, earthed up directly or by means of concrete, help in dispersing the earth currents and in carrying out an equipotential system.

According to plant characteristics, the Contractor will arrange for carrying out an interconnected assembly of the above two grounding electrode systems in order to guarantee the dimensional electric characteristics of the grounding system. The dispersion resistance of earthing system shall be not more than 5 ohm.

All the partial grounding systems realized for each section of plant (intakes, bottom outlet, irrigation valves, control house etc.) will be interconnected in several points, in order to carry out a single grounding system.

30.6.4 STRUCTURAL DETAILS

The grounding system shall consist of grounding mat, grounding conductor, and natural earthing such as metal pipes, structural steel work and metallic structure of reinforced concrete.

Grounding mat shall be made with bare copper conductors of minimum cross section 100 mm² embedded in the ground at an approximate depth of 80 cm. The grounding mat will be integrated with copper coated rods, 19 mm in diameter and 3 m in length, fixed vertically into the ground along the perimeter of the mat. The above grounding system will be connected to the grounding conductor laid on cable trays or fixed to the wall along all the galleries. In all the peripheral stations, gate and valve chambers the grounding conductor laid on the cable trays or fixed to the wall shall be connected to the concrete steel reinforcement and where possible shall be connected to the steel lining of conduits or to the embedded metallic structures which are in contact with the steel lining. Cross section of the grounding conductor shall be at least 100 mm2.

All electromechanical equipment metallic parts shall be connected to the grounding conductor with conductor of at least 50 mm² cross section.

All the grounding bolts or bars of electrical equipment shall be connected to the grounding conductor.

Natural earthing as much as possible shall be connected to the grounding conductor.

All grounding conductor shall be stranded copper. Grounding connections shall be made either by an exothermic welding or appropriate bolted connection. Connections, which are inaccessible, shall be by exothermic process.

30.6.5 CORROSION PROTECTION

All underground junction and junctions embedded in concrete shall be protected against corrosion. Electrolytic corrosion shall be prevented by selection of all junction components compatible with copper.

30.6.6 TESTS

The Contractor will have to carry out, when the mounting is finished, all the tests and measures necessary to verify the grounding system performance.

The earthing of all the equipment, all the metallic active and passive masses and the shutting of all the connections will be inspected.

For each single load, switchgear, board, and panel and for a quantity of lighting fixtures not less than 10% of the total (as chosen by the Employer's Representative), the check of the protection coordination with the measuring of the earth fault impedance loop will be carried out.

If the values resulting from the measuring carried out are not conform with the requirements of this specification and Standards, the Contractor has to make the appropriate changes in the grounding system, in order to contain the values within acceptable limits.

30.6.7 SPARE PARTS AND SPECIAL TOOLS

The Manufacturer shall supply his recommended spare parts, which he considers necessary for the satisfactory operation and maintenance of the equipment during the five initial years of operation.

All spare parts shall be interchangeable and of the same material and workmanship and shall meet the same requirements as the corresponding original parts.

The Contractor shall also supply the spare parts listed hereunder, which are to be considered as a minimum requirement:

- 100 m of copper conductor for each section;
- 10% of each type of installed accessory.

30.7 WATER LEVEL MEASUREMENT SYSTEM AND DIFFERENTIAL PRESSURE SET

30.7.1 GENERAL

The Supply shall include the following equipment:

- One (1) water level measurement and indicator for the headwater level;

The Supply shall also include all the spare parts and special tools herein required and all accessories and shall be complete with all the transducers necessary for remote indication and all parts to be embedded, including pipes.

30.7.2 DESIGN DATA

30.7.2.1 Water Level Measurement System

Type	Piezo-Resistive Type
Accuracy	±0.5%
Output signal	4-20 mA
Max water level	Approx. 1100 m.a.s.l
Min water level	Approx. 1070 m.a.s.l
Range of water level indicator	0-70 m with accuracy of at least 0.1% = approx. 3 cm

30.7.3 DESIGN CRITERIA

The water level measuring system shall be used for headwater level remote reading and recording.

Remote indicators shall be installed in the Dam Control Board. Remote indicator for water level shall be of digital type.

The water level measurement system shall be supplied complete with transducer and two adjustable limit switches for remote alarm.

Equipment of water level measurement system shall include a control cabinet where all the electrical equipment shall be installed.

The feeding for each control cabinet shall be from the relevant distribution board.

All the equipment shall be standard type of well-known manufacturers.

The Supply shall also include:

- Boards on which all the necessary equipment (valves, pressure reducer, manometer and differential manometer, pressure switches, flowmeters, etc.) shall be installed;

- All the stainless steel pipes complete with nipples and terminal stainless steel nozzles;

- Control cabinets where all the electrical equipment shall be installed.

- Contacts for remote indication of "High Flow" and "system failure" shall be provided.

30.7.4 TESTS

30.7.4.1 Shop Tests

Transducers, sensors, boards and cabinets shall be checked in order to ascertain their correct functioning.

30.7.4.2 Site Tests

Tests to be performed shall include but not be limited to the following:

- Checking of sensitivity;
- Checking water level measurement system correct functioning, including checking limit switches and correct calibration of the measuring devices.

30.7.5 PAINTING

The prescriptions of General Technical Specifications shall govern.

30.7.6 SPARE PARTS AND SPECIAL TOOLS

30.7.6.1 Spare Parts

The Contractor shall furnish his recommended spare parts, which he considers necessary for the satisfactory operation and maintenance of the equipment during the five initial years of operation.

All spare parts shall be interchangeable and of the same material and workmanship and shall meet the same requirements as the corresponding original parts.

The Contractor shall also supply the spare parts listed hereunder, which are to be considered as a minimum requirement:

- One (1) sensor of each type;
- 20% of contactors, circuit breakers, push buttons and relays of each type used (with a minimum of one).

30.7.6.2 Special Tools

The Contractor shall supply one complete set of special tools required for the erection and maintenance of the equipment

Chapter 0920

31 HYDROMECHANICAL GENERAL TECHNICAL SPECIFICATIONS (GTS)

31.1 GENERAL REQUIREMENTS

31.1.1 GENERAL

The purpose of this document is to establish general technical requirements for the PMCing, supply, manufacture, shop assembly, shop testing, painting, packing, shipment, storage at Site, assembly, installation and site testing that are applicable to all hydro-mechanical equipment to be furnished for the Project under this Contract.

The Scope of Work is specified in the Special Technical Specification. All material, works, consumables etc. necessary for a trouble-free, reliable and safe operation of the equipment, even if not explicitly listed in the documents shall be included in the Contractor's Scope of Work.

In case of any deviation between the drawings and the Specifications, the latter shall prevail. The requirements stated in these General Technical Specification are valid for all parts of the Special Technical Specification, however in case of contradictions the Special Technical Specification shall take precedence over the General Technical Specification..

31.1.2 UNIT OF MEASUREMENTS, SPECIFIC INFORMATION ON DRAWINGS

All measures, calculations, numerical results, specifications, final documentation shall be presented in SI units. Angles shall be given in the 360-degree system (360°). When requested, conversion of units and site data shall be the responsibility of the Contractor.

Each drawing shall contain a scale reflecting the appropriate meter spacing.

31.1.3 STANDARTS

The design, materials, manufacture, testing, inspection and performance shall unless otherwise specified conform to the relevant internationally recognised Standards as listed below:

Table 31-1: List of Standards Organizations

Abbreviation	**Standards Organization**
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
DIN	German Institute for Standardization
EN	European Standards
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization

More specific references to standards are provided in the relevant sections of this specification and in the Special Technical Specification.

The standards applied shall be the Standards in force at the date of issue of the Specification unless otherwise approved by the PMC.

When the Contract Documents contain more restrictive requirements than those of the Standards or Codes, the Contract Documents shall prevail.

The Contractor shall state on his drawings and documents the standards applied in the course of preparation of such drawings and documentation.

Should the Contractor propose a recognised equivalent standard to the PMC for approval and should this substituted standard be approved by the PMC then upon written request, the Contractor shall provide copies of such standard to the PMC and to the Employer.

31.2 CONTRACTOR DRAWINGS / DOCUMENTS

31.2.1 GENERAL

The Contractor shall prepare necessary conceptual, general arrangement, foundation drawings, drawings indicating forces acting on civil structures and detailed drawings and documents necessary for the manufacturing of the Equipment such as shop drawings design, manufacturing drawings, bills of materials diagrams, specifications, method statements and test plans.

For all hydro-mechanical and hydraulic steel structures general arrangement, detailed design and shop drawings shall be provided by the Contractor in suitable 3D and 2D views.

The structural integrity and serviceability of the equipment shall be demonstrated by design calculations.

For instruction of the future staff the Contractor shall prepare Operation and Maintenance Manuals.

If the Contractor fails to submit such design drawings and documents in time or to execute revision on change as directed by the PMC, and subsequent resulting in the additional cost and/or delays incurred thereby shall be deemed to be the Contractor's own responsibility.

The PMC reserves the right to request the Contractor additional documents as may be required for proper understanding of the construction, structure, operation, coordination or other matters.

All costs and expenses for preparation and submission of the design drawings and documents shall be borne by the Contractor including those for revision and resubmission of the documents.

The Employer and the PMC shall have the right without further authorization from the Contractor to use, copy, reproduce and forward to a third party the Contractor 's Documents if it is reasonably required for completing, operating, maintaining, adjusting and repairing the Works.

31.2.1.1 Symbols and Abbreviations

All symbols, marks, abbreviations, etc., using on all documents shall be explained clearly by a legend on the same document or separate sheets. Due descriptions and explanations shall be written additionally on the same documents or separate sheets, if required for proper understanding the documents.

The abbreviation and mark used for an individual device shall be identical throughout the complete documentation so as to avoid confusion.

31.2.1.2 Revisions

In case the Contractor will revise and replace the design drawings and documents previously and already submitted for approval, it shall be marked accordingly. The revised part of the said document and drawings shall be marked clearly.

31.2.1.3 Format

31.2.1.3.1 Drawings and Documents

The size of drawings/documents shall be unified entirely with the following module.

A1 (594 mm x 841 mm)

A2 (420 mm x 594 mm)

A3 (297 mm x 420 mm)

A4 (210 mm x 297 mm)

Design calculations, strength calculation, specifications, lists, instruction manuals and other documents shall in principle be prepared in A4 size.

All documents shall have a uniform title-block as accepted by the PMC, at the bottom right- hand corner, irrespective of the origin of the documents. The title-block shall show the drawing title, drawing number, revision affix (number, description and date of revision), date prepared, name of the Contractor and/or manufacturer, and the signature of the Contractor's representative.

The Contractor, if requested, shall adopt (in addition to his own numbering system) a numbering system provided by the PMC.

31.2.1.3.2 O&M Manuals

The final O&M manual the text, diagrams, drawings, brochures and all other instructions content shall be reproduced in carbon by electrostatic printing. Reproductions obtained by using dyes, chemicals or photo-sensitive or heat-sensitive materials are not acceptable.

All text shall be on size A4 paper except that brochures of smaller sizes will be accepted for minor components of proprietary equipment provided they have adequate binding margins.

The main text shall be on white paper. The paper used in the final version of the O&M manual shall be of the following archival quality material:

White sheets: 70 g/m² to 106 g/m^2;

Colored sheets: not less than 70 g/m^2

Diagrams and drawings provided as part of the O&M manual shall be size A3 wherever the original is size A3 or larger and size A4 for all others. The manual shall be strongly bound in a durable stiff cover bearing the title in approved legend.

In addition, the O&M Manuals shall be submitted electronically in PDF format.

31.2.1.4 Electronic Documents

The Contractor shall provide soft copies of all documents in pdf format. In addition, drawings shall be provided in common CAD (dwg) formats.

On request the Contractor shall provide documents in original format. On request the Contractor shall hand over electronic 3-D models in common CAD format (specific format subject to coordination).

31.2.1.5 Submission of Documents

31.2.1.5.1 Hardcopies

In general, the approval process shall be based on electronic documents. The following requirements applies to the final design documents (approved documents), as built documents and O&M Manuals.

Numbers of the drawings, documents and data to the PMC shall be as follows:

Table 31-2 Submission of Hardcopies

Description	**To the Employer**	**To the PMC**
Complete Set of approved documents	1 copy	2 copies
Complete set of bound prints of As-built status drawings, reduced from A1 to A3 size	3 sets	1 set

O&M Manuals	3 sets	1 set

31.2.1.5.2 Softcopies

The procedure of soft copy submission shall be defined later by the PMC. The Contractor shall follow these instructions. Most likely an electronic Data Management System (DMS) will be implemented by the PMC. The Contractor shall be obliged to upload and maintain his documents in the DMS at his own expenses. The same applies to conventional data transmittal by email or other electronic platforms (without implementation of a DMS).

31.2.1.6 Times for Submission of Drawings and Documents

The Contractor shall submit the design drawings and documents within the following specified times which shall be reckoned from the Commencement Date.

1. Within one (1) month:
    a. Master list of design drawings, documents and data as specified.
    b. Detailed construction time schedule.
    c. Quality assurance / quality control plan
2. Within five (5) months;
    a. General arrangement and lay out drawings of equipment.
    b. Specifications for all principal equipment and facilities.
    c. The test procedure and method of analysis for model testing of the gates.
3. In line with the general schedule of Works (Works Programme)
    a. Assembly drawings of each Equipment
    b. Execution drawings of each Equipment
    c. Design calculation of each Equipment
4. Documents for Approval;
    a. "Operation and Maintenance Instruction Manuals" before the first delivery of the Equipment to the Site.
    b. "Installation Manuals" before the first delivery of the Equipment to the Site (item / position wise)
    c. Inspection and Test Procedure at the Shop and at the Site along with design but not later six (6) weeks prior to procurement of materials or commencement of fabrication work.
    d. Qualification documents for welding procedure and for welder and welding operator's qualification six (6) weeks prior to commencement of fabrication work.
    e. "Painting and Surface Protection Specifications" color scheme and painting sample one (1) month prior to commencement of fabrication work.
    f. Spare parts list, maintenance equipment and tools list within one (1) month after approval of drawings for main components of the Equipment.

31.2.2 APPROVAL OF DOCUMENTS

31.2.2.1 Master List

The Contractor shall furnish to the PMC for information a master list of the design drawings and documents which shall be prepared and submitted under the Contract within the period specified in the Contract. The master list shall include the Contractor's target date to submit each technical document and drawing, along with the expecting approval date thereof.

In addition, the Master list shall indicate the class of documents as per following sections (for approval / for information).

31.2.2.2 Drawings and Documents for Approval

Prior to the commencement of materials procurement and manufacturing of Equipment, the Contractor shall submit due design drawings and documents for approval of the PMC.

All documents and drawings are subject to approval by the PMC except those specified in Section **Ошибка! Источник ссылки не найден. Ошибка! Источник ссылки не найден.**.

The Contractor shall allow a period of at least four (4) weeks after receipt of the PMC for such approval process, but always subject to quantitative volume and accuracy of design submission per a time, and another one (1) week for return mail. One (1) of them submitted will be returned to the Contractor with one of the following status:

APPROVED – Resubmittal required only if revised after approval

APPROVED AS NOTED – Update and resubmittal required

RETURNED FOR CORRECTION – Update and resubmittal required

Upon receipt of design drawings and documents which have been marked APPROVED or APPROVED AS NOTED, the Contractor is authorized to proceed with the contractual works provided the comments are accepted and then incorporated into the Contractor's drawings. APPROVED AS NOTED drawing shall then be resubmitted for approval with the indicated corrections made.

When the returned design drawings and documents have been marked RETURNED FOR CORRECTION, the Contractor is not authorized to proceed with the contractual works and shall make the necessary corrections and/or revisions to the design drawings and documents in a timely manner and shall resubmit them to the PMC. When the returned design drawings and documents are submitted for re-approval, the PMC will try to complete his review and/or approval of the design drawings and documents within

minimum two (2) weeks, however, this will be depending on the quantitative volume and complexity of the corrections/revisions which have to be checked. This procedure will continue until the design drawings and documents will have eventually been marked as APPROVED.

Claims nor extensions of time shall not be permitted on account of:

1. The late submission of design drawings and documents to the PMC/, or
2. For delays caused by design drawings and documents being returned by the PMC as not approved but for re-submission.

Approval of the design drawings and documents shall in no way relieve the Contractor from any obligation to satisfy the requirements of the Specifications or any responsibility of making modifications in their documents.

31.2.2.3 Documents for Information

Drawings and documents affecting the manufacturing process only (e.g. shop drawings indicating the cutouts of steel plates) do not need an explicit approval of the PMC, provided that the associated design drawings indicate all relevant information affecting the structural integrity, operation and lifetime of the equipment. These drawings however shall be submitted as well for information only. These drawings shall be marked as such in the Master List of documents.

31.2.2.4 Approved Drawings and Documents for Work

It is to be understood that approval of design drawings and documents does not exonerate the Contractor from any of its responsibilities under the Contract.

If an error is found in the Contractor's approved drawing(s) during the manufacture and/or rehabilitation works, the Contractor shall inform the PMC of it immediately. After having obtained the consent, the drawing may be revised accordingly and re-submitted to the PMC for approval. A defect caused by such error in the course of either the manufacture or the installation, without any statement shall be deemed to be of the Contractor's own fault.

31.2.3 AS-BUILT DRAWINGS AND DOCUMENTS

Aggregates shall conform to the requirements of ASTM C33. Gradation limits for coarse and fine aggregate fractions of shotcrete shall be as shown in the table below.

After all items of the Works have been manufactured, erected and passed and before Taking Over a complete set of the final "AS-BUILT" drawings along with documents and data which have been previously approved and/or modified consequently according to the requirements during course of fabrication and at site conditions, shall be submitted to the Employer and/or the PMC.as per Clause 2.1.5.1 of this Chapter.

The reduced size of the "AS-BUILT" design drawings into A3 size shall be bound in A4 size hard covers and be submitted to the Employer and to the PMC.

31.2.4 SPECIFIC REQUIREMENTS FOR DOCUMENTS

31.2.4.1 Drawings

31.2.4.1.1 General Arrangement and Layout Drawings

The general arrangement and layout drawings shall show the physical arrangement of equipment, equipment groups or complete units in relation to each other and also to civil structures such as dam structures, buildings and foundations, etc. The general arrangement drawings shall include principal dimensions, clearance and other details for coordination with the civil structures.

31.2.4.1.2 Assembly Drawings

Assembly drawings shall be submitted for all individual equipment units. The drawings shall indicate the main dimensions, elevations, tolerances, adjustments, clearances, capacities, BOQ tables with proper marking of each item and the reference numbers of the respective manufacturing drawings and part lists.

31.2.4.1.3 Foundation Drawings

The Contractor shall submit detail drawings, showing his requirements for the civil works in relation to:

1. Foundations;
2. Recesses, blockouts, openings;
3. Conduits;
4. Embedded parts to be provided in primary concrete;

The drawings shall include all essential and pertinent information required for the design and execution of the civil works, such as:

1. Dimensions,
2. Static and dynamic loads,
3. Anchor forces, pressures,
4. Contours of temporary or permanent installations.

31.2.4.1.4 Execution Drawings

The Execution Drawings shall include the manufacturing drawings, erection drawings, piping drawings process diagrams, parts lists, etc., showing the dimensions, design and data of all apparatus and equipment to be supplied and installed under this Contract.

Further, for all technical documents, which employ designation or equipment identification numbers, a respective list shall be furnished.

Execution drawings shall show:

1. Materials, dimensions, tolerances, surface roughness, weight, adjustment, clearance,

2. Reference to assembly or sub-assembly drawings, and parts lists,
3. Details of fabrication, manufacturing and heat treatment,
4. Assembly of the equipment in plan and elevation with main dimensions,
5. All necessary details of the parts connecting to equipment supplied by others,
6. Location and sizes of connections for oil, grease, water, etc., Location and size of the instruments and accessories provided, Methods of lubrication and sealing,
7. Instructions for heat treatment (if any), pressure tests, surface preparation and anticorrosive protection,
8. Full details of parts for which adjustment is provided or which are subject to wear,
9. Method and sequence of installation, field joints, erection and lifting devices, jacks, anchoring details, etc.
10. Shop drawings

31.2.4.2 Design Calculation

The Contractor shall submit state of the art design and strength calculation sheets with all formulae, standards, test results, basic assumptions and design criteria used for these calculations. Only submission of the calculation results shall be unacceptable. The calculation shall be traceable as much as possible. For essential parts of the equipment Finite Element Analyses shall be prepared as indicated in the Special Technical Specification.

The design and strength calculations shall be submitted with the corresponding drawings. Drawings shall not be approved without the related design and strength calculations.

31.2.4.3 Electrical and Control Documents

For electrical diagrams, general reference shall be made to IEC 61082 and IEC 60617.

31.2.4.3.1 Single Line Diagrams

The single line diagram shall be a simplified diagram of the essential equipment, instruments, protective relays and their interconnections. All circuits shall be represented by a single line only. It shall contain all required technical information of the equipment represented, e.g., kind, major ratings, quantity, interlocking, etc.

31.2.4.3.2 Circuit Diagrams

The circuit diagrams shall show the power circuits in all phases with the main apparatus as well as the pilot circuits (measuring and control circuits). It shall show in full the functioning of part or all installations, equipment or circuits with all required technical information.

31.2.4.3.3 Connection Diagrams

The internal connection or wiring diagrams shall show the wiring or tubing connections either within one apparatus or between several apparatus of one group. They shall

contain the single components or apparatus of one group arranged in the correct physical location including terminals and terminal boards. The connections shall either be represented by lines or, in case of a "wireless" connection diagram, by a wire table.

The external connection or interconnection diagram shall show the external wiring or tubing connections between the different units of an installation.

31.2.4.3.4 Block and Logic Diagrams

The block diagrams shall be used to show in a simplified manner the main inter-relationship between the elements of a system by means of symbols, block symbols and pictures with logical inter-connections between the elements. The symbols used for the individual kinds of components, e.g. servomotors, amplifiers, computing modules, etc., shall be explained clearly on the diagram or on an attached legend.

31.2.4.3.5 Terminal Diagrams

The terminal diagrams shall be prepared for any type of control panel, relay board, and local control boxes. Such diagrams shall show the terminals, which shall be properly numbered, and the internal and/or external conductors connected to them.

31.2.4.3.6 Hydraulic Control Schematic Diagrams

The Contractor shall submit for the PMC's approval a hydraulic schematic diagram, including all hydraulic controls, limit switches, position indication functions, size of piping, settings of all valves and pressure switches, pump and motor sizes. Each item of the schematic shall be assigned an item number and a table shall be furnished listing each item and its function.

31.2.4.4 Specifications

The Contractor shall prepare specifications for all principal equipment and facilities. The specifications shall describe the type, ratings, design, construction, materials, dimensions, corrosion protection and other performance of the Equipment.

31.2.4.5 Inspection and Test Procedures

The Contractor shall submit to the PMC for approval during or immediately following the submission of drawings however minimum 6 weeks prior to start manufacturing, the inspection and test procedures, describing each test to be performed at the Contractor's workshop, field workshop and at the Site.

The inspection and test procedures shall define the sequence of the tests, the equipment preparation and operation procedures to be followed and the detail procedures for conducting the tests, tolerance for dimension and/or quality controls and other necessary items for the tests.

The inspection and test procedures shall be separately prepared for the tests to be performed at the shop and at the Site.

31.2.4.6 Installation Manuals

The Contractor shall submit to the PMC for approval before the first delivery of the Equipment to the Site, the installation manual of the Equipment to be executed at the Site.

The installation manual shall be submitted for approval in the same manner as the design drawings as specified.

The installation manual shall describe and illustrate in detail the methods and procedures for installation of the Equipment, the use of the manpower, construction facilities and measurement devices together with their capacity and required number, field workshop and other necessary explanations on the installation work.

31.2.4.7 Operation and Maintenance Manuals

The Contractor shall provide an Operation and Maintenance Instruction Manuals (O&M manuals), the scope of which shall be suitable for fully informing the Employer's staff on all aspects of the operation and maintenance of the Equipment,

The content of the O&M manuals shall be directly applicable to the Equipment. Standard instructions covering a number of sizes and/or models of proprietary equipment will be accepted provided that they cover the items supplied and these items are clearly identified throughout the O&M manual.

Precautions and warnings relating to the safety of persons and of the equipment shall be clearly stated at the beginning of the manual.

Sketches or photographs shall be included in the text whenever necessary for clarity.

The first version of the O&M manuals shall be submitted for approval before the first delivery of the Equipment to the Site. In case of changes during commissioning the O&M shall be updated and submitted as new revision. This first revision of the O&M Manuals may be submitted in electronic format only.

The O&M manual content shall comprise as a minimum requirement the following separate parts:

2. Part 1: Description
    a. Function: Brief statement of the function of each Equipment
    b. Equipment Description
    c. Description of each Equipment, including as appropriate the type, design features, function and control and protection.
    d. Setting Data and Operating Limits: Tabulated setting data and operating limits of all quantities, control devices, indicators and alarms.
3. Part 2: Operation

a. Operating Sequences
b. Description with tabulated lists or sequence diagrams of all operating procedures such as:
c. starting sequences, manual/ automatic, preliminary conditions, auxiliaries, etc.
d. stopping sequences, normal, quick stop, emergency stop, etc.
e. In-Service Check List
f. Tabulated list of all conditions to be checked and the required frequency of checking while the equipment is in service. Also, the action to be taken if incorrect conditions are found.
g. Fault Diagnosis and Alarms
h. Fault diagnosis based on symptoms of malfunction including action to be taken on the receipt of each alarm.

4. Part 3: Maintenance
    a. Maintenance instructions:
    b. Schedule of all routine inspection, maintenance operations including:
    c. components and conditions to be checked;
    d. frequency of inspection, checking and lubrication
    e. acceptance criteria;
    f. action to be taken if criteria are not met.
    g. Assembly/Disassembly Procedures for parts which may require this action during their lifetime
    h. Detailed description with diagrams, of all assembly and disassembly procedures, including all adjustment, tolerance, clearance and alignment data and lubrication requirements.
    i. Typical repair and reconditioning procedures for non-replaceable components.
5. Part 4: Drawings and Documents
    a. One copy of each drawing referred to in the text or necessary for clear understanding and use of the text, including as necessary assembly, layout and arrangement drawings, and detail component maintenance drawings shall be attached. The drawings shall be preceded by a list with titles and numbers, in numerical order. The final O&M manual shall contain "as-built" drawings. The draft O&M manual shall contain drawings current at the time of submission.
    b. Further, a complete list of all design drawings and documents prepared for this Contract, the approved painting and surface protection specification, the maintenance tool list, the spare parts list shall be attached to this part 4.
6. Part 5: Brochures for Proprietary Equipment
    a. Manufacturers' brochures, instruction pamphlets, and the like containing the operation and maintenance instructions of all ancillary proprietary equipment shall be attached.
    b. The brochures shall be preceded by a section index outlining the content of each brochure.

c. The parts list for each component of item of the Equipment shall also be attached. Such parts list shall include manufacturer's code, serial numbers, business section & address and ordering instructions, etc. The parts list shall be detailed for only the Equipment supplied and shall not include general reference or description of similar Equipment which is of the same model but different only in detail.

31.3 DESIGN LOADS AND SAFETY FACTORS

31.3.1 GENERAL

This section applies to the hydro-mechanical equipment such as gates and steel linings. Requirements applying to cranes and winches are provided in related Section.

The loads to be considered for the design of the Equipment shall be as specified hereafter and in the Special Technical Specification and shall be in-line with the requirements of DIN 19704.

The Equipment shall be designed with the worst or possible combination of the acting loads under the design conditions.

The loadings specified herein shall be considered as minimum requirements. The Contractor shall therefore seek such an extra loading condition and combination thereof as shall likely to occur under the circumstances, in addition to the basic requirements specified herein as per DIN 19704.

31.3.2 DESIGN LOADS

31.3.2.1 Design Loads

In general, for hydro-mechanical equipment the loads as per DIN 19704 and the following loads shall be taken into account.

31.3.2.1.1 Hydrostatic Load

Hydrostatic load shall be the maximum upstream water level acting on the gates.

31.3.2.1.2 Dead Weight

31.3.2.1.3 Sedimentation Load

Maximum sedimentation load expected during the whole life of the project resulting from prolonged operation shall be used considering the high sediments in-flows in the river.

An equivalent density of sediments of 800 kg/m³ shall be considered assuming a hydrostatic pressure distribution (in addition to the max. water level). The friction angle to be considered for the friction between the sediment and the skinplate for the calculation of the required lifting force is 20°.

31.3.2.1.4 Operating Loads

Operating forces such as lifting forces shall be taken into account, where applicable.

31.3.2.1.5 Friction Forces

Friction forces shall be considered for the calculation of the lifting forces and closing safeties and for the structural calculations of effected parts. The friction coefficients shall be in line with the requirements of DIN 19704.

31.3.2.1.6 Hydraulic Dynamic Force Induced by Flowing Water

Hydraulic dynamic force such as water pressure variation and vibration force etc. induced by the flowing water shall be considered where applicable.

31.3.2.1.7 Dynamic Loads during Earthquake

For gates directly exposed to the reservoir, the Westergaard formula shall be used for the calculation of the added mass of the water.

For gates in a conduit the hydrodynamic pressure caused by the oscillating mass of the water shall be considered by the method of Wieland, issued in INTERNATIONAL WATER POWER & DAM CONSTRUCTION (October 2005).

As a general rule: for all equipment substantially exposed to seismic loads the dynamic response of the structure to these loads shall be taken into consideration. This shall be achieved by quasi static, response spectrum or fully dynamic (time history) analyses.

In case of quasi static analyses, the actual acceleration shall be determined based on the response spectra by performing a modal analysis considering the dead weight of the structure and the added mass of water. The actual acceleration shall be the acceleration corresponding to the natural frequencies (obtained from the modal analysis) as per response spectrum.

31.3.2.1.8 Thermal Effect

Thermal effects shall be considered where necessary. If consideration of temperature effects deems necessary and no requirements are provided in the Special Technical Specification, the Contractor shall assume design temperatures which are subject to approval by the PMC.

31.3.2.2 Design Loads for Steel Linings

The steel liner shall be designed for the following loads. More specific requirements are provided in the Special Technical Specification.

1. Internal (hydrostatic) water pressure
2. Internal dynamic water pressure during earthquake (as described above for gates)
3. External pressure due to seepage water for the parts embedded in concrete External pressure due to grouting
4. Concrete backfill pressure and resulting uplift and bending
5. Loads due to handling during fabrication, transportation and field installations

31.3.2.3 Design Loads for Cranes

Specific requirements related to cranes are provided in related Section.

31.3.3 DESIGN STRESSES AND SAFETY FACTORS

31.3.3.1 Gates

DIN 19704 in conjunction with EN 1993-1-1 shall be followed for the structural analysis of the gates, and other structural members subject to approval of the PMC.

The design philosophy of these standards is based on partial safety factors. The partial safety factors for loads γF and their combination shall be in line with Table 5 of DIN 19704 (2014) with the exception of No. 2, 3 and 4 persistent variable actions (hydrostatic, hydrodynamic actions and water loads) shall be considered with γF = 1.5 instead of 1.35.

The partial safety factors for material resistance γM acc. to Table 6 of DIN 19704 shall be increased by an additional safety factor of γMa =1.15. The overall safety factor on the material resistance side shall be therefore correspond to γMi* γMa.

For extreme loading conditions (e.g. earthquake, flood) this additional safety factor does not need to be taken into account γMa=1).

The load combinations for normal and extreme design conditions are given in each Section of the Special Technical Specifications. In case of conflicting requirements, the more stringent shall prevail.

31.3.3.2 Machine Parts of Gates

Machine Parts of the gates shall also be based on DIN 19704; however, the partial safety factor for the resistance of materials γM shall be increased to 1.65 (instead of 1.5) for normal operation conditions.

31.3.3.3 Steel Linings

In general, rectangular steel linings are mainly subject to bending, for this reason the design philosophy and safety factors defined for hydraulic steel structures (gates) as specified applies. More specific requirements and design approaches are provided in the Special Technical Specification.

31.3.3.4 Pressure Vessel Type Equipment

For pressure vessels and pressure vessel type equipment particularly in combination with Finite Element Analysis the ASME Boiler and Pressure Vessel Code, Section VIII, Division 2 may be used; however, the maximum allowable primary membrane stress, local membrane stress, local membrane and bending stress combinations, secondary membrane and bending stress combinations, and stress concentrations shall be reduced by 20%.

31.3.3.5 Cranes

Specific requirements related to cranes are provided in related Section.

31.3.3.6 Other Steel Structures

Steel structures other than hydro-mechanical equipment and cranes shall be designed according to EN 1993-1.

31.3.3.7 Permissible Concrete Compression

The strength class of the concrete used shall be C25/30 if not otherwise indicated. The permissible concrete compression shall be 11 MPa for normal load cases (characteristic value).

31.4 DESIGN PARTICULARS

31.4.1 MINIMUM THICKNESS

The thickness of all structural members of the equipment shall not be less than 12.0 mm, except those of the following parts or part as approved by the PMC. Minimum dimensions, without regard to stress considerations, shall be as follows:

Table 31-3: General Structural Member Minimum Thickness

Parts	**Min. Thickness (mm)**
Skin plate including corrosion allowance	12
Plate thickness of any structural part except webs or rolled shapes	12
1st stage embedded parts	12
2nd stage embedded parts	12
Stainless steel sealing plates	12
Corrosion resistant steel cladding after final machining	8.0
Diameter of adjusting bolts between frame or embedded part & welding pad	20

Table 31-4: Steel Liners Minimum Thickness	
Parts	**Min. Thickness (mm)**
Shell Plates for steel liners (pressure base plate)	15.0
Cladding Plates for steel liners (for abrasion)	as per Special Technical Specification

31.4.2 CRITICAL SLENDER RATIO

The critical slenderness ratio for major compressive members shall be less than 120, and 150 for secondary members.

31.4.3 MAXIMUM DEFLECTION

The maximum deflection of each component of the equipment shall not exceed the following value under the design condition.

Table 31-5: Maximum Deflection in Components	
Component	**Max. Deflection**
Fixed Wheel Maintenance Gate	1/1000 of the supporting span
Bonneted Sliding Gates	1/2,000 of the supporting span
Crane	acc. to relevant Standards

31.4.4 OPERATING SPEED

The operation speed is specified in the Special Technical Specification for each item.

31.4.5 LEAKAGE OF GATES

Water leakage under any head and without the use of any additional sealing materials per m length of seal shall be as follows:

1. for gates 0.1 l/s per m length of seal
2. Total leakage shall not be more than 1 l/s for the gate in total.

31.5 MATERIALS

31.5.1 GENERAL

All materials used in the Equipment shall be new and of high quality, selected particularly to meet the requirements for the proper operation of the Equipment, and indicated fully in the Contractor's manufacturing drawings for approval.

The materials shall comply with the requirements mentioned in the latest issue of the respective ISO, EN, ASTM, standards, and in accordance with those as listed below in the table or equivalent and/or better in quality or as approved in advance by the PMC, unless otherwise specified.

In case of an equivalent material, the comparison of chemical and mechanical properties shall be provided by the Contractor along with latest issue of that Standard for PMC's approval.

A list of materials is provided in Section 5.4. In case of contradictions between Section 5.4 and Section 5.3 the latter shall prevail.

31.5.2 COMBINATION OF MATERIALS

The combination of materials in contact to each other, particularly the combination of stainless and carbon steel elements and shall be carefully chosen. If there is a risk of galvanic corrosion between these parts e.g. caused by unfavourable surface ratio special measures shall be taken to prevent direct (metal to metal) contact between them by providing isolating materials.

31.5.3 BASIC REQUIREMENTS FOR MATERIALS

31.5.3.1 General

All materials used shall be new and shall be designed and manufactured in a sound manner, using materials most suited to the particular service. Material used in the manufacture of the specified equipment shall be of the kind, composition, and physical properties best adapted to their various purposes in accordance with the best engineering practice. All equipment shall conform to the applicable standards as to material, workmanship, design, and tests.

31.5.3.2 Chemical Analysis

Chemical analysis shall be performed for all materials. The carbon equivalent shall be indicated on the certificate.

31.5.3.3 Non-Destructive Testing

Non-destructive testing shall be carried out in accordance with the requirements stated in this General Specification, in the Special Technical Specification and in the applicable standards mentioned in these.

31.5.3.4 Mechanical Testing

Mechanical testing shall be carried out in accordance with the requirements stated in this General Specification, in the Special Technical Specification and in the applicable standards mentioned in these.

31.5.3.5 Acceptance Certifications

Certification shall be in accordance with EN 10204. See specific requirements stated in the following sections and the Special Technical Specification.

31.5.3.6 Basic Requirements for Structural Steel Plates

For fabricated structures especially such exposed to water pressure, only weldable, age resistant fine grain steels with low temperature toughness of following grades shall be used:

1. Non-Alloy structural steels acc. to EN 10025-2 or equivalent; whereby the use of grade JR shall be limited to auxiliary metal structures not exposed to water pressure. For structural parts of gates the min. grade shall be J2.
2. Normalized weldable fine grain structural steels acc. to EN 10025-3 or equivalent
3. Thermomechanically rolled fine grain structural steels acc. to EN 10025-4 or equivalent

In addition, in exceptional cases for parts subject to the use of:

4. high yield strength structural steels in the quenched and tempered condition acc. to
   EN 10025-6 or equivalent

may be considered however this requires the approval by the PMC.

The use of steel plate having a nominal yield strength > 700 MPa is prohibited, except for parts exposed to abrasion as per instructions of the Special Technical Specification.

The use of steel according to standards other than EN 10025 (equivalent standard) is subject to approval by the PMC. For an approval of an equivalent standard, the testing program of the plates in general and particularly in terms of Charpy V toughness shall correspond at least the requirements of EN 10025.

The toughness requirements in general shall correspond to EN 1993-1-10 which specifies the material grades based on the thickness.

Steel plates shall be in general suitable for the intended purpose and free of any defect. Surface condition of the plates shall comply with Class B3 acc. to EN 10163-2.

Steel plate for welded structures of importance shall be ultrasonic tested at the steel mill according to the standard EN 10160 Class S2.

All plate material and sections shall be identified by heat number at all phases of fabrication and erection. They shall be checked ultrasonically for internal defects in accordance and supplied with mill certificates including mechanical, chemical and non-destructive evaluation certificates.

For the material tests of the plates certificates of type 3.1 according to EN 10204 shall be provided. For certain parts as specified in the Special Technical Specification the certificate shall be of type 3.2.

31.5.3.7 Basic Requirements for Steel Casting

Steel castings of importance, in particular for constructions exposed to water pressure, shall be of a grade or class of an approved standard having guaranteed composition and properties, including low temperature ductility. The cast, cleaned, heat-treated and ready pre-machined casting shall be material-tested as specified. The test results shall comply with specified composition and properties. Steel castings shall be completely free of cracks, shrink holes, hot tears, and shall not contain sand spots and inclusions, segregation, gas and blow holes, unfused chaplets and internal chills to a degree affecting their strength and durability. All main steel castings shall be subject to approval of the Engine.

31.5.3.7.1 Steel Casts for Critical Parts

Steel castings of major critical components subject to internal pressure shall be cast and tested in accordance with the requirements of CCH 70-4.

The Contractor shall prepare and submit to the Employer for their review and acceptance prior to casting:

1. The quality sheets as per CCH70-4 section 4;
2. Details on any special requirements such as casting patterns and heat treatment.

All casting defects and weld repairs shall be mapped. All repairs must be carried out in accordance with CCH70-4 section 5. Major defects that reduce the stress-resisting cross-section by more than 30% or if the stress in remaining material exceeds the allowable stress by more than 30%, the casting may be rejected.

The Contractor shall carry out the following non-destructive testing of all components in accordance with CCH70-4 and the below requirements:

1. Liquid penetrant 100% of surfaces

2. Water passage surfaces, acceptance criteria Class 1
3. Non-water passage surfaces, acceptance criteria Class 3
4. Ultrasonic, 100% of component
5. Rotating components, acceptance criteria quality level 2
6. Non-rotating components, acceptance criteria quality level 3
7. For 100% of welds, acceptance criteria Class 2

Prior of destroying the patterns, the PMC shall be informed. It is then up to the PMC to decide if he likes to take over the patterns or part of it.

31.5.3.7.2 Steel Casts for General Applications

Steel Casts for general applications shall be in line with the following standards:

Table 31-6	**Design Standards for Steel Casts**
Standard	**Subject**
EN 10293	Steel Castings - Steel Castings for General Engineering Uses
ASTM A27	Specification for Mild-to-Medium-Strength Carbon- Steel Castings for General Application," Grade 65-35
ASTM A148	Standard Specifications for Steel Castings, High Strength for Structural Purposes

31.5.3.8 Basic Requirements for Cast Iron

Cast iron will only be accepted for secondary parts, such as counterweights, supports, etc.

31.5.3.9 Basic Requirements for Forging

Forgings shall be made of vacuum-de-gased steel and shall be forged thoroughly and throughout in accordance with EN 10222 for pressure applications and EN 10250 for general purpose applications.

Forging to shape, heat treatment (quenched and tempered, annealed or normalised as required) and rough machining shall be completed previous to material testing; results thereof must comply with specified compositions and properties. Forgings must be flawless, completely free from cracks and flakes, and shall not contain any other imperfection such as porosity, non-metallic inclusions, segregations, hard spots and residual tensions to a degree affecting their strength and durability. All main steel forgings shall be subject to approval of the PMC.

In accordance to the standards of acceptability of forgings, cracks, flakes and excessive hydrogen content as well as non-compliance with specified compositions and properties constitute reasons for rejection. Further, all imperfections as detected by non-destructive testing (dye check, radiographic or ultrasonic inspection, etc.) exceeding the nature of a local and tolerable imperfection may constitute a reason for rejection depending upon careful investigation in conjunction with and on the basis of the respective design.

The Contractor shall provide to the Employer the following information prior to manufacturing:

1. Quality sheet use to demonstrate the testing requirements such as non-destructive testing, destructive testing, dimensional checks;
2. Heat treatment requirements;
3. Acceptance criteria.

In addition to the testing requirements stipulated by the Contractor, the following inspections, tests and analyses shall be carried out:

1. Steelworks inspection;
2. Product analysis to the relevant forging standard including chemical analysis, mechanical tensile analysis and hardness test;
3. Ultrasonic inspection to EN 10228, quality class 4;
4. Magnetic particle inspection to EN 10228 quality class 4;
5. Liquid penetrant inspection to EN 10229 quality class 4 for all working surfaces;
6. Two test pieces per batch to be provided to the Employer for third party testing.

Hydraulic testing in accordance with EN 10222 is required for all forgings subject to internal water or oil pressure, the forging must be drip tight.

All indications revealed by NDT shall be mapped and the inspection report submitted to the PMC. Repair procedures shall be submitted to the PMC for acceptance. All repairs shall be examined by magnetic particle and ultrasonic test methods. If the defect (before repair) exceeds the stress-resisting cross-section by more than 30% or if the stress in remaining material exceeds the allowable stress by more than 30% or the repaired area does not meet the specified acceptance levels, the forging shall be rejected, and the Contractor shall supply a new forging at no extra cost to the Employer.

The largest fillets compatible with the design shall be incorporated wherever a change in sections occurs. All finished surfaces of forgings shall be smooth and free from tool marks.

The forging shall be clearly stamped with the heat number in such location as to be readily observed when the forging is assembled in a completed unit.

31.5.3.10 Basic Requirements for Stainless Steel

Stainless steels shall conform to EN 10088 or the American Iron and Steel Institute (AISI) specifications.

In general, the following grades shall be used on components to total or frequent immersion in water

1. Min. grade in terms of corrosion resistance when parts are accessible: 1.4301 / 1.4307 acc. to EN 1088, AISI 304/304L
2. Min. grade in terms of corrosion resistance when parts are not accessible: 1.4401 / 1.4404 / 1.4435 acc. to EN 1088, AISI 316/316L

Special requirements of the Special Technical Specification apply the parts subject to abrasion.

31.5.3.11 Basic Requirements for Non-ferrous Materials

When selecting non-ferrous materials such as copper, bronze, teflon, rubber, etc. the Contractor shall take into account their convenience for application, best modern practice, long life operation and minimum maintenance of the equipment supplied.

For non-ferrous materials he intends to use for the main parts the Contractor shall submit to the PMC, the name of the equipment where the material will be applied, name of manufacturer, its characteristics, test reports, site records, pamphlets and all other significant information.

Materials used and equipment installed without the approval of the PMC shall be at risk of subsequent rejection.

31.5.3.12 Design Standards for Seals

Table 31-7 Design Standards for Seals

Standard	Subject
ASTM D3293	Specification for PTFE Resin Molded Sheet
ASTM D3294	Specification for PTFE Resin Molded Basin Shapes
ASTM D3297	Practice for Molding and Machining Tolerances for PTFE Resin Parts

31.5.3.13 Seals

The material for large seals (such as for gate seals) shall conform to DIN 19704-2. And be of non-ageing synthetic rubber material, which shall be unaffected by wetting and drying or temperature changes. The sub-supplier and the material of seals are subjected to the approval of the PMC.

To reduce friction between the seals and the metal sealing surfaces special coatings may be used (e.g. PTFE, TCT, etc.) including the corner parts; however, in the calculations the coefficient of friction shall be assumed as not less than 0.5 taking into account of the wear effect.

In case of PTFE coatings, the fluoro-carbon sheath shall be bonded to the rubber on the sealing surface. The sheath shall be abrasion resistant. The outside surface of the fluoro-carbon shall be free of adhering or bonded rubber. The coating shall fulfil the requirements of the standards listed in 5.3.12.

31.5.4 SUMMARY OF MATERIALS

Table 31-8 Summary of Materials

Sr. No.	Components	Material Standard
1	Structural Steel for main components of gate leaf, rope drums, gantry and bridge crane bodies and built-up girders; embedded parts, (except seal and track plates and side guide plates which will be of stainless steel) and supports etc.	EN 10025 "Hot Rolled Products of Structural Steel" Part 2: "Non-alloy structural steels" S275 J0 / S355 J2
		EN 10025 "Hot Rolled Products of Structural Steel" Part 3: "Normalized rolled weldable fine grain structural steels" S275 N / S355 N / S460 N
		ASTM-A572, Grade 50 and above, "Standard Specification for High Strength Low – Alloy Columbium – Vanadium Structural Steel".
		Toughness requirements shall correspond to EN 1993-1-10 (applied to all types / standards).
		Part 5: Weldable fine grain steels, thermo-mechanically rolled, (e.g. P355M, P355ML, P460ML, P460ML1)
		Equivalent normalized or thermo-mechanically rolled weldable fine grain steels.
		Steel of strength higher than 460 MPa shall be subject to approval of the PMC.
		In general, the toughness requirements of all structural steel shall correspond to EN 1993-1-10.
2	Structural Steel for rectangular steel linings and bonneted gate casings	EN 10028 "Flat products made of steels for pressure purposes" Part 3: Weldable fine grain steels, normalized (e.g. P355N, P355NL, P460NL, P460NL)
		EN 10025 "Hot Rolled Products of Structural Steel" Part 3: "Normalized rolled weldable fine grain structural steels" S355 N / S355 NL / S460 N / S460 N
		Steel of strength higher than 460 MPa shall be subject to approval of the PMC.
		In general, the toughness requirements of all structural steel shall correspond to EN 1993-1-10.

Table 31-8 Summary of Materials

Sr. No.	Components	Material Standard
		To sections subject to abrasion special measures acc. to Special Technical Specification apply.
3	Structural Steel for general purposes such as ladder, platform, walkways etc.	EN 10025 "Hot Rolled Products of Structural Steel" Part 2: non-alloy structural steels S235 JR / S275 JR / S355 JR
		ASTM A-36, "Standard Specifications for Carbon Structural Steel"
4	Corrosion-Resisting or Corrosion Resistant Steel for sealing plates, guide bars, wheel tracks and seal clamping plates	Min. grade in terms of corrosion resistance when parts are accessible: 1.4301 / 1.4307 acc. to EN 1088, AISI 304/304L
		Min. grade in terms of corrosion resistance when parts are not accessible: 1.4401 / 1.4404 / 1.4435 acc. to EN 1088, AISI 316/316L
		Special requirements of the Special Technical Specification apply the parts subject to abrasion.
5	Hardened Corrosion Resisting Steel for wheels / rollers track plates, pins, rods etc.	EN 10088, "Stainless steels" Part 2: "Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for general purposes", Series 1.4057 and equivalent
		ASTM-A564: "Hot rolled and cold finished Age – Hardening Stainless Steel and Heat Resisting Steel Bars, Wire and Shapes".
6	Steel Bolts and Nuts	EN ISO 898: "Mechanical properties of fasteners made of carbon steel and alloy steel" Part 1/2/3
7	Corrosion-resistant stainless-steel fasteners, bolts, screws and studs	ISO 3506-1/2 Fasteners- Mechanical properties of corrosion-resistant stainless-steel fasteners, min. A2 or equivalent
8	Forged Steel	Steel forgings for pressure purposes: EN 10222, "Steel forgings for pressure purposes"
		Steel Forgings for general applications: EN 10250 for general purpose application
		ASTM-A668, "Specification for Steel Forgings, Carbon and Alloy, General Industrial Use."

Table 31-8 Summary of Materials

Sr. No.	Components	Material Standard
9	Cast Steel	EN 10293: 2015-04 – "Steel castings - Steel castings for general engineering uses"
		ASTM-A27, "Specification for Mild-to-Medium-Strength Carbon- Steel Castings for General Application," Grade 65-35.
		ASTM-A148, "Standard Specifications for Steel Castings, High Strength for Structural Purposes,"
		To critical parts CCH70-4 applies.
10	Corrosion-Resisting Steel Castings	EN 10283: 2019-06 - Corrosion resistant steel castings
		ASTM-A743, "Specification for Corrosion Resisting Iron-Chromium - Nickel Alloy Casting for General Applications" Grade CA-15 and CF-8.
11	Rubber Pads and Gaskets	ASTM-C 864 "Specification for Dense Elastomeric Compression Seal Gaskets, Setting Blocks and Spacers".
12	Lubricating Fittings	According to Manufacturer's published data.
13	Bronze Bushings, Sleeve Type Bearings and other Lubricated Wearing Parts	SAE Standard Specification No. 64 for Phosphor Bronze. Oil-Impregnated bronze bearings, ASTM-B438, "Specification for Sintered Bronze Bearings (Oil-Impregnated)."
14	Bronze Castings	ASTM-B584, "Standard Specifications for Copper Alloy Sand Castings for General Applications," C903.
15	Phosphorus Bronze Castings	ASTM-B505, "Standard Specifications for Copper-Based Alloy for Continuous Castings," C907.
16	Anti-Friction Bearings	According to manufacturer's published data.
17	Expansion Anchors	According to manufacturer's published data.
18	Concrete Anchor Studs	According to manufacturer's published data.

31.6 MANUFACTURING & WORKMANSHIP

31.6.1 GENERAL

All workmanship shall be of the highest class throughout to ensure long service life and smooth and vibration free operation under all possible operating conditions.

31.6.2 CUTTING AND WELD EDGE PREPARATION

Cutting and bending of plates shall be done entirely at the manufacturer's workshop. All plates shall be cut accurately to the dimensions shown on the approved drawings, with allowance provided for possible shrinkage during welding.

Members to be joined by welding may be cut to shape and size by mechanical means such as shearing, machining, grinding, or by gas or arc cutting, to suit the conditions.

Design of welded joints and selection of weld filler metal shall allow thorough penetration and good fusion of the weld with the base metal. The edges of surfaces to be welded shall be sound metal free of visible defects, such as laminations or defects caused by cutting operations, and free from rust, oil, grease and other foreign matter. All edges shall be inspected for sound metal and be free from laminations, surface cracks (by MT) and other injurious defects.

31.6.3 BENDING

Bending for plates shall be performed by cold rolling, no hot rolling shall be allowed. Correction of curvature by hammering shall not be permitted. Orientation of plates shall be such that the final direction of rolling is placed circumferentially.

Cylindrical shells shall be rolled to true curved sections, with continuous curvature between the edges.

31.6.4 WELDING AND HEAT TREATMENT

31.6.4.1 General and Design of Welds

Design, preparation, performance and testing of welded constructions shall suit the grade of risk, considering a supposed failure of the welded member:

1. Small Risk Structures: Stairs, rails, aux. metal works not subject to water pressure
2. Medium Risk Structures: Cranes, roof trusses
3. High Risk Structures: Steel linings, gates and other structures subject to internal or external water pressure

Any structure not especially mentioned shall be classified by the Contractor and shall be subject to approval by the PMC.

Designs shall be such as to minimize Site welding. All welds shall be continuous, watertight and free from voids.

The difference in thickness of adjacent butt-welded plates shall not exceed 2 mm. Where plates of greater thickness are to be welded, a transition with a gradient of 1:4 shall be formed.

All plate butt welds shall be full penetration back gouged and welded from both sides.

The minimum size of fillet welds shall be 4 mm (respectively 6 mm measured on the leg).

Principal welds shall be ground as specified in the approved welding procedure. Besides, all welds exposed to water having a velocity of 10 m/s or more, shall be ground flush with the plates unless otherwise approved by the PMC.

31.6.4.2 Welder's Qualifications

All welding shall be carried out by experienced and qualified welders. Qualification of welders shall be in accordance with ISO 9606-1. Certificates shall be submitted to the PMC before welding works starts.

For high risk structures parts, a performance test shall be mandatory for all new welders prior to any weldment at site or workshop.

31.6.4.3 Welding Procedures

This Section applies to all risk categories. No welds (even for temporary structures) or repair by welding may be undertaken without a valid welding procedure specification (WPS). The welding procedure shall include all steps to be taken in all operations to be carried out to build a welded structure complying with the quality criteria that is defined.

31.6.4.4 Qualification of Welding Procedure (WPQR)

This section applies to structures classified as mid and high risk as per Section 6.4.1. For other structures standard welding procedures may be used.

For high risk welded structures welding procedures shall be qualified by a qualification record in accordance with EN 15614 or equivalent. For these structures welding as per standard procedure specifications are not allowed.

As a general rule, the mechanical properties of the weld, particularly the strength and Charpy-V toughness values shall correspond at least to the minimum values of the base material required by the material standard.

In case qualification according to a different standard (e.g. ASME IX) is used for the qualification of the procedure, for high risk structures the minimum testing program shall be in line with the requirements of EN 15614: particularly all non-destructive and destructive examinations as per EN 15614 shall be carried out as part of the qualification

such as tensile test, Charpy V impact test, bend test, hardness test, macro examination even if not prescribed by the specific standard used (e.g. ASME IX).

31.6.4.5 Welding Works

Pieces to be joined by welding shall be cut accurately to size including the required allowances. The cut surfaces shall be free of all visible defects, such as laminations, surface defects caused by shearing or flame cutting operations. The edges and surfaces to be welded shall be free of rust, mill scale, grease, oil, paint or any other foreign matter. Welding over paint incl. zinc primer or zinc layer shall be prohibited; all painting materials next to the joint to be welded shall be removed well beyond the heat-affected zone.

Where possible, welding shall be carried out in the workshop. Welding which has to be performed in the field shall be clearly so indicated on the shop drawings.

The Contractor shall follow the steel manufacturer's recommendations concerning electrodes, welding and material pre- and post-heat treatment.

All welding shall be performed by the electric-arc method and where practical, with process controlled automatic machines.

Between plates of main load carrying members subject to tension or compression such as main girder and of skinplates of gates and steel lining only full penetration butt welds shall be permitted. Where possible these welds shall be welded from both sides. The backside of the first run shall be suitably gauged out to clear metal before the sealing runs are deposited.

Butt welds on the Site which can be welded from one side only shall be provided with permanent (metallic) or temporary (ceramic) backing strips on the whole length of the seam to be welded. However, one side welds with permanent metallic backing strip shall be limited to a minimum.

For any welding work, only the appropriate welding rod, either arc or gas, shall be used.

Tacks shall be removed before welding. Electrodes shall be dried in electric ovens before use according to manufacturer's specification.

After being deposited, welds shall be cleaned of slag and shall show uniform sections, smoothness of weld metal, feather-edges without overlap, and no porosity and clinker. Visual inspection of the ends of welds shall indicate good fusion with the base metal.

Where weld metal is deposited in successive layers, each layer shall be thoroughly cleaned (peened) before the next layer is applied.

Welds shall be balanced as far as possible to minimize distortion and residual stress. Box type girders shall be welded in such a way as to be completely airtight. (Leak testing is mandatory).

Particular care shall be taken in aligning and separating the edges of the members to be joined by butt welding so that complete penetration and fusion at the bottom of the joint will be ensured.

Undercutting not exceeding 1 mm shall be removed by grinding. Undercutting exceeding 1 mm shall be filled by welding.

For double welded butt joints, the root must be completely removed by grinding or back gauging before proceeding with the welding on the other side in order to prevent the presence of residues.

All pinholes, cracks and other defects shall be repaired by chipping or grinding the defects to sound metal and re-welding. Where fillet welds are used, the members shall fit closely and shall be held together during welding.

The ignition of weld electrodes shall not be started at the plate beside the weld, but at the seam flanks to prevent detrimental increments of local hardness. Where ignition points of electrodes are discovered, they shall be ground appropriately.

Welded-on fabrication aids shall be kept to a minimum. They shall be attached only by approved welders.

Where auxiliary structural members are welded to components for the purpose of assembly or installation, these connecting welds shall be given particular care.

These auxiliary structural members shall be removed not by knocking them off by grinding the affected areas flush with the plate, without producing additional thermal stresses. MT testing of these areas is mandatory.

31.6.4.6 Heat Treatment

Heat treatment shall be in-line with the qualified welding procedure specification. In general, so far practical all heat treatment shall be performed with process controlled automatic machines and electric blankets. Heat treatment by flame shall not be allowed.

The cost of any heat treatment shall be borne by the Contractor.

31.6.4.7 Thermal Stress Relieving

As a general approach thermal stress relieving shall be carried out according to the requirements of ASME Section VIII Division 1 for all welded structures with thicknesses exceeding 38 mm; however, the Contractor shall be responsible for process of thermal stress relieving.

For welded structures with excessive plate thicknesses, high stress level and complex multiaxial stress distribution the Contractor shall carry out the thermal stress relieving or shall demonstrate the structural integrity in as-welded condition (e.g. by fracture mechanical calculations considering residual stresses as well as external loads).

Particular care shall be taken for the temperatures and holding times, since these may have an impact on the mechanical properties of the material.

The cost of any thermal stress relieving shall be borne by the Contractor.

31.6.4.8 Production Weld Tests

This section applies to particular high risk structures as specified above. For these items production weld test shall be performed by the Contractor according to the requirements of the Special Technical Specification.

31.6.4.9 Welding Records

This section applies to medium and high risk structures. All welding works on these structures shall be recorded as part of the quality documentation. The record shall comprise as a minimum the following information:

1. Time, Date;
2. WPS;
3. Welders name;
4. Part number, weld number and allocation, welding position, and layer;
5. Batch number of electrodes and welding consumables;
6. All relevant temperatures including pre- and post-heating and interpass temperature;
7. Voltage, Power, Power source.

Records of welding procedures shall be made available to the PMC upon request.

31.6.4.10 Non-destructive Testing (NDT)

Non-destructive of welds shall be carried out by the Contractor. To the welds of high risk structures acc. to Section 6.4.1 the following the following non-destructive tests and acceptance levels apply:

Table 31-9 Non-destructive Tests and Acceptance Levels

Method	**Procedure for testing of welds**	**Acceptance level**
Visual Testing (VT)	EN ISO 17637	EN ISO 5817, quality level B
Magnetic Particle Testing (MT)	EN ISO 17638	ISO 23278, acceptance level 1
Penetrant Testing (PT) (for parts MT testing is not suitable)	EN ISO 3452	EN ISO 23277 acceptance level 1
Radiographic Testing (RT)	EN ISO 17636-1/2	ISO 10675-1, acceptance level 1
Ultrasonic Testing (UT)	EN ISO 17640	EN ISO 11666, acceptance level 2

Ultrasonic testing of time-of-flight diffraction technique (TOFD)	EN ISO 10863	ISO 15626, acceptance level 1

The VT, PT and UT testing criteria and acceptance levels of the table also apply to medium risk structures.

VT testing of welds shall be also mandatory for all other structures, incl. low risk structures. The minimum acceptance criteria for these structures shall be quality level C. Even for auxiliary structures no lower quality level shall be accepted.

The Special Technical Specification provide specific amount of testing for each particular part (position) of the equipment.

The Contactor shall elaborate a testing program for each part of the equipment, which is subject to approval by the PMC. The Contractor shall indicate in the corresponding drawings the type of non-destructive testing to be carried out during manufacturing and during Site installation or shall provide specifications and instructions, which clearly indicate the non-destructive testing of each weld.

Additional non-destructive testing procedures can be required when it is desired to examine the acceptability of any welds when, in the opinion of the PMC, serious doubt exists as to their quality; in this case, the expense of this examination shall be borne by the Contractor.

31.6.4.11 Defects and Repairs

Plates with laminations discovered after cutting shall be rejected.

Defects in welds which are to be repaired shall be chipped out to sound metal and the areas MT and UT tested to ensure that the defective material has been completely removed before repair of welding is carried out. The PMC shall be informed and given the opportunity of making an examination after the defect has been removed and before repair welding commences.

Repairs shall be carried out in accordance with the relevant Standards and to the approval of the PMC. The Contractor shall be fully responsible for the in-service performance of all welding work.

The repaired welds shall be 100% inspected again by the method used first to determine such faulty work or as directed by the PMC.

31.6.5 BOLTED CONNECTIONS

All bolts, studs, screws, nuts, and washers shall be to the ISO metric system except other standards will be considered for specific applications.

In general washers shall be provided for bolted connections. All ferrous nuts and bolts shall have their threads coated with an approved anti-seize compound.

Bolts, nuts and washers shall be adequately treated against corrosion. In general this treatment shall be by hot dip galvanizing according to EN ISO 10684 as far as applicable. Other galvanizing methods (e.g. by zinc electroplating) may only be used for non-essential bolted connections not subject to corrosion (indoor application, not submerged, well accessible).

As a general rule, all bolts, nuts, screws and other devices used to fix, clamp or adjust any parts which are:

1. Exposed to water or high humidity, or,
2. Subjected to frequent adjustment or frequent removal.

shall be of stainless steel.

Special attention shall be paid during design to avoid galling (cold welding) between of bolts and nuts. In case of stainless steel bolted connections the combination of materials shall be such that the risk of galling is minimized.

Special calculations of critical high strength and prestressed bolted connections shall be in line with VDI 2230 or equivalent standard.

To gates and hydro-mechanical equipment the requirements of Section 4.3 of DIN 19704 applies. In line with the general requirements listed above, all bolts nuts and washers of gate seals shall be made of stainless steel.

When in position, all bolts or screwed rods shall have an adequate projection through the corresponding nuts of at least one thread, but this projection shall not exceed three threads, unless more length is required for adjustment.

Securing of bolts shall be in line with the requirements of DIN 19704, section 4.3.4. For parts subject to vibration special washers shall be used to prevent loosening.

All bolts and studs which are too large (typically exceeding 50-60 mm) or which are not accessible for tightening and releasing by commercially available pneumatic impact wrenches or shall have an extension for pre-tensioning by hydraulic tools.

The Contractor shall supply extra 5 percent of all permanent bolts, screws and other similar items and materials used for installation at the Site. Any such bolts, screws, etc., which are surplus after the installation of the equipment has been completed shall become spare parts and shall be wrapped, marked and handed over to the Employer's Representative.

31.6.6 MACHINING

31.6.6.1 General

All tolerances, allowances and gauges for metal fits between plain cylindrical parts shall conform to the DIN, ISO or other approved equivalent standards for the class of fit as shown or otherwise required. Sufficient machining stock shall be allowed on locating pads to ensure true surfaces of solid material. Bearing surfaces shall be true and exact

to secure full contact. Journal and sliding surfaces shall be polished and all surfaces shall be finished with sufficient smoothness and accuracy to ensure proper operation when assembled. Parts entering any machine shall be carefully and accurately machined. All drilled holes for bolts shall be accurately located and drilled from templates.

31.6.6.2 Finished Surfaces

Surface finished shall be indicated on the Contractor's drawings and shall be in accordance with ISO or other approved equivalent. Compliance with specified surface will be determined by sense or feel and by visual inspection of the work compared to standard roughness specimens, in accordance with the provisions of the above stated standards.

31.6.6.3 Unfinished Surfaces

So far as is practicable, all works shall be arranged to obtain proper machining of adjoining unfinished surfaces. When there is a large discrepancy between adjoining unfinished surfaces, they shall be chipped and ground smooth, or machined, to secure proper alignment. Unfinished surfaces shall be true to the lines and dimensions shown on the drawings and shall be chipped or ground free of all projections and rough spots. Depressions or holes not affecting the strength or usefulness of the parts may be filled in an approved manner.

31.6.7 PINS AND PIN HOLES

Pin holes shall be bored to gauge, smooth and straight, and at right angles to the axis of the member. The boring shall be done after the member is securely fastened in position. Pins shall be of hardened and ground steel and positively held in position. Wheels or rollers for use in gates shall be mounted on removable pins and have self-lubricating spherical bearings or self-aligning roller bearings and brass washers.

31.6.8 ROUNDING, CHAMFERS, EDGES

The edges of surfaces to be painted shall be rounded (minimum radius 2 mm) or chamfered accordingly. This requirement must be stated in all shop drawings for the relevant parts.

31.7 MECHANICAL EQUIPMENT

31.7.1 GENERAL

All equipment shall be of an approved, reliable design providing the highest possible degree of uniformity and interchangeability.

All parts shall conform to the dimensions shown on and shall be built in accordance with the approved drawings. All joints, datum surfaces, and matching components shall be machined and all castings shall be spot faced for nuts. All machined finish shall be shown on the approved drawings. All screws, bolts, studs and nuts and threads for pipes shall conform to the latest standards of the International Organization for Standardization (ISO) covering these components and shall conform to the standards for metric size. The Contractor shall use exclusively the standards and size system presented in the Technical Specifications and accepted and incorporated in the Contract.

Special attention shall be paid to high temperature differentials in the summer and winter seasons and humidity conditions at Site, when the Contractor selects the components of the equipment, especially the electrical equipment.

All equipment shall be pre-assembled in the manufacturer's premises to an utmost extent. All equipment manufacturers, suppliers and materials shall be subject to approval of the PMC.

31.7.2 VIBRATION AND BALANCE

The amplitude of vibration of rotating Plant when measured on the bearing housings under steady state conditions at the designed operating speeds shall not exceed the values given by the 2.8 mm/s criterion of ISO 3945.

Provision shall be made for the reduction of vibration transmitted to covers, cladding, platforms and structures that are liable to vibrate. The vibration of any such radiating surface shall not exceed the values shown in Table 7 1.

Table 31-10 Surface Vibration Limits

Frequency (Hz)	Amplitude (mm) (Peak-to-peak)
5	0.40
10	0.20
25	0.08
50	0.04
100	0.02
120	0.017

31.7.3 NAMEPLATES

Each major and auxiliary item of equipment shall have a nameplate permanently affixed thereto showing in a legible and durable manner the serial number, name and address

of the manufacturer, ratings, characteristics, weight, manufacturing date and other significant information, as applicable. Nameplates of distributing agents only shall not be acceptable.

Additional nameplates shall be provided to indicate main operating instructions, caution or warning for personnel and operational safety. In addition, each panel-mounted instrument, position indicator, pushbutton, switch, light, or other similar device shall be identified by a permanently affixed nameplate that describes the control functions. Electrical wiring and instruments including relays shall also be labeled to correspond to the numbers assigned on the electrical control schematics.

The above general nameplate requirements shall be used in preparing nameplate lists and drawings shall be submitted to the PMC for review and approval. Contractor's Drawings for nameplates, as they will appear on the finished equipment, shall be submitted to the PMC for review and approval.

All nameplates shall be suitably engraved and shall be weather-resistant. All nameplates shall be permanently attached to the respective parts, components, or equipment items in clearly visible locations. Nameplates for control equipment shall be screw-mounted laminated plastic, white with black cores, with engraved capital letters 6.4 mm minimum height.

31.7.4 PLATFORMS, STAIRWAYS, LADDERS AND HAND RAILING

The Contractor shall provide all platforms, galleries, stairways and ladders necessary to give access to the various sections of the equipment being supplied under this Contract. The Contractor shall provide adequate means of access for all operation, inspection and overhaul purposes and shall be of sufficient strength to support workmen, tools and portions of equipment which shall be placed on them during maintenance and inspection periods.

Platforms, stairways and ladders shall be designed generally for a load of 250 kg/m², but where loads in excess of this are likely to be imposed during operation or maintenance, the Contractor shall make due allowance in the design. All necessary supports shall be supplied under this Contract.

Platforms, Stairways. Ladders and Hand Railing shall meet the requirements of EN ISO 14122.

Ladders shall only be permissible where stairways are both impractical and access is required for maintenance purposes or for emergency purposes.

As a general rule, stairways, platforms ladders and hand railing shall be hot dip galvanized as per requirements of Section 9.

Floors of all platforms, staircase treads and ladders shall be of hot dip galvanized mild steel open grid except in those cases where chequer plate is specified. Platforms shall

have edging strips extending to a height of not less than 150 mm above the platform preventing objects falling.

31.7.5 GATES

The design shall be in line with the requirements of DIN 19704. All welds must be continuous and welded all around to prevent water entering the gaps. As a general rule all guides, tracks and sealing surfaces shall be made of stainless steel.

All sealing seats and sealing surfaced, tracks and guides shall be thoroughly machined to ensure perfect planarity and finishing.

The seals shall be mounted in such a manner that they are according to the purpose and shall be designed and mounted in such a manner that they are adjustable and can be readily removed and replaced. All adjusting screws and bolts for securing the seals and seal assembly in place shall be of stainless steel. Clamping and spacing strips shall be of stainless steel and chamfered on the seal side. All rubber seals shall provide a suitable pre-compression, typically 3 mm or more.

More specific requirements are provided in the Special Technical Specification.

31.7.6 DRIVES AND GEARS

All moving parts of machinery including shafts, couplings, collars, projecting key heads, gear wheels, rope/belt-drives shall be completely guarded to provide full protection. All set screws on revolving shafts shall be countersunk or suitably protected. The guards shall be of approved design and shall be fitted, where necessary, with inspection doors/openings. All guards shall be arranged so that they can be removed without disturbing the parts of the gears and equipment which they protect.

Gears shall be designed so that all stresses are within allowable limits when the maximum loads are being handled. All gears shall be designed and calculated in accordance with AGMA, EN, ISO, DIN, or equivalent international standards, or widely-approved methods and to the individual experience of the manufacturer. The manufacturer shall submit the names of the manufacturers, materials and design calculations of the gears and input/output torques etc. to the PMC for approval.

Where worm gears are used as a direct drive, they shall have the same load and time rating as the motors driving them. The gears shall work in oil and the temperature rise of the oil bath shall not exceed 40°C – 50°C under normal working conditions at Site. The materials of the mating faces of worm wheel and worm shall be of a bronze/steel alloy.

Where practicable gear wheels shall be forced fit on the shaft and in addition, shall be keyed adequately to prevent any relative motion between the wheel and shaft. Where gears and couplings are secured in position by means of keys, they shall be easily accessible for tightening or removal. All keyways shall be machine cut. Couplings and collars shall be the shrouded or protected-type, free from projections of any kind.

All bearings shall be mounted in dustproof housings. Base of bearing supports shall be machined, and shall rest on machined-surfaces.

31.7.7 LUBRICATION, LUBRICANTS, FUEL

Efficient means of lubrication, suitable for use under Site conditions, shall be provided for all moving parts.

Self-lubricating types of bearings shall be given preference, unless otherwise specified or practicable.

The contamination of the air, water and soil by lubricants and fuel shall be precluded by applying an appropriate design and layout of the equipment in conformity with the latest recognized standards for modern engineering practice.

The number of different lubricants and oils for pressure systems, etc., used in the equipment shall be limited to a minimum in order to facilitate keeping stocks and maintenance.

The PMC reserves the right to request the Contractor to use certain types of lubricants, oils, etc. The Contractor shall not be entitled to claim extra payment for this request. All oils, lubricants, etc. to be applied are subject to the written approval of the PMC.

The first oil or grease filling for bearings, pressure oil systems, etc., including the necessary quantity for flushing and for the first oil change, shall deemed to be included in the scope of supply.

Environmentally friendly, fully synthetic fluids, based on saturated esters shall be used.

31.7.8 PIPING, FITTINGS, VALVES AND GATES

31.7.8.1 General

Unless otherwise stated, all piping shall be designed for a nominal pressure not less than PN 16. All piping shall be tested with 1.5 times the design or nominal pressure. All required piping shall be furnished complete with flanges, joints, expansion joints, gaskets, packing, valves, drains, vents, pipe suspensions, supports, etc.

All welded flanges shall be of welded neck type, connected by full penetration welds and fully testable by ultrasonic testing.

Welding as well as application of corrosion protection coats shall be done in the manufacturer's shop as far as possible. Flanged connections or joints shall be limited to a minimum.

If the piping crosses over joints of civil structures of different settlement, the piping shall be provided with flexible joints to allow for vertical, horizontal, and angular deviations.

Piping installation shall be sloped to prevent trapping of air bubbles. Where required suitable venting system shall be provided.

Pressurized pipes shall generally not be embedded in concrete.

31.7.8.2 Water Piping, Fittings

All not accessible (diameter < 500 mm) pipes (open or embedded in concrete or submerged in water) shall be of stainless steel.

Stress calculations of stainless-steel pipes shall be in accordance with DIN 2413, "Steel Pipes under Internal Pressure. The superimposed stress of bending, tension, compression, etc. shall not exceed the admissible stresses (stated in the above-mentioned standards) at maximum applied load at any point of the piping.

The maximum applied load shall take into account test pressure, water hammer pressure of waves, thermal forces, dead weight, etc. The calculation on pipe stresses has to be submitted by the Contractor and are subject to the PMC's approval.

The minimum stainless-steel pipe wall thickness shall be the "normal" or "standard" wall thickness as stated in the applicable standards.

Fittings of the cutting-ring type are not acceptable. Bends shall preferably be of the forged type. Mitre bends shall be allowed for larger sizes subject to the PMC's approval.

31.7.8.3 Valves, Gates

Small valves and gates shall conform to DIN 3230, "Conditions and Terms for Delivery of Valves".

Generally stainless-steel pipes shall be provided with stainless steel valves. Valves with nominal diameter ≥ 300 mm may be fabricated of ductile (nodular) iron or carbon steel provided the valve is completely isolated from the stainless-steel piping. Pistons, valve spindles and sealing surfaces shall be made of stainless steel in any case.

Valves shall be leak-proof in either flow direction (except for non-return valves) when the nominal pressure is applied.

All valves shall be workshop-tested according to EN 12266-1 for tightness and soundness of materials and provided with a certificate of type 3.1 acc. to EN 10204 as a minimum requirement.

Valves shall close clockwise and be provided with position indicators. The drive units of motor-driven valves shall also be provided with hand wheels for manual operation. The hand wheel shall be operable under all conditions with acceptable speed and effort and shall be independent of the motor drive. Further, it shall not be rigidly coupled to the motor drive and shall not compulsorily turn when the motor is energized.

All pressure reduction valves, safety valves and similar components shall be workshop-tested and provided with test report acc. to EN 10204-1 as a minimum requirement. The manufacturers and materials of all valves and the gates shall be subject to approval of the PMC.

31.7.8.4 Pipe Supports and Hangers

All pipework and accessories shall be mounted and supported in a safe and neat manner.

All brackets, stays, frames, hangers and supports for carrying and staying the pipes, including their fasteners shall be included in the supply and completed by the Contractor at the Site. Pipes and fittings shall be supported at or near flanges wherever possible.

Supports and hangers shall be designed and arranged so that any pipe can be withdrawn without disturbing the others.

All heavy valves and other mountings shall be supported independently of the pipes to which they connect, to the satisfaction of the PMC.

The Contractor shall supply drawings showing the location of each major anchor and support and the weight to be carried by that support.

31.7.9 MECHANICAL INSTRUMENTS

All mechanical parts of instruments shall be suitably protected against shocks and vibrations, heat, humidity and splash water, etc.

Pressure gauges shall be provided with a suitable damping liquid, to compensate vibrations.

31.7.10 PRESSURIZED OIL SYSTEMS

31.7.10.1 General

All the equipment supplied shall be from reputed international manufacturers with the best quality and grade of the materials for satisfactory operation throughout the life of the project. The pressurized oil system shall be in accordance with the requirements of DIN 19704-2.

The flow rates shall be in accordance with Section 10.1.7.2 of 19704-2.

Suitable isolation valves shall be provided to allow the cleaning or replacement of portions of the piping system and other hydraulic components.

31.7.10.2 Hydraulic Piping

The piping shall conform to the determinations of DIN 19704-2 in every aspect except the following deviations and clarifications:

1. Only the options with precision tubes made of stainless steel can be used regardless to location and size of the pipes – which means that the options a, b, c. and h according to DIN 19704 section 10.1.7.3 are not allowed.
2. The supporting structure shall be hot-dip galvanized. Between the stainless steel pipes and the supporting structure plastic pipe brackets shall be used which completely isolate the supporting structure to prevent galvanic corrosion.

All piping shall be subject to hydrostatic pressure test with a pressure not less than of 150% of the maximum system working pressure after completion of the assembly at the Site.

All stainless-steel hydraulic piping shall be acid-treated to guarantee clean surfaces, completely free from welding residues.

This treatment shall be applied to workshop and site manufactured piping respectively. Hydraulic hoses shall be equipped with stainless steel fittings.

31.7.10.3 Pressure Relief Valves

The arrangement of the pressure relief valves shall be in line with the requirements of DIN 19704-2.

31.7.10.4 Hydraulic Power Unit

Pressure oil for the operation of the gate shall be delivered by hydraulic power units consisting of electrically driven pumps, oil reservoir, valves and piping, all as described herein. The pumping unit shall include a hand pump for emergency operation with a maximum operating force of 10 kg.

The hydraulic power unit shall be provided with min. two (2) motors and one manual pump, each capable of operating the gates at a maximum operating pressure as given in DIN 19704. The oil pumps shall be located on top of the oil reservoir and be neatly arranged for easy maintenance and properly identified.

Maximum nominal oil pressure shall be determined by the manufacturer and is expected not to exceed 250 bar.

The components of the oil pumping unit shall form a compact assembly of pump, motor and associated valves and shall be accessible for adjustment and maintenance. Each element shall be marked with a reference number (e.g. KKS number in line with the instructions by the PMC), which, by means of the hydraulic diagram, shall permit to recognize its assignation.

Full flow filters of adequate capacity shall be included in the hydraulic circuit. It shall be possible to remove the filter element for cleaning without draining the system.

31.7.10.4.1 Oil Pumps

The oil pumps shall be a positive displacement type and direct motor driven through a flexible coupling. The pumps shall have a variable output.

Parallel to each pump or group of pumps operating in parallel, a relief valve of sufficient capacity to by-pass the full delivery of the pumps at a pressure only 10% above the maximum allowable working pressure shall be provided as a safety measure.

The pumps shall be provided with check valves and pressure switches for actuating the starting equipment. Hand operated valves shall be provided to isolate any pump from the hydraulic system and permit its removal without losing oil pressure.

Wherever possible, standard commercially available components shall be used to facilitate repair and replacement.

31.7.10.4.2Oil Tank

The oil tank shall have a capacity in line with the requirements of Section 10.1.6 of DIN 19704-2 and shall be provided with an access hole with removable cover and oil resistant gasket and oil level sight gauge. Connections to the tank shall be provided with isolating valves or non-return valves as required.

Oil sump tanks shall be provided as a minimum with the following:

1. Suitable access openings
2. Fine mesh strainer(s) combined with a magnetic filter/plug which all oil returning shall pass. The strainer(s) shall be readily removable for cleaning.
3. Humidity separating air filter
4. Flush mounted oil level indicator(s), covering most of the tank height.
5. Level switch shall stop the pump if the oil level falls below a predetermined safe level
6. Filler hole Filler / breather cap with a suitable strainer
7. Oil level sight gauge
8. Drain connection with hand operated shut off valve.

The interior of the tank shall be free of crevices, open joints, or dead-end holes, and all welds inside the tank shall be continuous. Oil sumps shall be made from stainless steel unless otherwise is approved by the PMC. The interior and exterior surfaces of any sump tanks not made from stainless steel shall be cleaned and painted as specified in these General Technical Specifications. Before being painted, the oil tank shall be tested by an approved method to ensure that it is leak-proof.

31.7.10.4.3Oil Sump Tanks

The hydraulic power unit shall be equipped with an oil sump pan (tank) for collecting of oil losses and leakages.

The capacity of the sump tank shall, unless otherwise specified, not be less than that required to contain all of the oil that can be discharged back into the sump by completely discharging the oil in the system.

31.7.10.4.4Four-way Valves

The four-way valves shall be suitable for use with light hydraulic oil having the characteristics specified for the pumping unit. The valves shall have steel socket-welding

flanges. The porting and operation of the valves shall be arranged so that pressure can be directed to either of two outlet ports as read on the indicator.

31.7.10.4.5Flow Control Valves

The flow control valves shall control flow in one direction and integral check valve to allow free flow in the opposite direction. The valves shall have steel socket-welding flanges and shall be suitable for incorporation into the piping assembly.

31.7.10.4.6Pressure Switches

The pressure switches shall have independent outside adjustments with a locking device for setting the cut-in and cut-out pressures, and the pressure setting shall show on a calibrated dial.

31.7.10.5 Hydraulic Fluids

The hydraulic oil to be used for the control system of the gates shall be in accordance to the requirements of DIN 19704-2 Section 10.1.5. The hydraulic oil shall have good stability, anti-floating, anti-oxidant, anti-corrosion and anti-wear properties. Sludge and slurries shall not be formed under any working conditions. Whenever suitable environmentally friendly, biodegradable fluids based on saturated esters shall be used.

The number of different lubricants, oils, fluids for pressure systems, etc., used in the equipment throughout the plant shall be limited to a minimum in order to facilitate keeping stocks and maintenance. Therefore, the contractor shall submit the following information to the PMC for approval:

1. Trade name and classification according to ISO 15380
2. Kinematic viscosity at 40° and 100° C, in cSt,
3. Viscosity Index
4. Total acid index, in mg KOH/g,
5. Flash point, in C,
6. Environmental compatibility

31.7.10.6 Hydraulic Cylinders

The oil hydraulic hoists and hydraulic cylinders shall be designed according to the guidelines of DIN 19704. Servomotors Hydraulic cylinders shall be provided with suitable connections for pressure gauges on the pressure and suction sides of the piston. A suitable protection for the piston rod seal must be provided.

Hydraulic cylinder rods are to be sized (designed) to withstand earthquake vibration in the fully extended position without permanent distortion or damage.

Raw material shall be procured from high quality suppliers subject to approval of the PMC. Piston rod shall be produced from "single piece" steel. No joints or welds shall be allowed. The material shall be subject to approval of the PMC by ultrasonic inspection in the workshop to ensure its quality. Seals shall be selected as per DIN 19704 (multi-lip) and highest quality available in the International market.

Bearings shall be maintenance free and corrosion resistance of highest quality available in the International market. Safety & burst valve block in high quality to be installed on cylinder (rod side if possible). The parts shall be manufactured by CNC machines.

The Contractor shall arrange regular inspections during all the manufacturing process of major equipment and final witness tests at manufacturer's company before delivery.

Manufacturer must have enough experience in design and supply for target industry (with reliable and successful reference list for Hydropower projects).

Hydraulic cylinder consists of a casing, upper and lower heads and piston with rod.

The cylinder casing shall be of seamless steel tubing or flat steel plates formed into a cylindrical shell, joined with not more than 2 longitudinal welds and bored and honed to a smooth surface finish of 0.4 micrometers measured on the centerline average scale.

The exterior of the cylinders shall be given a smooth machine finish.

Upper and lower heads shall be bolted to hydraulic cylinder casing with "0" ring or equivalent seals. The hydraulic cylinder shall be fixed on the steel base frame by means of bolted connection.

The cylinders shall be provided with lifting lugs to facilitate assembly.

Hydraulic cylinder lower head has a groove with synthetic rubber seal, bronze guide bushings and a scraper for piston rod.

The piston rod shall be connected to the boss provided to the gate leaf by the stem nut provided to piston rod with the connection rings.

All bosses for pressure oil piping and oil drain piping at the cylinders and vents and drains shall be provided. The cylinders shall be thoroughly inspected visually and all welds shall be tested by radiograph, UT and PT or MT before stress-relieving.

The piston and piston rod assemblies shall consist of one-piece rod, a piston cast in one piece, piston rings and oil seals. The piston shall be rigidly attached to the piston rod. The connection shall be designed to permit disassembly for maintenance purposes.

The piston rod shall be fabricated from solid, hardened, 18Cr/8Ni stainless steel with hard chromium plating of min. 50µm.

Dynamic seals shall be multi lip seals and shall prevent leakage of oil at any differential pressure up to 150 % of the design system pressure. The piston seals shall be replaceable by removing the top cylinder heads.

The cylinder heads shall be able to resist the piston force at maximum system pressure. A damping action shall be provided at both ends of the stroke.

The pistons shall have minimum 30 mm over stroke (additional travel) when the gates are completely closed to provide positive closure.

The cylinders shall be provided with bleed valves necessary for complete removal of trapped air.

Adjustable flow control devices shall be provided in the system to positively limit the rate of closure of the gates to the maximum rate for which they have been adjusted. The flow control devices shall be mounted on the cylinders, to minimize the risk should a fault develop in the piping system.

Hydraulic cylinders shall be subject to pressure testing in line with the requirements of DIN 19704 with a test pressure not less than 150% of the max. operational / rated pressure. The test pressure shall be held for a sufficient length of time to permit inspection of all leakages.

31.7.10.7 Compressed Air Systems

Hydraulic accumulator systems shall be in accordance with EN 14359. Vessels shall be of the cylindrical, vertical type and shall be mounted on a structural steel base.

Each accumulator shall pass a performance test in the manufacturer's workshop. Each vessel shall pass a pressure test as per EN 14359 however not less than 1.5 x nominal pressure of 8 hours duration in the manufacturer's workshop before coating is applied.

The ready assembled compressors, controls, and switchgear shall be subjected to functional tests. Each vessel shall be furnished with a test certificate of type 3.2 according to EN 10204.

31.7.11 CRANES

31.7.11.1 Crane Capacity

As a general rule, required crane capacities shall be selected by the Contractor, subject to the PMC's approval, based on the actual weight of the equipment and by lifting force calculations considering the safety factors and friction coefficients specified in DIN 19704. In addition, the minimum lifting capacities specified in the Special Technical Specification for particular cranes shall be taken into consideration.

31.7.11.2 Design and Calculation Standards

Generally, for design, stress calculation, manufacture and installation, the following standards and codes shall be applicable:

1. EN 15011 and EN 13001 or
2. FEM: Rules for the Design of Hoisting Appliances.

The Contractor shall state the various load combinations and factors of safety taken as a basis for calculation of the different components of the crane. In addition, the various factors of safety for the different load combinations shall be stated.

The crane girders and rails shall be calculated for a deflection not exceeding 1/1000 of the span at maximum nominal load.

The design of crane shall take into account the lateral stresses due to starting and stopping the crane suddenly when carrying the rated load. No creeping of the loads shall occur at any time. The crane shall be capable of operating while under rated load at any time.

31.7.11.3 Construction Requirements

The crane shall be of standard design applicable for the specified rated load and operating conditions. Bridge cranes shall be of two girder type. Steel structures of lifting equipment shall be of welded construction, which can be assembled at Site. All field connections and joints shall be bolted.

The manufacturers of the equipment shall be internationally reputed companies and shall be subject to approval of the PMC.

The space limitations of the chamber shall be taken into consideration in the design of the crane. The same applies to the transport and handling limits in regard to size and mass of packages.

The hoist shall consist of standard hoisting gear of compact design provided with rope drum with grooves, motor, reduction gear, hoist brake, overload-protection device, steel wire ropes, encased steel pulleys and forged steel hook provided with thrust bearing, and with a spring loaded safety catch.

The crane travel mechanism shall be so designed and fabricated such way that the travel shall be steady, free from racking and vibration, and with no tendency for the crane structure to go into misalignment while operating on the runway.

The travel of the crane shall be started and braked progressively thereby reducing swinging of the load to a minimum.

During lifting, the hook must remain in the same vertical axis and not be subject to any pendula movement

31.7.11.3.1Protection Measures

The crane shall be equipped with all protection measures according to the relevant standards however with not less than the following:

1. Overload protection: after triggering the overload protection only movements shall be allowed which reduce the load or safely set down the load.
2. Lift and lowering limit protection. After triggering of the limit protection a movement in opposite direction must be possible

3. Travel Limit Protection
4. Emergency power off protection
5. Short circuit protection
6. Slack rope protection.

31.7.11.3.2 Crane Bridge and End Carriage

The crane bridges shall be of two (2) girders type construction, reinforced with stiffening ribs, supported on end carriages, shall be designed to safely carry the load without undue vertical or lateral deflection or vibration.

The crane bridge shall be designed to provide at least a clearance of 400mm between the outside of the bridge and the adjacent wall for safe operation.

Most appropriate design shall be adopted for the spliced joints between the sections.

Bridge girders shall be mounted on equalizing type end carriages with buffers and shall be rigidly attached to the end carriages by machine fitted bolts. Heavy gusset plates shall be attached to the bottom of the trucks to keep them square with the main girders.

The rails for trolley shall be provided and be supported centrally on the bridge girders to hold in place by rail clips which shall be locked in position to prevent creeping of rails. The welded end- stop buffers shall be provided as stoppers for trolley/crane.

The end carriage of box type construction with openings at each end for receiving the end carriage wheels shall be made of steel and shall have adequate strength and stiffness.

Each end carriage shall have:

1. Rail double-flanged wheels with bearings running on suitable axles,
2. Suitable rail sweeps at each end of end carriages effective in both directions of travel,
3. Safety lugs to prevent the drop in case of axle or wheel getting broken, Buffers to contact with the end stops provided at each end of runway rails,
4. Suitable pads on each end carriage for all wheels for jacking of the crane for changing end carriage wheels, other wheels and bearings,
5. Hand holes with removal covers, in each closed compartment of end carriage to facilitate painting of the interior with a spray gun without major disassembly.

Wheel assembly shall be arranged in a way that replacement of any wheel can be achieved without undue difficulties. Special facilities such as articulated wheel supports shall be provided so that the crane can run on the rails with any scuffing or abrasion. The end carriages shall be designed to contact end stops.

The end carriages shall be designed so that the end reaction from the bridge girders is divided equally between the wheels.

31.7.11.3.3 Trolley

The trolley shall be made as a welded frame of structure in accordance with the following:

1. Provision of adequate bracing to withstand vertical, lateral and torsion strains
2. Properly machined to receive the drum wheels, axles and motors for hoisting and cross travel.

31.7.11.3.4Driving Machinery for Bridge and Trolley

One pair of wheels in each end of the bridge shall be driven by an electric motor driving a cross shaft through a helical spur, or herring bone gear speed reduced unit mounted near the centre of the bridge or by two electric motors without cross shaft and individual speed reducer units at each end.

The cross shaft shall be supported on self-aligning bearings along the bridge. Final driven pinions shall be mounted on shaft section of shaft coupled to the main cross shaft for convenience in assembly and replacement of parts.

The motor, speed reducer unit and brake shall be mounted on a common structural steel base, supported from the bridge drive-side girder.

The trolley drives shall be generally as described for the bridge drive except that crane motors may be provided with direct drive to the wheel shafts.

All gearing, other than final drive gears at the wheels shall be enclosed in oil tight gear cases designed for splash lubrication of the gears and bearings, enclosed within the case. Adequate inspection window with transparent cover shall be provided in each case, together with an oil filter plug, drain cock and oil level indicator or dipstick.

31.7.11.3.5Wheel and Axles

Wheel axles shall be of the rotating type, to be supported with self-aligned, anti-friction bearings and shall have the construction for easy maintenance and easy removal of wheels.

Axles shall be made from alloy steel heat treated when necessary, accurately machined and/or ground to size to receive the bearing inner races.

Wheels shall be forged or rolled steel double flanged of appropriate contour to suit the runway travel and bridge rails. Wheels shall be accurately machined and/or ground to exact diameter.

31.7.11.3.6Electric Motors

All drive and lifting motors shall be AC type and shall be controlled by AC static frequency control. Control speed shall be continuous-adjustable from creeping speed to the normal speeds. The motor controller shall be designed so that crane motors shall be started and stopped progressively as acting the brake and operated safely for any accident or incidental power supply failure.

The crane shall be designed for continuous operation cycles equivalent to 25% ED, starting with cold motors and brakes. The motor and speed controller shall be operated continuously under rated load and rated speed during the operation.

AC motor shall be squirrel cage type, rated for 25% ED. The motors shall be designed specifically for variable frequency operation per IEC 60034-25.

31.7.11.3.7Hoists

The hoist shall consist of drums with wire grooves, journal bearings, hoist motor, closed oil bathe lubricated change over gear, hoist brakes, overload protection device, wire ropes, encased pulleys, hook and all other necessary components for proper and safety operation.

The details of the construction of the hoists not specified herein shall be made by the Contractor, subject to approval of the PMC. The crane and the mechanism shall conform to the class specified in the Special Technical Specification.

31.7.11.3.8Hook Blocks

The main hooks shall be of forged type. The hooks shall be in accordance with EN 13001-3-5. The max. load or load capacity class shall be clearly indicated and durably marked on the hooks.

The hooks shall be swiveled and designed to turn easily on substantial sealed anti-friction bearings

Hooks shall be of forged steel properly annealed after forging, and shall be swiveled and designed to turn easily on substantial sealed anti-friction bearings.

The crane hook shall not shift laterally when lifted or lowered.

31.7.11.3.9Brakes

All power driven motions shall be under the control of a braking system at all times. Each hoisting motion of the crane shall be provided with a separate spring -actuated AC solenoid released brake capable of rapidly decelerating and holding the full load. The trolley drive shall also have a spring-actuated AC solenoid released brake capable of rapidly decelerating the trolley to rest from full speed with full load. Each brake shall be so arranged as to become automatically applied when power is cut off and shall also be arranged to release automatically upon application of power to the drive motor.

Power released brakes shall be used and they shall maintain their ability to stop the motion, at all times. Brakes shall be protected from the ingress of substances within the environment, which are likely to have a detrimental effect on the performance of the brake.

Mechanical service brakes shall engage automatically in the following cases:

1. the control device returns to its neutral position;
2. the power supply to the brake is interrupted;
3. the emergency stop device is activated.

The brakes of the hoist shall be designed to exert a restraining torque of at least 60 % greater than the maximum torque transmitted to the brake from the maximum hoist load. In addition, the hoist brake shall comply with EN 13135.

The main hoists shall be provided with:

1. An electro-hydraulic thruster brake for lowering speed control in slow operation. The electro- hydraulic thruster brake shall be capable of necessary intermittent operation at any step of speed control without overheating.
2. An over-speed safety device shall be incorporated in the hoist controls to interrupt the power supply and operate the spring-actuated solenoid released brake to stop the hoist if over-speed occurs, and
3. A multiple-disk, self-adjusting mechanical load brake, shall be capable of sustaining the load in the event of power failure and failure of the hoist electro-mechanical brake.

Manual brake release shall be possible to lower the lifting equipment in case of failure of the electrical power supply.

31.7.11.3.10 Runway Crane Rails

The runway crane rails (longitudinal travel rails) with fixing rail anchors shall be provided and be set along full length of the crane runway.

Each section of each crane runway rails shall be electrically interconnected and the rails shall be connected via earthing conductors to the earthing system of the gate chamber.

End stops (elastomeric or spring bumpers), complete with soleplates and anchor bolts shall be supplied and installed by the Contractor, at each end of each runway rail. The bumpers shall consist of suitable springs, steel housings and rams or, alternately, of adequately sized elastomeric pads.

Travel limit switch strikers shall be supplied and installed by the Contractor at each end of the runway. These shall be positioned to provide a possible over-run of 0.3 m from the point of actuation of the travel limit switch to the point of contact of the crane end stops.

The Contractor is responsible for limiting the deviations from the theoretical alignment and elevation of the rails in such a manner that he can ensure trouble free and safe operation of the crane.

31.7.11.3.11 Crane Controls

All operating maneuvers shall be made from a wireless control station. A cable connected control station shall also be supplied. The cable connected station shall be connectable by a quick disconnect plug.

The remote control shall comply with the requirements of EN 60204-32 9.2.7 or equivalent. The following minimum requirements apply:

1. Safe serial data communication, including system error detection
2. Triggering of a stop function in either of these cases:
    a. Receiving a stop signal
    b. A system error is detected
    c. No valid signal received in 0.5-2 s

The emergency stop function shall comply with Category 3 of EN 954-1 or equivalent.

In addition to the remote control an emergency stop button shall be provided at a convenient location, easily reachable from the chamber floor.

31.7.11.3.12 Switchboard

The switchboard containing all elements required for the travelling and lifting operations shall be installed.

The switchboard shall be watertight and shall include all necessary switchgear, relays and instruments for the power distribution, control, monitoring, signalling and protection of the crane and shall be easily accessible.

31.7.11.3.13 Wiring

All wiring on the crane and on its component, assemblies shall be completed at the Contractor's plant, except that wiring shall not be installed where it would be disturbed by or for shipment.

However, a sufficient quantity of cable and associated materials of the proper sizes and types shall be included with the shipment to permit completion of the crane wiring in the field.

The wiring shall comply with the requirements of Section 8 and the requirements of EN 60204-32 or equivalent standard.

31.7.11.3.14 Platforms and walkways

The crane and its platforms and walkways must be designed and built in such a way that all points necessary for the operation, set-up, maintenance and repair can be accessed at any position of the crane.

If there is no external connecting route to reach these points, one of the following accesses shall be provided by the Contractor:

1. Permanent access for maintenance and maintenance and inspection, which are designed in accordance with EN 13586.
2. Access by a mobile, height-adjustable working platform adjustable working platform.

Platform and walkways shall be provided with anti-slip hot dip galvanized chequere plates, tabular handrails and skirting. Safety distances to prevent hazard zones being reached shall comply with EN 13587.

31.7.11.3.15 Lubrication

All bearings requiring grease shall be fitted with grease fittings of approved type easily accessible from the crane walkways.

The Contractor shall advise the PMC in writing as to the recommended type and make of grease and other lubricating oils to be used. In addition, the Contractor shall state a lubricating cycle in the instruction manual to guide the Employer's operating staff in their maintenance work. The Contractor shall provide the initial lubrication for all the equipment, including the hoisting ropes.

The lubrication positions shall be clearly marked and arranged in and orderly and cleanly visual manner. Tooth gears in the vicinity of accessible place shall be enclosed. All screws, bolts and nuts shall be locked so that it is impossible for them to become loose in operation.

31.7.11.4 Testing of Cranes

31.7.11.4.1.1 Inspection and Test Plan (ITP)

The Contractor shall submit an Inspection and Test Plan (ITP) min. 6 weeks prior to starting fabrication. This ITP is subjected to approval by the PMC.

31.7.11.4.2Testing of Materials

The testing of structural steel materials shall be in accordance with the specified material (EN 10025). EN 10204 3.1 certificate for the used materials is requested.

31.7.11.4.3Weld Test

The Contractor shall submit an Inspection and Test Plan (ITP). This ITP is subjected to approval by the PMC. The non-destructive testing (NDT) of steel lining shall include the following as a minimum requirement:

1. 100 % visual testing (VT) of all welds
2. min. 30 % MT-testing of the fillet welds
3. 100 % MT testing of all welds of the main girder
4. 100 % UT testing of all butt welds

31.7.11.4.4Dimensional Checks

The Contractor shall prepare and submit drawings for dimensional checks for approval by the PMC. Dimensional checks shall be carried out by the Contractor for each part during manufacturing and installation.

31.7.11.4.5 Shop Assembly, Installation and Tests

Cranes and winch hoists shall be tested at manufacturer's workshop to the highest extent the conditions allow and as far as practical. The crane shall be completely assembled at the shop respectively divided into suitable sub-assemblies to allow inspection and performance of functional tests.

In particular, the following tests shall be carried out under the supervision of the PMC:

1. Checking of the main dimensions.
2. Operational test of all drives, including measuring of operating speeds and load switch adjustments.
3. Function tests of the complete control system, measurement of stator winding insulation resistance on all driving motors, voltage test and insulation test on electrical installations.

The test equipment and instrumentation has to be provided by the Contractor. When test equipment has passed the tests to the PMC's satisfaction, the equipment can be disassembled touch-up painted and packed for shipment.

31.7.11.4.6 Quality Documentation

Before carrying out the tests listed below, the quality documentation of the installation and shop manufacturing as specified herein particularly but not limited to material certificates, NDT test reports, weld records, dimensional inspection record, painting examination reports must be finalized and must be made available to the PMC.

31.7.11.4.7 Tests on Completion

The testing of bridge and gantry cranes shall be in line with the requirements of EN 15011 and shall include as a minimum the following tests:

31.7.11.4.8 Functional Test

All motions of the crane shall be operated throughout their range of movements, without load, up to their maximum operating speeds. During these tests the crane shall be monitored to check that it operates smoothly, the braking systems operate effectively and motion limiter and indicator settings are accurate. All functions of the crane equipment shall be tested, particularly those related to safety.

31.7.11.4.9 Static load test

The static test shall be carried out in accordance with the requirements of EN 15011 with a min test loads corresponding to 125 % of the rated capacity. The Contractor is responsible to make all arrangements necessary for the load test and to provide the test weight carriage and test weight.

The Load shall be positioned 100 mm to 200 mm above the ground.

Tests are considered successful if no fractures, permanent deformations or damages affecting the function or safety of the crane are visible and if no connections have loosened or show signs of damage.

31.7.11.4.10 Dynamic load test

Dynamic Test to be performed with a test load that is at least 110 % of the rated capacity. The tests shall include repeated starting and stopping of each motion, including all combined movements as provided by the intended use over the whole sequence and range of the movements.

During these tests the crane shall be continuously monitored to check for:

1. smooth operation of the crane;
2. effective operation of the braking systems;
3. effective operation of protection systems
4. effectiveness and accuracy of limiting and indicating devices;

During these tests the temperature raise of motors, bearings, and other mechanical and electrical parts shall be checked.

The protection performance of the rated capacity limiter shall be tested by lifting a load having a mass between 110 % to 125 % of the rated capacity as follows:

1. start lifting without prestressing the hoisting medium;
2. use maximum speed that the control system allows in this situation;
3. run the hoist mechanism up to the triggering point of the rated capacity limiter.

31.8 ELECTRIC EQUIPMENT

31.8.1 SCOPE OF WORK

The supply is inclusive of all electrical work for all permanent work areas including lighting, power sockets, temporary power until the permanent supply is connected, for all supplied equipment, motor starting equipment and controls for manual, automatic and remote operation of the equipment.

31.8.2 CONTROL PANELS

31.8.2.1 General

Control panels shall be per of stainless-steel construction, with IP65 rating per IEC 60529, except in dust filtered climate-controlled control rooms, telecommunication or server rooms, where open rack equipment will be acceptable. Control of condensation and control of the maximum interior temperature against the specified range of ambient temperatures shall be provided by heating and cooling units. Provide Peltier type cooling units wherever possible so that the IP level of the cabinets is not compromised. Filters with fans moving air from exterior to interior are not acceptable for control panels with IP65 enclosures.

Measurement and control instrumentation equipment shall have high electro-magnetic and radio frequency interference immunity and low emissions in accordance with the appropriate standards and shall not be affected by portable radio transmitters operated in the vicinity of the equipment when the cabinet doors are closed.

All electronic devices shall be protected against transient voltage levels. Surge protection, lightning protection and susceptibility to electrostatic discharge shall be in accordance with the appropriate standards.

Adequate electrical interference suppression, supply filtering and voltage stabilisation and filtering shall be provided as recommended by the equipment manufacturers.

Doors and inner doors shall not be used as equipment frames other than for panel indicators and controls and wherever possible all components shall be DIN rail mounted and fixed to the equipment mounting panel and not to the sides or tops of panels.

Control panels having a depth greater than 500 mm shall be fitted with an internal panel light that is operated by a door switch and protected by an earth leakage circuit breaker. Inner surface of control panels shall be painted white.

A single-phase equipment socket outlet shall be provided for the powering of small tools or portable test equipment.

Circuit labels, equipment labels, instruction labels and warning labels necessary for the identification and safe operation shall be supplied and installed.

Unless otherwise agreed, labels shall be of non-hygroscopic, non-deteriorating and non-warping material with engraved lettering of contrasting colour.

Warning labels shall be of a yellow colour with black lettering. These warning labels shall draw attention to the danger or risk with words in the language specified that attract attention and/or carry a symbol that graphically depicts the type of risk. All other labels shall be of a white colour with black lettering.

All the labels shall be securely fixed to the items with stainless steel rivets, plated, blunt-tipped, self tapping screws or other approved means. The use of adhesives is not permitted.

A minimum of 20% spare capacity shall be provided in all main signal cabling, junction box terminations, cables, input and output signals (including input/output (I/O) modules, interposing relays, internal wiring and terminations), instrument power supply miniature circuit breakers (MCBs) and fuses. A further 20% spare physical space will be provided within panels and instrument racks and on cable routes.

Aluminium components, unless otherwise specified, shall have an anodised finish

31.8.2.2 Interlocks and Barriers

Where appropriate to prevent danger from live parts, control panels shall be provided with either an approved form of mechanical door interlocked isolator or isolating switch.

For control panels where it is foreseen that access is required for maintenance or repair purposes whilst the panel power supply remains switched on, then the panel shall be designed for this. In such cases, the control panel power distribution equipment and other equipment operating above the normal control voltage shall be segregated from the control equipment within the enclosure. The segregated areas will be fitted with suitable transparent plastic barriers to shield the equipment and exposed terminals.

The barriers shall be designed to remain in place while the control equipment is maintained. The barriers and power distribution equipment shall have suitable warning signs applied and the barrier will require the use of a tool for removal.

31.8.2.3 Construction and Installation Requirements

Sheet steel control panels shall be of a modular or folded construction and rigid with the framework manufactured from steel sections and covered with sheet metal. They shall be constructed from at least 1.5 mm thick panels, a 2 mm thick door and a 3 mm thick equipment mounting panel (2 mm thick mounting plate for small control panels). The panels shall be complete with all the internal supports required for wiring, piping and support framework for equipment racks and shall be of adequate strength to support the weight. Floor mounted control panels shall be fitted on an integral 100 mm high plinth painted black. Plinths are required to have removable panels as needed to provide access below panel.

Adequate sloping roof rain canopies shall be provided where control panels are in an outdoor location or are subject to deluge fire protection and/or spray water.

Where the performance, reliability or life of the plant would be adversely affected by solar radiation, including the effects of prolonged exposure to ultra-violet light, suitable sunshades shall be provided. Such sunshades shall be constructed from materials that are able to withstand the effects of the ambient conditions on site without suffering any deterioration in material strength or effectiveness.

To avoid retention of moisture behind the enclosure all wall-mounted control panels shall be installed with spacers so that a clearance of at least 10 mm is provided between the rear of the enclosure and the wall.

The overall height of mounted control panels and cabinets as measured from the adjacent floor level, shall not exceed 2.25 m. Equipment, except heaters and earthing buses, mounted in control panels and cabinets shall be at least 0.5 m above floor level.

Doors shall provide an opening between 120° and 130° and all doors exceeding 1.2m in height shall be fitted with a doorstop. Means shall be provided for securing doors in the open position. A pocket shall be provided on the inside of all control panel doors for cable termination charts and/or circuit diagrams. Hinges shall be of sufficient strength to prevent doors from sagging when opened. The hinges shall also be constructed such that doors can be lifted off when required. Split pins shall not be used as hinges.

Control panels shall be sized in such a manner that sufficient room exists to enable ease of access to all equipment contained therein. A minimum of 20% spare equipment capacity shall be left available for any future installation.

Suitable provision shall be made for the safe lifting of each control panel. The removal of any temporary shipping lugs shall not degrade the construction, the ingress protection (IP) rating or the electro-magnetic compatibility (EMC) protection of the panel.

After painting, all holes where internal cables or wires pass through shall have their edges protected by PVC sleeves or equivalent.

All spare unused holes, for mounting equipment or cable entry, shall be sealed.

Each removable metal part of the control panel shall be provided with an earth stud and a conductive equipotential bond connection to the panel main earthing point.

Un-drilled detachable gland plates in the base of the control panel shall be provided for all electrical cables and instrument tubing. The gland plates shall be segregated by duty. Gland plates for floor mounted control panels shall be at least 250 mm above the floor of the panel.

No penetrations are permitted through the roof of outdoor control panels.

Control panels housing equipment that is susceptible to or that generate emission of electromagnetic interference shall be constructed so as to minimise that effect. If the

equipment concerned can be housed in a shielded enclosure within the control panel, then the preventative measures apply to the shielded equipment enclosure.

Metal cable glands complete with EMC seals and/or gaskets shall be used to ensure continuity.

31.8.3 ELECTRIC VARIABLE SPEED DRIVEs (VSDs)

31.8.3.1 General

Electric Variable Frequency Drives (VFD) shall comply with all the international standards applicable for the VFD components.

VFDs shall be of well-proven, high reliability design backed by long site operational experience in environmental conditions compatible with the plant. It shall comprise the complete drive system including motor and typically, static converters, dc link reactor, and associated control equipment.

If necessary, converter supply transformers may be included. Motor supply transformers shall not be used.

31.8.3.2 Converters

The Converters shall be of the variable voltage/variable frequency type utilising power semiconductor technology to supply power to the VFD motors. Each converter shall include a rectifier stage, dc. link with smoothing reactor and an inverter. The inverter shall be of the voltage source type using PWM ac. waveform generation.

The scope of supply of the converters shall include all necessary controls, auxiliary supplies, protection, alarm and measuring equipment required for operation of complete VFD.

31.8.3.3 Motors

VFD motors shall be cage induction motors. Where VFDs using brushless synchronous motors are economically competitive and/or are advantageous for the particular application, these may be offered as alternatives. In all cases, the motor shall be designed for variable speed control.

31.8.3.4 Harmonic Distortion

The total harmonic distortion under the most adverse operating conditions shall not exceed the limits laid down in the UK Engineering Association's Engineering Recommendation G5 (current version), or other approved standard; these limits shall apply both at the point of common coupling and at other switchboards within the plant's distribution system.

If the calculated levels of distortion exceed the limits laid down above, the Contractor shall provide one or more harmonic filters to reduce the harmonic distortion to a level to be approved. The harmonic filter(s) may include power factor correction, where required or specified.

Calculated levels of distortion shall be submitted with the Bid, taking into account individual VFD and the effect of the maximum number of VFDs running on a common supply system.

31.8.3.5 Critical Speeds

Critical speeds of the VFD motor and driven equipment shall not lie within the operational speed range.

31.8.3.6 Miscellaneous Technical Requirements

Full technical details shall be provided including but not limited to:

1. Transient Torque Performance
2. Torque Pulsations
3. Control Linearity
4. Radio Interference
5. Protection

The VFD shall be designed to withstand the mechanical, electrical and thermal stress which may arise from short circuits or other fault conditions, and to limit the damage caused by faults to the component concerned. Injury to personnel shall be completely prevented.

31.8.3.7 Pushbuttons and Separately Mounted Pushbutton Stations

Pushbuttons, which may be of the illuminated or non-illuminated type, shall be shrouded or well recessed in their housings in such a way as to minimise the risk of inadvertent operation.

In instances where "enable" pushbuttons are required they shall be electrically interlocked with the normal control such that deliberate operation of the "enable" push-button is required before the normal control can take place.

The colour of pushbuttons shall be as follows:

1. When mounted on pushbutton stations adjacent to running plant the stop button shall be coloured red and the start button coloured green.
2. When mounted on the front of the contactor panel the stop button shall be coloured red and the start button coloured green.
3. When mounted on panels or desks with adjacent indication lights both buttons shall be coloured black, unless required otherwise.

Loose pushbutton stations unless supplied as weatherproof free-standing enclosures shall be of the metal-clad weatherproof type suitable for wall or bracket mounting with a minimum enclosure classification of IP54. All outdoor mounted pushbutton stations shall incorporate a protective cover or guard (e.g. toughened glass door) to prevent inadvertent operation.

Control stations shall be clearly labelled showing the duty or drive to which they are applicable. Location of ammeters shall be subject to approval.

Pushbuttons used on desks, panels etc. may of necessity required to be of special types (e.g. miniature, illuminated). The Specifications and requirements for these special pushbuttons shall be subject to approval.

Emergency stop pushbuttons shall be provided adjacent to all motors and machinery with exposed moving parts, couplings etc. to prevent danger, and on main and local control panels. These pushbuttons shall have a large "mushroom" head, be coloured red and incorporate a protective cover or guard to avoid accidental operation. These buttons shall automatically lock in the depressed position, requiring twist or key resetting. Contacts shall be provided to cause tripping of the associated circuit, prevent restart of the circuit and bring up an alarm.

Stop pushbuttons mounted local to motors shall trip the associated circuit breaker or contactor regardless of the control position selected.

The contacts of all pushbuttons shall be shrouded to minimise the ingress of dust, and accidental contact, and shall be amply rated for voltage and current for the circuits in which they are used.

31.8.4 DISTRIBUTION PANELBOARDS

Circuit breaker type distribution boards shall be provided throughout the plant for local distribution of lighting, small power and welding supplies.

LV distribution boards shall conform to IEC 61439. All distribution boards shall be of the weatherproof enclosure type to IP54 and shall be arranged so that the door or cover can be locked in the closed position.

Distribution boards shall be capable of withstanding without injury the mechanical and electrical stresses set up by the maximum prospective fault current for twice the period required to disconnect such fault on any circuit.

All MCB's or MCCB's shall comply with the requirements of this section of the specification.

Distribution boards shall be provided with removable top and bottom undrilled gland plates for the outgoing cables corresponding to the circuit capacity of the distribution board and a suitable brass earthing stud.

Indoor distribution boards shall be of galvanised or enamelled sheet steel with a paint finish. The finished colour of all indoor distribution boards shall be chosen to match the adjacent switchboards.

Outdoor distribution boards shall be of galvanized sheet steel with a paint finish. The finished colour of all outdoor distribution boards shall be subject to approval of the PMC.

Neutral bars shall be drilled for an appropriate number of ways relative to the size of the board.

The metal surface adjacent to any live part and all spaces between phases shall be protected by barriers, or fireproof insulation material.

Switch fuse units or disconnectors connected on the incoming side of a distribution board shall be mechanically attached to the board with solid copper electrical connections between the units. A suitable insulated barrier shall be supplied to prevent copper or carbon dust released under fault conditions passing from one unit to the other.

The current rating of the bus bars in each distribution board shall not be less than the sum of the maximum current rating of all outgoing circuits. The neutral connection for each circuit is to be direct to the neutral bus bar.

The distribution boards shall be either single pole and neutral or triple pole and neutral type and shall be equipped with means to provide over current protection to each circuit. This protection may compromise an HRC fuse or MCB, both of which shall be removable without exposing live connections.

Fuse holders shall be of an approved non-hygroscopic insulation suitable for the receipt of HRC fuses.

Miniature circuit breakers when used shall comply with the requirements of this section of the Specification.

The cables feeding the distribution boards shall be connected directly to the incoming isolator or neutral bar as appropriate unless otherwise indicated by the Specification.

Cabling to distribution boards shall generally be bottom entry. However, for indoor boards top entry maybe permitted subject to the approval.

Distribution boards for use on direct current systems shall be double pole types equipped with adequately rated fuses.

Approved type title labels shall be fitted externally on the front cover of each distribution board describing its function with a suitable designation to enable the equipment to be identified on the record drawings or schedules.

31.8.5 ELECTRIC CABLE

31.8.5.1 General

The insulating, sheathing and non-metallic filler materials used in the cables shall be selected to ensure compliance with statutory and Project particular requirements for flame retardance, reduced propagation or low emission of smoke, halogens and acids for the cable as a whole.

Cables installed on or connected to equipment that is subject to vibration, movement and/or expansion shall have stranded copper conductors throughout. Cables shall have crimped connectors for the termination of the conductors.

Only conductors carrying signals of the same category shall be contained within any one multi-core cable. To reduce the risk of common mode failure all cabling associated with high integrity signals, such as data transmission signals, signals from fiscal metering systems or with protection and/or safety systems shall be segregated from control cabling over the entire length of the cable run. This segregation shall also apply to junction boxes and terminations. A further segregation is required to ensure that conductors forming part of intrinsically safe circuits are contained in cables reserved solely for such circuits.

A minimum of 20% spare capacity shall be included in all cables carrying either binary or analogue signals.

31.8.5.2 Multi-Core Control Cables

Multi-core cable shall be used for control applications with working voltage less than 450 volts (AC or DC) and with continuous currents less than 5 A and where low impedance is essential, e.g. secondary wiring of current or voltage transformers or for circuit breaker or contactor controls. It shall also be used for unbalanced circuits e.g. change-over contacts or interconnections between control systems.

Multi-core control cables shall be generally in accordance with the appropriate international standard having a voltage rating of 450/750 V. Conductors shall comprise stranded copper wires with a cross-sectional area of 1 mm2, 1.5 mm2, 2.5 mm² or 4 mm2, with the use of the latter reserved for applications where a higher current or short-circuit rating or lower circuit impedance is required. Standard designs shall be for cables with 2, 3, 4, 7, 12, 19, 27 and 37 cores.

The individual cores shall be of colored coded per international standards with black printed numerals for core identification.

31.8.5.3 Multi-Pair Control Cables

Multi-pair control cables shall be used for instrumentation and control purposes as an alternative to multi core cables, providing that their use is restricted to circuits with

working voltage 125 V (AC or DC) or less and continuous currents typically 100 mA or less. Their use is also restricted to balanced circuits. These cables shall not be used for the secondary wiring of current or voltage transformers or for circuit breaker or contactor primary controls. They shall not be used for high current devices requiring long cable runs.

These cables shall comprise multiple twisted pairs, with copper conductors sized 0.5 mm² minimum (1/0.8 mm diameter or 16/0.2 mm stranded), polyethylene or PVC insulated, laid up and screened overall. Each pair may be individually screened, where required to minimise crosstalk or interference between pairs. Cables which are to be direct buried or installed in accessible areas without external mechanical protection shall be armoured. In areas that are subject to vibration and/or movement the copper cable conductors shall be stranded.

The combinations of multiple twisted pair cables used shall be restricted to 2, 5, 10, 20, 30, 50 and 100 pairs. The insulation of the cores shall be colour coded in accordance with an appropriate international standard.

31.8.5.4 Telecommunication Cables

The application of telecommunication type cables shall be restricted to voice and data communication purposes.

These cables shall comprise multiple twisted pairs, triples or quads, with copper conductors, polyethylene or XLPE insulated, laid up and screened overall. Each pair/triple/quad may be individually screened, where required to minimise crosstalk or interference. Cables which are to be direct buried or installed in accessible areas without external mechanical protection shall be armoured. Un-armoured cables shall have a braided screen.

Minimum 20% spare capacity shall be included in all cables. The insulation of the cores shall be colour coded in accordance with an appropriate international standard. In addition the colour coding, construction, marking, etc., of telephone cabling shall be subject to any requirements laid down by the local telephone company or authority.

Telephone type cables laid in the ground alongside power cables shall be capable of withstanding induced voltages from the power cable.

31.8.5.5 Fibre Optic Cables

Fibre optic cable shall be made up cores sheathed in 125 µm cladding, coated and reinforced using strengthening fibres for protection against crushing forces and excessive tension during installation. All fibre optic cables shall comply with an appropriate international standard. The outer jacket shall be made of a flame-retardant polymer.

A loose tube with minimum strain configuration that provides protection from external forces shall be used in dry and indoor applications. Specific measures shall be taken to protect the fibres from the ingress and propagation of moisture. The outer sheath shall be resistant to water and hydrocarbon contamination. Gel filled loose tubes shall not be used for vertical cable runs or in submerged applications.

Tight buffered or ruggedised fibre optic cable type shall be used for long runs or where the cable is to be buried or submerged. Each cladded core shall have two coatings, the first coat 250-900 µm plastic layer; the second coat 200-400 µm layer of waterproof acetate.

Direct buried fibre optic cable shall be of a steel wire or steel tape armoured construction.

Single-mode fibre optic cables shall be used when there is only one propagation mode (single wavelength) or where there is a long transmission distance. The fibre optic cores shall be either 7.1 or 8.5 µm diameter. The cable shall be suitable for transmission of laser light. The optical cable shall be of the single mode type equipped with at least 24 fibres and shall be suitable for direct burial underground. The fibre cladding diameter required is 125 micron, optimised for 1310 nm, but suitable for transmission at 1550 nm wavelength.

Construction and type testing shall be in accordance with the appropriate international standard with a maximum cabled fibre attenuation not exceeding 0.4 dB/km at 1310 nm; and not exceeding 0.35 dB/km at 1550 nm.

Multi-mode fibre optic cables are not allowed.

Fibre optic cables shall be installed in one length without joints, however where joints cannot be avoided the Contractor shall complete all jointing as specified below.

Joints shall be housed in a weatherproof joint box. Joint boxes shall be provided with the cable. The joint box shall be made of corrosion resistant aluminium alloy or similar material. The cover shall be provided with a long-life neoprene gasket to provide a seal against moisture and dust in an ambient environment of 100% humidity and 55 ºC. The cable inlet shall be similarly sealed. If joint box locations will be exposed to the sun then sunshades are required and these shall be provided with the joint boxes.

Intermediate cable joint boxes will be provided at approximately 2 km intervals, subject to the maximum fabrication/drumming requirements from the manufacturer.

The joint box shall be placed in suitably accessible positions and be appropriately marked. The fibres shall be spliced by fusion techniques for minimum signal loss. A heat shrink optical supporting sleeve with inner mechanical reinforcement shall protect the splice.

Terminations at either end of the cable runs will be performed by the Contractor into patch panels using ceramic ST connectors. The Contractor shall supply the patch panels unless otherwise stated in the Project particular requirements. A fan out kit to protect

each fibre strand in its own buffer sheath shall be used when terminating loose-tube cables.

Patch cords shall be used between patch panels and equipment cabinets within buildings. Patch cords shall be preformed, tight buffered, single or duplex fibre cables, 62.5/125 micron, multi-mode type, provided in standard lengths complete with factory-installed ceramic ST connectors and with sheathing suitable for internal building use. All patch cords shall be supplied and installed by the Contractor. All patch cord runs between cabinets shall be mechanically protected in conduit or closed trunking provided and installed by the Contractor. The conduit or trunking shall contain only fibre optic cables.

The Contractor shall supply and fit fibre optic patch panels for all fibre optic cables in their supply. The supply shall include any cabinet or enclosure necessary for their installation or protection. Patch panels shall be provided with sufficient ports to terminate all fibres entering the respective building, with 20 % spare installed connectors. Connector type shall be ST. Sufficient room shall be allowed within the patch panel for adequate cable and fibre management, allowing for bend radius control. Independent patch panels and splice trays shall be provided. Smooth fibre and tube management shall be provided.

After cable installation and splicing the completed fibres shall be inspected and tested using an Optical Time Domain Reflectometer (OTDR). The OTDR traces generated shall provide as-built evidence of the actual losses on the installed cables.

31.8.5.6 Straight Through Cable Joints

Each control cable shall run in one continuous length except where the run of cable exceeds maximum drum lengths. Straight through joints will not be permitted unless specifically authorised in writing.

Joints shall not be made in cables run on trays. When approved by the PMC, joints shall be made in boxes by terminating the cables on terminal strips. Cables shall be adequately supported in the box and at entry points. Each cable termination shall be clearly labelled using the specified identification method to indicate the cable number, conductor numbers. The joint number shall be indicated on the cover of the joint box.

Where cables are shielded, the shield wires be terminated in the same manner as the conductors on the terminal strip except that the shield conductors shall be insulated by using heat shrink tubing. Control cable shield shalls only be bonded to earth at designated locations approved by the PMC and will be at one of the endpoints of the run.

31.8.5.7 Cable Terminations

The Contractor shall be responsible for making all terminations, checking and setting to work the completed installation. All cables provided as part of the contract shall be terminated at both ends.

For control and instrumentation wiring the cable tails shall be so bound that each wire may be traced back to its associated cable without difficulty. Cores in twisted pairs or groups shall be kept together. Any spare cores shall be numbered and terminated in the spare terminals furthest away from the cable gland. All cables shall be long enough to permit a second termination, if necessary, at a future date.

Cable glands shall be used at all equipment to support the weight of cable from the terminations and to seal the cable to the equipment, unless otherwise approved by the PMC.

PVC, polyethylene, silicon rubber and PTFE insulated cables shall be terminated using the appropriate type glands. Glands in all outdoor locations and within the plant or other areas where water may impinge on cables shall have waterproof inner and outer seals.

PVC shrouds shall be supplied and installed over each gland installed in dusty or damp environments.

31.8.5.8 Terminating and Jointing Conductors

Compression (indentation) type cable lugs and ferrules shall be provided and all necessary tools including dies and other materials for making compression joints shall be provided by the Contractor, who shall comply with the recommendations of the supplier of cables and lugs in the preparation and execution of each termination.

For stud type terminals approved crimping lugs shall be used.

Where clamp type terminals are used, the conductor shall be terminated without lugs with the exception of flexible conductors having stranded conductors. These shall be fitted with crimps. Not more than one conductor shall be terminated in each clamp.

31.8.5.9 Core Identification

Approved numbered ferrules shall be supplied and fitted to every cable core of control and instrument cables at each termination. The ferrules or sleeves shall be of insulating materials which shall have black text engraved on a white background. The ferrules or sleeves shall be unaffected by oil or damp. Adhesive markers shall not be used.

All markings for terminal blocks, cables, cable conductors and wiring shall be located on the corresponding design drawings.

A common system of ferrule numbering shall be adopted such that ferrule numbers at field terminations shall agree with ferrule numbers on the internal wiring of equipment.

31.8.5.10 General Methods of Control Cable Installation

All cables routed under roads and access ways usable by vehicular traffic shall be installed in ducts. At all such crossings spare ducts shall be installed, the number of

spare ducts shall be two or 20 % of the total number of ducts installed at each crossing, whichever is greater.

As a minimum, ducts and duct banks shall be of rigid PVC and shall be surrounded by 150 mm minimum thickness of concrete.

Sunshields shall be provided in all locations where the cable would otherwise be subjected to direct sunlight.

All cables routed in concrete trenches shall be suitably supported by means of cleats or racks and raised from the trench floor by means of suitable spacers. All cables shall be run in a neat and orderly manner and the crossing of cables within the trench shall not be acceptable without the prior approval of the PMC.

Instrument cables and control cables shall be segregated from power cables and should not be run in parallel. A spacing of 300 mm is required from AC power cables up to 10 A rating. For higher ratings the spacing shall be progressively increased. Where a cross-over between signal and power cable is unavoidable, the cables shall be arranged to cross at right angles with a separation of at least 300 mm. Cables carrying signals for safety and protection systems shall be fully segregated from all other cables. Cables shall generally be routed on steel racks or trays; where cables have to be installed on buildings and building framework the cables shall be held by spacer saddles or cleats screwed or welded in position. The Contractor shall supply all necessary spacer saddles or cleats and fix these in position in the least obtrusive manner possible.

The Contractor shall provide all necessary cable trays and racks, which shall be fixed at not more than 1 m centres. All cable trays shall be perforated. All trays and racks shall be galvanised and of thickness not less than 1.6 mm and shall be PVC coated in exposed areas.

Cable clamps shall be used at any change of direction of a cable route and at fixed intervals on straight runs. Cable ties of approved design only may be used.

31.8.5.11 Cable Installation Materials

31.8.5.11.1 Cable Terminal

1. The termination of each end of each cable shall, unless otherwise specified, include the following:
   a. Fixing gland the cable as approved (or clamp for bottom entry into floor - mounted indoor cubicles).
   b. Fitting an approved lug to each core (except spare cores).
   c. Fitting an approved phase or polarity identification to each power cable core. Identification of each control and alarm cable core and cable identification tag (31.8.5.11.2 – Cable Identification Tags).

31.8.5.11.2 Cable Identification Tags

1. The Contractor shall provide non-ferrous identification tags with appropriate dimensions to each cable. The tag shall be fixed longitudinally along the cable.
2. Each identification tag shall be stamped indelibly with the appropriate cable number in accordance with the cable schedules, the letters and figures being not less than 5mm high.

31.8.5.11.3Cable Glands

1. Cable glands shall be of approved type and non-ferrous metal. Plastic made is not acceptable. Cable glands for outdoor use shall be of the weatherproof compression type

31.8.5.11.4Cable Ties

Unless otherwise approved, the following type of cable ties shall be used:

1. For multi-core cables, nylon cable ties with a minimum tensile strength of 500N.
2. For single core power cables protected by HRC fuses:

a. For holding in trefoil formation, stainless steel ties complete with stainless steel buckles, with a minimum tensile strength of 2 kN.

b. For fixing to cable ladders, nylon cable ties as specified above.

3. For single core power cables not protected by fuses, for holding in trefoil formation, stainless steel ties complete with stainless steel buckles with a minimum tensile strength of 4 kN.

The Contractor shall submit evidence that the proposed ties have the required strength.

31.8.5.12 Trefoil cable

1. Trefoil cable cleats shall be of non-magnetic material, fitting the contours of the cable and securely anchoring the cable into position. The cleats shall be capable of withstanding bursting forces of 4kN due to fault current in the cable.

31.8.6 ELECTRIC CABLE PROTECTION

31.8.6.1 Junction and Marshalling Boxes

Junction and marshalling boxes for use in non-hazardous areas shall be of substantial sheet steel construction, having an enclosure classification in accordance with the requirements of this section of the specification. They shall be fitted with external fixing lugs and finished in accordance with the requirements of the specification for cleaning, painting and finishing. The boxes shall allow ample room for wiring, with particular regard to the routing of wires from the point of entry.

Outdoor boxes shall have an anti-condensation finish and all boxes shall be designed such that any condensed water cannot affect the insulation of the terminal boards or cables. No cables shall be terminated into the top of outdoor boxes unless specifically approved.

All necessary gland plates shall be provided undrilled.

Boxes shall be complete with suitably inscribed identification labels.

Boxes for use in hazardous areas shall have all entries factory pre-drilled. Every unused screwed entry shall be sealed by means of a tamperproof screwed plug-in accordance with IEC 60079.

Hazardous area boxes with bolted or screwed lids shall require the use of special keys or spanners for lid removal.

Where weatherproof types of hazardous area boxes are not available, the gaps should be protected against the ingress of moisture, by an approved means, compliant with local standards.

All box covers are to be arranged for padlocking and padlocks with keys shall be supplied.

All boxes shall be provided with adequate earthing bars and terminals.

Conduit and Accessories

Conduit installations shall comply with IEC 60364, and IEC 60981 unless otherwise approved.

All conduit and conduit fittings shall comply with IEC 60423. Unless otherwise approved, all conduit and conduit fittings, shall be threadable steel conduit with enclosure classification IP55, at least heavy mechanical protection and high resistance to corrosion inside and outside.

No conduit smaller than 20 mm diameter shall be used.

Standard circular boxes or machined face heavy-duty steel adaptable boxes with machined heavy type lids shall be used throughout. For outdoor mounting all boxes shall be galvanised, weatherproof and fitted with external fixing lugs.

Where conduit is terminated so that the bare end of the conduit is exposed the conduit end shall be fitted with a brass bush.

The use of running threads, solid elbows and solid tees will not be permitted.

Conduit ends shall be carefully reamed to remove burrs. Draw-in boxes shall be provided at intervals not exceeding 10 m in straight-through runs.

Conduit runs shall be in either the vertical or horizontal direction unless otherwise approved and shall be arranged to minimise accumulation of moisture. Provision for drainage shall be made at the lowest points of each run.

Conduits shall be supported on heavy galvanised spacer saddles so as to stand off at least 6mm from the fixing surface.

All conduits run in any circuit are to be completed before any cables are pulled in.

Flexible metallic conduit shall be used where relative movement is required between the conduit and connected apparatus, and a separate earth continuity conductor shall be provided.

The maximum number of cables in any conduit shall be in accordance with IEC 60364.

31.8.6.2 Steel Trunking

Steel trunking (cable management ducts) may be used for running numbers of insulated cables. The trunking thickness shall not be less than 1.2 mm.

Connections of conduit to trunking shall be made with a socket and a male bush.

All trunking shall be manufactured from hot-dip zinc coated steel sheet conforming to BS 4678 Part 1 Class 3 or IEC 61084.

31.8.7 EARTHING AND BONDING

The main earthing conductor is provided for equipment located in the main dam.

The main earthing conductors for connection to all electrical equipment, cables, motors, panels, etc., shall be provided for connection to the main earthing system.

All non-current carrying metal parts of electrical equipment shall be bonded to an earth terminal or terminals mounted on the equipment and readily accessible.

All equipment terminals provided for an external earth connection shall be identified by indelible means unless such terminals are directly and visibly mounted on metallic equipment frames or earth bars, when such marking may be omitted.

Identification marks for earth terminals shall comprise the colours green/yellow in combination or a reproduction of the symbol no. 5019 in IEC 60417.

Assemblies containing electrical equipment, including switchboards, control boards and control desks, shall be provided with a separate copper earth bar running the length of the assembly. All metal parts and the earth terminal or terminals shall be bonded to this earth bar. Earthing connections shall not depend upon the bolting of steel/steel joints between adjacent panels or cubicles.

Earth bars shall be of adequate size and suitably supported and braced to carry the rated short circuit current for the associated electrical circuits for the rated short-circuit current duration, without damage or excessive heating likely to damage joints, associated or adjacent components.

Switchgear and control gear assemblies shall be provided with two or more earth terminals unless otherwise specified. The copper earth bar shall be sized to withstand the maximum system earth fault current for three seconds without deterioration.

The size of the copper earth bar in control panels, control desks or similar enclosures containing low voltage apparatus shall be such as to comply with the specified requirements for withstanding prospective short-circuit currents. The size of this bar shall be a minimum of 120 mm² cross-sectional area, providing that sufficient mechanical integrity is provided by adequate supports and terminals, and also providing this size is not less than the size of the largest incoming power supply conductor.

The metal cases of all instruments, relays and the like shall be connected to the panel earth bars by copper conductors of not less than 1.5 mm² cross-sectional area, or by other approved means.

31.9 CORROSION PROTECION

31.9.1 GENERAL

All parts and equipment other than made of stainless steel or other non-corrosive material shall be provided with a "fit for purpose" and reliable corrosion protection according with the specifications and standards stated herein.

In general, the corrosion protection of all parts specified herein shall be applied in the workshop; site application shall be limited to the protection of site welds, except for steel linings.

The protection of site welds shall comply with the requirements specified in this section, including proper surface preparation by sand blasting.

The Contractor's services shall cover the procurement of all materials, and the preparation and application of the painting and other protective coats as specified. The Contractor shall provide a complete, reliable coating system.

31.9.2 STANDARDS AND SPECIFICATIONS

The following standards shall be considered:

1. ISO 12944 Part 1- 8
2. ISO8501 Part 1- 3
3. ISO8502 Part 4, 6 and 9
4. ISO8503 Part 1, 2, 4 and 5
5. ISO8504 Part 1- 3
6. ISO 2409
7. ISO 4624
8. SSPC

Other standards subject to approval by the PMC.

31.9.3 PAINTING MATERIALS

Coating materials shall be standard products of a paint manufacturer with proven experience in the field of corrosion protection of the type of Works to be supplied.

The Contractor shall submit for the PMC's approval full details of the preparation, type of materials, methods and sequences he proposes to use to comply with the requirements for the protection of the Works.

The entire paint material for a particular specified paint system shall be supplied by one manufacturer only (except for purchase parts), who shall guarantee the compatibility and quality of the paint material. For multicoated painting systems each coat shall have a different color.

Details of manufacturer's test records to substantiate this selection shall be submitted to the PMC.

With regard to materials, the Contractor shall submit full details including the source of the basic raw materials, volatile matter content, nature of solvent, number of components, type of coat, coverage, time interval between coats and number of coats, compatibility of each coat with the previous coat, toxic properties, physical properties, shelf life, resistance against chemical attack, resistance against ozone and UV-radiation, compatibility with drinking water standards, etc.

The Contractor shall describe in detail the treatment he proposes to apply in order to give adequate protection during transport, site storage, building and concreting and subsequent erection.

The different coats of primer and subsequent coats shall be each of different shades of color where practicable.

The Contractor shall submit to the PMC for approval an overall painting scheme in accordance with the specification. All final coats shall be in the colors approved by the PMC. On request of the PMC, painting samples for the different coats and colors shall be provided. A complete list of the proposed paint material shall be submitted to the PMC.

All paint material shall be delivered in unopened original sealed containers packed by the manufacturer bearing the manufacturer's brand name and color designation, storage directions and handling instructions. The manufacturer's instructions for preparation and application of all painting and protective coats shall be strictly followed.

Paint materials shall be stored and mixed by the Contractor in strict accordance with the manufacturer's instructions. Paint material shall be used before the expiration of the shelf life. All safety regulations shall be observed, especially with regard to fire.

31.9.4 WORKMANSHIP

31.9.4.1 Contractor's Equipment

The Contractor shall observe all safety and health precautions to protect his workers and others during painting works. The necessary equipment, such as fans, air-conditioning units, safety masks, nets, etc. shall be provided by the Contractor. All equipment shall be in strict accordance with the respective safety codes and regulations assuring efficient work of high quality.

31.9.4.2 Preparation of Paint Material

Paint shall be delivered ready mixed wherever possible. Adding of diluting agents and mixing of two or multi-component systems shall be done in the field in accordance with the directions of the manufacturer. Mixing and homogenizing of the paint material shall be done by a mechanically driven paddle or agitator in the original container. After mixing,

the paint shall be poured into a clean container to ensure that no settled pigments are at the bottom.

31.9.4.3 Surface Preparation

The term "preparation", as used below, includes any cleaning, smoothing or similar operations that shall be required to ensure that the material to be painted attains a suitable condition.

To be ready for painting, a surface should be clean, dry and sound. The surface to be coated shall be free from any deleterious material liable to impair good paint adhesion or attack the coat.

For removing rust and mill scale on structural steel, piping and other steel surfaces, those parts suitable for sandblasting shall be sandblasted to a grade specified or required in accordance with EN ISO 12944-4.

All parts of the Works shall be sandblasted at the shop unless otherwise specified or approved by the PMC to the degree provided in Clause 10.6 below. The roughness shall be measured with an ISO-Comparator acc. to ISO 8503-2 and verified with a replica tape acc. to ISO 8503-5 or stylus gauge acc. to ISO 8503-4.

The Contractor shall proceed with blast cleaning only when the following time and relative humidity schedule for application of the first coat can be achieved and maintained:

Table 31-11 Humidity / Time schedule

Relative Humidity	Time
85% or above	Do Not Blast
80 - 84%	2 hours
70 - 79%	4 hours
60 - 69%	10 hours
50 - 59%	12 hours
30 - 49%	24 hours
under 30%	1 Week

Parts which cannot be sandblasted shall be cleaned of rust by power tool cleaning to the highest degree possible.

Hot-dip galvanized surfaces which are to be painted shall be lightly sandblasted prior to through cleaning.

31.9.4.4 Application

The most commonly used methods of application are painting by brush, roller, pressure and airless spraying equipment. Selection of the application method depends on the surface to be painted. The quality of the paint shall in no way be negatively influenced. The manufacturer's directions shall govern the choice of application method.

Inaccessible surfaces shall be painted prior to erection with prime and finish coats according to the specification. Areas inaccessible to spraying equipment shall be painted by brush. Corners and edges shall be pre-coated. Bolts, screws, studs, rivets etc. shall be painted as a whole with the complete paint system after erection.

The primer shall be applied to an absolutely clean and dry surface only. Temperature and dry-out time shall be in accordance with the manufacturer's directions. Whenever possible the prime coat as well as one intermediate coat shall be applied in-doors at the Contractor's shop.

During painting the air temperature shall be at least +5°C and the temperature of the items being painted must be at least 3°C above the dew point. During drying of the paint, the temperature shall not be below 0°C. For all paints the surface temperature of the metal shall not be higher than +50°C during the painting. Concerning special paints, the requirements set by the paint manufacturer shall be followed.

Cleaning and painting work shall be interrupted outdoors and in non-conditioned rooms under the following conditions: rain, fog, dew, polluting winds, sand and other dusts. Surface preparation and application of the first paint layer are parallel operations to be carried out within a maximum delay of 4 hours.

All painting shall be free of cracks and blisters and all runs shall be brushed out immediately. After application of the last coat the paint system shall be free of pores. After erection of the equipment all damages to painted surfaces shall be repaired. Welds, rusty spots, beads, flux deposits etc. shall be repaired and repainted. For touching up, the same materials shall be used as for the main painting work. Repaired finish coats shall be of the same appearance as the original coating.

Parts which are embedded in concrete must not be protected against corrosion. However, transition zones of large steel pipes and of steel linings shall be painted over a length of 1 m within the concrete, all other steel surfaces except stainless steel materials, embedded in concrete over a length of 100 mm within the concrete.

In linings surrounded by concrete, surface preparation and painting works shall be carried out after all Works such as concreting, welding, grouting and cleaning have been completed. The Contractor shall take into account the local climatic conditions and use adequate installations for sandblasting, dust control and sand extraction.

It shall also be the Contractor's entire responsibility to protect equipment and structures not being painted such as nameplates, instruments, panels, floors, walls, etc. and he shall provide and install all necessary drop cloths and screens.

A properly equipped paint shop shall be set up at the Site with a crew of specialists experienced and skilled in the preparation and application of protective coatings, to deal with all site-protective treatment.

31.9.4.5 Quality Control

The minimum dry-film thickness prescribed in these Specifications shall be observed. No measured thickness shall be less than the specified thickness. Where the minimum thickness is not achieved, the coat shall be repaired to reach the specified minimum dry-film thickness. The dry-film thickness shall be measured by approved gauges.

For checks on porosity, the Contractor shall furnish a DC variable high-tension test instrument with built-in pore counter. The test voltage shall not exceed 2,000 V. The tests shall not be performed within 0.5 m distance from uncovered, corrosion resistance surfaces.

Upon completion of each coat, the painter shall make a detailed inspection of the painting finish and shall remove from adjoining work all spattering of paint material. He shall make good all damage that can be caused by such cleaning operations.

A detailed inspection of all painting work shall likewise be made, and all abraded, stained, or otherwise disfigured portions shall be touched up satisfactorily or refinished as required to produce a first-class job throughout and to leave the entire work in a clean and acceptable condition. Adherence tests shall be performed and the acceptance criteria shall be in accordance with EN ISO 12944-7.

31.9.5 PROTECTIVE COATING SYSTEMS

All materials mentioned below are only seen as an example for the material specification. All equivalent materials are considered as suitable and are subject to the approval of the PMC.

31.9.5.1 Coating Systems

Table 31-12 Intake Maintenance Gate Coating System

Surface Preparation	Coating System	NDFT (µm)	Remarks
Abrasive Grit Blasting **Preparation Grade:** Sa 2 1/2 - ISO 8501-1 **Profile Grade:** "G Medium" - ISO 8503-1 Surface roughness according to technical data sheet (TDS), if not given in the TDS Rz = 50-75 µm.	**Primer Coat:** 2-Comp, EP-Coating Material - High build & Surface Tolerant Epoxy for improved abrasion resistance properties **Product:** Jotamastic 90 GF or Equivalent	250	High build, reinforced glass flakes with solid content 80±2% (shall be available in any RAL Color)
	Intermediate Coat: 2-Comp, EP-Coating Material - High build & Surface Tolerant Epoxy for improved abrasion resistance properties **Product:** Jotamastic 90 GF or Equivalent	250	High build, reinforced glass flakes with solid content 80±2% (shall be available in any RAL Color)
	Top Coat:	60	aliphatic acrylic polyurethane coating

Table 31-12 Intake Maintenance Gate Coating System			
Surface Preparation	**Coating System**	**NDFT (µm)**	**Remarks**
	2-Comp, chemically cured aliphatic acrylic polyurethane coating. Product: Hardtop XP or equivalent		Low VOC with solid content 60±2%
	Total Nominal dry film thickness NDFT	560	

Table 31-13 Coating System Chamber Bonneted Gates			
Surface Preparation	**Coating System**	**NDFT (µm)**	**Remarks**
Abrasive Grit Blasting **Preparation Grade:** Sa 2 1/2 - ISO 8501-1 **Profile Grade:** "G Medium" - ISO 8503-1 Surface roughness according to technical data sheet (TDS), if not given in the TDS Rz = 50-75 µm.	**Primer Coat:** 2-Comp, EP-Coating Material - High build & Surface Tolerant Epoxy for improved abrasion resistance properties **Product:** Jotamastic 90 GF or Equivalent	2 x 200	High build, reinforced glass flakes with solid content 80±2% (shall be available in any RAL Color)
	Intermediate Coat: 2-Comp, EP-Coating Material - High build & Surface Tolerant Epoxy for improved abrasion resistance properties **Product:** Jotamastic 90 GF or Equivalent	200	High build, reinforced glass flakes with solid content 80±2% (shall be available in any RAL Color)
	Total Nominal dry film thickness NDFT	600	

Table 31-14 Coating System Embedded Parts at Intake			
Surface Preparation	**Coating System**	**NDFT (µm)**	**Remarks**
Abrasive Grit Blasting **Preparation Grade:** Sa 2 1/2 - ISO 8501-1 **Profile Grade:** "G Medium" - ISO 8503-1 Surface roughness according to technical data sheet (TDS), if not given in the TDS Rz = 50-75 µm.	**All Coats** 2-Comp, High build, EP Coating with excellent abrasion resistance properties in splash or tidal zone, having cathodic disbandment resistance properties **Product:** Marathon 1000 GF or equivalent	2 x 500	Glass reinforced, Solvent Free, Solid content 96±2%
	Total Nominal dry film thickness NDFT	1000	

Table 31-15 Coating System Steel Liners and Chamber Gates Embedded Parts			
Surface Preparation	**Coating System**	**NDFT (µm)**	**Remarks**
Abrasive Grit Blasting **Preparation Grade:** Sa 2 1/2 - ISO 8501-1 **Profile Grade:** "G Medium" - ISO 8503-1 Surface roughness according to technical data sheet (TDS), if not given in the TDS Rz = 50-75 µm.	**All Coats:** 2-Comp, High build, EP Coating with excellent abrasion resistance properties in splash or tidal zone, having cathodic disbandment resistance properties **Product:** Marathon 1000 GF or equivalent	2 x 500	Glass reinforced, Solvent Free, Solid content 96±2%
	Total nominal dry film thickness NDFT	1000	

Table 31-16 Coating System Hoisting Systems, Hydraulic Cylinders, Bridge Cranes, General Steel Works Indoor			
Surface Preparation	**Coating System**	**NDFT (µm)**	**Remarks**
Abrasive Grit Blasting **Preparation Grade:** Sa 2 1/2 - ISO 8501-1 **Profile Grade:** "G Medium" - ISO 8503-1 Surface roughness according to technical data sheet (TDS), if not given in the TDS Rz = 50-75 µm.	**Primer Coat:** 2-Comp Ep Zinc Primer, Low solvent epoxy (ASTM D520 Type2) **Product:** Interzinc or equivalent	75	min. 80% Zinc content low-solvent
	Intermediate Coat: 2-Comp, EP-Coating Material - High build & Surface Tolerant Epoxy **Product:** Jotamastic 90 or Equivalent	1x200	High build, with solid content 80±2% (Shall be available in any RAL Color)
	Subsequent Coat: 2-Comp, EP-Coating Material - High build & Surface Tolerant Epoxy **Product:** Jotamastic 90 or Equivalent	1x200	High build, with solid content 80±2% (Shall be available in any RAL Color)
	Total nominal dry film thickness NDFT	475	

Table 31-17 Gantry Structure Coating System, Hoist Machine, General Steel Works Outdoor			
Surface Preparation	**Coating System**	**NDFT (µm)**	**Remarks**
Abrasive Grit Blasting **Preparation Grade:** Sa 2 1/2 - ISO 8501-1 **Profile Grade:** "G Medium" - ISO 8503-1 Surface roughness according to technical data sheet (TDS), if not given in the TDS Rz = 50-75 µm.	**Primer Coat:** 2-Comp Ep Zinc Primer, Low solvent epoxy (ASTM D520 Type2) **Product:** Interzinc or equivalent	75	min. 80% Zinc content low-solvent DFT = 70 µm (If required)
	Intermediate Coat: 2-Comp, EP-Coating Material - High build & Surface Tolerant Epoxy **Product:** Jotamastic 90 or Equivalent	250	High build, with solid content 80±2% (Shall be available in any RAL Color)
	Subsequent Coat: 2-Comp-acrylic polyurethane finish Coat **Product:** Hardtop XP or equivalent	60	Low VOC with solid content 63±2%
	Total nominal dry film thickness NDFT	385	

Table 31-18 Surfaces Exposed to Oil Coating System			
Surface Preparation	**Coating System**	**NDFT (µm)**	**Remarks**
Abrasive grit blasting **Preparation Grade:** Sa 2 1/2 - ISO 8501-1 **Profile Grade:** "G Medium" - ISO 8503-1 Surface roughness according to technical data sheet (TDS), if not given in the TDS Rz = 50-75 µm.	**Primer Coat:** 2-Comp – High solid Phenolic / novolac Epoxy, for chemical resistance especially designed for tank linings **Product:** Tankguard Storage or equivalent	150	High build, Epoxy Phenolic with solid content more than 60%
	Subsequent Coat: 2-Comp – High solid Phenolic / novolac Epoxy, for chemical resistance especially designed for tank linings **Product:** Tankguard Storage or equivalent	150	High build, Epoxy Phenolic with solid content more than 60%
	Total nominal dry film thickness NDFT	300	

31.9.6 Color Code

The Color Code for HM equipment is not provided in the Tender Documents as it shall be agreed upon after award of the Contract according to the Employer's requirements. As a general rule all confined spaces such as internal faces of steel linings shall have a bright color.

The coloring of piping, moving parts, etc., shall be according to internationally recognized standards subject to approval of the PMC and the Employer.

31.9.7 REFERENCE AREA

For each paint system a reference area in accordance with the paint system specification, shall be established. The PMC, the paint supplier and the contractor witness and accept the coating of the reference area, the paints and coating equipment used, the applicators and application methods.

The reference area is used to establish the minimum acceptable quality of the paint work, to verify the information provided by the manufacturer or supplier (contractor), and to enable validation of the performance of the coating at any time after application (ISO 12944-7).

All reference areas must be recorded meticulously, and can also be marked permanently on the structure (ISO 12944-8).

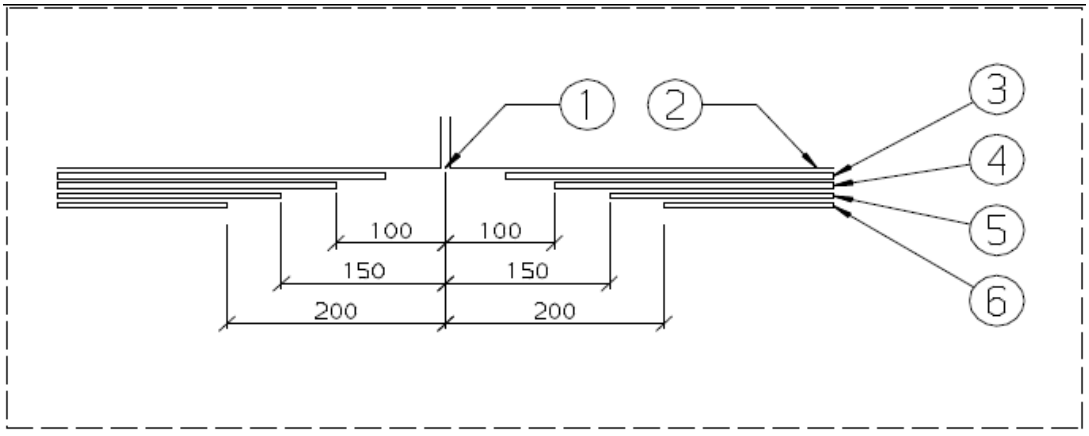
The size and number of the reference area must be in reasonable proportion, both in practical and economical terms, to the total surface area of the structure (ISO 12944-8)

31.9.8 REPAIR OF PRIMER AND FINISH COATS

For touching up, the same paint shall be used as for the original painting work. Repaired finish coats shall be of identical appearance with the original and no different in the color shall occur. The PMC may require which are severely to be removed and repainted.

31.9.9 ON-SITE WELDING AREAS

The corrosion protection of areas next to on-site welds shall be finished with overlapping paint layers according to following sketch. Material and number of layers according to original paint system of the welded structures.



1 weld
2 base material
3 primer coat
4 to 6 intermediate and top coats (workshop)

Figure 31-1 Corrosion Protection Next to On-Site Welds

31.9.10 HOT DIP GALVANIZING

Unless otherwise specified, all structural steel including ladders, platforms, hand rails shall be hot dip galvanized according to EN ISO 1461.

The corrosion protection of bolts is specified in Section **Ошибка! Источник ссылки не найден.**. The minimum coating thickness shall correspond to the requirements of EN ISO 1461.

31.9.10.1 Cleaning

All material to be galvanized shall be cleaned carefully of rust, loose scale, dirt, oil, grease, and other foreign matters. Particular care shall be taken to clean slag from welded areas.

31.9.10.2 Straightening after Galvanizing

All plates and shapes which have been warped by the galvanizing process shall be straightened by being re-rolled or pressed. The material shall not be hammered or otherwise straightened in a manner that will injure the protective coating. Materials that have been harmfully bent or warped in the process of fabrication or galvanizing shall be rejected.

31.9.10.3 Repair of Galvanizing

Material on which galvanizing has been damaged shall be re-dipped unless the damage is local and can be repaired by soldering or by applying a galvanizing repair compound; in this case, the compound shall be applied in accordance with the manufacturer's instructions.

31.9.10.4 Protection of Machined Surfaces

Machine-finished surfaces shall be thoroughly cleaned of foreign matter. The surfaces shall be protected by suitable products (e.g. Tectyl).

Finished surfaces of large parts and other surfaces shall be protected with wooden pads or other suitable means. Unassembled pins or bolts shall be oiled or greased and wrapped with moisture-resistant paper or protected by other approved means.

31.9.10.5 Rounding, Chamfers, Edges

The edges of surfaces to be painted shall be rounded (minimum radius 2 mm) or chamfered accordingly. This requirement must be stated in all shop drawings for the relevant parts.

31.9.11 GUARANTEE

The guarantee period for all painting shall be as mentioned against their painting systems, starting from the issue of the "Taking- Over Certificate". This painting guarantee period shall be effective regardless of any other guarantee periods for the project or parts of the project.

At the end of the painting guarantee period the anti-corrosive protection of the painted or galvanized surfaces shall not have a degree of rusting higher than RE 0 (Zero) according to DIN EN ISO 4628.

Duration of protection “high durability” and Corrosiveness Category C4 according to EN ISO 12944.

31.10 PACKING, DELIVERY & STORAGE

31.10.1 PACKING

Each shipment or package of the equipment shall be seaworthy and shall be suitable for the inland transportation from the port of Destination to the Site.

Each crate or package shall contain a packing list in a waterproof envelope and a copy in triplicate shall be forwarded to the PMC prior to delivery. All items of material shall be clearly marked for easy identification against the packing list.

All cases, packages, etc., shall be clearly marked on the outside to indicate the total weight, to show where the weight is bearing and the correct position of the slings and shall bear an identification mark relating them to the appropriate shipping documents.

Cases which cannot be marked as above shall have metal tags with the necessary marking on them. The metal tags shall be securely attached to the package with strong steel wire or equivalent.

The PMC shall reserve the right to inspect the packing before delivery to the Site. The Contractor shall be entirely responsible for ensuring that the packing is suitable for transit and such inspection will not relieve the Contractor from responsibility for any loss or damage due to faulty packing.

All packing materials shall remain the property of the Contractor and shall be removed from the Site at the earliest opportunity and be disposed at the places/areas which shall be instructed by the PMC.

The shipping mark shall consist of the following information in-sequence and in frame commensurate with the size of package:

1. Consignee :
2. Project Name :
3. Contract No. :
4. Port Destination :
5. Item number, if applicable :

Package number in sequence and qty per package

1. Description of contents :
2. Net & gross weight :
3. Cubic measurement :

31.10.2 Delivery

The Contractor shall deliver all Equipment provided under the Contract to the Site in adequate time for its preparation and erection according to the approved Work Programme.

The coordination of shipment is in the full responsibility of the Contractor. The Contractor shall be responsible for all clarifications and studies related to the transportation of oversize shipments. The Contractor shall also be responsible for obtaining from the local railway or highway authorities any permit that may be required for the transport of loads exceeding the normal sizes and weights.

No major part of the Equipment shall be delivered to the Site until conducting successful FAT and getting approval from the PMC for such deliveries.

Notification of such delivery shall be given to the PMC in writing not later than thirty (30) days prior to the scheduled shipping date for any equipment to be shipped.

The Contractor shall notify the PMC about shipments not later than thirty (30) days prior to shipment. Each notification shall include a complete shipping list of the contents of each package to be delivered and shall indicate the expected date of delivery and the serial number for each component to be used for identification and copies of the insurance policy arranged for it.

The Contractor shall be responsible for the unloading and reception at the Site of all deliveries for the purpose of the Contract.

The Contractor shall at his responsibility inspect the cargoes at the Site upon arrival of the cargoes and shall report in writing the particulars, quantities, conditions, damages, if any, of the cargoes to the PMC within three (3) days after arrival.

31.10.3 Storage at Site

All the Equipment shall be stored and maintained by the Contractor at Site.

The Contractor shall be responsible for all routine maintenance i.e., lubricating, inspection and adjusting of all Equipment, until the issuance of the Taking-Over Certificate. Any storage facilities required for the Equipment, including maintenance thereof, shall be arranged by the Contractor at his own cost and expense.

The Contractor shall arrange at his own expense for covered storage or other protection of all materials and equipment against corrosion and mechanical damage for short and prolonged storage as directed by the PMC. Any corrosion or damage that may occur to any time of the Equipment shall be made good before that item of the Equipment is to be installed.

The Contractor shall provide all drainage and weather protection for storage of the Equipment to meet the requirements of the PMC.

The minimum requirement is that all items shall rest on wooden blocks which elevate the base at least 150 mm above floor or ground level. No items shall rest on the floor or ground directly.

All machined surfaces and surfaces with corrosion protection coating shall be protected by adequate measures. Piling and stacking of these parts on each other without adequate protection is strictly prohibited.

Equipment provided with corrosion coating shall be protected from sun exposure.

Rubber parts shall be protected against light and air. Moisture absorbent crystals shall be included with all items enclosed in plastic or other impervious material.

All cases containing important machinery and electrical parts shall be placed in the air-conditioned building, or as directed by the PMC.

Weatherproof items and structural steel members may be stored in the open, but in all instances shall be protected. The Contractor shall be responsible for the adequacy of all protection.

If large (mechanical) parts are stored in the open air, they shall be provided with weather resistant and fire-resistant covers. Electrical parts which are not packed in heavy duty polyethylene foil and those so packed but whose packing has been damaged shall be kept in suitable indoor places from the moment of storage up to the starting of installation.

All packing material, except that required for storage of spare parts, shall remain the property of the Contractor and shall be removed from the Site. Only parts for immediate use shall be delivered from the works storage area, and their packing material shall be removed quickly from the installation site and disposed of to the satisfaction of the PMC.

31.11 INSTALLATION WORKS

The work shall be done in accordance with the approved method statements, instructions, and the procedure and requirements for levelling, alignment, and the tolerances required in the placing of parts.

31.11.1 INSTALLATION OF GATES

The gates shall be erected in accordance with the details as shown on the approved manufacturer's drawings and in accordance with the approved installation instructions. All joints shall be checked for water tightness.

The bottom of the gates shall be erected in true alignment to ensure proper bearing of the rubber seals on the embedded sill beams. The sides of the gates shall be in true alignment so that the rubber/metallic seals when installed shall have proper bearing on the embedded side sealing surfaces. The rubber seals shall be installed after the gates have been painted. The metallic seals shall be machined after fixing in the workshop for true alignment with their sealing surfaces.

31.11.2 INSTALLATION OF EMBEDDED PARTS

Each set of 1st and 2nd stage embedded parts (welding pads, steel lining, frames, bearing plates, track plates, pressure rails, seal plates, guides, and related appurtenances) shall be assembled in their blockouts, brought to line and grade within the specified tolerances mentioned on the approved drawings, and firmly secured in place on the alignment bolts. The alignment bolts shall be located with care so that there is no bending or forcing of bolts required to match them with the corresponding bolt holes in the embedded members. The bolts shall then be welded to the embedded pads. Alignment bolts shall be adjusted and torqued adequately to hold the parts securely in position while concrete is being placed. Additional bracing shall be provided where necessary to assure the required alignment.

Extreme care shall be taken to ensure that the guiding, bearing, and sealing surfaces are within the tolerances indicated on the approved drawings and/or installation instructions throughout their entire length.

The 2nd stage concrete shall not proceed until the frames and guides have been completely assembled, cleaned of dirt, aligned, and secured within required tolerances throughout the height of the openings. Use of the gate as a support or brace for the guides during placement of concrete shall not be permitted. The concrete shall be placed with care to avoid distortion and displacement of the steel lining, frames and guides. Before and after each lift of concrete placement, alignment tolerances shall be checked and remedial action shall be taken if displacement has occurred. Suitable windows shall be provided in the concrete forms to facilitate placement and inspection. After all blockout concrete has been placed and forms removed, the blockout concrete shall be inspected and the embedded parts shall be sounded by hammering to detect any voids. All voids

shall be filled by pressure grouting. Grout holes shall not be drilled in the sealing or bearing surfaces.

31.11.3 INSTALLATION OF HYDRAULIC HOISTS

Each hydraulic hoist, complete with hydraulic power units, piping systems, controls and all accessories, shall be assembled and installed in accordance with the manufacturer's installation drawings and instructions approved by the PMC. The hoist cylinders shall be located and adjusted so that they are in true alignment with the gate and shall be installed with great care to avoid contamination of the hydraulic system. Special care shall be taken to protect the cylinder piston rod against mechanical damage, including light scuffing and scratching. The whole hydraulic system shall be thoroughly flushed with an approved flushing fluid, compatible with the system operation hydraulic oil before the hydraulic oil is placed in the system. Flushing fluids shall be circulated through a filtration system. Flushing operations shall be in accordance with the procedures and acceptance standards and, in addition, to the satisfaction of the PMC and manufacturer's supervising erectors. Hydraulic oil placed in the system shall first be filtered through a filter press.

31.11.4 INSTALLATION OF ROPE & DRUM TYPE HOIST

Each wire rope hoist, complete with all accessories, shall be assembled and installed in accordance with the manufacturer's drawings and instructions approved by the PMC. Special care shall be taken to protect all components, including wire ropes, gearboxes, brakes, electric motors and controls etc. from the humidity and other adverse environmental effects. The couplings shall be tightened properly and the transmission shafts shall be in true alignment to avoid un-due deflection during operation of the hoist. Wire rope assemblies shall be adjustable type to provide equal lifting forces on each side of the gate/bulkhead. Wire ropes and sheave and drum grooves shall be cleaned and lubricated before field testing.

31.11.5 INSTALLATION OF BRIDGE & GANTRY CRANES

The rails and the cranes shall be assembled, erected, and tested as directed by and in the presence of the crane manufacturer's Supervising Erector or Test Engineer. All equipment shall be assembled and installed in accordance with the applicable approved drawings, approved written instructions and applicable codes, standards, and specifications. The Contractor shall be responsible for full coordination of works. The installation tolerances shall be as per applicable Standards and as shown on approved installation drawings.

31.11.6 INSTALLATION OF THE STEEL LINING

The installation of the steel liner including the site storage at the field shop, transport to the work spot, installation, erection, welding, inspection & tests shall be carried out in the accordance with the approved drawings and installation procedures.

The Contractor shall provide construction electricity supply, dollies, handling equipment, temporary winches, welding machines, air compressors and all other equipment required to install the steel liner according to the approved Contractor's plan, method and schedule.

The railing system with fitting and bolting materials for the Contractor's installation dollies shall in principle be provided in the tunnels by the Contractor to install the steel liner.

31.12 QA/QC PROGRAMME

The parts and components produced and the services provided in fulfilling the requirements of the Contract shall be performed in accordance with a Quality Assurance Program to be established by the Contractor. This Contractor's Quality Assurance Program shall be documented in sufficient detail to assure the PMC that the Contract requirements will be met during the design, procurement, manufacture, assembly, delivery, erection, installation, construction and test of all materials and components of the Works. The Contractor's Quality Assurance Program, as a minimum, shall provide the implementing details as given hereinafter.

Inspection activities shall be performed by qualified independent individuals.

31.12.1 QUALITY PLAN

Quality Plan prepared by the Contractor with reference to his Quality Assurance Manual and as per ISO Standard shall be submitted to the PMC. This plan will reflect the know-how of the Contractor as well as the requirements of the Contract. Contractor's Quality plan shall include, but not be limited to, detailed procedures, instructions, or statement covering the followings

31.12.1.1 Organization and Procedures

The Quality Plan shall describe Contractor's Quality Assurance organization and delineate the responsibility and authority of the various personnel and groups involved. The Quality Assurance Department's relationship with other departments shall be defined and their independence of engineering, construction, cost, and scheduling shall be stated. An organizational chart shall be included with lines of authority and communication.

31.12.1.2 Procurement Control

The Contractor's procurement process shall assure that purchased items, whether purchased directly or through his sub-suppliers comply with the Specification. This assurance shall be provided by the inclusion of the quality requirements into the Contractor's procurement documents and adequate inspection of the material at its source or upon receipt.

Prior to procurement of major parts of the equipment or critical items such as base material, hydraulic power units, hydraulic cylinders, cranes, drives, etc., the Contractor shall furnish to the PMC, a list of Sub-Contractors and vendors suppliers with whom orders are to be placed for materials and equipment which will be incorporated directly into the Works. The Contractor shall also furnish such pertinent information as to capacities, efficiencies and sizes, and such other information as may be required by the PMC.

31.12.1.3 Inspection and Test Programme

The Contractor shall elaborate and submit for approval an inspection and test program for each equipment including the testing of materials.

Specific requirements are provided in the Special Technical Specification.

31.12.1.4 Material Control

The Quality Plan shall provide assurance that procured and subsequently processed material meets the Specification requirements. Material identification shall be provided and maintained throughout the manufacturing cycle. Controls shall be provided for the documentation and disposition of non-conforming material, parts or components, and their subsequent rework or repair and re-inspection.

Specific requirements are provided in the Special Technical Specification.

31.12.1.5 Special Processes

Special Processes such as welding, soldering, brazing, heat treatment, cleaning, non-destructive examination, etc., shall be performed in accordance with documented process procedures and by quality personnel. The procedure shall describe the process sequence and methods, process pre- requisites, equipment, qualification of personnel and equipment, and acceptance criteria. The procedures shall also describe the preparation and retention of documents used to record the results of special processes.

31.12.1.6 Non-Destructive Testing

Non-destructive examination shall be performed in accordance with documented process procedures and by quality personnel. The procedure shall describe the process sequence and methods, process pre- requisites, equipment, qualification of personnel and equipment, and acceptance criteria. The procedures shall also describe the preparation and retention of documents used to record the results of special processes.

Specific requirements are provided in Sections **Ошибка! Источник ссылки не найден.** and 31.13.5 of the this Specification and in the Special Technical Specification.

NDT personnel shall be qualified and certified in accordance with the current edition EN ISO 9712 (or SNT-TC-IA).

31.12.1.7 Calibration

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

devices shall be documented and shall be performed using certified measurement Standards.

31.12.1.8 Level of Criticality and Control

The level of quality control shall be adjusted to the importance of the equipment in terms of cost of repairs, personnel safety and loss of production as applicable. In respect of inspection and approval, the levels of criticality of the equipment and phases of construction will be divided into three categories as follows:

1. Type R (R for Record): The Contractor shall send to the PMC the record of the tests or inspections. This generally applies to items whose failure would have no effect on production, personnel, ecology or environment. Replacement of equipment or spare parts would be readily available and treated as routine maintenance.
2. Type I (I for Invitation): The PMC shall be invited to be present during the tests or inspection and the PMC will decide whether to assist in the tests and to inspect the works or not. If the PMC decides not to be present, the works will go on.
3. Type S (S for Stop): The works (manufacturing, erection, placing, construction, testing) shall be stopped and the work shall be resumed only after the PMC has given his approval. This generally applies to those items whose operability and reliability is vital for operation. Shutdown due to malfunction or failure of one of these items would result in loss of production and/or replacement costs, or pose potential hazard to personnel safety, and could cause damage to the environment.

31.12.1.9 Documentation

The Quality Plan shall include a system to ensure that the documentation necessary to attest the completion of fabrication, erection, and installation, use of correct material; completion of required inspections and tests and acceptability of results are generated, reviewed, maintained and turned over to the PMC 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

Documentation to be submitted to the Employer and the PMC, generated and maintained during manufacturing and site works period as applicable, shall include at least:

1. Raw material test report (mechanical, chemical, radioscopic, etc.) as per Standards. In the case of materials for which such practice is usual, the PMC may accept the manufacturer's certified mill and laboratory certificate
2. Inspection and test procedures
3. Weld and weld repair procedure
4. Surface treatment, painting procedures inspection, quality checks, thickness measurement record
5. Dimensional inspection report

6. Inspection and test reports

If a demonstrable satisfactory service record is available for a material, certain specified tests may be waived by the PMC.

In the case of Standard labeled stock products which have a record of satisfactory performance in similar works over a period of not less than 2 years, the PMC may accept a statement from the Manufacturer attested by a certified laboratory certifying that the product conforms to the applicable specifications

7. Vendor surveillance reports
8. Packing and shipping procedure
9. Certificate of compliance

31.12.2 NON-CONFORMITIES

During manufacture and site works, after each assessment or measurement of quality, cases of non-conformity, identified either by the Contractor's quality control supervisors or by the personnel in charge of execution or by the PMC, will be divided into four categories:

1. NC.1-Minor defects which shall be repaired immediately, then recorded on standard follow-up documents.
2. NC.2-Defects which can be repaired according to a pre-established procedure. The repairs shall be carried out immediately and recorded on special documents.
3. NC.3-Defects which cannot be repaired according to a pre-established procedure. The decision to repair, modify or rebuild or remanufacture the item shall be proposed by the Contractor for the PMC's approval.
4. NC.4-Main defects on critical items. The Contractor shall propose a solution to the PMC. Then the PMC, after due consultation, will notify the Contractor the final decision. Non-conformities shall be recorded and shall be part of the final documentation.

31.12.3 PROCEDURES OF COMMUNICATION

Procedures of communications between the Contractor, the PMC and the Employer will be established by the PMC. As a rule, any documents issued by the Contractor including letters, various Reports, Notes, etc. shall be addressed to the PMC with copies sent simultaneously and directly by the Contractor to the Employer and when applicable to Representatives on site. Particular procedure will be established for communications on site.

31.13 TESTS & INSPECTIONS

31.13.1 GENERAL

All equipment, including all materials, components, apparatus, etc. specified in these Specifications while in the process of procurement, manufacturing and during installation and commissioning shall be subjected to such tests and inspections as required by these Technical Specifications, pertinent standards, as may be the standard practice of the manufacturer and as deemed necessary by the PMC to prove compliance with the requirements of these Specifications.

The Contractor shall prepare an inspection and test program including all tests during and after manufacture (except for stock material) which shall form part of the Contract and which shall describe the inspections and tests for each major component and item. The program shall include a sufficiently detailed manufacturing schedule with all expected dates of inspections and tests, a description of each inspection or test (including the test method) to be performed and the applicable standards.

The inspection and test program and the related schedule shall be up-dated by the Contractor at two-month intervals with clear indication of revised inspection and test dates of each structure.

The Contractor shall convene shop inspections, and factory acceptance tests, at a suitable schedule, mutually agreed to with the PMC, in its manufacturing workshops and equipment supplier's factories.

The Contractor shall be responsible for the execution of all inspections and tests.

The equipment shall be manufactured in such a sequence that each lot could be inspected during its material procurement, manufacturing and assembly in the workshop before its shipment.

The Contractor shall notify the PMC and the Employer in writing, prior to any shop assembly or test, a minimum of four (4) weeks in advance for out of Uzbekistan shops inspections or one (1) week in advance for domestic (Uzbekistan) shops inspections. The Contractor shall also arrange random shop inspections of the PMC as requested during all major fabrication works.

Free and unrestricted access to the Contractor's factory and shops (including those of his Subcontractors) shall be granted to the Employer upon reasonable notice at all times.

The Contractor shall pay all costs relating to the PMC's and Employer's staff's participation in all shop inspections and factory acceptance tests (at-least 2 persons per visit for HM inspections except random short visits) and up to 3 persons per visit for the hydraulic model testing) and will be reimbursed for all round-trip air fare charges, all staying and living charges as well as domestic travel charges and personnel expenses at a rate equivalent to US Dollars two hundred (US$ 200) per day a person for foreign inspections. The direct cost shall cover the actual costs of such airfares, any medical

and its associated hospitalization charges etc. and per diems, substantiated by invoices or other documentation acceptable to the Employer as per actual. The per diem for such trips shall include all staying and travel time both ways. In case of any delay from the Employer's staff in timely participating the inspections due to Visa process, the Contractor shall arrange a subsequent visit for the same inspection; however, without delaying the manufacturing and the shipment schedule for that lot.

In case the PMC/Employer could not timely visit the workshop for inspections, as an alternative and last choice, the PMC may direct the Contractor to hire reputed third parties for these inspections at the manufacturer's workshop. In this case, the Contractor will submit names and profiles of three internationally reputed third-party companies for review and approval of the PMC. All the expenses of third-party inspections shall be borne by the Contractor. However, in such cases, keeping in view the criticality of the equipment, the PMC reserves the right for the inspection of that equipment.

Approval of assemblies, tests, inspections, related procedures, etc. shall in no way relieve the Contractor of his contractual obligations for furnishing the Works in accordance with the provisions of these Specifications.

Should an agreed inspection not be feasible as proposed due to lack of preparation, negligence or material and/or equipment being presented in a state which is clearly not acceptable, all costs incurred for the PMC/Employer for repeated inspections shall be fully borne by the Contractor.

31.13.2 TEST CERTIFICATES

Test records, test certificates, performance curves, tables, etc. of all inspections and tests, whether or not attended by the PMC / Employer, shall be supplied as soon as practicable after performance of each inspection or test. After completion of all testing, the above-mentioned documents shall be supplied properly bound in books.

All test certificates shall be endorsed with sufficient information for identification of the equipment and material to which the certificates refer. In addition, the following references shall be entered in the top right-hand corner:

1. Employer's name
2. Project name
3. Equipment designation
4. Related Contractor's drawings (No.)
5. Date of test
6. Certificate issue date

31.13.3 MATERIAL TESTS

For all materials, which are of significance for the structural integrity and the performance of the constructions, acceptance certificates according to EN 10204, shall be issued.

Material test shall be of type 3.1 as a minimum requirement, for critical parts as per PTS type 3.2 certificates are required.

31.13.4 RANDOM SAMPLE TESTS

Random tests shall be carried out on random samples of a lot of equipment, parts or material. Selection of samples to be tested shall be done by the PMC and all the equipment, parts, etc. shall be presented for this purpose. The number of samples taken shall be either at the discretion of the PMC, particularly for smaller lots, or shall conform to the generally accepted rules and standards of statistical testing.

Should a single sample fail during random sample testing then the following shall apply:

1. Small lots: all pieces shall be fully tested

Large lots: a second set of samples, identical in number with the first one, shall be chosen and tested.

If this set passes all tests satisfactorily, the lot shall be considered to be acceptable. If again one or more samples fail in one or more tests either the whole lot shall be rejected or all pieces of the lot shall be fully tested individually, as determined by the PMC.

Pieces of lots which have been declared unacceptable and samples which have failed in test shall be marked immediately and shall not be presented for test again.

31.13.5 NON-DESTRUCTIVE TESTING

Ultrasonic, radiographic, magnetic particle or liquid penetrating tests shall be conducted on components as appropriate or directed by the PMC. All flaws shall be removed by thermal or mechanical gauging processes and replaced by welding. The replacement weld and contiguous parts of the original weld if any shall then be tested by UT and radiographic method. All radiographs shall become the property of the Employer.

Specific requirements on non-destructive testing are provided in the Special Technical Specification.

31.13.6 TESTS AT MANUFACTURER'S WORKS

31.13.6.1 General

Before any material, equipment, apparatus, component etc. is packed or dispatched from the Contractor's or his Subcontractor's works all tests, inspections, checks, examinations, etc. required by pertinent and internationally accepted standards, rules or codes shall be carried out as far as practicable and agreed in same parties' premises.

All materials, apparatus and other parts or components of the equipment to be tested, inspected, checked, examined, etc. at the Contractor's or his Subcontractor's works shall be made properly accessible for testing and inspection work. There shall be no

interference or disturbance from other shop activities when conducting checks, tests and inspections.

All equipment, materials, apparatus and other parts or components shall be adequately sheltered and protected against the weather whilst being tested, inspected, checked and examined.

31.13.6.2 Dimensional Checks and Visual Inspection

Dimensional checks shall be performed on all major equipment/parts, components and partial assemblies, especially when close tolerances and fits are involved.

The Contractor shall prepare measurement drawings which indicate all relevant dimensions and allowable tolerances.

If the dimensional checks show discrepancies in measurements which may affect the fit, assembly or dismantling of the various parts or components, the same shall be corrected accordingly.

Such correction or modification shall, however, in no way lead to sacrifices with respect to reliability of operation or inter-changeability, and shall be performed only after the agreement of the PMC has been obtained. If the correction of modification cannot be carried out in accordance with the terms mentioned above, the part or component concerned may be subject to rejection.

31.13.6.3 Shop Assembly

The gates, embedded parts / frames etc. shall be assembled in the manufacturer's workshop. All parts shall be correctly doweled and match marked to facilitate assembly at site.

31.13.6.4 Corrosion Protection Checks

The corrosion protection work shall be checked by the PMC. The checks shall include:

1. surface preparation
2. thickness and adhesion of coats
3. quality check of the materials applied.

The thickness of the coats shall be adequately checked. For the acceptance, the guaranteed thickness of the coating shall be decisive.

31.13.6.5 Hydrostatic Pressure Test

Parts subject to internal pressure shall be hydrostatic pressure tested as far as practical and appropriate. This applies to water piping and valves as well as to pressurized oil and air systems. The costs of these tests shall be borne by the Contractor.

31.13.6.6 Performance Tests of Lifting Devices

Requirements are provided in Section 7.

31.13.7 PERFORMANCE TESTS AFTER COMPLETION

The tests enumerated hereafter are subdivided in dry tests and operation and performance tests. They shall be performed by the Contractor's personnel under presence of the PMC/Employer.

31.13.7.1 Dry Tests

After conclusion of the erection, tests and inspections without water shall take place as mandatory requirement during which all operations shall be tested, as far as they can be performed without water. The following points shall be especially reported:

1. Unconstrained running of all machined rotating and sliding parts;
2. Free/maintained space between moving and fixed parts;
3. Existence and operating conditions of all lubrications (if any);
4. Prestressing of bolts;
5. Working of valves, and other mechanical devices;
6. Lifting and lowering speed;
7. Oil pressure curve of the hydraulic drive over the entire range of lifting and lowering;
8. Electrical control of correct wiring and cabling of all control, alarm and auxiliary power circuits;
9. Measurement of the heating at critical transmission parts (gears, bearings, etc.);
10. Vibrations and noise of drives, bearings;
11. Switching and signalling operation;
12. Measurement of the gap between seal and seat
13. Any other tests

The Contractor shall record the results in a detailed report to the PMC. If the inspections and tests did not show a satisfactory result, the delivery must be improved or imperfections corrected until all requirements are fulfilled.

31.13.7.2 Operations and Performance Tests

Following the conclusion of the preliminary tests, operation and performance tests shall be carried out. Aspects to be checked are in particular but not limited to the following:

1. Oil pressure curve of the hydraulic drive over the entire range of lifting and lowering;
2. Measurement of the heating at critical transmission parts;

3. Vibrations of drive, gate, valves, bearings and other structures;
4. Seal leakages
5. Trial of operating conditions of the gates and hoists, including closure under flow at the normal and emergency lowering speed;
6. Lifting and lowering speeds

The Contractor shall be responsible for providing all facilities required. The Contractor shall prepare a testing program, subject to approval of the PMC.

The PMC shall issue the Taking Over Certificate after the tests have proven the readiness for service or the structures have been improved as necessary.

31.13.7.3 Inspections and Tests at the End the Defect Liability Period

Before the expiry of the Defect Liability Period the equipment shall undergo testing and joint inspection by the PMC / Employer and the Contractor to recheck its correct performance.

31.14 TRAINING AT SITE

The Contractor shall give thorough local training on the operation and maintenance of all works supplied by him to the staff appointed by the Employer for operation and maintenance of the supply. The training shall be divided into two main parts, one during the erection period and the other during the commissioning period, and the understanding and practical use of the maintenance manuals and instructions shall be a part of the training.

Such training shall be organized by the Contractor under the supervision of the PMC and shall be performed by qualified, English-speaking personnel. It shall take place prior to and during the Commissioning Period of the supply item.

The training program shall be elaborated by the Contractor and shall be subject to the PMC's approval. The total training time shall not be less than 6 weeks.

The O&M Manuals shall be available min. 6 weeks prior to the start of training. In addition, the Contractor shall prepare dedicated training documents e.g. presentations for the training in English language. These documents shall be available min. 4 weeks before the training.

The staff appointed for training purpose will come in addition to the unskilled labor provided by the Employer.