

# **ELECTRICITY GENERATING AUTHORITY OF THAILAND**



**INVITATION FOR BIDS NO. EGAT 8/2568-LTK2-H1**

**LAMTAKONG HYDROPOWER PROJECT**

**VOLUME III**

**TECHNICAL SPECIFICATIONS - CIVIL WORKS**

# **ELECTRICITY GENERATING AUTHORITY OF THAILAND**

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**GENERAL REQUIREMENTS**

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## **PART 1 GENERAL REQUIREMENTS**

### **1.1 GENERAL**

The Contractor shall design, procure and construct the powerhouse, appurtenant structures and related Civil Works as shown on the Drawings and/or as described in details in this Volume. Also the Contractor must take into account the Equipment Works in Volume II.

In event of discrepancies or conflicts among the EGAT's Bid Documents in Volume III, the Part with less number shall govern. For instance, Part 1 shall prevail over Part 2 or 3, except as and only to the extent determined or agreed to be otherwise by the Engineer.

### **1.2 SITE INFORMATION**

Lamtakong Hydropower Project (LTK2-H1) is located on the downstream side of Lamtakong dam at Ban Klong Phai, Lat Bua Khao sub-district, Sikhio districtis, in Nakhon Ratchasima province, Thailand. The distance by road from Bangkok to Site is approximately 203 km. and 23 km. from Muang district, Nakhon Ratchasima province. The routes from Bangkok are highway No.01 (Phaholyothin) and No.02 (Mittraphap). The site location of Lamtakong Hydropower Project is shown on the Drawings, Volume IV.

### **1.3 FACILITY ARRANGEMENT**

General arrangement and layout of the powerhouse, appurtenant structures and vicinity are shown on the Drawings. The arrangement and layout are considered to be preliminary, and they are only intent to define the EGAT's basic equipment layout requirements in which shall be conformed to by the Contractor. The Contractor is required to finalize powerhouse, and related structure arrangement for the supplied equipment under this Contract. The Contractor shall incorporate the EGAT's arrangement requirements specified herein and submit it for the Engineer review and approval.

### **1.4 DESIGN CRITERIA**

#### **1.4.1 General**

The powerhouse and related structures shall be designed with provision for good maintenance access service and for ease of maintenance. All routine maintenance shall be achievable from permanent work platforms with suitable access and safety devices.

##### **1.4.1.1 Safety of Construction**

##### **a) Safety of Public**

Where the Public could be exposed to danger by any of the Site activities, the Contractor shall provide appropriate flagmen, barriers and/or warning signs in English and/or Thai, all to the approval of the Engineer.

Where shown on the Drawings or instructed by the Engineer, the Contractor shall provide alternative safe access routes together with viewpoints and suitable parking areas with adequate shelter and toilet facilities.

The important consideration in the construction of the project's components are to ensure the construction, excavation and the dumping area for excavated materials shall not adversely affect to the vicinity area. The Contractor shall prepare the safety plan and the mitigation measures for construction.

#### **b) Safety of Personnel**

The Contractor shall responsible for the safety of all personnel on the site and shall provide his employees and his subcontractors employees working on the site with personal protective equipment (PPE) appropriate to the tasks upon which they are engaged, including helmets, high visibility vests or jackets, safety footwear and where required, gloves, lamps, dust masks and/or safety belts. The use of such safety equipment shall be compulsory, as deemed necessary the standards or otherwise directed by EGAT.

Personnel working on steep slope or otherwise subject to possible falls from levels not protected by fixed guardrail or safety nets, shall be secured by the safety belts and lifelines.

For the drilling work activities where the personnel are exposed to harmful noise levels and dust, ear protectors and masks shall be furnished and required to wear.

#### **c) Storage and Use of Explosives (Not applicable)**

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

Explosives shall be stored, transported, handled and used in accordance with the best practice as approved by the Engineer and in accordance with the provision of the law. The contractor shall comply with all special rules and regulation that may be made by the authorities having jurisdiction, and the requirements of the Engineer regarding construction and storage in magazines, precautions on blasting and the like. The Contractor will indemnify the Employer against all claims for damage caused by blasting.

Explosives and detonators shall not be transported in the same vehicle.

Explosives shall be stored in suitable magazines in approved location. Detonators shall be kept in a separate magazine. The magazine shall be plainly marked with large letters EXPLOSIVES-DANGEROUS in English, Thai and any other relevant languages, and shall be locked and guarded at all times. Keys to unlock the magazines shall be kept only by magazine keepers. Each magazine shall have around it a cleared area suitably barricaded with a security fence.

Each magazine keeper shall be competent, trustworthy, and familiar with the handling, transportation, care, and storage of explosive and detonators, and shall be responsible for maintaining the cleared area around the magazine. No magazine keeper shall be allowed to work more than ten hours in any twenty-four-hour period and shall not be required or allowed to perform any other duty that will interfere with his duties as a magazine keeper.



**d) Warning of Blasting (Not applicable)**

The Contractor shall install and operate a siren of sufficient volume to be easily heard above the general site noise from all points within a radius of 1.0 km of surface blasts.

Hand operated sirens will only be accepted in areas of restricted access such as tunnel headings where access is fully controlled.

The Contractor shall submit details of his blasting procedures to the Engineer for consent and shall ensure that such procedures are adhered to at all times.

**e) Lightning**

The Contractor shall take precautions against lightning with regard to earthing of metalwork and conductors on the Site. The lightning protection system ground terminals shall be bonded to the building or structure grounding electrode system.

**1.4.1.2 Design Earthquake**

The effects of earthquake shall be considered in design.

**1.4.1.3 Dewatering Requirements**

The Contractor shall design dewatering systems and shall furnish, install, maintain and operate all necessary pumping, piping, gutter and other equipment and temporary structures for dewatering. The powerhouse and related structures shall be free from water during construction and, as required, for inspection, safety and installations by other contractors or the Engineer or, it directed, after any part of structures are completed.

Subsurface joints are expected to be essentially watertight. Intersected clay bands in or above the excavation may produce some quantities of water. In such condition, an appropriate dewatering approach shall be applied.

**1.4.1.4 Cofferdam Requirement**

For excavation and construction of the powerhouse and its tailrace channel, a cofferdam may be constructed as necessary to keep the working area dry but it shall not, at any time, obstruct the irrigation operation of Royal Irrigation Department (RID).

On completion of the construction, cofferdam shall be removed to give a slightly appearance, and so as not to interface in any way with the operation or usefulness of the powerhouse and appurtenant structures. Additionally, the Contractor shall be responsible for any damage of the powerhouse included appurtenant structures and RID's existing structures caused by the removal of the cofferdam.

For construction and removal of the cofferdam, the Contractor shall adopt prevention measure to prevent the dispersion of turbidity of natural channel.

#### **1.4.1.5 Temporary Water Supply System**

During installation of penstock and wye branch, the Contractor shall arrange of the existing pressure conduit dewatering and shall also arrange for the existing RID's outlet work temporary plug. The Contractor shall consider to prevent the excessive negative internal pressure developed from dewatering which may result in collapsing or buckling of the pressure conduit.

Temporary Water Supply System performed by the Contractor shall not cause any damages to the existing structures and shall not obstruct or interface water resource management controlled by RID.

On the completion of the work, the temporary plug shall be removed to give a well clear water way and so as not to interfere in any way with the operation of RID irrigation control outlet and powerhouse.

#### **1.4.1.6 Unit**

Unless otherwise indicated, the Metric Units shall be used for drawings and calculation.

### **1.4.2 Codes and Standards**

The entire powerhouse and appurtenant structures shall be designed in accordance with applicable industry codes, standards, and specifications. Design of the entire powerhouse and appurtenant structures shall also conform to requirements and recommendations of all applicable Thailand's Law and The Ministerial Regulations, Codes, and Standards pertaining to the design, construction, and operation of Hydro Power Plants.

The applicable date of codes and standards shall be that in effect as of the date of Notice to Proceed. The design, equipment and materials forming part of the Contract shall comply in all respects with all Applicable Laws and Applicable Permits currently in force.

It is the responsibility of the Contractor to obtain statutory approvals, producer statements, design reviews, construction reviews, design verifications, and other approvals required by Thailand law.

To ensure compliance with Codes and Standards, the Contractor shall have all civil design ratified by Thai Registered Charter Engineer with adequate competence in the design being ratified.

The following list of Codes and Standards is not complete and does not relieve the Contractor from complying with any other requirements and regulations applicable to the entire spillway, powerhouse and embankment dam. DIN and JIS standard codes are acceptable, other international codes and standards are acceptable upon prior approval by EGAT. Additional codes and standards may be referenced throughout this specification.

The translation of codes and standards into English or Thai is necessary for the other languages apart from English or Thai.

### Civil Design Codes and Standards

- Specifications for materials will generally follow the standard specifications of the American Society for Testing and Materials (ASTM), the American National Standards Institute (ANSI), and the Thai Industrial Standards (TIS).
- Field and laboratory testing procedures for materials will follow standard ASTM specifications and the American Society for Non-destructive Testing (ASNT).
- Design and placement of structural concrete will follow the recommended practices of the American Concrete Institute Code (ACI), the Concrete Reinforcing Steel Institute (CRSI), and the Engineering Institute of Thailand under H.M. the King's Patronage (EIT). If not specified, the latest version of these codes and standards shall be used.
- Design fabrication and erection of structural steel will follow the recommended practices and the latest version of the American Institute of Steel Construction Code (AISC).
- Steel components for metal wall panels and roof decking will conform to the American Iron and Steel Institute (AISI) Specification for the Design of Light Gage Cold-Formed Structural Members.
- Welding procedures and qualifications for welders will follow the recommended practices and codes of the American Welding Society (AWS).
- Preparation of metal surfaces for coating systems will follow the specifications and standard practices of the Steel Structures Painting Council (SSPC), National Association for Corrosion Engineers (NACE) and the specific instructions of the coatings manufacturer.
- Fabrication and erection of grating will follow applicable standards of the National Association of Architectural Metals Manufacturers (NAAMM).
- Design, fabrication, and erection of prestressed concrete members will follow the recommended practices of the latest version of the Precast/Prestressed Concrete Institute (PCI) manual for the structural design of architectural prestressed concrete panels.
- Design and erection of masonry materials of brick, concrete block, or structural tile will follow the recommended practices and codes of the latest revision of the ACI Concrete Masonry Structures Design and Construction Manual.
- Plumbing will conform to the National Plumbing Code and EIT.
- Design will conform to the requirements of the Occupational Safety and Health Administration (OSHA).
- Design of roof coverings will conform to the requirements of the National Fire Protection Association (NFPA) and Factory Mutual (FM). In addition, fire doors and windows and other building construction features will follow the recommended practices and codes of NFPA, where applicable.
- Roadway design will conform to the requirements of the American Association of State Highway and Transportation Officials (AASHTO).

- Precast and prestressed concrete beams and piles manufacturer and supply of piles will be in accordance with recommendations of the Portland Cement Association (PCA), the American Concrete Institute (ACI), and the Precast/Prestressed Concrete Institute (PCI). The ACI Committee 543, "Recommendations for Design, Manufacture and Installation of Concrete Piles" latest edition is available in the ACI Manual of Concrete Practice.
- Design, fabrication, and installation of elevators will follow standard specification and codes of safety code for elevators ASME/ANSI A17.1-87 and local accepted standards.
- UBC - Uniform Building Code.

#### 1.4.2.1 Abbreviations

Abbreviations used in this document have the following meaning:

<u>Abbreviation</u>	<u>Title</u>
AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASNT	American Society for Nondestructive Testing
ASTM	American Society for Testing and Materials
AWS	American Welding Society
AWWA	American Water Works Association
BS	British Standard Specification
CRSI	Concrete Reinforcing Steel Institute
DM7	Design Manual by Naval Facilities Engineering Command
DOH	Department of Highways, Ministry of Transport of Thailand
E.I.T.	Engineering Institute of Thailand under H.M. the King's Patronage
EM	Engineering Manual by Department of the Army, US Army Corps of Engineers
FM	Factory Mutual
JIS	Japanese Standard Specification
NAAMM	National Association of Architectural Metals Manufacturers
NACE	National Association for Corrosion Engineers
NEC	National Electric Code
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
PCA	Portland Cement Association
PCI	Precast/Prestressed Concrete Institute
SFS	Standard of Finland Specification
SSPC	Steel Structures Painting Council
TIS	Thai Industrial Standard by the Industrial Standard Board of Thailand
UBC	Uniform Building Code

### 1.4.2.2 Design

The specified or updated edition of the following codes and standards shall apply to all civil works design unless otherwise noted herein:

- a) Concrete
  - ACI 318-19 Building Code Requirements for Reinforced Concrete
  - E.I.T. 011007-19 Standard for Reinforced Concrete Buildings (Working Stress Design)
  - E.I.T. 011008-21 Standard for Reinforced Concrete Buildings (Strength Design Method)
  - E.I.T. 1009-34 Standard for Prestressed Concrete Buildings
  - EM 1110-2-2502 Retaining and Flood Walls
  - EM 1110-2-2104 Strength Design for Reinforced Concrete Hydraulic Structures
- b) Structural Steel
  - AISC ASD Manual of Steel Construction: Allowable Stress Design 9<sup>th</sup> Edition
  - AISC LRFD Manual of Steel Construction: Load and Resistance Factor Design
  - E.I.T. 1015-40 Standard for Hot-Rolled Structural Steel Buildings
  - E.I.T. 1024-53 Standard for Cold-Formed Structural Steel Buildings
  - The Ministerial Regulation No.48
  - The Ministerial Regulation No.60
- c) Plumbing and Wastewater Treatment
  - ANSI A 40.8 American Standard National Plumbing Code
  - E.I.T. 1004-16 Standard for Thai Plumbing
  - The Ministerial Regulation No.44
  - The Ministerial Regulation No.51
- d) Road and Bridge
  - AASHTO A Policy on Geometric Design of Highways and Streets
  - AASHTO Standard Specification for Highway Bridge
  - Standard for Highway Construction (DH.-S) by Department of Highways, Ministry of Transport and Communications, Thailand.

Method for asphalt pavement thickness design shall be The Asphalt Institute (1991), Group Index, McLeod Method and Road Note 29.

- e) Fire Protection
  - NFPA80 Standard for Fire Doors and Other Opening Protectives
  - NFPA101 Life Safety Code
  - NFPA 252 Standard Methods of Fire Tests of Door Assemblies
  - E.I.T.3002-51 Standard for Fire Protection
  - The Ministerial Regulation No.48, 60
  - The Industry Ministerial Promulgation

### 1.4.2.3 Materials

Materials shall be selected based on the latest edition of the ASTM, TIS, or equivalent, such as:

ASTM A 325	Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
ASTM A 497	Standard Specification for Steel Welded Wire Fabric, Deformed, for Concrete
ASTM A516M	Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate and Lower-Temperature Service
TIS 17	Standard for Unplasticized Polyvinyl Chloride Pipes
TIS 20	Reinforcing Steel: Round Bar
TIS 24	Reinforcing Steel: Deformed Bar
TIS 49	Covered Electrodes for Arc Welding of Mild Steel
TIS 57	Standard for Hollow Load-Bearing Concrete masonry unit
TIS 58	Standard for Hollow None-Load-Bearing concrete masonry unit
TIS 107	Standard for Hollow Steel Sections for General Structural Purposes
TIS 128	Standard for Precast Reinforced Concrete Drainage Pipe
TIS 171	Standard for Bolts Screws Nuts and Studs, General Data
TIS 249	Standard for Malleable Cast Iron Screwed Pipe Fittings
TIS 276	Standard for Steel Pipes
TIS 277	Standard for Galvanized Steel Pipes
TIS 291 Part 1	Hexagon Head Bolts: Product grades A and B
TIS 291 Part 2	Hexagon Head Bolts: Product grade B (Shank diameter pitch diameter)
TIS 291 Part 3	Hexagon Head Bolts: Product grade C
TIS 431	Standard for Copper Alloy Gate Valves
TIS 528	Standard for Hot-Rolled Mild Steel Plate, Sheet and Strip
TIS 597	Rods and Wires for Gas-Shielded Arc Welding of Mild Steel
TIS 1032	Standard for Solvent Welding Cement for Use with Unplasticized PVC pipes and fittings
TIS 1227	Hot-Rolled Structural Steel Sections
TIS 1228	Cold-Formed Structural Steel Sections
TIS 1479	Hot-Rolled Carbon Steel Coil, Strip, Plate and Sheet for General Structure

### 1.4.3 Geotechnical Work

#### 1.4.3.1 General

Preliminary soil/rock investigation data is provided in the Supplementary Data, Volume V. The Contractor may perform additional soil/rock investigation to obtain more accurate geotechnical data used in the analysis and design of the geotechnical works. The soil/rock samples may be drilled from the location where penstock, and wye branch, powerhouse, tailrace structure and tailrace channel will be constructed. The Engineer shall not be responsible for any interpretation, deduction or conclusion which may be made of the information given on the Supplementary Data, Volume V. The Contractor shall be fully responsible for the proper and safe design of geotechnical works, or for liability of injuries to, or death of persons.

### 1.4.3.2 Design Parameters

The Contractor shall have adequate soil/rock information from field and laboratory test for analysis and design of slope stability and underground structure to resist all loads, soil pressure and hydrostatic pressure.

- a) Rock Parameters shall include, but not be limited to:

- Unit Weight
- Permeability
- Uniaxial Compressive Strength
- Poisson's Ratio
- Allowable Bearing Pressure on Sound Rock
- Rock Quality Designation (RQD)
- Hardness
- Degree of Weathering
- Spacing, Inclination and Width of Joint System

- b) Soil Parameters shall include, but not be limited to:

- Gradation Analysis
- Liquid Limit
- Plastic Limit
- Natural Water Content
- Soil Classification
- Specific Gravity
- Unit Weight
- Permeability
- Total Strength
  - Cohesion
  - Friction Angle
- Effective Stress
  - Cohesion
  - Friction Angle

### 1.4.3.3 Foundation

All main permanent structures of the Project and in particular all water retaining structures, shall be founded on rock or pile foundation.

Foundation of structure on soil and rock shall be designed to give an acceptable safety factor against ground failure. Soil foundation design will provide for acceptable deflections and stresses on the structures.

Terzaghi's formula shall be applied for bearing capacity analysis of foundation. A factor of safety of 2.5 (F.S.=2.5) shall be applied on the ultimately calculated bearing capacity to the allowable bearing capacity.

In case of rock foundation, Bowles recommended to reduce the ultimate bearing capacity base on RQD as (Joseph E.Bowles, Foundation Analysis and Design 4th Edition, Clause 4-16, Page 234)

#### 1.4.3.4 Pile foundation

##### **Pile design criteria:**

The pile capacities shall be determined based on geotechnical investigation. The pile size and length shall be determined during the detailed geotechnical analysis. The pile tip shall be placed in rock layer. Filled layers shall not be taken into account for friction resistant of pile. The piling shall be suitably designed to resist all loadings.

The computation of pile capacity shall be calculated from static theory according to subsoil exploration records and design safety factors for all load cases shall be as follows:

- 2.5 for compression
- 3.0 for uplift capacity
- 2.0 for lateral load

The pile shall be able to withstanding earthquakes. The determination of the interaction of the entire structure system (structure and pile) with the movement of surroundings soil shall be performed.

In the design of pile for machine foundation, which subjected to dynamic loads, the response of the foundation, in the form of modal frequencies, deflection, stress, strain, and so on, shall be determined.

Prestressed concrete solid square pile or bore pile shall be applied for this project. Hexagonal piles are allowed for pile foundations of lightweight facilities such as fence, trench, duct bank, manhole, etc.

Bored pile shall be constructed in accordance with the latest version of EIT 1019-46 standard or related standard and vertical reinforcement as well as spiral reinforcement shall be provided throughout the whole length of pile. For wet process bored pile utilizing polymer slurry or bentonite slurry shall be constructed. The polymer slurry or bentonite slurry used for bored piles shall conform to the latest version of EIT 1019-46.

The type and size of piles for all structures and equipment foundations shall be proposed to EGAT for approval.

#### 1.4.3.5 Design of Slopes

Design of slope shall include the following:

- Penstock, wye branch, tailrace structure and tailrace channel excavation
- Backfill or embankment
- Spoil disposal areas
- Powerhouse excavation
- Cofferdam



### 1.4.3.6 Excavation Slope Stability

Minimum required factor of safety is listed in the following;

Case	Analysis Loading Condition	Required Minimum F.S.
1	End of Construction	1.3
2	End of Construction with Earthquake	1.0
3	Operation Condition	1.5
4	Operation Condition with Earthquake	1.0

Slope stability analyses shall be conducted based on the results of the geotechnical investigations, geological studies, and laboratory tests to establish permanent and temporary excavation slopes.

Earthquake condition shall be considered for each above condition. The magnitude shall be based on the Ministerial Regulation, Thailand (B.E. 2564) or Standard No.1301/1302-61: Guideline for Seismic Loading of Buildings of Thailand issued by the Department of Public Works and Town & Country Planning, Ministry of Interior, Thailand.

In order to guarantee slope stability during the construction, strengthening measures such as soil/ground improvement, rock bolts and shotcrete or even soil/rock anchors may be adopted.

### 1.4.3.7 Fill/Embankment Slope

The loading conditions for the embankment can be defined as follows;

- End of construction*: the pore water pressure is developed during the compaction of the impervious zone, while the other rockfill/filter zones are considered to be free draining material.
- Operation (Impounding)*: the embankment will carry the water pressure on the upstream slope of embankment. In this condition, seepage analysis will be carried out for determining the water pressure in the embankment body before commencement of stability analysis.
- Rapid drawdown*: this condition occurs when the water level on the upstream decreases rapidly; the seepage water inside the embankment body will seep back to the upstream. It will be the cause of instability on the upstream slope.

Earthquake condition shall be considered for each above condition. The magnitude shall be based on the Ministerial Regulation, Thailand (B.E. 2564) or Standard No.1301/1302-61: Guideline for Seismic Loading of Buildings of Thailand issued by the Department of Public Works and Town & Country Planning, Ministry of Interior, Thailand.

The minimum factors of safety (F.S.) are listed in the following

Case	Analysis Loading Condition	Slope	Required Minimum F.S.
1	End of Construction	U/S and D/S	1.30
2	End of Construction with Earthquake	U/S and D/S	1.00
3	Operation – Normal water levels	U/S and D/S	1.50

4	Operation – Normal water levels with Earthquake	U/S and D/S	1.00
5	Operation – Extraordinary water level	U/S and D/S	1.30
6	Operation – Extraordinary water level with Earthquake	U/S and D/S	1.00
7	Rapid Drawdown	U/S	1.20
8	Rapid Drawdown with Earthquake	U/S	1.00

The stability of fill/embankment shall be analyzed based on the 2-D limit equilibrium method. Moreover, the seepage analysis shall be adopted in order to study the pore pressure of water flowing through the embankment and foundation.

#### 1.4.3.8 Settlement Analysis

Foundation settlement will be determined from the following criteria:

- Structures founded on rock shall be assumed to have negligible foundation settlement following the end of construction.
- Structures founded on soil deposits shall be assumed to have settlement based on material type and the weight of the structure. The settlement characteristics for such materials will be established on the basis of laboratory testing and/or International References accepted by the Engineer.

The design for, or control of total and differential settlement between critical elements of a structure such as penstock is essential for the proper and safe functioning of the structure. The total and differential settlement shall be sufficiently low so as to prevent the development of shear and/or tensile stress within the structure in excess of tolerable limits and to insure the proper functioning of all equipment and features.

Limiting angular distortion,  $\eta$ , shall be as follow

Powerhouse :  $\eta < 0.002$

Other Structures :  $\eta < 0.003$

Where  $\eta = (\delta/l) - \omega$

$\delta$  = Differential settlement

$l$  = Lateral dimension of the structure

$\omega$  = Tilt

#### 1.4.3.9 Seepage Analysis

Design of the seepage control systems will be directed towards minimizing seepage quantities, limiting seepage-induced pore pressures to ensure stability, and preventing internal erosion or piping of embankment and foundation soils.

#### 1.4.3.10 Foundation Treatment

The foundation treatment of powerhouse can be specified as follow:

- The foundation for powerhouse structures shall be reach to slightly weathered rock with RQD not less than 50%. If the rock foundation is not met the requirement, the consolidation grouting shall be adopted for foundation treatment. However, the

concrete leveling (dental concrete) shall be applied in case of over-break of rock mass foundation. The strength of dental concrete shall be class A.

- Consolidation grouting: This grouting is performed to improve foundation of structures. Generally, the consolidation grouting will be performed at least 5 m depth.

#### **1.4.3.11 Excavation Techniques**

A conventional drilling, chemical expanding agents, or mechanical wedging shall be used for rock excavation. The use of explosive is not permitted in this project. Excavation works shall meet the requirements specified in Civil Works Technical Specification, Chapter 6, Open Excavation. The slope stability of any case of during construction and operation phase shall be compiled to Clause 1.4.3.6 Excavation Slope Stability.

Temporary wall and soil/rock support shall be provided during excavation work. Unstable rock condition shall be improved by rock-bolting and support, grouting or drainage, sodding or soil slope protection applicator. The soil/rock supports shall be installed as soon as possible after the excavation is made and the cost of these activities shall be included in the excavation works.

#### **1.4.3.12 Instrumentation**

The instrumentation or monitoring such as inclinometer and settlement plate, etc. shall be installed for measurement of soil/rock movements and deformations during excavation and construction. The location of instrumentation or monitoring shall be proposed in his bid. The location of the instruments installation and measurement shall be submitted for review by the Engineer.

The depth of instrument installation shall be 1.50 m. below the deepest excavation level.

Regarding to the existing dam and appurtenant structures safety, The Contractor shall submit the calculation document to the Engineer for consideration and install the necessary temporary geotechnical instruments to monitor and evaluate the safe performance of dam under all construction activities at all times.

### **1.4.4 Civil Works**

The civil works shall include but not be limited to the followings; steel saddle and concrete encasement of penstock and wye branch, powerhouse, control building, steel hatch cover, laydown area, tailrace structure, stormwater drainage system, access road, plumbing, toilet room, transformer foundation, gate, fence, guard house and wastewater treatment system and site work.

#### **1.4.4.1 Stability Analysis**

##### **a) Powerhouse**

The following criteria shall be used for stability analysis of powerhouse, but is not limited to:

- Case (a) First stage concrete only and powerhouse structure completed
  - No tailwater
  - No uplift

- Case (b) First stage concrete only and powerhouse structure completed  
 - Normal high water level (NHWL)  
 - Normal tailwater level (NTWL)
- Case (c) As case (b) but no tailwater
- Case (d) Powerhouse structure completed and all units installed (Operation Case)  
 - Normal high water level (NHWL)  
 - Normal tailwater level (NTWL)
- Case (e) As case (d) but empty waterway and units are removed (Maintenance Case)

Note:

- Case (a) to Case (c) are during construction stage
- Case (d) to Case (e) are in operation and maintenance stage

The following values for principal factors of safety shall be used for structural design:

Criteria	Permanent Work w/o Earthquake	Permanent Work with Earthquake	During Construction w/o Earthquake
Bearing	F.S. $\geq$ 3.00	F.S. $\geq$ 2.00	F.S. $\geq$ 2.00
Sliding	F.S. $\geq$ 1.50	F.S. $\geq$ 1.20	F.S. $\geq$ 1.25
Uplift (Floating)	F.S. $\geq$ 1.50	F.S. $\geq$ 1.10	F.S. $\geq$ 1.30
Overturning	F.S. $\geq$ 1.50	F.S. $\geq$ 1.20	F.S. $\geq$ 1.25

b) Retaining wall

The following design criteria shall be used for stability analysis of retaining wall, but is not limited to:

- Case (a) Groundwater level at finished grade behind retaining wall and no tailwater
- Case (b) Groundwater level at finished grade behind retaining wall and the rapid drawdown from tailwater level at return period 100 years to minimum tailwater level.

Note:

- Case (a) is during construction stage
- Case (b) is in operation and maintenance stage

The following values for principal factors of safety shall be used for structural design:

Criteria	Permanent Work w/o Earthquake	Permanent Work with Earthquake	During Construction w/o Earthquake
Bearing	F.S. $\geq$ 3.00	F.S. $\geq$ 2.00	F.S. $\geq$ 2.00
Sliding	F.S. $\geq$ 1.50	F.S. $\geq$ 1.20	F.S. $\geq$ 1.25
Overturning	F.S. $\geq$ 2.00	F.S. $\geq$ 1.20	F.S. $\geq$ 1.50
Uplift(Floating)	F.S. $\geq$ 1.50	F.S. $\geq$ 1.10	F.S. $\geq$ 1.25
Overall stability	F.S. $\geq$ 2.00	F.S. $\geq$ 1.30	F.S. $\geq$ 1.50

#### 1.4.4.2 Electro-Mechanical Equipment Loads

For design purposes, the major equipment loads shall include, but not be limited to:

- Runner
- Weight of turbine rotating parts
- Unbalanced hydraulic downthrust

- Unbalanced hydraulic upthrust
- Runaway speed, no load, at net effective head
- Flywheel effect
- Generator installed
- Rotor
- Rotor Poles
- Lower part of rim with spider
- Upper part of rim with spider
- Rotor lifting beam
- Maximum generator torque
- Main transformer
- Other loads as per recommendation of manufacturer

All above data shall be confirmed with the equipment suppliers before final design be carried out.

#### 1.4.4.3 Live Loads

The following live loads shall be used for structural design.

- Roof (Hatch Cover / Metal)	100	kg/m <sup>2</sup>
- Electrical room	1,000	kg/m <sup>2</sup>
- Control room	1,000	kg/m <sup>2</sup>
- Generator floor (as recommended by equipment manufacturer but not less than)	3,000	kg/m <sup>2</sup>
- Battery Room	1,000	kg/m <sup>2</sup>
- Toilet room	200	kg/m <sup>2</sup>
- All other area	500	kg/m <sup>2</sup>
- Surcharge load during construction	1,500	kg/m <sup>2</sup>
- Ladder	100	kg
- Surcharge load for completed structure	1,000	kg/m <sup>2</sup>
- Wheel load	8 ton/wheel, 16 ton/axle for HS20-44 truck	
- Mobile crane	as required during construction and erection	
- Laydown area	as required for storage of heaviest equipment and supplies.	

If weight of equipment is less than the above live load, the structural system shall be designed for the live load.

#### 1.4.4.4 Crane Loads (Not Applicable)

The crane loads for design shall be taken as recommendation by manufacturer. For preliminary design of structure, the design crane loads shall be as following;

##### 1) Vertical Loads

Impact or dynamic allowance is applied only to crane vertical wheel loads and is only considered in the design of runway beams and their connections. The vertical load including impact shall be taken as 125% of the total wheel loads.

## **2) Side Thrust**

Crane side thrust is a horizontal force of short duration applied transversely by the crane wheel to the rails. The side thrust shall be taken as 20% of the total wheel loads.

## **3) Traction Load**

Longitudinal crane tractive force is of short duration caused by crane bridge acceleration or braking. If the number of driven wheels is unknown, take the tractive force as 20% of the total wheel loads.

### **1.4.4.5 Wind Load**

Wind load calculation shall conform to the Standard No. 1311-50 of Department of Public Works and Town & Country Planning, Ministry of Interior, Thailand or ASCE 7-05. The design wind speed shall be greater than 25 m/s.

### **1.4.4.6 Seismic Load**

Structures and equipment shall be designed to resist earthquake force according to the Ministerial Regulation (B.E. 2564) or Standard No.1301/1302-61: Guideline for Seismic Loading of Buildings of Thailand issued by the Department of Public Works and Town & Country Planning, Ministry of Interior, Thailand.

### **1.4.4.7 Seismic Design Criteria**

#### **1.4.4.7.1 General**

The facility shall be designed and constructed to minimize the risk of damage and to facilitate the expeditious restoration of electricity supply following an earthquake.

The seismic design for the buildings, plant and equipment shall be based on the approach defined in the International Building Code (2018), ASCE 7-05, the Ministerial Regulation (B.E. 2564) or Standard No.1301/1302-61: Guideline for Seismic Loading of Buildings of Thailand issued by the Department of Public Works and Town & Country Planning, Ministry of Interior, Thailand. Response of structure and foundation, i.e., soil-structure interaction or lateral instability or uplift, due to seismic forces shall be considered.

#### **1.4.4.7.2 Seismic Loading**

The seismic load shall be calculated based on the Standard No.1301/1302-61: Guideline for Seismic Loading of Buildings of Thailand issued by the Department of Public Works and Town & Country Planning, Ministry of Interior, Thailand, illustrated the design response spectrum used for Equivalent Static Design Method and for Dynamic Method, respectively.

The structure shall be classified as essential facilities. For anchorage of machinery and equipment, the seismic importance factor shall be taken as 1.5.

Seismic loading will be used in the design of structures only when they are greater than the computed wind loads and will be computed in accord with the Standard No. 1311-50, Guidelines for Seismic Loading of Buildings of Thailand issued the Department of Public Works and Town & Country Planning, Ministry of Interior, Thailand.

### 1.4.4.7.3 Mechanical and Electrical Equipment

#### a) General

Equipment supported above ground level in buildings shall be designed using the appropriate section of the International Building Code (2018).

Seismic design for all equipment shall allow restoration of safe plant operation within reasonable time duration. The design shall also consider the following.

1. Safety of operating personnel shall be ensured.
2. Potential costs of repair or replacement

Seismic loads shall be considered to act in the direction that produces the worst structural support and equipment stresses. The resulting seismic actions shall be combined with the normal loads in the equipment and with other actions that are required to be assumed coincidental with an earthquake event.

#### b) Analysis

The equivalent static method as provided for in the International Building Code (2018) may be used. The structures shall be classified as essential facilities. For anchorage of machinery and equipment, the seismic importance factor shall be taken as 1.5. Alternative method such as modal response spectrum or time history method may be used subject to prior review by EGAT. All equipment weight shall be considered in the analysis. Pipe work shall be considered full.

#### c) Design Strength of Materials

For the serviceability limit state, the design strength of equipment and equipment supports, when subjected to the design load combinations, shall not exceed the following:

C-1. For porcelain and other brittle components, either:

- 40 % of the guaranteed minimum breaking strength, or
- 50 % of the average tested breaking strength less three standard deviations;

C-2. For ductile components:

The serviceability limit state strengths given in the relevant AISC or ACI code or other approved codes; and,

C-3. For equipment anchoring arrangements:

The maximum strengths used in designing equipment anchoring arrangements and fastenings, shall not exceed the normal serviceability strengths allowed for the materials.

### 1.4.4.8 Static Lateral Earth Pressures

Earth pressure parameters for horizontal or inclined fill against a vertical wall shall be calculated based on Coulomb's theory, Rankine's theory or finite element method.

Wall friction is taken equal to zero for all cases.

Hydrostatic or groundwater conditions, surcharge pressure and earthquake shall be considered in wall design.

Ground water level for calculation shall be at 2/3 of wall height.

#### 1.4.4.9 Concrete

##### a) Code Requirements

The concrete design shall follow ACI 318-19, E.I.T. 011007-19, E.I.T. 011008-21, or the updated versio.

##### b) Concrete Classes

Concrete shall be divided into 4 classes as follows:

<u>Class</u>	<u>Compressive Strength (<math>f'_c</math>)</u> <u>kg/cm<sup>2</sup></u>	<u>Application</u>
A	140	Lean backfill concrete and dental concrete
B	240	Concrete other than Class A, Class C, Class D such as drainage system, building, fence, etc.
C	280	Powerhouse, transformer foundation, laydown area, penstock and wye branch concrete encasement, tailrace structure, secondary stage concrete, bridge
D	350	Prestressed concrete

Notes: - The compressive strength ( $f'_c$ ) is considered as minimum ultimate compressive strength of concrete at 28 days (standard cylinder test).

- The minimum cement content of concrete shall conform to the Technical Specification.

##### c) Modulus of Elasticity

Concrete	$4270w_c^{1.5}\sqrt{f'_c}$	kg/cm <sup>2</sup>
Steel	2,040,000	kg/cm <sup>2</sup>
where $w_c$ = unit weight of concrete; T/m <sup>3</sup>		

##### d) Poisson's Ratio

Concrete	0.18
Steel	0.30

##### e) Unit Weights

Reinforced Concrete	2,400	kg/m <sup>3</sup>
Steel	7,850	kg/m <sup>3</sup>
Water	1,000	kg/m <sup>3</sup>

##### f) Coefficient of Thermal Expansion

Concrete	$10.3 \times 10^{-6}$	/°C
Structural Steel	$11.3 \times 10^{-6}$	/°C

##### g) Minimum Reinforcement

For hydraulic structure, temperature and shrinkage reinforcement shall be 0.0030 times to the gross cross-sectional area. The sectional area shall be distributed equally on both faces. However, this shall not be less than 420 mm<sup>2</sup>/m or more than 2,100 mm<sup>2</sup>/m per face as clause 2 – 9 of the EM 1110-2-2104 (USACE, 2023).



For typical structural concrete member e.g., slab, beam, column etc., minimum reinforcement and temperature and shrinkage reinforcement shall be determined as ACI 318-19.

#### i) Minimum Concrete Cover

The minimum concrete cover shall be conformed to Part 3 – Technical Specifications, Chapter 11, article 11.3.3 Placing.

#### j) Reinforcement Details for Seismic

The reinforcement details for seismic shall be provided for all concrete building as required by ACI 318-19, the Ministerial Regulation (B.E. 2564) or Standard No.1301/1302-61: Guideline for Seismic Loading of Buildings of Thailand issued by the Department of Public Works and Town & Country Planning, Ministry of Interior, Thailand.

#### 1.4.4.10 Steel

##### a) Reinforcing Steel

Reinforcing steel shall comply with TIS 20 for round bar and TIS 24 for deformed bar, and consist of the following Grades:

<u>Bar size(mm)</u>	<u>Grade</u>	<u>Min.Yield Strength</u> (kg/cm <sup>2</sup> )	<u>Min. Tensile</u> <u>Strength(kg/cm<sup>2</sup>)</u>
RB6, RB9	SR-24	2,400	3,900
DB10 to DB32	SD-40/SD40T	4,000	5,600
	SD-50/SD50T	5,000	6,200

##### b) Structural Steel

Structural steel shall comply with TIS 1227, Grade SS400:

Minimum yield strength	2,500 kg/cm <sup>2</sup> (245 N/mm <sup>2</sup> )	for thickness ≤16 mm
Minimum yield strength	2,400 kg/cm <sup>2</sup> (235 N/mm <sup>2</sup> )	for thickness >16 mm
Ultimate tensile strength	4,080 kg/cm <sup>2</sup> (400 N/mm <sup>2</sup> )	

##### c) Electrode

Electrode shall comply with TIS 49, type E43, E49, or equivalent.

Ultimate tensile strength of

Electrode E43	430 MPa
Electrode E49	490 MPa

##### d) Bolts and Nuts

Bolts and nuts shall comply with TIS 291, Part 1, Part2, Part3, or equivalent.

TIS 291 Part 1	Hexagon Head Bolts: Product grades A and B
TIS 291 Part 2	Hexagon Head Bolts: Product grade B (Shank diameter pitch diameter)
TIS 291 Part 3	Hexagon Head Bolts: Product grade C

#### **1.4.4.11 Wye Branch, Bifurcation, Penstock encasement, Thrust blocks and Draft Tube**

Design of steel wye branch, bifurcation, penstock and draft tube are under the Equipment Works, Volume II responsibility.

Thrust blocks and encasement shall be reinforced concrete and shall be designed to resist, but not be limited to the following forces: soil embankment, seismic, mobile crane load, surcharge load, ground water pressure, grouting pressure and temperature forces.

The encasement shall be provided for wye branch, bifurcation and penstock.

The encasement shall be designed to resist the internal pressure from hydrostatic and hydrodynamic load without sharing ratio analysis between steel lining, surrounding rocks and other external pressure.

The encasement shall also be designed to resist the external pressure from soil embankment, ground water pressure, mobile crane load, surcharge load, seismic and temperature without sharing ratio analysis between steel lining and other internal pressure.

#### **1.4.4.12 Valve Chamber (Not applicable)**

The valve chamber shall be reinforced concrete underground structure or manhole. The flexural member of underground structure such as wall and slab etc., except beam, shall be designed as single reinforcement, which wall and slab thickness shall have adequate shear capacity with shear reinforcement.

Waterstops shall be provided at all construction joints within the structures. The installation of Polyvinylchloride (PVC) waterstops or swellable waterstops at construction joints shall be based on principles and requirements to prevent infiltration of water into the joint system and/or to prevent seepage into dry spaces.

#### **1.4.4.13 Surge Tank (Not applicable)**

Surge tank shall be the orifice type. Hydraulic analysis shall be performed to achieve the effective dimension of surge tank. The height of surge tank shall be less than the height of existing dam. The height of surge tank shall be extended above the maximum upsurge. The maximum downsurge shall be higher than the top of penstock level. The following design criteria shall be used for hydraulic analysis:

- Case (a) Maximum upsurge in surge tank
  - Maximum water level of the existing reservoir
  - Guide vanes are suddenly closed
  - Closing time shall refer to recommendation of turbine manufacturer
- Case (b) Maximum downsurge in surge tank
  - Minimum water level of the existing reservoir
  - Guide vanes are suddenly opened
  - Opening time shall refer to recommendation of turbine manufacturer

#### 1.4.4.14 Powerhouse

##### a) Turbine and Generator Floor

To assure satisfactory performance of the electro-mechanical equipment, turbine and generator floor shall be designed to eliminate the possibility of resonance. In addition, a static analysis or a dynamic analysis shall be performed to determine the natural frequencies of the floor. To preclude resonance, the natural frequency of the floor shall be at least 40 percent different from the operational frequency of the equipment.

Nevertheless, the elimination of resonance does not mean that the respective overstressing is negligible. The stresses of turbine and generator floor shall be analyzed by equivalent static method or dynamic analysis method. In case the equivalent static method is used for calculation, the formula shall be as follow:

Force transmissibility ratio (TR):

$$TR = \sqrt{\frac{1+4\xi^2r^2}{(1-r^2)^2+4\xi^2r^2}}$$

Where  $\xi$  = Damping ratio

$r = \omega/\omega_n$

$\omega$  = Frequency of machine

$\omega_n$  = Natural frequency of foundation structure

##### b) Substructure

The flexural member of powerhouse underground structure such as wall and slab etc., except beam, shall be designed as single reinforcement, which wall and slab thickness shall have adequate shear capacity with shear reinforcement.

Waterstops shall be provided at all construction joints within the structures. The installation of Polyvinylchloride (PVC) waterstops at construction joints is based on principles and requirements to prevent infiltration of water into the joint system and/or to prevent seepage into dry spaces.

To accomplish these objectives, the PVC waterstops shall be used in:

- All contraction joints subject to water pressure
- Vertical and horizontal construction joints subject to water pressure
- Waterstops to prevent infiltration of water into the joint system shall be installed as close to the source of water pressure as practicable.

##### c) Superstructure

- Roof structure

The steel roof structure of control building and related structures shall be designed as either truss system or frame system. Entrance room shall be the reinforcing concrete roof.

The powerhouse shall be founded on rock or pile foundation.

#### **1.4.4.15 Tailrace Structure**

Design of tailrace structure shall conform to EM-1110-2-2502, UFC 3-220-20 (DM 7.2) or related standard.

The tailrace structure shall be reinforced concrete structure with drainage system. The bracing beam is allowed if necessary. The bracing beam is not allowed to block the waterway.

The drainage system shall be provided for the tailrace structure, for example, weep holes with pockets of coarse-grained material at the outside of wall and impervious surface with a gutter for collecting runoff above backfill layer.

Tailrace structure shall be found on rock or pile foundation.

#### **1.4.4.16 Tailrace Channel (Not applicable)**

The tailrace channel shall be rectangular or trapezoidal open channel lined with the reinforced concrete. The tailrace channel shall be reconditioned from the powerhouse to the existing natural channel confluence. Side slope and berm of channel shall be lined with concrete as shown on the Drawings. For concrete lining, the slope shall be re-excavated from +245.00 to +250.00 m MSL as shown on the Drawings. The drainage provision for groundwater shall be provided for example; weephole, filter material with geotextile as specified in Chapter 7, Miscellaneous Fills, Riprap and Geotextile.

The slope stability of the channel shall be considered with factor of safety as required in geotechnical design criteria. The slope protections for erosion control are provided as specified in the Drawings.

Moreover, the warning sign shall be installed at both banks of channel. The location and details of warning sign shall be submitted for approval.

The downstream cofferdam construction and removal shall be the Contractor's responsibility.

#### **1.4.4.17 Control Building**

The control building shall be designed to suit the space requirements defined by the dimensions of the electrical equipment and maintenance conditions. The foundation of control building shall be situated on the rock, good load-bearing soil layer or pile foundation.

The Control building shall be designed as the reinforced structure or container. It shall be enclosed building and designed to resist equipment load, wind load and earthquake in accordance with applicable codes, standards and specifications in Vol. III Part 1. The building consists of the control room, electrical room (MV, LV and HV switchgear) and battery zone.

Emergency door shall be provided per requirement stipulated in relevant laws enforced in Thailand. Ventilating and air conditioning system (VAC) shall be provided to maintain proper environmental conditions for personnel and equipment.

#### 1.4.4.18 Road and Bridge

Loads exert on bridges, roadway pavements, parking and unloading areas, buried piping, box culverts, and embankments shall be reviewed and selected prior to design of the underlying items. The Load Standard HS- Trucks (HS20-44 Loading) shall be utilized for the design of bridges, roadways, and parking and unloading areas.

However, where appropriate, loadings such as loaded scrapers, crawler cranes, stator transport trailers, etc., might exceed these loadings and therefore shall be considered.

Design loadings shall incorporate conditions that allow for the removal and maintenance of plant equipment. Structural members shall be designed in accordance with the latest editions of AASHTO, AISC, and ACI 318, except noted otherwise.

Design, material test and construction of road and bridge shall conform to AASHTO standard and Standard for Highway Construction (DH.-S) by Department of Highways, Ministry of Transport of Thailand.

Method for flexible highway pavement design shall be AASHTO, The Asphalt Institute (1991), Group Index, McLeod Method and Road Note 29.

The slopes of road embankments and cut slopes shall be designed so that an acceptable stability is maintained during the life of the Works, including the construction period.

Contractor shall design the horizontal and vertical alignments of all roads and walkways to meet the requirements of future vehicular traffic and the relevant Local Authority. Super elevation shall not be used for the design. The Contractor shall also take into account the requirement of delivery, operation and maintenance of station equipment in determining minimum geometric design.

Additionally, the Contractor shall improve and maintain all the existing service roads of the project area at satisfaction of EGAT/Engineer for guaranteeing normal traffic for any kind of vehicle.

The Contractor shall be responsible for the safety of the roadways and related work, during the construction and usage of the same. Additionally, he will be responsible for protecting the damage to any part of works and the property of others in relation to the performance of this works.

The newly designed road shall compose of the followings:

- Design Speed 40 km/hr
- Maximum gradient 8 %
- Cross-fall of carriageway 2.0%
- Carriageway 4.00 m
- Reinforced concrete pavement
- Pavement structure and subgrade properties shall be based on standard road of Department of Rural Road (DRR), Thailand.
- The side ditch shall be trapezoidal or rectangular ditch as shown on the Drawings. Weep holes and filter materials shall be provided for groundwater drainage.
- The parking area shall be concrete pavement.

Parking, turnaround for maintenance, guard rail and guide post shall be provided

For adequate safety, Guard rails and guide posts shall be intermittently provided along the road where necessary especially at curve. The post shall be 0.15 m x 0.15 m x 1.30 m (minimum) reinforced concrete embedded into the ground by 0.50 m minimum. The remaining 0.80 m above the ground shall be painted black in 0.15 m and white in 0.25 m striping. The reflective sheeting shall be provided at the foreside and backside of the post as DOH standards.

Guard rail shall be provided along roadside where dangerous situations, such as bridge approach, horizontal curve where radius is less than 50 m. Guard rail shall be designed conforming to DOH standards. Material of guard rail shall be conformed to TIS 248.

Road marking shall be provided according to the DOH standards.

The Contractor shall furnish and install traffic signs at access roads, junctions, turns, curves, parking areas or any other point according to the DOH standards. Materials, types, shapes, dimensions and installation method for traffic sign, shall be in accordance with the latest specifications of DOH standards.

Signs shall also be provided at strategic positions inside and outside the plant site.

Direction signs and any other necessary signage shall be provided as required by EGAT.

The roadway formation shall be kept clean, free from mud and slurry and properly shaped and compacted by rolling to an even and uniform surface to match with the pavement. Temporary or permanent roadside drains shall be provided.

#### **1.4.4.19 Valve House**

Valve House shall be reinforced concrete or steel structure. It shall be enclosed building and designed to suit the space requirements defined by the dimensions of the electrical equipment and maintenance conditions. The foundation of Valve House shall be situated on the suitable foundation which shall not result in structural damage due to settlement.

#### **1.4.5 Architecture**

The functional requirements of the Architectural Proposals shall be as follows:

- The building arrangement layout should follow the tentative plant layout and the site layout. However, the Contractor may propose a different building arrangement/layout based on his experience.
- The buildings shall be designed to remain stable, serviceable, and to allow for normal operation of all contained systems, while resisting natural phenomena specified in the site design conditions.
- The Contractor shall propose plan and elevation of all buildings.
- To satisfy the aesthetic requirements of a prominent group of structures with regard to their context (i.e. site and geographical location), their scale (i.e. the need to co-exist in appearance, notwithstanding the disparate forms, size and function); and finally their

durability (i.e. the need for them to maintain a high standard of sound appearance, with minimum maintenance both in use and when subjected to environmental conditions).

The building dimensions shall be selected to suit the space requirements defined by the dimensions of the electromechanical equipment and maintenance conditions. ***However, area required of each room shown on the Drawings shall be minimum requirement.***

Wherever possible, the building dimensions shall be fitted into a grid system facilitating the construction and allowing standardization of materials, and economy of design.

The architectural components provide exterior and interior enclosure for the powerhouse building. The exterior enclosure protects the enclosed equipment and systems, and personnel, from adverse weather condition, and allows for a controlled interior environment. The interior enclosure subdivides area into spaces; seals surface against external abuse, and facilitate maintenance. Chemical resistance coating shall be applied where appropriate.

The aspect of the buildings shall be considered in order to avoid unreasonable heat accumulation in the buildings due to natural sun radiation, adequate insulation, and heat protection shall be provided. Fire separating walls, escape routes and general fire protection measures shall be incorporated as necessary to meet good practice according to the National Thai and International Standards such as The Ministerial Regulation No.48 and The Industry Ministerial Promulgation, etc.

In order to meet these requirements and with regard to the sub-tropical site considerations, strong recommendations shall be given to the following environmental criteria.

- 1) Sun Shading
- 2) Air Conditioning
- 3) Rain Protection
- 4) Thermal Insulation
- 5) Thermal Reflection
- 6) Light Reflection
- 7) Pest & Insect Protection
- 8) River bank Protection
- 9) Adequate Ventilation

The foundations of the building shall provide supports enclosure and access to the system contain within their boundary. The function of the access component of the powerhouse building is to provide means for entrance and exit, and to allow access to the contained systems for operation and maintenance. The access component consists of doors, stairs, and floors shall be provided where appropriate in accordance with detail specifications. The Aesthetic Requirements shall be addressed as follows:

- Context
- Scale
- Visual Harmony
- Standards of Appearance

The Contractor shall provide an overall architectural submission that complies with the requirements of this specification particularly with respect to visual harmony and standards of appearance. This submission shall take the form of an “Artist’s Impression” on the proposed

power station complex which follows the approval of EGAT, and forms the basis of the detailed architectural design of the Work. The Contractor detailed design shall comply with the minimum requirements of functions and process control required for each system. The architecture of the miscellaneous buildings shall be consistent with the architectural theme of the overall plant facilities.

#### 1.4.5.1 Exterior Architecture

General design criteria for the exterior architectural systems shall be as follows:

##### a) Metal roof system

Roofing for control building shall consist of metal sheet roof panel with insulation unless specified otherwise. Insulation shall be placed between metal sheets. Ceiling and roof slope shall be used as specified in the Drawings.

##### b) Windows

###### - Aluminum Windows

Windows frames shall be made of extruded aluminum. Ventilation portions shall be compatible with the frames providing a weathertight seal.

###### - Steel Windows

Windows shall be framed with formed metal frame, with metal stop. Frames in stud wall shall be wrapped around style.

Window frames shall be finished in a color to harmonize with the exterior wall. Windows shall be designed for inside glazing type and shall also be designed to resist wind load.

##### c) Louvers

Ventilation openings shall be provided with drainable storm-proof blade louvers and bird screen. On long expanses of louvers, a continuous blade concealed support system shall be provided. The metal mesh shall be provided to protect from nuisance animals.

##### d) Doors

###### - Aluminum Doors

Door frames shall be made of extruded aluminum. Ventilation portions shall be compatible with the frames providing a weathertight seal.

###### - Steel Doors

Doors shall be the hollow metal type, insulated and with formed hollow metal frames. Both doors and frames shall be galvanized, primed, and finish painted. In areas where excessive negative pressure hinders normal door operation, special balanced door hardware shall be provided.

Doors shall have a glazed vision panel when required by door function. Glazing shall consist of tempered safety glass or float glass.

Doors at all levels shall swing in the direction of fast egress. Heavy duty hardware shall be used.

##### e) Steel Shutter (If Applicable)

Large access exterior doors shall be vertical lift coil type, with weather seals and windlocks. Component shall be formed from galvanized steel, factory primed, and finish painted. The main



access doors shall be both motor and manual operation. All other doors shall be manually operated.

f) Wall

Masonry wall, such as the wall of a control room and battery room shall be constructed of concrete block masonry with minimum thickness of 100 mm (including plaster wall) satisfying the requirements of TIS 58.

An exterior weather protective surfacing composed of cement plaster shall be applied to all exposed areas. Finish plaster surfaces shall be sealed to be moisture resistant.

Fire wall shall be 2 hours fire resistance rating.

g) Anti Bird Netting Door (If Applicable)

The Anti Bird Netting Door shall be installed in front of roller shutter door. Door shall be sliding type with roller and rail and shall be divided into 2 parts. The door frame shall be made from galvanized steel. The netting materials shall be a weave galvanized metal mesh as square form. The spacing shall be 25 x 25 mm. with wire diameter 3 mm.

#### 1.4.5.2 Interior Architecture

Interior architectural systems shall conform to the following general design criteria.

a) Partitions

Interior walls shall be constructed of masonry; metal studs with gypsum board, panel, or factory finished assembled demountable type partitions.

Interior walls, where durability or high moisture resistance is required, shall be constructed of concrete block masonry, or reinforced concrete. Plaster finish shall be applied in selected areas.

b) Windows

Interior Windows shall be similar construction to exterior windows.

c) Doors

Interior doors shall be similar construction to exterior doors. Frames in stud walls shall be the knockdown style. Doors and frames shall be primed and painted.

Interior doors shall have a glazed vision panel as required. Glazing for the vision panel shall be tempered safety or float glass as required.

Heavy -duty hardware shall be used.

d) Ceilings

Ceilings in unfinished areas shall have the overhead structural frame exposed. The exposed structure shall be painted in unfinished areas.

Ceilings in finished areas shall generally consist of a suspended, exposed or concealed grid, lay-in acoustical type or gypsum board.

e) Floor Coverings

For high moisture areas of toilets, unglazed or anti-slip ceramic tile shall be used.

Office area floor shall be glazed ceramic tile, vinyl flooring or others specified herein.

Floor covering for control room shall be PVC static dissipative floor tile. The finish elevation of control room shall be similar to the adjacent area.

All stairs shall be provided with aluminum stair nosing.

f) Wall Coverings

Wall coverings shall be used to enhance the appearance, cleanliness, and wall protection, where appropriate, particularly in office areas.

Glazed tile over concrete block shall be used in toilet areas to maintain a sanitary and easily maintained wall.

Where specific wall coverings are not desired for the above applications, all finished area walls shall be painted in accordance with Part 2 of this Volume.

g) Sanitary Facilities

Toilet and shower facilities shall be provided for personnel at control building. Toilet shall be floor mounted.

Shower fixtures and other sanitary facilities shall be wall mounted. Partitions shall be damp-proof or masonry glazed tile as required.

Emergency shower, eye and face wash shall be provided in battery room with full accessories for washing.

### 1.4.5.3 Painting and Coating

Painting shall include the protection of exposed surfaces, both interior and exterior, for finished building structures, equipment, and other surfaces which are visible for painting. Unless specified otherwise in other clauses of Volume III, painting and coating shall conform to this clause and Civil Works Technical Specification, Chapter 20, Painting and Coating.

All atmospheric exposed surfaces of steel and metal works shall be coated. In addition, all visible and exposed surfaces of structural steel and metal works shall also be painted.

Surfaces of powerhouse building needed to be painted shall conform to the Finishing Schedules specified in the Drawings.

Exposed surfaces of electrical conduit, conduit boxes, and fittings shall be painted only when they are adjacent to the painted parts of the building structure or equipment. These surfaces shall be painted the same color as the adjacent building surfaces.

Abraded or damaged areas of shop primed surfaces shall be cleaned and touch-up painted before applying finish paint system. Abraded or damaged areas of shop finish painted surfaces

shall be repaired by spot priming and repainting with materials of similar type and color to the existing shop paint system.

Unless otherwise specified in the Drawings, the following surfaces shall not be painted:

- Aluminum surface
- Brass
- Bronze
- Chromium plated metals
- Stainless steel surfaces
- Galvanized steel surfaces

## **1.4.6 Stormwater Drainage, Plumbing and Wastewater Treatment**

### **1.4.6.1 Stormwater Drainage**

The rainfall intensity design basis in mm per hour shall be shown in the Figure 1:

The Rational formula shall be adopted for stormwater discharge while time duration for overland flow (to) to the farthest sewer shall not be more than 20 minutes. Runoff coefficient (C) shall be submitted to EGAT for approval. Designed return period of rainfall intensity shall not be less than 1 in 10 years. Moreover, flow velocity in the stormwater drainage system shall be in between 0.6-2.0 m/s.

The stormwater drainage system shall be designed as rectangular reinforced concrete ditch. The bottom width shall be not less than 0.40 m and the minimum depth shall be 0.30 m. The steel grating of the open drains shall be designed for heavy duty condition where it is in the vicinity of the roads or heavy external loading is expected.

Erosion protection shall be provided at the end of drainage outlet where the storm water is discharging into the existing natural channel.

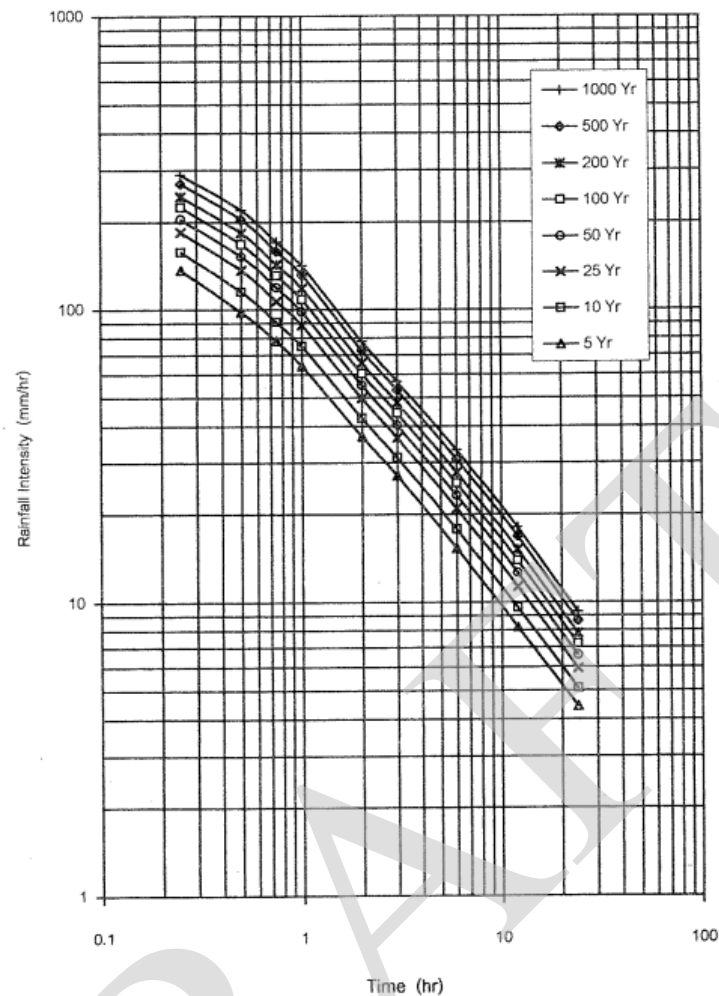


Figure 1 Rainfall Intensity Duration Frequency Curve

#### 1.4.6.2 Plumbing

There shall be an automatic water pump operating for a toilet room. Capacity of the water supply pump shall not be less than 50 l/min at 20 m total dynamic head. The pump motor shall be at least 400 watts and single-phase with built-in thermal overload protection.

Water filter shall have the minimum capacity of 50 l/min and composed of turbidity removal unit and activated carbon unit. The valves, piping and accessories shall be provided. It shall be equipped with backwash system.

Water storage tank shall be made of fiberglass or stainless steel and the minimum storage volume shall be 5,000 liters. The tank level shall be controlled by a float shut-off valve supplied with the tank.

Water supply, waste, soil and vent pipes shall be PVC pipes as specified in Civil Works Technical Specification, Chapter 23, Plumbing. All plumbing fixtures shall be installed with angle stop valves.

After the installation of water supply, waste, soil and vent piping systems, the Contractor shall test the leakage of the systems to comply with the requirements of codes and standards.

#### **1.4.6.3 Wastewater Treatment System**

Wastewater pipes shall be designed at a gradient giving adequate velocity for self cleaning flow. Wastewater pipes shall be led to a package wastewater treatment tank. Effluent from the tank will be discharged to the nearest sump, then discharge to the existing natural channel. Pipe cleanouts shall be required at every distance not more than 15 m.

Where wastewater pipes cross under water supply pipes, the top of sewer pipe shall be approximately 300 mm below the invert of the water pipe.

Design for wastewater treatment system in the powerhouse and guard house shall be based on the following criteria.

- Wastewater flow rate 1,000 l/day for powerhouse and 200 l/day for guard house
- Biological oxygen demand (BOD<sub>5</sub>) at inlet 200 mg/l
- Discharge BOD<sub>5</sub> will be less than 40 mg/l

#### **1.4.6.4 Powerhouse Floor Gutter and Oil Separator**

Design for drain gutter of all floors in powerhouse building shall be based on the following criteria:

- Minimum quantity of drained water discharge shall be 10 litre/s.
- Floor gutter shall be provided for all floors and shall be adequate to collect wash water, seepage and possible leakage.
- Minimum width and depth of gutter shall not be less than 0.30 m and 0.10 m respectively.
- Bottom slope of gutter shall not be less than 1:500.

Moreover, design for oil separator shall be based on the following criteria:

- Minimum volume of oil storage in the oil separator shall be equal to total oil used in all equipments but not be less than 200 liters and oil shall not be leaked from the separator.
- The oil separator shall be easy to access for maintenance of oil skimming and all equipments.
- The floor of oil separator shall have floor gutter and drain sump and shall consist of pumps (with stand-by unit) to drain water in the oil separator to the proper site.
- The invert level of oil separator shall be minimum 1 m. below the level of oil leakage sources.

#### **1.4.6.5 Transformer Gutter and Oil Separator**

The transformer area shall consist of gutter to contain oil that can be released from transformers in case of emergency. The total volume of gutter shall not be less than 3 times of volume of oil used in the transformer. In addition, the gutter shall be filled with No.2 coarse gravel.

Furthermore, oil separator shall be provided for the transformer area and the volume of oil to be contained shall not be less than volume of oil used in the transformer.

## **1.5 DESIGN DESCRIPTION**

The design of powerhouse-and related structure shall be performed by the Contractor within the constraint provided in Bidding Documents. A preliminary conceptual design is provided herein. The Definition in Part 2, the Technical Specification in Part 3 and Drawings in Volume IV, referred to one extent or another. The Contractor shall incorporate all these criteria and requirements into his design with reasonable engineering judgment. The Contractor shall be responsible for final design. Any significant deviations shall be clearly identified and itemized by the Contractor during the Bid Stage. Any deviations not so identified and approved by EGAT, may be rejected by EGAT later without creating a basis for additional payment to the Contractor.

## **1.6 SCOPE**

The scopes for Civil Works are:

1. Site Work and Cofferdam
2. Steel saddle for Penstock
3. Penstock and Wye Branch Concrete Encasement
4. Powerhouse and Control Building
5. Tailrace Structure
6. Laydown area
7. Access road
8. Stormwater Drainage System
9. Plumbing and Wastewater Treatment System
10. Transformer Foundation
11. Disposal Area
12. Other Civil Work Relating to the Equipment Work

These works are described in the definitions included in Part 2 and shown on the Drawings in Volume IV.

## **1.7 BID DRAWINGS**

### **1.7.1 General**

The Bid Drawings for Civil Works have been prepared for bidding purpose.

These drawings are a conceptual nature and are not intended to supersede the written Bid Documents in Part 1, 2 and 3 of this Volume or to preclude the use of specific manufacturer's equipment or system that is in compliance with the written specifications. Omissions of specified equipment or systems from the Bid Drawings shall not relieve the Contractor from providing the omissions in accordance with the specifications.

### **1.7.2 Detailed Design Requirements**

The Bid Drawings for Civil Works have been included with the Bid Documents to illustrate to the Contractor the conceptual design requirements. Dimensions, drawing scales, line sizes, capacities, ratings, etc., indicated on the Bid Drawings are preliminary design only.

The Bid Drawings for Civil Works identify minimum design requirements for the powerhouse and appurtenant structures. During detailed design, the Contractor shall confirm, update, and finalize these drawings in accordance with the criteria and requirements contained in these specifications, and as required by the Contractor's design. Modifications shall not adversely affect powerhouse operation or availability, and shall be acceptable to the Engineer. Such modifications, by themselves, shall not be constituted a valid basis for a contract price adjustment.

End of Part 1

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## **PART 2**

### **DEFINITIONS**



## PART 2 DEFINITIONS

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## PART 2 DEFINITIONS

### 2.1 SITE WORK

#### 2.1.1 Temporary Access, Access Road and Service Road

The Contractor shall design, construct and maintain the temporary access (road for carrying out the work during construction), Access road (permanent road leading to project area) and Service road (permanent road leading to main structure), bridges and related work that may be necessary, from the existing roads to the powerhouse area, and other areas such as access to the camp, stores, plants, borrow areas, disposal areas and any other areas which include facilities related to the powerhouse construction works.

Additionally, the Contractor shall improve and maintain all the existing service roads of the project area at satisfaction of EGAT/Engineer for guaranteeing normal traffic for any kind of vehicle.

The Contractor shall be responsible for the safety of the roadways, bridges and related work, during the construction and usage of the same. Additionally, he will be responsible for protecting the damage to any part of works and the property of others in relation to the performance of this works.

The horizontal and vertical alignments of all roads shall be designed to meet the requirements of future vehicle traffic and the relevant local Authority. Super elevation shall not be used for the design. The Contractor shall also take into account the requirements of equipment in determining geometric design.

The parameters required for road design are as followings:

- Roadway half width, meters	:	2
- Design speed, km/h	:	40
- Maximum grade, percent	:	8
- Design cross slope, percent	:	2
- Minimum vertical clearance from crown, meters	:	5.00
- Minimum horizontal clearance from center line, meters	:	4.00
- Intersection centerline radius, meters (outside only)	:	14
- Reinforcement concrete pavement	:	yes

Pavement shall consist of subgrade, subbase, crushed stone base, binder course and wearing course.

All culverts and other services crossing the road must be completed before commencement of pavement works.

Parking, turnaround for maintenance, guard rail and guide post shall be provided. Location of guard rails and guide posts shall be as shown on the Bid Drawings. The materials of guard rails and guide posts are specified in Civil Works Technical Specification, Chapter 24, Sundries.

For adequate safety, Guard rails and guide posts shall be intermittently provided along the road where necessary especially at curve. The post shall be 0.15 m x 0.15 m x 1.30 m (minimum) reinforced concrete embedded into the ground by 0.50 m minimum. The remaining 0.80 m above the ground shall be painted black in 0.15 m and white in 0.25 m striping. The reflective sheeting shall be provided at the foreside and backside of the post as DOH standards.

Guard rail shall be provided along roadside where dangerous situations, such as bridge approach, horizontal curve where radius is less than 50 m. Guard rail shall be designed conforming to DOH standards. Material of guard rail shall be conformed to TIS 248.

Road marking shall be provided according to the DOH standards.

The Contractor shall furnish and install traffic signs at access roads, junctions, turns, curves, parking areas or any other point according to the DOH standards. Materials, types, shapes, dimensions and installation method for traffic sign, shall be in accordance with the latest specifications of DOH standards.

Signs shall also be provided at strategic positions inside and outside the plant site.

Direction signs and any other necessary signage shall be provided as required by EGAT.

The roadway formation shall be kept clean, free from mud and slurry and properly shaped and compacted by rolling to an even and uniform surface to match with the pavement. Temporary or permanent roadside drains shall be provided.

### **2.1.2 Back and Side Slope Protection (If applicable)**

The slope protection of back and side slope shall be shotcrete with rock reinforcement. All of slope protection shall provide surface drain and under drain. Details and locations shall be as shown on the Bid Drawings. The material and dimensions of shotcreting are specified in Civil Works Technical Specification, Chapter 22, Rock Stabilization and Supports.

### **2.1.3 Fencing and Gate**

Fencing and gate shall be installed as shown on the Bid Drawings. The fence shall have a height of 1.80 m and the gate opening of 6.0 m. The fence shall be steel wire mesh fence. The materials for fencing and gate are specified in Civil Works Technical Specification, Chapter 24 Sundries. The gate shall be structure steel rectangular section. Details of fence and gate shall be as shown on the Bid Drawings.

### **2.1.4 EGAT Site Office**

EGAT Site Office building shall be provided by the Contractor for EGAT staffs during construction period. The location, site plan, architecture and facilities shall be submitted to EGAT for approval. The office building shall include a 40 sq.m meeting room, 16 sq.m office room, common office area of 60 sq.m, kitchen, toilets, and other facilities.

The office shall be of substantial construction, resistant to insects, well insulated and weather tight. The floor shall be raised at least 30 cm above ground level. Doors shall be provided

with a lock and the windows shall be hinged, glazed, and insect screened and provided with substantial shutter fastening on the inside. In addition, the undercover parking lot shall be provided for EGAT. The fire extinguisher shall be provided and the installed position shall be submitted to EGAT.

Water supply shall be provided. Sewage treatment type shall be septic tank with anaerobic filter or other means as approved by EGAT. Size of sewage treatment tank shall be adequate to treat wastewater from EGAT activities.

The office shall be fitted with electric lighting and wall mounted socket outlets. Air conditioners shall be provided in each room exclude toilet and kitchen. Offices shall be furnished with electric power supply and internet connection. The local area network (LAN) and Wi-Fi access point shall be provided for the office area. The maintenance during construction period shall be responsible by Contractor. However, the monthly bill for water, internet and other communications will be EGAT's responsibility.

The office shall be furnished with desk and desk chair in each office, 12 desks and chairs in the common office area. The office shall include shelving in each room appropriate for storage of documents, drawings, books, etc.

The office accessory for EGAT using in the duration of the project including personal computer with office software 10 units, color laser printer A4 1 unit, laser printer A3 1 unit, projector 1 unit and microphone and audio conference system for meeting room, shall be provided in accordance with the minimum requirements of EGAT (Site).

The meeting room for the office shall be equipped with a meeting table and chairs sufficient for 30 persons. A white board, projector screen and other facilities shall be provided as appropriate for use as a construction office.

The kitchen shall be equipped with refrigerator, microwave oven, and other facilities sufficient for use by EGAT staffs.

Road access to the office shall be paved to control dust and the site ditch shall be arranged for control of drainage. The office shall be attractively landscaped with lawn, shrubbery, walkway, patio area, the parking area and other facilities as directed by EGAT.

Wastewater Treatment Tank shall be provided and conform to Sub-clause 2.7.2.

### **2.1.5 Project Sign Board**

Project sign board shall be decorated with aluminum composite and stainless-steel letters. Details of project sign board shall be as shown on the Bid Drawings.

### **2.1.6 Flag Pole (Not applicable)**

Flag pole shall be made of galvanized steel pipe with overall height of 7.50 m. The outer diameter shall be 6 inches at the bottom and 4 inches at the top. The foundation shall be reinforced concrete structure. Flag pole shall be located as shown on the Bid Drawings.

### **2.1.7 Landscape (Not applicable)**

Landscape shall be arranged in the construction area in order to rehabilitate the construction area and also to produce a neat and attractive environment after the construction. Top soil and sods shall be prepared as specified in Civil Works Technical Specification, Chapter 24, Sundries. The hose bibb for watering system shall be provided.

### **2.1.8 Existing Toe Drain (If applicable)**

The Contractor shall reconstruct the existing toe drain of dam which shall be demolished and also connected from the existing toe drain outlet to the proper position such as the existing outlet. The drainage capacity of the newly drain shall be adequate.

### **2.1.9 Temporary Water Supply System**

All work related to RID's water supply shutoff and/or obstructing waterway, such as penstock and bifurcation installation, cofferdam construction and etc., shall be planed and performed in the appropriate period, according to the Hydrological Report as shown in Volume V, Supplement Data.

The Contractor shall submit the calculation report, method statement and drawings for temporary water supply and protective existing structures works for EGAT approval.

Moreover, the Contractor shall provide, install and construct the Temporary Water Supply System to continue supplying water to the existing water supply system. The among of water shall be compiled with the RID's operation.

All costs related to the construction of the Temporary Water Supply System during RID's water supply shutoff shall be borne by the Contractor.

## **2.2 CONCRETE SUPPORT AND STEEL SUPPORT FOR WYE BRANCH AND PENSTOCK**

Concrete support and steel support shall be capable of withstanding the forces from water flow and all positions which change in direction or gradient of the penstock and must be substantial structure.

The void between steel lining and concrete support shall be filled with contact grouting conform to Chapter 8 of Technical Specification, Grouting.

## **2.3 VALVE CHAMBER (Not applicable)**

Valve chamber shall be designed as underground structure or manhole. Waterstop shall be provided for all underground joints.

Concrete roof shall be removable for valve and all equipment maintenance.

Valve chamber structure shall have one removable galvanized steel cover for maintenance purpose. An adequate size of galvanized steel cover with pick or hook holes shall be provided

for lifting up and good access. Material of galvanized steel cover shall conform to the requirements specified in Civil Works Technical Specification, Chapter 13, Metal Work.

Fixed step ladder shall also be provided in Valve chamber structure as shown on the Bid Drawings.

The drainage system shall be provided at the bottom of Valve chamber structure to drain water from Valve chamber structure to oil/water separator system of the powerhouse.

The top elevation of Valve chamber structure shall be at least 0.50 m above the top of adjacent roads and the top of galvanized steel cover shall be at least 0.10 m higher than the top of Valve chamber structure.

## **2.4 SURGE TANK (Not applicable)**

Surge tank shall be reinforced concrete structure. At the top of the tank shall be opened to the atmosphere and galvanized steel hand rails shall be provided around the inside and outside tank perimeter. The top elevation shall not more than +198.50 m.MSL. Outside surface of the tank shall be plastered with painting and inside surface preparation shall be plastered with epoxy coating. Details of painting and coating shall conform to Chapter 20 of Technical Specification, Painting and Coating. Galvanized steel ladders with landing, both inside and outside of tank shall be provided. Minimum requirements for ladder shall conform to International Standards such as ANSI and OSHA, etc. Maximum height between landing shall be 5.00 meters. PVC water stop shall be provided for construction joint.

## **2.5 POWERHOUSE BUILDING AND CONTROL BUILDING**

### **2.5.1 Powerhouse**

Powerhouse shall be designed as a semi-underground reinforced concrete structure. The powerhouse shall consist of two floors as mentioned below:

#### **(1) Turbine Floor**

This floor-consists of one set of turbine and generator with the installed capacity of 1x1.5 MW. This floor shall be planned for convenience in operation and the equipment shall be spaced to permit easy circulation, easy access to equipment for repair or replace unit. Floor shall be steel trowel with floor epoxy and wall shall be waterproofed and moisture resistance paint.

Gutter shall be provided for collecting a wash water, seepage, and possible leakage and drain to the oil separator. Particular attention shall be paid to all details to avoid damage to all equipment and structures caused by leaks or clogged drain. The designed capacity shall be adequate to collect water from powerhouse floor. Any drains that may contain a mixture of oil and water shall be connected to the oil separator.

#### **(2) Deck Floor**

This floor is the roof of powerhouse, as reinforced concrete slab, that consists of an entrance room and removable hatch covers. This floor shall be waterproof concrete. Slope of

reinforced concrete slab shall not be flatter than 0.005. Material of the steel hatch covers shall conform to Civil Works Technical Specification, Chapter 13, Metal Work. The steel hatch covers shall be painted as specified in Civil Works Technical Specification, Chapter 20, Painting and Coating.

Moreover, general requirements for powerhouse are as follows:

The main access from deck floor to turbine floor shall be reinforced concrete stair and emergency exit from turbine floor to outside of powerhouse shall be provided as steel ladder. The location and details of emergency exit shall be as shown in the Bid Drawings.

The powerhouse equipped with artificial illumination shall have adequate reliable illumination provided for emergency standby and egress to exit facilities. Emergency escape lighting shall illuminate the run of the escape routes in order to guide personnel out of the powerhouse building under emergency conditions. Emergency escape lighting system shall conform to Volume II, Equipment Works chapter TE 12.

In addition, powerhouse shall also be designed to accommodate equipment, which helps controlling maximum overspeed of machine and maximum hydraulic pressure in the penstock as specified in TM-1, i.e., pressure relief valve and/or external flywheel (if required).

Platform (if required) shall be provided to access equipment which requires regular maintenance, operation, inspection or calibration. Daily access platform shall be provided with a fixed stair. Others may be access by fixed ladders. All platforms shall have means of emergency egress.

Ventilation inside of powerhouse building shall be provided. The arrangement for ventilation shall be done in accordance with the requirements specified in Volume II, Equipment Works.

Steel pipe handrail shall be provided at stair and walkways adjacent to the opening and other places as required by safety requirements.

Four (4) settlement points shall be set up on the deck floor of powerhouse. The settlement measuring points shall be made of stainless steel.

Waterstop shall be provided for all underground joints.

The gap between concrete and Mechanical & Electrical equipment shall be filled with grouting conform to Chapter 8 of Technical Specification, Grouting.

### **2.5.2 Control Building**

Control Building shall consist of control room, electrical room and battery area as shown in the Bid Drawing. The building shall be designed for convenience in operation and the equipment shall be spaced to permit easy circulation, easy access to equipment for repair or replace unit, and convenient installation of future equipment. The building foundations shall be constructed with suitable reinforced concrete foundation as shallow or pile foundation. The Contractor shall provide appropriate and adequate power cable supports or space for the

power cable installation inside the Control Building and meet requirement of electrical equipment and maintenance conditions.

The top surface of floor shall be elevated at least 1.00 m. above the surrounding site finished grade and historical flood level shall be considered. Stair and ramp shall be provided for access and maintenance purpose.

Roof and cover shall be provided for Electronics Building which shall be covered to avoid the sunlight, rainfall and other weather conditions. Roof and cover shall be metal roof panel system, including insulation, flashings, fasteners and appurtenances. Other materials shall be submitted to EGAT for approval. Roof and cover shall resist the severe weather condition such as humidity, acidity, rust etc. Roof steel structure shall be painted as specified in Civil Works Technical Specification, Chapter 20, Painting and Coating.

The fire protection including painting for the building (Structural members, wall, floor, ceiling, doors, block out etc.) shall be fire resistance rating at least 2 hours.

Doors or removable panels of adequate size shall be provided to accommodate the installed equipment.

Component materials shall conform to the AISI or TIS specifications or standards and codes as specified in Volume III, Part 1, clause 1.4.2.

The air ventilation and air conditioning system shall be provided to conform electrical equipment standard.

Control Building's layout and finishing schedule are shown in the Bid Drawing.

Container Building (if applicable) shall have a covered building that shall be reinforced concrete or steel structure supported on shallow foundation or pile foundation. Roof of the covered building shall be insulated metal roof panel with non-perforated metal liner. The Contractor shall propose the exterior and interior architectural design including all interior and exterior material for EGAT's approval.

### **2.5.3 Transformer Yard**

The transformer yard is situated on cut area near by the powerhouse building. Reinforced concrete slab shall be provided in front of the transformer for maintenance and inspection.

Steel and chain link fence shall be provided around the boundary of transformer with inside drainage gutters and pipe drains. The reinforced concrete firewall with at least 2.00 meters height shall be provided conforming to E.I.T. 022001-22. Transformer foundations shall be constructed with suitable reinforced concrete foundation as shallow or pile foundation. Oil separator shall be provided.

### **2.5.4 Laydown Area**

Laydown area shall be provided for temporary storage of equipment and supplies as well as for the purpose of maintenance. Laydown areas shall be reinforced concrete slab to ensure accessibility and safe maneuverability for transport and off-loading of vehicles. The laydown area shall be shown in the Bid drawings.



## **2.6 STORMWATER DRAINAGE**

Powerhouse building, roads, parking area and yard areas shall have the collecting drains discharging to the tailrace channel or existing irrigation channel or existing spillway. Hill side slope collecting drains shall be provided and shall be drained to the existing natural channel.

Road crossing drains shall be provided for collecting the stormwater to the existing natural channel. Road crossing drains shall be culverts with drain sumps or catch basins. Culvert design shall take into account vehicle loading expedited in the construction area. Storm water discharged through the culverts shall be computed to determine the required culverts size. For this purpose, in the case of pipe culverts, open channel flow shall be used with 300 mm freeboard.

The stormwater drainage system shall be designed as open or underground drains and shall be designed with a return period of 10 years. Locations of open drains with galvanized steel grating are shown on the Bid Drawings. In addition, the steel grating of the open drains shall be designed for heavy duty condition where it is in the vicinity of the roads or heavy external loading is expected.

All drains shall be designed at a gradient giving adequate velocity for self-cleaning flow. The invert to sumps and outgoing drains shall not be accumulated water at any time. Sumps shall be provided at all changes in direction or gradient of the pipelines.

Erosion protection shall be provided at the end of drainage outlet where the storm water is discharging into the existing natural channel.

## **2.7 PLUMBING AND WASTEWATER TREATMENT SYSTEM**

### **2.7.1 Plumbing System**

#### **2.7.1.1 Water Supply System**

The water supply system shall comprise of pump, water filter, water storage tank, float/level switch, valves, piping, etc. The system shall be located in the powerhouse except the water storage tank. Raw water for the system shall be tapped from the penstock and transmitted to the water filter. The filtered water shall be transmitted to the water storage tank. There shall be an automatic water pump operating for a toilet, an emergency eye and face wash in battery room and a toilet. The pump shall be non-self-priming, horizontal centrifugal pump with mechanical shaft seal and extended pump/motor shaft. The pump shall be equipped with a diaphragm pressure tank keeping uniform water pressure and shall also be supplied with other accessories such as check valve, automatic start/stop switch, pressure gauge, etc. Capacity of the pump shall not be less than 55 l/min at 20 m total dynamic head. The pump motor shall be at least 450 watts and single-phase with built-in thermal overload protection. The final schematic arrangement of all equipment shall be designed by the Contractor and submitted to the Engineer for approval.

Water filter shall have the minimum capacity of 1,500 liters/hour and composed of turbidity removal unit and activated carbon unit. The valves, piping and accessories shall be provided. It shall be equipped with backwash system.

Water storage tank shall be made of fiberglass or stainless steel and the minimum storage volume shall be 5,000 liters. The tank level shall be controlled by a float shut-off valve supplied with the tank. A high and low level alarm switch for remote annunciation in the control room shall be supplied.

Water supply piping shall be PVC pipes as specified in Civil Works Technical Specification, Chapter 23, Plumbing. All plumbing fixtures shall be installed with angle stop valves.

After the installation of water supply piping system, the Contractor shall test the water leakage of the system to comply with the requirements of codes and standards specified in Clause 1.4, Design Criteria, Part 1 of this Volume.

### **2.7.1.2 Sanitary Drainage System**

#### **a) Stormwater Drainage**

Drain from deck floor slab shall be collected by gutters and then discharged directly into tailrace channel.

All drains shall be designed to a return period of 10 years and at a gradient giving adequate velocity for self-cleaning flow.

Sumps shall be provided at all changes in direction or gradient of the pipelines.

#### **b) Wastewater and Vent Piping System.**

Wastewater means all used water from toilet whether it has dregs or not. Wastewater and vent pipes shall be PVC pipes as specified in Civil Works Technical Specification, Chapter 23, Plumbing.

Wastewater pipes shall be designed at a gradient giving adequate velocity for self-cleaning flow. Wastewater pipes shall be led to a package wastewater treatment tank. Effluent from the tank will be discharged to the nearest sump, then discharge to the existing natural channel. Pipe cleanouts shall be required at every distance not more than 15 m.

Where wastewater pipes cross under water supply pipes, the top of sewer pipe shall be approximately 300 mm below the invert of the water pipe.

Vent pipes shall be led to outside the building. Where vent pipes passing through the roof, the special arrangement shall be provided to prevent the leakage. The end of vent pipes shall not led to or near doors, windows, or ventilators of the building.

The system will be tested for the water leakage in accordance with the codes and standards specified in Clause 1.4, Design Criteria, Part 1 of this Volume.

All exposed pipes shall be securely installed.

#### **c) Floor drain system**

Drainage from all floors shall be collected by the perimeter gutters or drain pipes and discharged to the floor drains, then routed to oil separator. Drains from valve chamber which

may be contaminated shall be routed to oil separator by a minimum 150 mm pipe. Trash screen shall also be provided.

Drain pipes shall be PVC pipes as specified in Civil Works Technical Specification, Chapter 23, Plumbing, and all floor drains shall be trap types.

All exposed pipes shall be securely installed as specified in Civil Works Technical Specification, Chapter 23.

## **2.7.2 Wastewater Treatment System**

The Wastewater Treatment System shall be a prefabricated package tank. The tank shall collect wastewater from the powerhouse and toilet and be located in the enclosed pit outside of the powerhouse. Effluent from the tank shall be discharged to the existing natural channel.

The body of the tank shall be made of fiberglass or other corrosion-resistance material. There shall be inflow and outflow pipes. The tank shall consist of self-contained sewage system of the extended aeration and include, but not be limited to, the following stages.

- Sewage introduction
- Separation chamber
- Aeration chamber
- Sedimentation chamber (with sludge return to the aeration chamber)
- Disinfection chamber
- Discharge.

The wastewater flow rate for wastewater treatment tank will be at least 1000 litres per day. The total Biological Oxygen Demand (BOD<sub>5</sub>) load will be at least 0.25 kg/d. Discharge BOD<sub>5</sub> shall be less than 20 ppm.

A separate air pump shall be in an accessible location. Approximate air capacity shall not be less than 40 litres per min.

All chambers shall be accessible through top-mounted manhole. The tank shall be located in an enclosed pit outside of the powerhouse.

## **2.8 TAILRACE STRUCTURE AND TAILRACE CHANNEL**

### **2.8.1 Tailrace Structure**

Tailrace shall be located at downstream side of the powerhouse and shall be rectangular shape reinforced concrete structure.

### **2.8.2 Tailrace Channel (Not applicable)**

Tailrace channel shall be designed to convey flow from powerhouse and discharge to the existing natural channel. The channel shall be rectangular or trapezoidal reinforced concrete retaining wall or slab.

At the junction where the tailrace channel meets with the existing natural channel, a smooth flow shall be taken into account for a geometric design. Protection with riprap on geotextile

shall be made to the existing natural channel to prevent any damages caused by changing in flow direction.

## **2.9 IMPROVEMENT OF THE EXISTING NATURAL CHANNEL (If required)**

The Contractor shall improve the existing natural channel starting from the outlet of tailrace channel up to the downstream direction. Location and details of the improved natural channel shall be as shown in the Bid Drawings.

Slope stability of the improved channel shall be considered for minimum tail water level and maximum ground water level. Factor of safety shall be in accordance with Volume III.

## **2.10 PAINTING AND COATING**

Unless specified otherwise in other clauses of Volume IV, painting and coating shall conform to this clause and Civil Works Technical Specification, Chapter 20, Painting and Coating.

All atmospheric exposed surfaces of steel and metal works shall be coated. In addition, all visible and exposed surfaces of structural steel and metal works shall also be painted.

Surfaces of powerhouse building needed to be painted shall conform to the Finishing Schedules specified in the Bid Drawings.

Exposed surfaces of electrical conduit, conduit boxes, and fittings shall be painted only when they are adjacent to the painted parts of the building structure or equipment. These surfaces shall be painted the same color as the adjacent building surfaces.

Abraded or damaged areas of shop primed surfaces shall be cleaned and touch-up painted before applying finish paint system. Abraded or damaged areas of shop finish painted surfaces shall be repaired by spot priming and repainting with materials of similar type and color to the existing shop paint system.

Unless otherwise specified in the Bid Drawings, the following surfaces shall not be painted:

- Aluminum surface
- Brass
- Bronze
- Chromium plated metals
- Stainless steel surfaces
- Galvanized steel surfaces

## **2.11 REMOVAL OF THE EXISTING STRUCTURES**

The Contractor shall perform temporary removal of the existing structures, which shall include, but not limited to, existing maintenance road, toe drain, outlet channel, existing of dam instrument, dam facilities, public structures, RID's structure and storm drain.

The Contractor shall submit detailed descriptions, methods and stages of removal of the existing structures including the associated excavation work schedule as applicable. The Contractor shall provide temporary protective system to prevent any damages from disturbing the existing facilities. Access to the work shall be made and the Contractor shall fully evaluate its access restrictions on his own visit to the site or during the site visit organized by

EGAT. Temporary downstream maintenance road, toe drain and downstream storm drain shall be constructed during the construction. All removal of the existing structures shall be reinstated to the original conditions.

## **2.12 VALVE HOUSE**

Valve House shall consist of control panel and hydraulic unit. The building shall be designed for convenience in operation and the equipment shall be spaced to permit easy circulation, easy access to equipment for repair or replace unit, and convenient installation of future equipment. The Contractor shall provide appropriate and adequate lighting, power cable supports or space for the power cable installation inside the Valve House and meet requirement of electrical equipment and maintenance conditions.

Roof and cover shall be provided for Valve House which shall be covered to avoid the sunlight, rainfall and other weather conditions. Roof and cover shall be metal roof panel system, including insulation, flashings, fasteners and appurtenances. Other materials shall be submitted to EGAT for approval. Roof steel structure shall be painted as specified in Civil Works Technical Specification, Chapter 20, Painting and Coating.

Doors or removable panels of adequate size shall be provided to accommodate the installed equipment.

Component materials shall conform to the AISI or TIS specifications or standards and codes as specified in Volume III, Part 1, clause 1.4.2.

The air ventilation shall be provided to conform electrical equipment standard.

Valve House's layout and finishing schedule are shown in the Bid Drawing.

End of Part 2

**PART 3**  
**TECHNICAL SPECIFICATIONS**

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# **CHAPTER 1 - SURVEYING**



# TECHNICAL SPECIFICATION

## CHAPTER 1 - SURVEYING

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## **CHAPTER 1 - SURVEYING**

### **1.1 GENERAL**

#### **1.1.1 Scope**

The Contractor shall render all services for topographical as well as hydrographical survey and measurement required for the performance of the Works.

These services cover in general the establishment of axes centerlines, alignments of project structures and features; the setting out for construction thereof; the accompanying control surveys for correct locations, dimensions and elevations as well as the necessary surveys for measurement to permit quantity calculations for invoicing.

Such surveys shall be based on and/or referred to a basic grid of datum points and benchmarks extended adjacent to the Works in the project area. This grid shall be the sole basis of reference for all survey work and measurement.

#### **1.1.2 Submissions**

At least seven (7) days prior to the commencement of any survey work the Contractor shall inform the Engineer of his intention to perform the survey work. The Contractor shall indicate the purpose of the survey, the area to be surveyed, the structure or facilities involved, the methods to be applied and the survey period.

### **1.2 MATERIALS AND INSTRUMENTS**

The Contractor shall provide, maintain and operate suitable and appropriate equipment, instruments, materials and auxiliary equipment, commensurate with the various tasks and precision requirements of the survey works.

Type and accuracy of the survey equipment to be used by the Contractor shall correspond to the nature of the construction/erection works and the construction technique.

All equipment, instruments, materials and auxiliary equipment shall be in perfect operation condition. Prior to the start of survey activities, equipment, instruments, etc. shall be checked as to their proper functioning and accuracy.

During the construction period the survey instruments shall be checked and, if necessary, adjusted at regular time intervals.

Instruments and equipment which have suffered from use, damage or accidents to degree making them unfit for further use at the site, shall be removed from the site and replaced immediately.

The number of sets of instruments shall be sufficient to meet the requirements of the construction time schedule. Delay of start of construction or construction progress caused by insufficient quantity and quality of survey equipment including provision of professional staff shall be at the Contractor's responsibility.

## **1.3 EXECUTION**

### **1.3.1 General**

For the execution of the survey work the Contractor shall employ and provide experienced professionals and auxiliary staff. All survey and measurement work shall be recorded and filed thoroughly.

The Contractor shall provide, maintain, adjust when necessary and operate the required survey and auxiliary equipment for the performance of the Works.

All survey and measurement activities shall be recorded in maps and field books as directed and approved by the Engineer. Where required, the production of drawings and maps shall be deemed to be part of the Works.

The Engineer shall have the right to check work performance, accuracy, stations, etc. and all survey results, measurements and calculations as well as conformity with plans and drawings.

The Contractor shall keep and maintain professional records of all field surveys and measurements, the related computations and calculations, manuscripts, plans, drawings and maps, and shall make them available to the Engineer whenever requested.

If, in the opinion of the Engineer, deficiencies and/or inaccuracies in field and office work have been found, such work shall be repeated and made good to the satisfaction of the Engineer at the Contractor's expense.

### **1.3.2 Preparatory Works**

Prior to starting survey works the Contractor shall inform his surveyors of the general construction procedure, survey requirements and time limits. The surveyors shall make adequate terrain investigations with respect to sightings, vegetation to be removed, placement of monuments, taking into consideration future construction work which may affect the survey points, monuments and benchmarks. Based on these investigations a survey plan shall be developed comprising existing basic data, the survey grid to be developed, the equipment required for the particular survey task, staff and time requirements arranged in a way to warrant smooth progress of construction works.

All survey works shall be done with greatest care and precision.

### **1.3.3 Verification of Survey Grid**

The basic survey grid shall be verified by the Contractor, and the other Contractors and the Engineer shall be informed on the results, the reliability, the accuracy and the acceptability of such grid and data for further surveys.

All coordinates and elevations as shown on the Drawings are based on the basic survey grid. If, after having executed the verification, the basic survey grid reveals inconsistencies which may affect the location, alignment and elevation of structures of the Project, the Engineer shall be forthwith informed of these inconsistencies by the Contractor.

The Contractor shall record all calculations, control surveys, setting out and check surveying in a suitable permanent form for verification, which shall be available to the Engineer on request at all times. The Contractor shall supply two (2) copies of any such calculations to the Engineer upon his request.

#### **1.3.4 Augmentation of Basic Survey Grid**

Existing datum points and benchmark closely located to the permanent structures may be endangered by construction activities. The Contractor shall therefore in due time establish additional datum points at safe locations and elevations to augment or extend the basic grid.

The new datum points shall be of permanent nature and shall be constructed as directed by the Engineer.

The Contractor shall also establish reference monuments for center lines and line control of structures which need frequent and extended control surveys of embankment axis, tunnel alignment, etc.

New datum points, reference monuments and benchmarks shall be protected and maintained in the same way as the original grid points.

#### **1.3.5 Survey of Ground Profiles**

##### **1.3.5.1 Original Ground Profiles**

The Contractor shall inform the Engineer in writing, at least 14 days before commencing such work, of his intention to perform any work which will result in a change to the topography of the existing site for the permanent works and or for temporary works. Thereupon, before commencing any works, the Contractor shall survey the original topography to the approval of the Engineer over the entire area to be occupied or disturbed. Such survey may again be required after removal of vegetation, topsoil or other overburden.

The information so obtained shall be recorded by the Contractor on a drawing or drawings which shall be signed by both the Contractor and the Engineer. The Contractor shall then provide the Engineer with a reproducible copy of each drawing to serve as a permanent record for the purpose of determining the quantities of excavation or earthworks carried out in the construction of the permanent structures, and the extent to which Temporary works shall be removed or temporary excavations shall be refilled upon completion of the Works.

##### **1.3.5.2 Excavated and Final Ground Profiles**

The Contractor shall survey all excavated and final surfaces for the purpose of recording as-constructed details, and for the measurement of quantities:

- a) on completion of excavation and prior to commencement of embankment, banking, placing concrete or other works;
- b) on completion of embankment, banking, placing concrete or other works.

The survey results shall be recorded and agreed as set out in Clause 1.3.5.1.

### 1.3.6 Setting out of Works

The Contractor shall perform all setting out and check surveying of the Works in accordance with methods approved by the Engineer. The methods and program of checking shall be such as to ensure the construction of every part of the Works to the correct line and level. The Engineer may, at any time, request the Contractor to submit document proofing that his own setting out has been satisfactorily checked.

The number of points required for setting out as well as the spacing between these points shall be determined by the Contractor in accordance with the type of the Works. The Engineer may require that some or all of the given points and datum levels be clearly marked during construction in such a way that the marks can be retained after completion of construction.

### 1.3.7 Setting out Checks

The Engineer will perform check surveys during the course of construction and the Contractor shall cooperate with and provide assistance to him as required.

The Contractor is expected to liaise with EGAT to program the check survey to be carried out during non-production periods or in parallel to construction activities such that the minimum delay or inconvenience is caused to production work, wherever and whenever possible. The Contractor shall afford EGAT every cooperation and assistance in this regard including but not being limited to the provision of survey equipment, drainage, lighting, ventilation and the removal of Contractor's equipment and other obstructions such that they do not interfere with the setting out checks.

### 1.3.8 Accuracies and Tolerances

#### 1.3.8.1 Accuracies

Accuracy of survey work shall be within the following tolerances:

#### Triangulation

Allowable error of closure	
- Average not to exceed	5 seconds
- Maximum not to exceed	10 seconds

#### Traversing

Allowable error of closure	1/3,000
Allowable error of distance	1/5,000

#### Leveling

Allowable error for each 1 km measured forward and backward	10 mm
Allowable error for closure	$10 \sqrt{S}$ mm
(where S is the total distance of leveling expressed in km.)	

### 1.3.8.2 Tolerances

The tolerances given below shall be the maximum permissible deviations from the specified dimensions, levels, alignments, positions, etc. as shown on the Drawings of the structures or structural elements.

In addition, at the interfaces with mechanical components, concrete surfaces shall be finished flush and shall also meet any additional tolerances required by the mechanical designs or works, respectively.

However, monuments and benchmarks at the embankment to observe settlements shall initially coincide with the axis determined by reference monuments or a parallel line thereto with 1.0 mm tolerance, to permit settlements measurements of the embankment at regular intervals.

- Slope protection  
Benchmarks and subsidiary monuments intended to observe slope movements shall be placed with tolerances not exceeding  $\pm 15$  mm.
- Rockbolts and prestressed anchors
 

Position	$\pm 150$ mm
Deviation from direction	$\pm 5^\circ$
- Foundations and General Structures
 

Position plan	20 mm
Direction	$\pm 1^\circ$
Level	$\pm 20$ mm
- Project Service Roads
 

Position	$\pm 50$ mm
Level	$\pm 25$ mm
Gradual Irregularity	10 mm per 3 m
- Drainage
  - Open Drains  
The maximum permissible deviation of the level of the invert of the open drain including gutters, catch drain, side ditch, etc. from the designated level shall be  $\pm 35$  mm and/or nowhere shall the invert have an adverse grade.
  - Subsurface Drains  
The maximum permissible deviation of the level of the invert of the subsurface drain including drainage trench, drainage conduit, drain pipes, etc. from the designated level shall be  $\pm 25$  mm and/or nowhere shall the invert have an adverse grade.

### 1.3.9 Subsidiary Monuments and Benchmarks

The Contractor shall erect and establish all necessary additional survey monuments, fix points, benchmarks, etc. required for setting out of the Works and construction control including

determination of coordinates and elevations. Monuments and benchmarks placed which may be affected or disturbed by construction activities shall be referenced by the contractor by surveying and placing auxiliary benchmarks in safe position.

End of Chapter 1

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## **CHAPTER 2 - SOIL / ROCK INVESTIGATION**



**TECHNICAL SPECIFICATION**  
**CHAPTER 2 - SOIL / ROCK INVESTIGATION**  
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## **CHAPTER 2 - SOIL / ROCK INVESTIGATION**

### **2.1 GENERAL**

#### **2.1.1 Scope**

The works covered by this chapter shall include all services necessary for executing the specified range of soil/rock investigation, including the required site installation, for acquiring all data and knowledge necessary to execute the Works safely.

#### **2.1.2 Submissions**

The Contractor shall submit to the Engineer a description of testing equipment, facilities as well as a description of his laboratory equipment, and state the range and methods of tests which can be performed with his equipment and what Standards would be applied. He shall also provide information on the capacity of his testing equipment and facilities and the degree of accuracy obtainable by his testing methods.

The Contractor shall prepare and keep records on tests, evaluate the results and compile and prepare comprehensive test reports.

Test reports shall be handed over to the Engineer within three (3) days after completion of the testing works. However, the Engineer shall have the right to obtain interim test results or test results available prior to the completion of the test reports.

Test reports shall be prepared by the Contractor in 3 copies covering in general the following items:

- Type and Number of particular tests.
- Standards applied.
- Location of testing place, including coordinates.
- Date or period of testing works in field and laboratory.
- Weather conditions during field tests or sampling works.
- Supporting documents like field records, sketches, profiles, bore logs, measurements.
- Results of tests performed in tabular form supported where applicable by diagrams for field tests and laboratory tests.
- Evaluation of results.
- Particular observations.

### **2.2 EQUIPMENT, MATERIAL AND PERSONNEL**

#### **2.2.1 Equipment**

The Contractor shall provide, maintain and operate all testing equipment, facilities, devices, apparatus, and auxiliary equipment required for the performance of soil/rock material field testing. The Contractor shall further provide, maintain and operate a completely equipped

soil/rock material testing laboratory including all auxiliary equipment required for the performance of tests as required.

### **2.2.2 Material**

The Contractor shall provide at the site any material and consumables such as fuel, water, bags, containers, boxes and tools which will be required for timely execution of the testing works.

### **2.2.3 Personnel**

The Contractor shall provide and employ for the performance of the soil/rock material testing works as follows:

- a) only such technical assistants or personnel as are skilled and experienced in their respective fields, and such foremen as are competent to give proper supervision to the work, and
- b) such skilled, semi-skilled and unskilled labour as is necessary for proper and timely execution of the testing works and services.

## **2.3 EXECUTION**

### **2.3.1 General**

The Contractor shall perform services for sampling and field testing work including all auxiliary services.

For tests which cannot be performed by the Contractor, the Contractor shall avail of the services of an independent qualified testing laboratory which shall be approved by the Engineer.

The Contractor shall provide all equipment, testing facilities, instruments, labour, power, water supply and other required appliances and devices including transportation, maintenance supplementation and other auxiliary services.

The scope of works shall include the restoration of sites where sampling and field testing works were performed and shall include also removal and disposal of all debris from laboratory testing works as per instructions of the Engineer.

The Contractor shall perform the necessary geodetic survey to determine testing locations for their transfer into drawings and plans.

EGAT/Engineer shall at any time have access to testing works and facilities and may order the preparation of tests which in his opinion are not performed according to standards.

### **2.3.2 Borings**

The Contractor shall provide, maintain and operate exploratory drilling equipment suitable for the recovery of continuous cores in cohesive and non-cohesive soils and rock.

The drilling method shall permit the performance of Standard Penetration Tests (SPT) within the borehole. Furthermore, the recovery of undisturbed soil samples shall be possible if requested by the Engineer.

The continuous cores shall be stored in coreboxes. Selected samples shall be preserved in plastic bags or suitable airtight containers as indicated by the Engineer.

If necessary, casing has to be used to ensure the stability of the borehole. The Contractor will not be entitled to any compensation or additional payment for casing.

### **2.3.3 Borelogs**

Detailed borelogs shall be kept for all borings and SPT or core tests.

Data obtained in borings shall be recorded in the field and shall include the following:

- name and location of job
- date of boring
- time of start and finish
- boring number and coordinate
- surface elevation
- direction/inclination and diameter(s)
- sample number and depth
- type and size of sampler
- description of soil and rock
- thickness of layer
- depth to water surface
- loss of water
- artesian head; time at which reading was made
- type of machine
- size of casing, depth of cased hole
- names of crewmen, and
- weather, remarks

### **2.3.4 Test Pits**

The Contractor may excavate test pits for taking disturbed and undisturbed samples.

The test pits shall have a bottom width of at least 100 cm. The maximum depth will not be more than three (3) meters unless otherwise determined by the Engineer. The Contractor will be responsible for keeping the pit in such a condition that the stability of the walls is warranted

and that inspection of the bottom and walls is possible at all times. Protection of the pits shall be provided by the Contractor to prevent accidents.

The Contractor shall take samples and shall keep them in watertight bags or boxes. After the completion of the investigations by the Engineer, the Contractor shall refill the pits as directed.

### **2.3.5 Samples**

All soils sampled by SPT, disturbed sampling or core barrel, shall be kept and sorted adequately. Non-cohesive soils shall be kept in watertight bags and core boxes, cohesive soils including rocks shall be kept in normal core boxes. Borehole number and depth of sample shall be written on the cover of the bags and boxes. It shall be ensured that the cores are placed in the boxes in the order taken.

The corresponding depth of the material shall be written continuously on the partition walls of the boxes. The limits between different strata and sections of core loss shall be fixed with thin boards and marked with the depth. The core boxes shall be designed for approximately 5 m of continuous samples. The boxes shall be accessible to the Engineer at any time.

The Contractor shall supply equipment to take undisturbed samples from cohesive soil for laboratory tests, according to international standards. The samples shall be handled in a manner adequate to avoid disturbances or drying out.

### **2.3.6 Standard Penetration Tests (SPT)**

In boreholes, Standard Penetration Tests shall be performed in sections down to the bottom of the borehole. The tests shall be carried out every 1.50 m and at every change of soil condition. The number of blows required to drive the sound each 15 cm into the soil has to be counted and kept in the borelog.

### **2.3.7 Permeability Tests In-situ**

Permeability tests according to the method of "constant head" or "falling head" shall be performed. The standpipe, properly sealed in the borehole, shall be of sufficient length reach at least 0.50 m above ground.

During the tests, the temporary level of the groundwater level in nearby other boreholes shall be recorded.

The Contractor shall provide all necessary equipment for the performance of these tests, such as pumps, standpipes, measuring devices for water quantity and time, etc.

The test report shall give among other items borehole number, depth of borehole, depth of casing or standpipe, diameter of same, water level before and after testing, absorption per minute for the constant water level at the head of the standpipe, elevation of the head of the standpipe above ground, and the readings of the sinking or rising water level at suitable time intervals.

The results of the permeability tests shall be shown on the borelogs in a manner satisfactory to the Engineer.

### **2.3.8 Laboratory Tests**

The Contractor shall perform laboratory tests in order to acquire the necessary information for physical and mechanical parameters of soil and rock.

The laboratory tests shall be carried out in conformity with ASTM or any other approved International Standards in the Contractor's field laboratory or if not possible, at other laboratories to be approved by the Engineer.

The test shall be as follows, but not be limited to

- Unit weight, natural water content
- Specific gravity
- Atterberg's limit (LL, PL, PI) (if necessary)
- Grain size analysis (if necessary)
- Traiaxial test or unconfined compressive test of cohesive soil (if necessary)
- Consolidation test (if necessary)
- Compaction test of sample from test pit (if necessary)
- Traiaxial test of compacted sample from test pit (if necessary)

End of Chapter 2

## **CHAPTER 3 - CONSTRUCTION FACILITIES**

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## **CHAPTER 3 - CONSTRUCTION FACILITIES**

### **3.1 GENERAL**

#### **3.1.1 Scope**

This chapter covers the construction of Contractor's camps, construction buildings, construction plants, electric power supply, water supply, sewage and drainage, and telecommunication system necessary for the execution of the Works.

#### **3.1.2 Definitions**

- a) "Construction Building" is defined as a building necessary for the services in connection with the performance of the Works, which will include, but not be limited to, warehouses, repair shops, workshops, powder magazines, field laboratory and offices.
- b) "Construction Plant" is defined as a structure that is required to carry out the provisional and permanent works.

#### **3.1.3 Submissions**

At least 30 days prior to commencing the Works, the Contractor shall submit the drawings of layout and details of camps and facilities, electric power supply, water supply, sewage and drainage and telecommunication system to the Engineer for review.

### **3.2 MATERIALS**

**(Not applicable)**

### **3.3 EXECUTION**

#### **3.3.1 Camp and Facilities**

##### **3.3.1.1 General**

The Contractor shall, at his own expense, design, supply, install, equip, operate and maintain the construction facilities necessary for the proper performance of the Works which will include, but not be limited to, the following:

- a) Camps necessary for housing the personnel
- b) Construction buildings necessary for the services in connection with the performance of the Works
- c) First aid station in case of emergency
- d) Construction plant necessary for the performance of the Works
- e) Construction of temporary access, service road and detour road

The Contractor shall, at his own expense, rent houses or acquire land suitable for construction of camp and related facilities.

The Contractor shall submit location of construction building and related facilities to the Engineer for approval.

The Contractor, upon completion of the Works, shall remove camps and facilities and fill in all excavated areas as directed by the Engineer, and shall remove all refuse, debris and other objectionable materials and leave the camp and construction areas in a clean and sightly condition to the satisfaction of the Engineer.

### **3.3.1.2 Camp**

The Contractor shall construct, equip, maintain and operate the temporary camps, complete with the services and facilities necessary for all his personnel. It is understood that the personnel will consist of his own personnel as well as any additional personnel such as the security personnel, medical personnel, erection supervision personnel, subcontractors, etc.

All the camp constructions shall be structurally sound, compatible with the weather conditions of the site and of a neat appearance.

The dormitory buildings shall be properly ventilated and illuminated. They shall be provided with electric energy, potable water, sewer system and permanent garbage disposal service.

The accommodations shall comply with the appropriate Thai regulations and all buildings shall at any times be opened for inspection by the Engineer and any instruction given by the Engineer for the proper cleaning, disinfection and general maintenance in a sanitary and hygienic condition of any building must be forth with carried out by the Contractor. Before any buildings are occupied, the Contractor shall draw up a code of rules and regulations for their control which shall be approved by the Engineer.

### **3.3.1.3 Construction Buildings**

The Contractor shall construct, equip, maintain, and operate the temporary construction buildings complete with the corresponding related services.

Construction buildings shall include, but not be limited to, warehouses, repair shops, workshops, powder magazines, field laboratory and site office.

The buildings shall be structurally sound and compatible with the weather condition of the Site.

The warehouses and storage facilities shall be of sufficient capacity to satisfy the Contractor's needs.

The field laboratory shall be of a sufficient capacity to accommodate his staff and equipment necessary for the prosecution of the Works. The laboratory equipment shall be efficient and dependable, capable of performing all tests required by this Specification.

The Contractor shall establish a main office as mentioned in Part 2 Definition, 2.1.4 Office Building where his technical, administrative and financial services can easily be accessed for the Engineer looking for information.

#### **3.3.1.4 First Aid Station**

The Contractor shall establish, equip, operate and maintain the first aid station, which shall be of sufficient capacity to satisfy the emergency needs. The Contractor shall provide an available appropriate personnel at all time at first aid station and all persons connected with the Works shall be obliged to use. The Contractor shall provide, in case of emergency, the ambulance to take the patient to the nearby hospital.

The Contractor shall furnish and maintain first-aid cabinets at each of the work fronts.

#### **3.3.1.5 Construction Plant**

The Contractor shall design, furnish, install, construct, operate, maintain, dismantle and remove from the Site, all the construction plants that are required to carry out the provisional and permanent works.

#### **3.3.1.6 Temporary Access Service Roads, and Detour Road**

The Contractor shall design, construct and maintain the service tracks, temporary access and service roads, bridges and related work that may be necessary, from the existing roads and tracks to the various work areas, and other areas such as access to the camps, stores, plants, borrow areas, disposal areas and any other areas which include facilities related to the Works.

Additionally, the Contractor shall improve and maintain all the existing service roads and tracks of the project area at satisfaction of the Engineer for guaranteeing normal traffic for any kind of vehicle.

The Contractor shall be responsible for the safety of the roadways, bridges and related work, during the construction and usage of the same. Additionally, the Contractor shall be responsible for protecting against damage any part of the Works and the property of others in relation to the performance of this Works.

The main temporary access and service roads built or improved by the Contractor, shall be wide enough to allow heavyweight traffic in both directions. The longitudinal roadway grades shall be as required by the traffic conditions and in any case shall not be greater than 10%, except for short sections where grades of up to 15% may be allowed. The cut and fill slopes shall be as required by the material characteristics and by the safety of any part of the Works and of the property of others.

The roadway surface shall consist of a well-compacted layer of selected material. The roads shall be provided with appropriate ditches. Other related structures necessary to maintain traffic throughout the construction period shall also be constructed.

### **3.3.2 Electric Power Supply**

The Contractor shall, at his own expense, furnish, install and maintain the electrical distribution system to the required areas for his work.

The Contractor may arrange himself for a connection with the nearest existing Provincial Electricity Authority power line.

The Contractor shall install generator and related facilities at his own expenses in case of an excessive energy demand.

### **3.3.3 Water Supply**

The Contractor shall, at his own expense, design, construct, equip, operate and maintain the installation necessary for the adequate supply of both raw water for construction use and drinkable water for human consumption at various work areas as well as at the camps. Regulating, transporting, treating and distributing the water shall be included.

Only adequately treated water which complies with the current sanitary standards will be accepted for human consumption. Installation of non-potable water supply systems in the camp areas will not be permitted. Storage tanks with a reserve capacity equivalent to two (2) days of normal usage will be required for the drinking water system.

The Contractor shall take drinking water samples from time to time if requested by the Engineer. The samples shall be sent at, his own expense, to approval's laboratories, and the results of the analyses shall be obtained within 15 days of the sampling date. If the sampling and testing are not properly performed, EGAT may perform the same directly and charge the Contractor for the relevant expense.

### **3.3.4 Sewage and Drainage**

The Contractor shall, at his own expense, design, construct, equip, operate and maintain all the installation necessary to properly collect, treat and dispose of sewage from his camps and other construction facilities.

The Contractor shall not, under any circumstances, discharge sewage or contaminated water into natural streams or any open areas.

Treatment and disposal of sewage shall be performed in accordance with the current related standards and laws in force in Thailand and always subject to the Engineer's approval.

The drainage systems shall be designed taking into account the high rainfall rate in the area and the disposal of rainwater shall be accomplished in such a way that no erosion problems are caused which may alter the stability of the soil.

End of Chapter 3

## **CHAPTER 4 - CARE OF WATER**

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## **CHAPTER 4 - CARE OF WATER**

### **4.1 GENERAL**

#### **4.1.1 Scope**

This chapter covers the work necessary to construct, install, operate, maintain and remove temporary structures, materials and equipment to protect the works from surface and subsurface water, so that the permanent works can be performed free from water.

#### **4.1.2 Submissions**

##### **4.1.2.1 Detailed Planning of Dewatering and Water Treatment**

At least thirty (30) days prior to commencing the work, the Contractor shall submit to the Engineer for review, the detailed planning of the dewatering systems and the water treatment systems.

The detailed planning of the dewatering systems and the water treatment systems shall include the followings.

- Detailed description of the systems;
- Drawings showing layout and all details of the systems including water treatment equipment;
- Design calculation for the systems including cofferdam, well points, pumps, pipe lines, settling basins, etc.;
- Installation procedure and schedule of the systems;

### **4.2 MATERIAL**

#### **4.2.1 General**

The Contractor shall furnish, install, operate and maintain all pumps, piping, supports, electrical installations, water treatment equipment and necessary accessories to keep the various works free from water and treat the drained water during construction.

The Contractor shall also provide measuring devices for recording and monitoring of water quality where required.

#### **4.2.2 Dewatering and Water Treatment Equipment**

The choice of type, capacity and amount of equipment and determination of locations for the dewatering system shall be left to the discretion of the Contractor and subject to prior approval by the Engineer.

The type, capacity and amount of equipment, and chemicals for the water treatment system shall guarantee the requirements of the discharged water.

The Contractor shall submit to the Engineer relevant documents certifying the required quality of the proposed equipment.

All equipment and power supply systems to be used for the dewatering and water treatment systems shall be provided only from manufactures, whose products have already proven to be reliable on other sites.

The Contractor shall supply lubricants, accessories, spare parts, etc. required for continuous functioning of the dewatering and water treatment systems.

The provision of pumps shall include the complete excavation of pump sumps as required, the installation of electrical connections, the supply of fuel, the disposal of water and all other elements required to ensure an effective operational system.

The pumps shall be located away from permanent structures wherever possible and in any event the location shall be agreed upon after consultation with the Engineer.

The provision of pump sumps and channels of the dimensions required shall include all necessary excavation of any kind of soil above and under water, backfill and consolidation, sheeting, bracing, stiffening, sealing, scaffolding accesses, as well as the disposal of water and all auxiliary works.

The Contractor shall have at his disposal sufficient stand-by pumps with a capacity of at least equal to that of the installed pumps and all required auxiliary equipment. The reserve units shall be kept ready for service when any failure of the installed units occurs.

All equipment, instruments, machines, tools, etc. required for the execution of the work shall be of such quality as to withstand the climatic conditions of this region. They shall be kept serviceable and in good repair throughout the operating periods.

### **4.3 EXECUTION**

#### **4.3.1 Dewatering and Water Treatment**

##### **4.3.1.1 General**

The Contractor shall design, install, construct, operate and maintain all dewatering and water treatment systems, and where necessary, channels, troughs, drainage works, inlet gutters and all required works to keep construction areas free from water from any source and to keep the required water quality.

The removal of any amount of water that may be present at any moment and the control of water and seepage is the entire responsibility of the Contractor. Furthermore, the Contractor shall ensure that all drainage water will be disposed of without causing interference to his own work and other the Contractors' operating elsewhere on the construction site.

The Contractor shall be responsible for any accidents, damages and inconveniences that may be suffered by his equipments or materials, due to insufficient or inadequate control of water including water quality, poor operation and maintenance, or failure of the dewatering system.



The dewatering system shall be designed and installed in such a way that alterations and extensions of the systems during operations are possible.

#### **4.3.1.2 Dewatering**

The duration of dewatering will be determined according to the construction time schedule and to other factors, e.g., other the Contractors' work which has to be carried out under the protection of this dewatering system.

Pump operations shall not be stopped, nor pipes, channels and equipment for dewatering removed or altered in any way, except with the permission of the Engineer. Until then, the dewatering systems shall be kept in proper working order without extra payment being granted.

The Contractor shall maintain ready-for-service and regularly clean all dewatering equipment and accessories so that they can immediately and safely be used without risk of accident.

#### **4.3.1.3 Water Treatment**

Any water shall not be discharged directly into rivers without being disposed of through the water treatment system.

Particular attention shall be paid to possible pollution from oil or solvents coming into contact with the water prior to its disposal. Oil separators shall be provided within the dewatering system, if such cases arise.

The Contractor shall submit his proposal for treating polluted and/or turbid water by either settling basins, filters, oil separators, chemicals or any other method to be approved by the Engineer.

#### **4.3.1.4 Removal of Dewatering and Water Treatment System**

Upon completion of dewatering work the Contractor shall remove all installations for the dewatering and water treatment systems, and fill in all excavated areas such as sumps, channels, etc. to the lines and grades of the finished works, as shown on the Drawings or as directed by the Engineer.

Upon completion of dewatering work, all pipes shall be closed off and the pump sumps shall be removed and tightly filled by injection of cement mortar or by underwater concreting. These works shall require the prior approval by the Engineer.

#### **4.3.1.5 Emergency Dewatering System**

The Contractor shall take into account the possibility of a temporary power failure. So that emergency power units shall be installed with sufficient capacity for dewatering units during the failure. There shall be neither time extensions nor additional compensation granted in case of failure of the power supply.

The emergency power unit shall be tested at least once a week by trial run of at least 30 minutes duration.

The costs for mounting and removal of the emergency generating set and stand-by equipment, including all necessary connections, switches and electrical auxiliaries and controls as well as trial runs shall be part of the entire dewatering system.

### **4.3.2 Cofferdam**

#### **4.3.2.1 General**

The Contractor shall be responsible for design and construct cofferdam, if required.

#### **4.3.2.2 Operation and Maintenance of Cofferdam**

The Contractor shall, at all times, take adequate precautions to thus the safety of the labour force and equipment in the relevant structure. Particularly, he shall do among others the following:

- inspect the cofferdam periodically to ascertain water seepage and to satisfy himself of the stability of the cofferdam;
- have available sufficient pumping capacity to cope with seepage water;
- have available, particularly during the monsoon season, bags filled with sand or any other means suitable to increase on short notice the height of the cofferdam temporarily;
- prepare in advance an emergency plan for a quick evacuation of the labour force and equipment.

#### **4.3.2.3 Removal of Cofferdam**

Upon completion of the structure, the Contractor shall remove material of the cofferdam to the lines and grades conforming to the original topography.

End of Chapter 4

## **CHAPTER 5 - CLEARING, GRUBBING AND STRIPPING**

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## **CHAPTER 5 - CLEARING, GRUBBING AND STRIPPING**

### **5.1 GENERAL**

#### **5.1.1 Scope**

This chapter covers work necessary to clear, grub and strip the areas of the relevant works including the disposal areas shown on the Drawings.

#### **5.1.2 Definitions**

- a) Clearing means the removal and disposal of materials above ground level including overhanging branches except things that the Engineer 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 objectionable materials.
- b) Grubbing means the removal and disposal of buried logs, stumps, roots and all unsuitable obstacles to a depth beneath the original ground surface.
- c) Stripping means the removal and disposal of topsoil to a depth beneath the original ground surface.

### **5.2 MATERIAL**

**(Not applicable)**

### **5.3 EXECUTION**

#### **5.3.1 General**

Clearing, grubbing and stripping operations shall be strictly limited to the area to be occupied by the indispensable works unless otherwise approved by the Engineer. No trees shall be cut outside the areas mentioned above without approval.

Clearing and grubbing shall extend to approximately five (5) meters beyond the limit of works for permanent structures. As for temporary works, the extension shall be a minimum as required for the Works.

All materials obtained by the clearing, grubbing and stripping operations shall be removed and disposed as specified or directed by the Engineer. Top soil shall be stockpiled for later use in the Works.

Care shall be taken to see that the burning of such material does not destroy or damage public or private property and adjacent vegetation. The Contractor shall be fully responsible for destruction, damage, or nuisance.

All depressions below the ground surface due to the removal of stumps or roots shall be refilled with suitable materials and compacted to the satisfaction of the Engineer.

### 5.3.2 Protection of Other Areas

The Contractor shall ensure that trees and other vegetation outside the areas of the permanent works as well as areas required for temporary works including access are protected and preserved from damage.

Any 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 Engineer unless otherwise specified.

The Engineer 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.

### 5.3.3 Disposal of Materials

Stumps, roots, logs and other objectionable matter from the site preparation operation shall be removed from the limits of the Works and dispose.

The disposed materials shall be buried in horizontal layers alternating 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 3 m. with slope less than 4/1 (4 horizontal to 1 vertical) in adequate conditions in regard of safety for the stability of the deposit. Vegetal matter shall be covered with 1 m. of earth material.

Burning will be permitted only at times when conditions are considered favorable for burning and at locations approved by the Engineer. Materials to be burnt shall be piled neatly and shall be burnt completely in a suitable condition.

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 the burnt 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.

### 5.3.4 Auxiliary Works

The auxiliary works comprise, but are not necessarily limited to, of the following:

- Removing and storing of boundary stones, benchmarks, protection of surveying points ; survey and protection of all secondary survey points, profiles, etc.
- Difficulties to be overcome where excavation may have to be carried out on steep slopes.
- Difficulties in transport due to existing access conditions.
- Sorting of excavated material which, if necessary, is to be used for special purposes.
- Conveying and dumping equipment that may be required.

End of Chapter 5

## **CHAPTER 6 - OPEN EXCAVATION**

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## CHAPTER 6 - OPEN EXCAVATION

### 6.1 GENERAL

#### 6.1.1 Scope

This chapter covers all excavation work required in connection with the Works. It shall include excavation of material of whatever properties from the open cut excavation including the excavation under water, as shown on the Drawings and as instructed by the Engineer.

#### 6.1.2 Definitions

a) Open Excavation

All and every excavation work made by open cut from the ground surface including the excavation under water.

b) Topsoil

The surface or top layer of soil, including fine roots, the herbaceous vegetation and grasses being characterized by the presence of organic material.

c) Common Excavation

Excavation of earth, sand and all materials other than Soft Rock and Rock Excavation.

d) Soft Rock Excavation

Excavation of all materials other than Rock Excavation including gravel, conglomerates, boulders or loose rock smaller than one cubic meter and friable or weathered rocks which can be ripped with a 300 Hp crawler tractor equipped with a single shank, short tip ripper.

e) Rock Excavation

Excavation of material which requires loosening by drilling, blasting, barring, wedging and other quarrying techniques. This material may occur in bedrock formations or in detached rock blocks and boulders of volumes greater than one cubic metre (1 m<sup>3</sup>).

f) Excavation Line

(Not applicable)

g) Overbreak

Excavation beyond the excavation line according to geological condition.

h) Scaling

Scaling of rock faces or surfaces including the removal of all loose, shabby, broken, altered or unsound rock.

i) Dental Excavation

Removal of loose, friable or weak materials encountered after exposure of rock excavation faces.

j) Perimeter Holes

A row of holes neatly and uniformly drilled along the excavation line.

k) Controlled Blasting (Not applicable)

Controlled Blasting requires special drilling and blasting methods to produce smooth rock faces conforming to the prescribed neat excavation lines and to minimize blasting-induced fractures in the rock outside the excavation lines. These methods include pre-splitting, smooth blasting, line drilling and cushion blasting.

i) Pre-splitting

Pre-splitting consists of drilling a single row of closely spaced perimeter holes, loading all the holes lightly and continuously, stemming the entire length of each hole and then firing them as a completely separate operation before any adjoining main excavation area is blasted, to produce a crack along the line of split holes which a subsequent primary blast can break. Completion of 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.

ii) Smooth Blasting

Smooth blasting consists of drilling a single row of closely spaced perimeter holes with an accepted burden/spacing ratio, loading all the holes lightly and continuously, stemming all holes and then firing them as the last or intermediate delay period in the round.

iii) Line Drilling

Line drilling consists of drilling a single row of very closely spaced perimeter 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 drill holes and a limit on the distance between these lines.

iv) Cushion Blasting

Cushion blasting consists of drilling a single row of closely spaced perimeter holes with an accepted spacing/berm width ratio, loading all the holes lightly and

continuously, stemming the entire length of each hole and then firing them to remove the berm left in place from the previous primary blast.

l) Bench Lift (Not applicable)

The vertical depth of rock loosened by any one blasting cycle.

m) Blasting Consultant (Not applicable)

Blasting expert to be engaged by the Contractor.

### 6.1.3 Submissions

a) General

At least 30 days prior to commencement of common excavation and rock excavation, the Contractor shall submit to the Engineer for review, his detailed plans of proposed excavation methods and sequences, together with pertinent data for each stage of excavation in each work area.

For each area of the work, the contractor shall submit shift report giving the details of all excavation activities to the Engineer.

b) Stockpiling

At least 30 days prior to commencement of stockpiling of excavated materials, the Contractor shall submit to the Engineer for review, detail of the source, type and end uses of materials to be stockpiled. The details to be submitted include the area to be occupied, height, side slopes, access requirements, programming of end use, erosion protection measure, drainage and other pertinent details.

## 6.2 MATERIAL

(Not applicable)

## 6.3 EXECUTION

### 6.3.1 General

#### 6.3.1.1 Excavation Method

Excavation shall be carried out by suitable methods proposed by the Contractor. The proposal shall include the detail description of work schedule, quantity, type and capacity of the equipment, working methods to be applied for excavation, for transportation and for stockpiling and/or dumping of excavated material, the characteristics of the explosives, the distribution and quantities of the charges, the diameter, depth and spacing of holes, the type and number of blasting caps, the firing system, the foreseen security measures and any other data required by the Engineer.

The review of the excavation methods shall not release the Contractor from his sole responsibility for the safety of the Works, of his personnel and of third parties involved in the excavation works.

#### **6.3.1.2 Excavation Line, Grades and Dimensions**

Excavation shall be carried out to the final dimensions, lines, slopes and grades shown on the Drawings and/or established by the Engineer. Extra excavation for the convenience of the Contractor and overbreak performed by the Contractor without written orders of the Engineer shall be at the expense of the Contractor and shall be filled with suitable materials as approved by the Engineer at the expense of the Contractor. In any case the method and material of filling such overbreak have to be approved by the Engineer prior to execution of any such work.

The lines, grades and dimension of the excavations may be changed during the progress of the work from those shown on the Drawings.

The Contractor shall remove from the designated excavation line all loosened and fractured rock and/or loosened material which may tend to slide.

All objectionable materials, such as, oil, mud, rock fragments, loose rock, chips, mortar, organic matters, stagnant water, shall be removed from the surface of the foundation and such cost shall be included in the unit prices for excavation in the Schedule of Quantities and Prices.

Furthermore, the most suitable equipment, adequate extra facilities and stand-by plant shall be provided. If used equipment is applied, it shall be still in good quality and allow a safe and reliable execution of the Works.

On the basis of the reference points indicated on the Drawings the Contractor shall establish all required setting-out points to guarantee a safe and correct setting-out of the Works.

#### **6.3.2 Common Excavation**

The bottom and side slope of common excavation upon or against which structures are to be placed shall be finished accurately to the established lines and grades.

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 water and other objectionable materials shall be either pumped out or removed.

Approved material from excavation shall be used in the permanent construction. Unsuitable materials shall be removed by local excavations below the general surface of excavation, to the lines and depth and dimensions directed.

#### **6.3.3 Rock Excavation**

The bottom and side slopes of rock excavation shall be excavated to the required dimensions as shown on the Drawings or established by the Engineer.

If the materials below and beyond the prescribed lines of excavation are shattered due to misoperation or reasons attributable to the Contractor, the shattered materials shall be removed to the satisfaction of the Engineer, and filled with suitable materials.

### **6.3.4 Drilling and Blasting (Not applicable)**

#### **6.3.4.1 General**

The Contractor shall comply strictly with the regulations as required by the authorities regarding purchase, storage, issuance and use of explosives and transport of the same to and from Site, and shall deem to be included in the Schedule of Quantities and Prices all costs arising from the use, storage and transport of explosives and from supervision of blasting by security forces.

Blasting shall be strictly and in every case subject to the Engineer's permission. When blasting is carried out, trees, structures, etc. in exposed position shall be adequately protected from damages.

All blasting shall be carried out carefully by approved experts only and the Contractor shall be fully liable for any claims arising from damages or alleged damages, injury to the public, etc. due to blasting.

Fuses, detonators or blasting caps shall not be transported or stored together with explosives in any case. The location and design of the storage places, the transportation methods and the precautions that shall be taken to prevent accidents shall be subject to the Engineer's review.

Drilling patterns and blasting schedules shall be designed to meet the following requirements:

- Fracturing and loosening of all excavation surfaces shall be minimized. This may require controlled blasting and/or excavation without explosives.
- The excavated material shall yield suitable required embankment material.
- The least possible amount of overbreak shall occur.

Drilling patterns and blasting schedules shall be submitted well in advance for the Engineer's review prior to commencement of any blasting work. These schedules may be modified by the Engineer during the course of the Works as required by conditional encountered.

Drilling and blasting shall be arranged and, where necessary, the rock being blasted shall be protected, e.g., by mesh cover, so as to prevent any scattering of the rock liable to cause injury to the public or damage to buildings and other property and the Works.

During thunder storms and other electrical disturbances, no charging or firing will be permitted. If the Contractor intends to use electric detonators, lightning detectors will have to be installed and operated.

Blasting shall be carried out at specified times to be agreed upon by the Contractor and the Engineer. Sufficient notices and barriers shall be erected immediately before blasting, and adequate warning shall be given to workers at the Site and to the public so that no one may

come within the danger zone until blasting is finished. Upon completion of blasting an "all clear" signal shall be given. This signal shall be withheld by the responsible blasting master or blasting engineer until he is satisfied that all charges loaded have been detonated and that no delayed explosions or misfirings can be expected. Adequate warning, as mentioned above, shall be given and the portion of the Site shall be cleared before electrical resistance measuring or testing of the firing line is carried out.

The Contractor shall be liable for any damage caused by scattering of rock, boulders or other material being blasted and for the scattering of any material whatsoever overlying or in the immediate vicinity of the rock, boulder or other material which is being blasted, and all such fragments shall be removed.

Location, extent and protection with all and any blasting shall be such, that under no circumstances any hazard may be involved to permanent or temporary structures.

#### **6.3.4.2 Field Trials for Blasting Technique**

Prior to commencing excavation work, the Contractor shall carry out field trials to verify that the proposed drilling patterns and blasting schedules meet the requirements of the Specification.

During the progress of the excavation, the applied drilling and blasting method shall be varied as necessary to suit rock conditions and to obtain the best practicable excavation surfaces after blasting. Any modification of the applied methods shall at all times be subject to the prior review by the Engineer.

#### **6.3.4.3 Requirements for Charging with Explosives**

All pertinent specifications regarding the general requirements for storage and care of explosives shall be applicable taking into account the following items:

- blasting caps shall be separately packed in clearly marked boxes and shall be sent to the work fronts in a car; this car shall be followed by another one carrying the explosives; all remaining caps and explosives shall be taken away before the blast;
- the hole's net depth shall be checked before placing the charge;
- in case of electrical detonators, the wire ends shall be protected with insulating caps or neoprene fittings; such insulators shall be removed after charging the holes;
- each of the prepared blasting charges shall be checked by a special ohm-meter to guarantee the continuity of the complete network;
- the ends of the main wires shall be connected to the detonator immediately before the blast at a distance of at least 300 m from the front;
- in case an ignition system without electrical detonators is used, the manufacturer's recommendations shall be strictly followed.

#### **6.3.4.4 Controlled Blasting**

Controlled blasting shall be carried out where more closely controlled faces of permanent excavation slopes are required, in areas where concrete is to be placed directly against rock surfaces. Controlled blasting comprises e.g. presplitting, smooth blasting, line drilling, cushion drilling, barring and wedging, micro-second delay or other approved methods to avoid loosening of rock surfaces and overbreak. In special cases, e.g., in areas with adjacent concrete structures, instructions to excavate without explosives may even be issued.

### **6.3.5 Protection and Supports**

#### **6.3.5.1 General**

The Contractor shall secure the stability of any excavation by using, where necessary, suitable protection and supports in quantities sufficient to avoid loosening and slides and to guarantee the safety of the Works. The Engineer may order at any time the installation of additional protection and supports when in his opinion the safety of personnel involved in the work or of the Works is endangered.

#### **6.3.5.2 Temporary Protection and Supports**

According to the difficulties encountered during the excavation of the work, the Contractor may select temporary protection and supports he deems most convenient and suitable to stabilize unstable material and to facilitate the installation of permanent protection and supports.

The bottom and side slope of excavation upon or against which concrete is to be placed shall be protected from cracking or weathering with such material as jute mats, plastic sheets or other methods approved by the Engineer until concreting or placing of embankment material will commence.

Temporary protection and supports shall be removed by the Contractor when the excavation work is completed or otherwise timely, and it shall be the Contractor's responsibility to conduct his operations in a way, that temporary protection and supports can be removed when required by the Engineer.

### **6.3.6 Special Provisions for Open Excavation**

#### **6.3.6.1 General**

No distinction will be made between types of common soil. However, the Contractor shall perform its excavation in two stages, i.e., first the top soil layer shall be stripped of and separately stockpiled, followed by the ordinary excavation procedure.

To avoid loosening of common soil, heavy equipment like bulldozers and power shovels shall not operate within 0.30 m of the final lines and levels.

The Engineer may, when necessary, order the Contractor to excavate beyond the established excavation lines due to geological or other physical causes. In such cases the Contractor shall

excavate to the lines established by the Engineer, and shall, after completion of the excavation, submit a drawing showing the actual lines and dimensions of the performed excavation to the Engineer for review.

Where, in the opinion of the Engineer, the material is deemed unsuitable to form a firm foundation, further excavation and filling will be ordered in writing by the Engineer.

#### **6.3.6.2 Protection of Existing Structures during Blasting (Not applicable)**

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

In any case, the particle velocities shall be limited to 15 cm per second at new concrete structures which have attained design concrete strength; 10-15 cm per second at structures 7 to 28 days old; and 0-4 cm per second for structures 0 to 7 days old, proportionally.

The above limits shall be approached gradually with caution using a commercially available velocity seismograph and with immediate inspection of structure for evidence of stress after each blast operation.

In the event of stress evidence, the limiting particle velocity shall be reduced to that of the blast prior to the one causing stress evidence and maintained at that level with continued velocity and stress monitoring as described above. If the structure cannot be inspected, particle velocity shall be limited to 5 cm per second.

#### **6.3.7 Cleaning of Excavation Surface**

Excavation surface shall be cleaned, trimmed, and all unsuitable materials and water shall be removed before any concrete or other permanent material is placed. All loose materials on the surface shall be tamped or rolled with suitable tool and equipment to form a firm foundation for the structure.

Excavations for foundations of structures on rock shall be cleaned of all loose, fractured or unsuitable rock, fragments, spalls, dirt, sand, gravel or other unsuitable materials. Unsuitable materials are defined as, but not limited to, broken, sheared, chemically altered or badly fractured rock in seams, fault zones or local pockets of poor rock.

Cleaning shall be carried out by approved means. After cleaning and before any concrete or other permanent material is placed on the rock, all standing water shall be removed and flowing water shall be diverted away from the foundation area. Cracks, fissures, shears, lenses, depressions and pockets shall be cleaned and opened out to enable these to be filled with approved material compatible with the associated permanent structure.

When the excavation has been completed to the lines specified or shown on the Drawings and the surfaces cleaned as specified, the Contractor shall notify the Engineer of his readiness for inspection and no excavation surface shall be covered with concrete or other material until it has been inspected.



### **6.3.8 Stockpiling and Disposing**

#### **6.3.8.1 General**

The Contractor shall plan and manage the excavation work so that the suitable material from each zone shall be placed in its final position or shall be stockpiled in the approved area and then reloaded and transported to its final destination.

#### **6.3.8.2 Stockpiling**

Excavated material suitable for use in the permanent works shall be placed in its final position as much as possible.

In the event that excavation of suitable material from the required excavation proceeds at the faster rate than placing of the material in the work area, the excavated material may be stockpiled.

The Contractor shall be responsible for the sufficiency of the material in case the suitable material from required excavation being disposed of for the convenience of the Contractor.

All top soil shall be stockpiled separately from other suitable excavated material for use.

Stockpile area shall be cleared of all downed and standing vegetation prior to placing material there on. Any stockpile exceeding 10 m in height shall be provided with 6 m wide berm for every 10 m height.

No payment shall be made for such stockpiling, neither for reloading and hauling of the material to the embankment, nor for placing or disposing of this material in any place other than the embankment.

#### **6.3.8.3 Disposing**

The material coming from the excavations and not suitable to be utilized for fills, backfills and aggregates shall be unloaded in disposal areas indicated on the Drawings or designated by the Engineer.

The placing of materials within the disposal areas shall be made in layers in order to obtain an appreciable degree of compaction by means of the transportation equipment and/or if required by appropriate compaction equipment.

The Contractor shall be responsible for any damage caused by disposal of unloaded materials.

End of Chapter 6

## **CHAPTER 7 - MISCELLANEOUS FILLS, BACKFILLS, RIPRAP AND GEOTEXTILE**

**TECHNICAL SPECIFICATION**  
**CHAPTER 7 - MISCELLANEOUS FILLS, BACKFILLS,**  
**RIPRAP AND GEOTEXTILE**  
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## **CHAPTER 7 - MISCELLANEOUS FILLS, BACKFILLS, RIPRAP AND GEOTEXTILE**

### **7.1 GENERAL**

#### **7.1.1 Scope**

This Chapter covers the performance of all works in connection with miscellaneous fills, backfills riprap and geotextile as shown on the Drawings.

#### **7.1.2 Submissions**

At least 30 days prior to the used of materials, the Contractor shall submit sources and detail properties of materials to the Engineer for review.

### **7.2 MATERIAL**

#### **7.2.1 General**

a. Source The materials shall be obtained from required excavations or other approved sources and/or borrow areas.

The area from which the materials for fills, backfills and riprap will be taken shall be cleared and stripped to the depth needed to expose the required material.

No brush, roots, topsoil or other unsuitable materials shall be used or mixed with the specified materials.

All materials shall be subject to the review of the Engineer.

b. Backfills The material to be used for backfills shall consist of any and all types of materials, except clayey mud, loam and clay with high plasticity, but including clay with low plasticity, sand, gravel and rock fragments, mixed in them so that from the standpoint of compacted stability they are suitable to be used in the various fills.

Fine materials passing No.40 sieve shall not exceed 20 % by weight, unless otherwise approved by the Engineer.

The maximum size of stone which may be incorporated in the mass of the fills shall not be more than 2/3 of the specified compacted layer except different approval of the Engineer, and the quantity of stone over 25 cm in size shall not exceed 30% by volume.

Fill placed within 50 cm of the culverts and pipes shall be well graded and free of all stones over 10 cm in size.

### 7.2.2 Riprap

a. **Plain Riprap** This riprap shall consist of individual rock fragments, dense, sound and resistant to abrasion and free of cracks, seams and other defects that would tend to increase unduly their susceptibility to destruction by water action. The inclusion of objectionable quantities of dirt, sand, clay and rock fines will not be permitted.

Rock fragments in riprap shall be nearly rectangular in shape and not slabby.

Riprap shall be reasonably well graded as specified herebelow:

Size of Fragment	Finished Riprap Thickness(m)		
	0.50-0.70	0.30	0.15-0.20
over 30 cm	Not over 30 %	Not over 20 %	-
over 15 cm	over 70 %	over 70 %	Not over 20 %
over 7 cm	over 90 %	over 90 %	over 80 %
under 3 cm	under 5 %	under 5 %	under 5 %

b. **Grouted Riprap** Stone for grouted riprap shall consist of rough uneven quarry stone as nearly rectangular in section as possible. The stone shall be sound, tough, durable, dense, resistant to the action of air and water, and suitable in all respects for the purpose intended.

Unless directed otherwise, the stone pieces shall range in weight between 20 - 45 kg. with not less than fifty percent (50 %) of the stones weighing more than 35 kg.

### 7.2.3 Geotextile

The Contractor shall furnish and install the non-woven geotextile beneath the riprap protection and the drainage work as required.

The geotextile described herein shall have the following properties:

Description	Type I	Type II	Test Standard
Thickness (mm)	≥ 1.2	≥ 2.1	ISO 9863 or ASTM D-5199
Nominal weight (g/m <sup>2</sup> )	≥ 120	≥ 250	ISO 9864 or ASTM D-5261
Wide width tensile strength at break, ave.(kN)	≥ 9.0	≥ 19	ISO 10319 or ASTM D-4595
Wide width tensile elongation at break (%)	≤ 45	≤ 60	ISO 10319 or ASTM D-4595
CBR Puncture resistance (N)	≥ 1500	≥ 2800	ISO 12236 or ASTM D-6241
Grab strength at break, ave. (N)	≥ 500	≥ 1100	ASTM D-4632
Grab elongation at break (%)	≤ 70	≤ 75	ASTM D-4632
Water flow at 100 mm head (l/m <sup>2</sup> /sec)	≥ 150	≥ 90	ISO 11058 or BS 6906 Part 3
Pore size D 90 (micron)	≤ 120	≤ 90	ISO 12956

The environmental behavior of the geotextile shall meet the following requirement:

a) Material Composition	100% polypropylene or 100% polyester (accepted in case of installation in no chemical contaminated condition) or as approved by the Engineer
b) Chemical Resistance (installation in chemical contaminated condition)	Resistance to all naturally-induced soil alkalis and soil acids, chemical contaminated water, concrete or cement and all material having pH 2 to pH 13
c) Biological Resistance	Geotextile shall not be affected by bacteria and fungi
d) Reaction to temperature	The mechanical properties of the geotextile at 21 degree Celsius shall remain the same at whatever level of temperature
e) Ultra-violet rays resistance	Geotextile shall be the high resistance to Ultra-violet rays 80% or greater of the strength of the product shall be retained after exposure to 60,000 langley's isolar radiation

Geotextile will be accepted pending on manufacturer's certification of conformation with the Specifications but permission to ship on certification shall in no way release the Contractor from responsibility for furnishing the geotextile meeting the requirements of this Specifications. The geotextile rolls shall be clearly labeled showing manufacturer, type of geotextile and batch identification number.

Geotextile shall not be stored directly on the ground or in any manner in which they may be affected by heat. The method of storage shall be in accordance with the recommendations of the manufacturer.

Geotextile shall be covered by rock riprap or aggregate material specified in the drawings within sufficient time. The fabric shall not be allowed to expose to Ultra- violet radiation of natural sunlight exceeding 7 days for Ultra-violet material and 14 days for Ultra-violet protected and low Ultra-violet susceptible polymer geotextile.

The sampling and testing of geotextile shall be responsible by the Contractor. One representative sample for every 5000 m<sup>2</sup> of geotextile shall be tested for the wide width tensile strength and CBR puncture resistance conforming to the test standard mentioned in the above table. The positions of sampling shall be indicated by the Engineer. Whenever the Engineer has reason to believe that testing is necessary, he may order the fabric to being sampled and tested at any time. The Contractor shall provide facility satisfactory to the Engineer for the ready procurement of adequate test samples. The geotextile sample shall be tested, guaranteed, approved and verified at a certified laboratory conforming to the Ministerial Regulations No. 6 according to the Building Act (B.E. 2522). The Engineer or his representative shall present during sampling and delivery samples from site to the laboratory.

The Contractor shall provide the statement of quality proving that the geotextile complies with all requirements of this specification.

### **7.3 EXECUTION**

Backfill, as used herein, is both excavation refill around structures and excavation refill of trenches and pits.

#### **7.3.1 Lines and Grades**

Fills and backfills shall be performed to the lines and grades shown on the Drawings. The modified lines and grades to fit condition encountered during construction and such changes or modifications shall not be construed by the Contractor as a basis for additional compensation.

#### **7.3.2 Foundation Preparation**

The suitability of each fill foundation shall be reviewed by the Engineer.

No filling operation shall be started by the Contractor or any part of the foundation, until the Engineer has inspected it.

When excavation operations are completed, the foundation surfaces shall be compacted to a depth of 30 cm with the density specified for the fill to be placed thereon unless otherwise instructed by the Engineer.

#### **7.3.3 Dumping and Spreading of Fill Materials**

After dumping, the material shall be spread by bulldozer, grader or other approved means in approximate horizontal layers over the area. The maximum thickness of each layer, after compaction, shall be 40 cm for random fills and 20 cm for backfills having a dry density of ninety two percent (92%) of the maximum dry density determined by Modified Proctor Compaction Test Designated ASTM D1557 or as shown on the Drawings or as approved by the Engineer.

The placing operations shall be such that the materials when compacted will be blended sufficiently to secure the best practicable degree of compaction and stability. Prior to and during compaction the material shall have, when necessary, the optimum practicable moisture content required for maximum compaction and the moisture content shall be uniform throughout each layer. In-so-far as practicable, moistening of the material shall be performed both at the site of excavation, and at the site of compaction by sprinkling, if necessary. If the moisture content is less than optimum for compaction, the compaction operations shall not proceed, except with the specific approval of the Engineer, and if the moisture content is greater than optimum for compaction, the compaction shall be delayed until such time as the material has dried to the optimum moisture content, and no adjustment in price will be made on account of any operation of the Contractor in drying the materials or on account of delays occasioned thereby.

Placing of backfill directly against structures, culverts and pipes shall be done carefully so as not to damage the permanent works involved.

In no case shall backfill be placed unless fourteen (14) days have elapsed after concreting of the structures.

#### **7.3.4 Compaction**

Each layer forming fills and backfills, shall be compacted by not less than six (6) complete passes of vibrating roller weighing not less than 28 kg/cm of drum axis or by another approved roller able to supply an equivalent degree of compaction.

Compaction of material in pits, depressions, restricted areas and in other places where it is impracticable to use the specified roller, shall be performed by the use of approved power tampers or vibrating plate compactors to obtain compaction equal to that specified above for vibrating roller.

One (1) pass is defined as continuous motion of a compactor in one direction only. Each pass will overlap the adjacent one for about 30 cm so as to ensure a complete coverage of the entire layer.

Vibrator rollers shall be of padfoot or smooth steel drum type. The weight requirement shall not be met by the addition of water tanks, or other non-standard weight increasing devices, to the roller as normally supplied by the manufacturer. The vibration frequency of the roller shall be between 1,200 and 1,800 vibrations per minute. When compacting, they shall be vibrated at the frequency most suited to the compaction of the fill material being compacted. Roller towing speeds, when compacting, shall not exceed 3 km per hour. The roller drum shall be equipped with suitable cleaning devices.

Compaction of each layer shall proceed in a systematic, orderly and continuous manner so as to ensure a uniform coverage by the compactors. Rolling shall in general be performed parallel to the direction of fill placement.

Hand Tamping or suitable equipment shall be used for compaction near structure as directed by the Engineer.

#### **7.3.5 Protection and Maintenance**

The Contractor shall protect and maintain all fill and backfill and riprap in a satisfactory condition during and after construction up to the Final Acceptance of the Works.

In the event of slipouts in any part of the fill prior to Final Acceptance of the Works, the Contractor shall remove the material from the slip area, as directed, and shall rebuild such portion of the fill.

#### **7.3.6 Placing of Riprap**

a. Plain Riprap Riprap shall be placed to the nominal thickness shown on the Drawings. The rock fragments in riprap shall not be compacted but shall be placed by crane or other approved equipment and graded of in manner to ensure that the larger rock fragments are uniformly distributed, that the smaller rock fragments fill the spaces between the large



fragments, and that compact uniform layers of large fragments, and that compact uniform layers of riprap of the specified nominal thicknesses result.

b. Grouted riprap The beds for grouted riprap shall be excavated to the required depths and properly trimmed and shaped.

Stone shall be placed by hand. It shall be laid with broken joints and shall be firmly bedded fitting the adjoining stones as closely as practicable. The vertical joints in each course shall break joints with those in adjoining course by at least 15 cm.

The riprap shall be thoroughly compacted as laying progresses and the finished surface shall present an even tight surface. Stone placed against slopes or ditch walls shall be laid with the largest stone used in the lower courses, gradually reducing in size as laying progresses upwards. Interstices between stones shall be chinked with spall firmly rammed in place.

Unless otherwise specified, grouted riprap shall be at least 20 cm in thickness, measured perpendicular to the slope.

Spaces between stones shall be filled up with mortar. Prior to filling the spaces of stones with mortar, the riprap shall be sufficiently moistened with water. All joints shall be filled with sufficient mortar to completely fill all voids. All surfaces or joints of grout riprap shall be swept clean after mortar initially set. After grout has sufficiently set, the surface shall be cured by spraying or covering the surface with sacks and constantly wetted for a period of at least seven (7) days.

Weep holes shall be constructed as shown on the Drawings or as required.

### **7.3.7 Geotextile Jointing Method**

The width or length of the geotextile shall be extended by overlapping. The required overlapping length, if not indicated on the Drawing, shall be varied between 0.35 m and 0.5 m for horizontal and graded profile, respectively. Except for placement underwater, the minimum lap length shall be 1.0 m.

The shear strength of the overlap shall not be less than 80% of the geotextile material jointed by sewing or welding with heat.

To prevent the overlapped fabrics from becoming separation due to push-forward aggregate, the continuation roll must be tucked under the material already in place. Care must be taken to avoid under stress at the overlap to prevent the fabric displacement.

End of Chapter 7

## **CHAPTER 8 - GROUTING**

## TECHNICAL SPECIFICATION

### CHAPTER 8 - GROUTING

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## CHAPTER 8 - GROUTING

### 8.1 GENERAL

#### 8.1.1 Scope

This Chapter covers engineering requirements for grouting work.

#### 8.1.2 Definitions

(a) Cement Grout

Cement Grout is defined as a mixture of cement and water with the addition of admixtures, sand, and fly ash, if required, which is forced under pressure into prepared holes or pipes in order to fill voids.

(b) Grout of Bases for Equipment and structures

All equipment and structural baseplates shall be grouted with Portland cement grout or nonsrink grout as required by design or specified. The turbine generator and rotating equipment shall be grouted with nonsrink grout.

Limited spaces and small blockouts where equipment bearing plates, anchors, rails, etc. are placed, shall be grouted under pressure.

(c) Nonsrink Grout

Nonsrink grout shall be furnished factory premixed so only water is added at the jobsite.

(d) Grouting of Dowels

Grouting of dowels shall be done with epoxy grout.

(e) Contact Grouting

Contact grouting shall be carried out to ensure that the voids and gaps between the steel lining and the surrounding concrete will be filled.

#### 8.1.3 Submissions

At least 60 days prior to the start of the grouting works, the Contractor shall submit for review fully detailed proposals and a detailed layout of his proposed arrangements for grouting, including specifications of all equipment, tools and all grouting materials to be used, and qualification and experience of the proposed personnel.

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

## 8.2 MATERIALS

### 8.2.1 General

The following kinds of grout mixes may be used:

- i) Neat cement grout, possibly with admixture
- ii) Cement – sand grout, possibly with admixture
- iii) Chemical grout such as polyurethane, one or two component type

The quantities of sand will depend on the permeability of the rock and the size of the voids to be grouted.

Cement, sand, water, admixtures, and fly ash for use in grout mixes shall conform to the requirements of Chapter 10 “Concrete”, except as specifically amended hereafter.

### 8.2.2 Cement

Cement shall have a minimum specific surface of 3,500 cm<sup>2</sup> per gram as determined by the Blaine air-permeability method (ASTM C 204). Cement Type I shall be used pending confirmation, that the ground water is not aggressive. The cement/pozzolan mix shall have a Blaine fineness of 4,500 cm<sup>2</sup>/gr. minimum with the percent retained on No. 200 and No. 325 meshes not to exceed 2% and 5%, respectively.

### 8.2.3 Sand

Sand in grout might be required for small portions of the work in highly fissured or fractured rock zones, and for contact and fill grouting. Sand shall have the following grading.

Sieve Size (mm)	Percentage Passing (by Weight)
2.4 (No.8)	100
1.2 (No.16)	95-100
0.6 (No.30)	60-85
0.3 (No.50)	20-50
0.15 (No.100)	10-30
0.074 (No.200)	0-5

Sand shall comply with stipulations listed in Chapter10 of this specification, and shall not contain more than 30% of flat or elongated particles having a maximum dimension in excess of four times the minimum dimension.

### 8.2.4 Water

Water shall not contain more than 2,000 ppm of suspended colloidal solids and no particles larger in size than the cement particles. It shall not be aggressive. The chloride content shall

be less than 50 mg/l and the sulfate content less than 100 mg/l. The temperature of water used for the preparation of grout shall not exceed 25°C.

### **8.2.5 Admixtures**

Admixtures shall be added to grout mixes to optimize the strength, viscosity, density, decantation, setting time, and shrinkage.

Only admixtures proved by testing prior to the start of grouting may be used. Manufacturer's certificates or guarantees will not be accepted as relieving the Contractor of his responsibility for the suitability of any admixture. Admixtures shall be Intraplast-EP with expansion effect, Intraplast- L 30, or Intraplast C, supplied by SIKA of Switzerland, or approved by the Engineer equal.

### **8.2.6 Chemicals**

When chemicals are required or proposed, they shall be accompanied by the manufacturer's certificates that they been previously commercially used with satisfactory service in similar type of work. The storage, handling and usage shall be in strict compliance with the manufacturer's printed instructions.

The use of toxic chemicals as acrylamide shall not be permitted for use in the Works.

## **8.3 EXECUTION**

### **8.3.1 Composition of Mix**

The water-cement ratio (W/C) is the proportion of water to cementitious material measured by weight. Composition of sandy mix is denoted herein as W:C:S; for example W:C:S= 1:1:1, means a mixture of 1 t water, 1 t cement and 1 t sand (t = metric ton).

### **8.3.2 Grouting of Bases for Equipment and Structures**

All equipment and structural baseplates shall be grouted with Portland cement grout or nonsrhink grout as required by design or specified. The turbine generator and rotating equipment shall be grouted with nonshrink grout.

Limited spaces and small blockouts where equipment bearing plates, anchors, rails, etc. are placed, shall be grouted under pressure.

Before placing grout, the surfaces of the base concrete to which the grout will be conducted shall be roughened and cleaned of all laitance, loose or defective concrete, any coatings or other foreign material, followed by thorough washing with water. Forms for grouting shall be installed where necessary and care shall be taken that the grout fills all spaces under the plates leaving no voids. The exposed surfaces of the grout shall be cured as recommended by the manufactures and no loads shall be applied until the grout has reached the design strength.

### **8.3.2.1 Proportions and Mixing**

Unless otherwise specified or indicated, Portland cement grout for use in grouting bases shall be composed of a mixture of Portland cement, sand, and water. The proportions of cement to sand for flat base where the gouging space does not exceed 40 mm shall be 1 kg. of cement to 1.6 kg. of sand. For thicker mortar or grout beds up to 60 mm, the amount of sand shall be increased to 2.4 kg per kilogram of cement. Bases which are hollow and are to be filled full or grout shall be filled to an elevation 25 mm above the outside rim with a mortar mixed in the proportions of 1 part by volume of cement, 1-1/2 parts sand, and 1-1/2 parts of 8 mm per gravel.

All grout or mortar mixtures shall be thoroughly mixed for not less than 5 minutes in an acceptable type of mechanical mixer. After mixing, the grout shall be used immediately and before any stiffening.

### **8.3.2.2 Nonshrink Grout**

Nonshrink grout shall be furnished factory premixed so only water is added at the jobsite. Grout shall be mixed in a mechanical mixer for a minimum of 3 minutes. No more water shall be used than is recommended by the manufacturer. The ingredients for acid resistant and chemical resistant grout shall be furnished premeasured. Mixing of the grout shall be as recommended by the manufacturer.

### **8.3.3 Grouting of Dowels**

Grouting of dowels shall be done with epoxy grout. Epoxy grout shall consist of a component liquid epoxy adhesive and inert aggregate filler component. Components shall be packaged separately at the factory and field mixed in a mechanical mixer. All proportioning and mixing of the components shall be in accordance with the manufacturer's recommendation. Materials and methods for grouting dowels shall be as recommended by the manufacturer of the epoxy grout unless otherwise specify herein.

### **8.3.4 Contact Grouting**

#### **8.3.4.1 General**

Contact grouting shall be carried out to ensure that the voids and gaps between the steel lining and the surrounding concrete will be filled.

#### **8.3.4.2 Contact Grouting into Voids between Lining/Filling Concrete and Rock Surface (Not applicable)**

Contact grouting shall be carried out to ensure that all voids between lining concrete/filling concrete and the rock surface will be filled with mortar grout.

Lining concrete or filling concrete shall have been poured at least 30 days prior to grouting work. Grout shall be injected at low pressure not exceeding 5.0 kg/cm<sup>2</sup> for each section.

The grout to fill such voids shall be injected through grout pipes embedded in concrete. The grouting of any hole shall not be considered complete until the grout taken is less than

1 l/min. for at least 15 minutes under  $5.0 \text{ kg/cm}^2$ . No pressure washing or testing shall be required prior to grouting.

Vent pipes for the release of air and water during grouting of crown and overbreak cavities which cannot be filled with concrete shall be provided at such locations as approved by the Engineer.

After finishing grouting of any holes, the pressure shall be maintained by means of a stop cock or other suitable device until the grout has set to the extent that it will be retained in the hole.

Check grouting shall be carried out to verify that the voids have been completely filled with grout. The requirements will be regarded as fulfilled, if the pressure can be maintained for at least 15 minutes without further injecting.

#### **8.3.4.3 Contact Grouting into Gaps between Steel Lining and Concrete**

Where specified herein, the gap between steel lining and the concrete shall be filled by pure cement grout in order to ensure continuous contact between steel and concrete. The pressure of the contact grouting shall not exceed  $5.0 \text{ kg/cm}^2$ . All care must be taken not to exceed the maximum pressure even for a short time.

The contact grouting shall be completed by continuing operation for at least 15 minutes after the take becomes substantially zero. If additional holes will be opened, such contact grouting between steel lining and concrete shall be executed around the draft-tube and the spiral casing.

After completion of the contact grouting, the Contractor shall clear the threaded holes.

A knocking test will verify the effectiveness of contact grouting. Where the test proves necessary, the Contractor shall drill additional holes, thread and plug them and inject grout until the test produces a solid uniform sound everywhere.

Other methods for contact grouting into gaps between steel lining and concrete shall be conducted as approved by the Engineer

#### **8.3.5 Sampling and Testing**

The Contractor shall prepare and test the trial mixes at least 30 days before commencement of any grouting. Materials for use in grout mixes shall be tested for compliance with the applicable requirements stipulated in "Grouting Materials", given in Clause 8.2

The following tests shall be required:

a) Laboratory tests:

- Grain size distribution and moisture content to sand
- Atterberg limits
- Chemical analysis of water and solids
- Compressive strength



- Viscosity (by fan-viscosimeter and Marsh cone)
- Density
- Decantation and setting time (by Vicat needle)
- Shrinkage of the grout

b) Field test:

- Density by hydrometer or mud balance
- Viscosity by Marsh cone

Sampling and testing shall be done with the present of the Engineer.

All chemical grouts shall be tested under conditions identical to those to which they will be subjected in the field, in order to determine the suitability of various chemicals and proportion of the ingredients to satisfactorily complete the work.

During the actual grouting operations, the Contractor shall carry out tests on grout mixes just prior to commencement of grouting, and shall plot values of viscosity, sedimentation limits, compressive strength, and maximum viscosity possible for the grouting on a diagram. If a significant change in the cement source occurs, sampling and testing must be repeated.

### **8.3.6 Equipment**

#### **8.3.6.1 General**

Only modern, properly operating grouting equipment and operated by trained and experienced crew shall be used for the performance of the work. This shall be specifically observed when dealing with chemical products.

Grouting equipment shall consist of grout pumps, weighting scale for additives and cement, grout mixers, water meters, agitator sumps, pressure gauges, packers, pipe lines and fittings, and miscellaneous tools specifically designated for grouting purposes.

Grouting equipment shall be capable of effectively mixing and stirring the grout and forcing it into the grout holes or grout connections in a continuous, uninterrupted flow at any specified pressure up to a maximum of 40 bar plus the groundwater pressure may be required. Accordingly, grouting pumps able to supply continuous grout mix at a pressure up to 70 bar shall be available. The equipment shall be capable of accurately controlling grout flows and pressures and of accurately measuring the grout take; and shall be suitable for neat cement, cement-sand, and chemical grouts.

Spare gauges, valves and fittings shall be kept available at the Site, and a two-way communication system between the mixing plant and place of grouting shall be provided if the distance exceeds 60 m.

Standby equipment which can be activated immediately shall be furnished to ensure continuity of work in the event of main equipment breakdown. The standby equipment shall be able to operate at the above listed pressures.

Graduated water discharge meters shall be accurate to within 5%

Equipment for proportioning grout mixes based on number of cement bags or weighting of cement from bulk silo shall maintain dosing accuracy to within 2 and 5%, respectively.

Prior to commencement of work, during the work as specified or as requested by the Engineer, and at the end of the work all pressure gauges, recorders and discharge meters shall be checked and calibrated.

The grouting equipment shall always be maintained to the Engineer's satisfaction in order to guarantee continued and efficient performance during grouting work.

#### **8.3.6.2 Grout Mixers and Agitator Sumps**

Grout mixers for mixing the stable mixtures shall be of the mechanically operated, high speed colloidal type of sufficient size, and operating at 1,500 to 2,000 rpm to ensure complete dispersion and activation of the mix, such as manufactured by Colcrete, Swibo, or Hny, with electric or pneumatic drive.

For mixing the unstable mixtures the paddle mixers may be used.

Hand-powered mixers or concrete mixers shall not be permitted for preparation of grout mixtures.

Mixers shall be provided with equipment for measuring weight and volume of mix components with an accuracy within 2% and a water meter calibrated in liters with a reset switch for zeroing after each delivery.

After mixing, the grout shall be discharged through a 5 mm mesh screen into an agitator sump equipped with stirring paddle to prevent settling and to remove any air bubbles from the mix. The stirring paddle shall be of such arrangement to guarantee a complete circulation of the entire sump content. The agitator sump shall have at least the same capacity as the mixer so that one batch of grout can be pumped while the next batch is being mixed.

Capacity of the equipment shall be sufficient to cope with 2 times anticipated peak quantity of the works as foreseen from values listed in the construction schedule. At least 3 mixing stations shall be installed.

#### **8.3.6.3 Grout Pump**

Grout pumps shall be capable of delivering a flow of 50 l/min of thick grout ( $w/c = 1$ ) at specified pressure and shall be able to achieve and hold a pressure of up to 40 bar. For the tunnels the capacity of the pumps shall correspond to a continuous flow for a  $W:C = 2:1$  mix at a rate of 50 l/min at a pressure of 60 bars. They shall deliver grout at constant pressure and flow, without pressure surges.

Pumps shall be of the duplex acting piston-type as manufactured by Wirth or a single acting plunger type as manufactured by Hny or similar and approved by the Engineer. The pump

body shall be of high wear and shock resistant material. The plunger unit shall be of stainless steel, highly resistant to abrasion.

The pump shall have either pneumatic drive or electro-hydraulic drive.

The pumps shall be equipped with precise pressure and capacity control valves which allow the setting of both, the maximum pressure and the flow independently. The pump shall automatically stop whenever the preset pressure is reached, and shall maintain that pressure without fluctuation. Alternatively, each grouting connection shall be equipped with a bypass valve and a return pipe, which will be automatically activated should the grout pressure at the top of the hole exceed the specified grouting or water pressure.

For works requiring a small volume of grout such as crack grouting or rock bolts grouting, the Contractor may use hand operated grout pumps. These pumps shall be able to achieve a pressure of up to 40 bar.

#### **8.3.6.4 Pressure Gauges**

The contractor shall provide pressure gauges for both low and high pressure ranges (0-15 bar and 0-50 bar). Two gauges for the appropriate range shall be provided in each grout line, one at the pump for use by the pump operator, the other at the hook-up connection, i.e., directly at the collar of the hole. The required pressure for each particular hole shall be measured on the hook-up pressure gauge, not at the pump.

Pressure gauges shall be accurate to within 3%. A minimum of two standardized pressure gauges for each range shall be calibrated and certified by an independent laboratory prior to the commencement of grouting works. One gauge for each range shall remain at the disposal of the Engineer, and the other shall be used by the Contractor for checking and calibration of working gauges. Working gauges shall be used for no longer than 2 shifts before being cleaned and recalibrate. All working gauges shall have reference numbers for identification, which shall be quoted in the grouting reports to be submitted to the Engineer.

#### **8.3.6.5 Connections to Grout Holes and Packers**

Supply and return lines equipped with quick release couplings shall be able to withstand an internal pressure greater than the maximum produced by the pump. The internal diameter of the lines shall be such that no appreciable settlement of grout will take place when pumping at the minimum discharge capacity of the pump.

Valves shall be provided at the pump, in the supply line and at the collar of the hole being grouted. Suitable screens shall be incorporated in the supply line for removing oversize particles and foreign matter before injection into the grout hole.

Packers shall be the same as used for water-pressure.

#### **8.3.6.6 Embedded Pipes and Fittings for Grouting**

Standard mild steel pipes and fittings for grouting shall be set in the rock and concrete as the Engineer may direct, or where shown on the Construction Drawings. The pipes and fittings embedded in concrete shall be cleaned thoroughly of all dirt, grease, grout and

mortar immediately before embedment and shall be firmly held in position and protected from damage or displacement while the concrete is being placed. A standard coupling and nipple wrapped to facilitate eventual removal shall be attached to the grout pipe where embedded in concrete. No portion of the pipe shall be allowed to remain within 50 mm of the concrete surface and the resulting recess, after removal of the pipe or fitting, shall be filled with dry-pack mortar.

Care shall be taken to avoid premature blockage of pipes. Any pipe that becomes blocked before completion of operations shall be cleaned out in a satisfactory manner or replaced by the Contractor.

End of Chapter 8

## **CHAPTER 9 - ROAD WORK**

## TECHNICAL SPECIFICATION

### CHAPTER 9 - ROAD WORK

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## CHAPTER 9 - ROAD WORK

### 9.1 GENERAL

#### 9.1.1 Scope

This chapter covers the following work:

- a) The construction of service roads as designated on the Drawings;
- b) Reconstruction of existing roads.

Road work consists of the construction of subgrade, subbase, crushed stone base, asphalt concrete surfacing, bituminous surfacing and concrete pavement.

#### 9.1.2 Submissions

At least thirty (30) days prior to the works, the Contractor shall submit to the Engineer for his review the followings, but not be limited to:

- Work schedule of subgrade, subbase, crushed stone base, asphalt concrete surface bituminous surfacing and concrete pavement;
- Setting out methods for alignment and slope of roads;
- All materials to be used for subgrade, subbase, crushed stone base, asphalt concrete surfacing, bituminous surface treatment, concrete, reinforcing steel, joint filler and joint sealant;
- Work procedure and equipment of asphalt concrete surfacing, bituminous surface treatment and concrete pavement.

#### 9.1.3 Standards and Codes

ASTM C88	Soundness of Aggregate
ASTM C131	Los Angeles Abrasion Test
ASTM D977	Specification for Emulsified Asphalt
ASTM D1557	Density-Water Content Relationship
ASTM D1559	Resistance to Plastic Flow of Bituminous Mixture
ASTM D2027	Specifications for Cutback Asphalt
ASTM D2028	Specification for Cutback Asphalt
ASTM D2041	Maximum Specific Gravity of Bituminous Paving Mixture
ASTM D2049	Relative Density of Cohesionless Soil
ASTM D4318	Liquid Limit, Plastic Limit and Plasticity Index of Soil
AASHTO T193	California Bearing Ratio
AASHTO M20-63	Specification for Asphalt Cement
TIS 865	Specification for Cutback Asphalt
TIS 851	Specification for Asphalt Cement

Specifications for Highway Construction Department of Highway (DOH), Thailand

## 9.2 MATERIALS

### 9.2.1 Subbase

Subbase shall consist of approved materials, free from organic or other objectionable materials. The gradation of the material shall conform to the following:

The gradation of the material shall conform to the following:

**Table 9.2-1 Soil-Aggregate Subbase**

Sieve Designation mm. (inch)	Percentage by weight passing square mesh sieves				
	Grading A	Grading B	Grading C	Grading D	Grading E
50 (2)	100	100	-	-	-
25(1)	-	-	100	100	100
9.5 (3/8)	30-65	40-75	50-85	60-100	-
2 (No. 10)	15-40	20-45	25-50	40-70	40-100
0.425(No.40)	8-20	15-30	15-30	25-45	20-50
0.075(No. 200)	2-8	5-20	5-15	5-20	6-20

The fraction of material passing the No. 200 sieve shall not be greater than two-thirds of the portion passing the No. 40 sieve. The portion of the material passing the No. 40 sieve shall have a liquid limit of not more than 35 and a plasticity index of not more than 15 when tested in accordance with ASTM D4318. The material shall obtain a minimum CBR value of 9, tested in accordance with AASHTO T193, when compacted to 95 % of maximum dry density as determined by ASTM D1557, or other applicable method.

### 9.2.2 Crushed Rock Soil Aggregate Type Base

Crushed stone base shall be constructed of hard, durable particles of both fine and coarse fragments of crushed rock or gravel. At least 50 % by weight of the particles of coarse fragments retained on a 19.1 mm sieve shall have one fractured face. The material shall have a percent of wear of not more than 40 % by weight for 500 revolutions as determined by ASTM C131 and shall not show a total loss greater than 12 % when subjected to 5 cycles of the sodium sulfate soundness test as determined by ASTM C88.

The gradation of the material shall conform to the following:

**Table 9.2-2 Crushed Rock Soil Aggregate Type Base**

Sieve Designation		Percentage by Weight Passing		
mm.	(inch)	A	B	C
50.0	(2)	100	100	-
25.0	(1)	-	75-95	100
9.5	(3/8)	30-65	40-75	50-85
4.75	(No. 4)	25-55	30-60	35-65
2.00	(No. 10)	15-40	20-45	25-50
0.425	(No. 40)	8-20	15-30	15-30
0.075	(No. 200)	2-8	5-20	5-15



The fraction passing the No. 200 sieve shall not exceed one-half of the fraction passing the No. 40 sieve. The portion of the material passing the No. 40 sieve shall have a liquid limit of not more than 25 and a plasticity index of not more than 6 when tested in accordance with ASTM D4318. The material shall obtain a minimum CBR value of 80, tested in accordance with AASHTO T193, when compacted to 100 % of maximum dry density as determined by ASTM D1557.

If the material does not contain a sufficient quantity of natural cementitious material to bond readily under the action of traffic, a binder, consisting of 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 uniformly in the base, during the progress of the work, and in the amount specified.

### 9.2.3 Aggregate for Single Surface Treatment

Aggregate shall consist of crushed stone or crushed gravel, free from adherent film of clay. The moisture content of the aggregate shall not be so high as to prevent it from being readily coated with the bituminous material. At least 70 % by weight, of the particles retained on the No. 4 sieve shall consist of fractured angular pieces.

The grading of the aggregates shall conform to the following:

**Table 9.2-3 Soil-Aggregate Subbase**

Nominal Size Millimeter (Inch)	Percent Passing Sieve by Mass						
	25.0 mm.	19.0 mm.	12.5 mm.	9.5 mm.	4.75 mm.	2.36 mm.	1.18 mm.
19.0 (3/4)	100	90-100	0-30	0-8	-	0-2	0-0.5
12.5 (1/2)	-	100	90-100	0-30	0-4	0-2	0-0.5

Either 19.0 millimeter (3/4 inch) size or 12.5 millimeter (1/2 inch) size can be used for the first layer of cape seal.

## 9.2.4 Material for Cape Seal Road

### 9.2.4.1 Material for Single Bituminous Surface Treatment

Cutback asphalt, RC-800, RC-3000, conforming to the Thai Institute of Standard, “Cutback Asphalt”, Standard No TIS 865

Emulsified asphalt, CRS-2, conforming to the Thai Institute of Standard, “Cationic Emulsified Asphalt for Road”, Standard No TIS 371.

Asphalt cement, AC 60-70, conforming to the Thai Institute of Standard, “Asphalt Cement for Road Work”, Standard No TIS 851

Range of application temperature for aforementioned asphalts shall be in accordance with Table 9.2-4.

**Table 9.2-4 Range of Application Temperature**

Type of Asphalt	Range of Temperature	
	°C	°F
AC 60-70	145-175	295-345
RC-800	100-120	210-250
RC-3000	120-160	250-310
CRS-2	50-85	125-185

Approximate quantity of crushed aggregate and asphalt content shall be according to Table 9.2-5.

**Table 9.2-5 Approximate Material Quantity**

Nominal Size Millimeter (Inch)	19.0 (3/4)	12.5 (1/2)
Crushed Aggregate	16-22	12-18
Kilogram per square meter		
Asphalt at 15°C		
Asphalt Cement, Liter per square meter	0.7-1.7	0.5-1.3
Cutback Asphalt, Liter per square meter	0.9-1.9	0.7-1.5
Emulsified Asphalt, Liter per square meter	1.1-2.3	0.8-1.6

### 9.2.4.2 Material for Slurry Seal

Asphalt shall be emulsified asphalt CSS-1h which shall pass quality test and conform to the Thai Industrial Standards. “Cationic Emulsified Asphalt for Roads”, Standard No TIS 371 or any asphalt which is approved by the Engineer.

Gradation of aggregate, asphalt content and rate of spreading shall be according to Table 9.2-6.

**Table 9.2-6 Gradation of Aggregate, Asphalt Content and Rate of Spreading**

Type of Slurry Seal	2	3
Sieve Size Millimeter (inch)	Percent Passing Sieve by Mass	
9.5 (3/8)	100	100
4.75 (No 4)	90-100	70-90
2.36 (No 8)	65-90	45-70
1.18 (No 16)	45-70	28-50
0.600 (No 30)	30-50	19-34
0.300 (No 50)	18-30	12-25
0.150 (No 100)	10-21	7-18
0.075 (No 200)	5-15	5-15
Asphalt Residue content percent by Mass of Dry Aggregate	7.5-13.5	6.5-12.0
Rate of Spreading by Weight of slurry Mixture kg/sq.m.	6.1-9.3	9.3-14.6

Slurry seal over the first layer shall be according to the following criteria.

- 1) Slurry seal type 2 shall be spreaded on the first layer with Crushed Aggregates of 12.5 millimeter (1/2 inch) size according to Table 9.2-3 by a single spreading. The quantity of slurry mixture shall be according to Table 9.2-6.
- 2) Slurry seal type 3 shall be spreaded on the first layer with Crushed Aggregates of 19.0 millimeter (3/4 inch) size according to Table 9.2-3 by spreading into 2 applications. The total quantity of slurry mixture shall be according to Table 9.2-6.

### **9.2.5 Asphalt Concrete**

The asphalt concrete 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 limestones dust, dolomite dust, or similar rock dust, portland cement, hydrated lime or other non-plastic mineral matter approved by the Engineer. 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 asphalt concrete shall have the following characteristic:

1. Marshall Stability (lb) not less than 1,200 lb
2. Marshall Flow (0.01 in) not less than 8 nor more than 16
3. Correlation Ratio of Marshall Stability (lb) and Marshall Flow (0.01 ins) less than 125
4. Air voids in Mix: 3-5 %
5. Voids filled with Asphalt: 75-80 %
6. Voids in Mineral Aggregate: 15-20 %

### 9.3 EXECUTION

#### 9.3.1 Lines, Grades, Dimensions and Tolerances

Road shall be constructed in accordance with the alignments, slopes and sections shown on the Drawings.

The road shall be constructed so that variations in dimension, alignment and grade of any finished surface from the dimensions, locations and grades as shown on the Drawings, shall be within the tolerances specified in the following table.

Description	Tolerance in Centimeters
a) Elevation of Subbase	+ 0 - 3
b) Elevation of Crushed Stone Base	+ 2 - 2
c) Crown Elevation	+ 2 - 1

No reduction of the required thickness of subbase, crushed stone base and asphalt concrete surfacing indicated on the Drawings shall be allowed.

The Engineer may instruct the Contractor to remedy or remove at his own expense, any material that exceeds the limits above specified.

The Contractor shall remove banking material placed outside the prescribed profiles.

The Contractor shall remove from the banking any material which is unsuitable, and shall transport it to a designated disposal area as instructed.

#### 9.3.2 Preparation of Foundation Surface

After clearing, grubbing and stripping in accordance with Chapter 5, ground surface shall be scarified, plowed, broken up, pulverized, moistened or aerated as necessary, and thoroughly mixed and compacted with the top 15 cm having a dry density of ninety five percent (95 %) of the maximum dry density determined by Modified Proctor Compaction Test Designated ASTM D1557.

Local unstable soil and loose material below foundation level shall be excavated and backfilled with sand or fill similar to adjacent natural soils, and compacted in layers not exceeding 20 cm. Removal, backfilling and compaction of visually observed soft spots shall be also performed.

#### 9.3.3 Subbase and Crushed Stone Base

The specified material shall be spread on the prepared foundation to such thickness that, when thoroughly compacted, it will conform to the prescribed grades and dimensions.

Each layer shall be of uniform thickness after compacted.

Segregation of coarse and fine particles shall be avoided, and any segregated material shall be remixed by harrowing and blading.

Hauling and spreading shall be accompanied by blading and/or dragging, and the surfacing shall be free from corrugations and waves. If necessary to produce proper compaction, water shall be added to the surfacing material, either at the source or after it has been spread on the roadway. The method of incorporating water in the surfacing material shall be subject to approval of the Engineer.

Immediately following final spreading and grading, each layer shall be compacted to full width by means of smooth-wheel vibrating rollers or pneumatic-tired rollers.

Each layer shall be compacted in place at optimum moisture content and to the maximum dry density and/or a relative density of 95 % and 100 % for subbase and crushed stone base respectively, of ASTM D1556, as determined by ASTM D1557 and ASTM D2049.

Rolling shall progress gradually from the sides to the centre, and shall continue until the whole surface has been rolled. Any irregularities or depressions that develop shall be corrected by the Contractor shall be subject to approval of the Engineer. Compaction shall be done in longitudinal direction along the banking and shall begin at outer edges and progress towards the center.

#### **9.3.4 Asphalt Concrete Surfacing**

##### **a) Prime Coat**

Prime coat shall be applied only to a dry surface of crushed stone base which has been swept using mechanical brooms. The primer shall be applied only when the road surface temperature is at least 24°C and no rain is threatening. The application rate of between 1.2 and 1.5 litres/m<sup>2</sup> and the temperature of application for the prime coat shall be reviewed by the Engineer. The use of primer protection sand shall be limited to areas designated by the Engineer, elsewhere the prime coat shall be left uncovered to penetrate and to cure completely.

##### **b) Asphalt Concrete**

###### **i) 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 method in the material testing laboratory reviewed by the Engineer.

The selection of mix design shall be based on the following limitation:

Gradation of aggregate and filler

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%.

ii) Placing and Compacting

Asphalt concrete surfacing having a maximum aggregate size of 20 mm shall be placed to a compacted thickness of 50 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, reviewed by the Engineer. Each paving machine used shall work in conjunction with two road rollers, a steel drummed roller for breakdown rolling and a multi-tyred roller for finish rolling. The steel drummed roller shall have a mass of at least eight (8) tons. The multi-tyred roller shall have a mass of at least ten (10) tons and shall have at least nine (9) tyres each capable of inflation to a pressure of 830 kPa (8.0 kg/cm<sup>2</sup>). Each roller shall incorporate a means of keeping the drums (tyres) 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 Engineer may direct the formation of a construction joint in the mat before placement resumes.

The Engineer may direct control testing to be undertaken by the Contractor on days when asphalt concrete is being placed. The Engineer 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.

### 9.3.5 Cape Seal

The work shall consist of construction of surface or shoulder with the first layer being single surface treatment on any prepared roadbed and spreading with one layers of slurry seal.

#### 9.3.5.1 Single Surface Treatment Construction

The construction which consists of one application of asphalt and one spreading of crushed aggregates and compaction to required denseness, shall be operated as follows.

- (1) Asphalt application is done by the distributor at the specified temperature in Table 9.2-4 at the specified rate.
- (2) When the asphalt application is finished, crushed aggregates shall be immediately spreaded over the asphalt by the specified quantity. If there are areas partially uncovered with the crushed aggregates or the aggregates are not uniformly distributed, the spreading shall be done manually until the crushed aggregates are closely and uniformly distributed.
- (3) In case that there are many passes of asphalt application, spreading of crushed aggregates over the first pass of asphalt application shall be 100 to 150 millimeters from the inside edge of the applied asphalt. The next pass of asphalt application shall overlap the exempted area such that asphalt shall be applied at proper quantity and uniformly over the area.

In case that special nozzles, which capable to apreinforcing ply asphalt at the quantity on the outside edge uniformly equal to the quantity inside the area, are installed at the outermost of the spray bar, the spreading of crushed aggregates can be done for the full surface of the pass. The special nozzles shall pass the tests of uniformity of transversely asphalt application in accordance with DH-T 401 "Method for Determination of Asphalt Quantity Applied on the Road in Transverse Direction" and shall be permitted by the Engineer.

- (4) While spreading crushed aggregates over the asphalt, pneumatic tired rollers shall roll over the full surface for a few passes.
- (5) At least two pneumatic tired rollers are to be used and if in one hour, the work can be done over 500 meters for one traffic lane, one additional pneumatic tired roller is required. The number of additional pneumatic tired roller is by the judgement of The Engineer.
- (6) After rolling for a few passes, the aggregate sweeper shall be used to sweep the crushed aggregates which is overlayered to uniformly distributed over the asphalt but to remove the crushed aggregates which have already been embedded in the asphalt. The spreading shall be done twice for the full surface.
- (7) Pneumatic tired rollers shall continue rolling over the surface until the crushed aggregates are properly embeded in the asphalt having uniform, surface and the asphalt has already been hardened or set.

- (8) In some cases, it may be necessary to use a self-propelled steel-tired roller having a gross weight of 4-6 tons for final compaction. It shall be done for the full surface but not over 2 passes and not break the crushed aggregates subject to the judgement of the Engineer.
- (9) The road shall be closed to traffic as long as possible if the traffic can be by-passed. However, if the road cannot be closed to traffic, the vehicle speed shall be limited to not greater than 30 kilometers per hour for a minimum 24 hours.
- (10) After the asphalt adheres to the crushed aggregates and completely dry, a broomer or any appropriate equipments shall be used to remove all excess crushed aggregates but not that adhered to the asphalt.

#### **9.3.5.2 Slurry Seal Construction**

Construction of the second layer (slurry seal) shall be done as follows:

- (1) Emulsified asphalt, CSS-1 or CSS-1h, mixed with water at the proportion of 1:1 shall be applied on the first layer at the rate not less than 0.6 liter per square meter by the fog spray method. Slurry seal shall be spreaded afterward.
- (2) Spreading of slurry seal on the new constructed first layer shall be done within the period not before than 4 days but not after 4 weeks. Application of emulsified asphalt by the fog spray method should be done at a suitable time before spreading of slurry seal.
- (3) Before spreading of slurry seal, the surface to be overlaid shall be cleaned by a broomer and if necessary washed by water to clean all the loose material and other dirty substance.
- (4) Before spreading of slurry seal, if the surface to be overlaid is dry, it shall be lightly sprayed with water to be moist. No water ponding is allowed.
- (5) Slurry mixture, when spreading on the surface, shall be constantly proportioned as required.
- (6) The mixture shall be uniformly distributed in the spreader at sufficient quantity for sealing to the full width as required all the time.
- (7) The mixture shall not be piled or lumped. There shall be no aggregate without bound with emulsified asphalt, no breaking of emulsified asphalt and segregation of fine and coarse aggregates. There shall be no sedimentation at the bottom of the mixture. If there are such cases, the mixture shall be taken off the surface.
- (8) There shall be no streaking; for example, from large coarse aggregate, apparent on the finished surface of sealing. If there is such a case, it shall be correctly shaped or improved. The Engineer may order to screen aggregate before mixing.
- (9) Longitudinal or transverse joints shall not be ridged or too apparent. If there is such a case, it is necessary to drag gunny bag or any method by the approval of the Engineer.



- (10) In case that the spreader cannot be used, because of confined area, manual spreading shall be done by the approval of the Engineer.
- (11) Slurry seal type 2 or the first application of slurry seal type 3 shall be compacted with a pneumatic-tired roller to the full width not less than 5 passes. Rolling shall begin soon after no adhesion of asphalt to the tires but not over night. The second application of slurry seal type 3 shall be done as soon as possible but not later than 4 weeks after finishing the first application. The second application, normally, needs no rolling.
- (12) Slurry seal shall be cured for some time before the roadway is opened to traffic until the breaking of emulsified asphalt is completed. If it is necessary, stone dust or sand may be spreaded on the area of prior passing of vehicles i.e., intersection, connection road.

Breaking of emulsified asphalt in the slurry seal shall be checked by observing the change of color of the mixture from brown to black. Absence of water in the mixture shall be checked by using paper to absorb water on the slurry seal. If there is no water, it can be opened to traffic Normally, it should be not over 3 hours. Cure time shall be by the judgement of the Engineer.

End of Chapter 9

## **CHAPTER 10 - CONCRETE**

# TECHNICAL SPECIFICATION

## CHAPTER 10 - CONCRETE

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## **CHAPTER 10 - CONCRETE**

### **10.1 GENERAL**

#### **10.1.1 Scope**

This chapter deals with the construction of cast-in-place concrete as shown on the Drawings or as specified herein.

The ready mixed concrete can be used, proving that it has the same quality as the concrete specified in this chapter and with the approval of the Engineer.

#### **10.1.2 Definitions**

a) Fine Aggregate

Fine aggregate is defined as the part of aggregate having a maximum dimension of 4.8 mm.

b) Coarse Aggregate

Coarse aggregate is defined as the part of aggregate having a minimum dimension of 4.8 mm and maximum one of 38.1 mm.

c) Construction Joint

Any surface created by an interruption of concreting long enough for hardening of the concrete to such an extent, that the vibrator will not penetrate within 3 minutes, is to be considered a construction joint.

Whenever work is suspended on any section for more than one hour, concrete surfaces shall be treated as a construction joint.

d) Expansion or Contraction Joint

All joints allowing relative movement of concrete structures with respect to an adjacent one, due to expansion, shrinkage, settlement of foundations, etc. are to be considered expansion or contraction joints.

#### **10.1.3 Submissions**

a) Cement

The Contractor shall submit at least thirty (30) days before the use of cement, a typical mill test report regarding the control tests performed at the factory, including the physical and chemical properties of the cement proposed for the works.

b) Aggregates

At least thirty (30) days prior to placing any concrete, the Contractor shall submit to the Engineer for review the confirmation of sources, processing procedures, gradation curve and quality assurance.

c) Batching Plant Facilities

Complete description and drawing showing the general plant arrangement and equipment for processing, handling, storing and proportioning concrete ingredients shall be subject to the Engineer's review.

d) Mix Proportion

At least thirty (30) days prior to placing any concrete the Contractor shall submit details of his proposed mix proportion for the various classes of concrete specified, for the review of the Engineer.

e) Conveyance Facilities

Description of equipment and methods proposed for the transport of concrete from the batching plant to the works including placement equipment such as cranes, conveyors, concrete pumps and similar shall be subject to the Engineer's review.

f) Forms

The Contractor shall submit to the Engineer for review, prior to the start of any concrete construction, the detailed design he proposes to adopt for formwork, but approval of the drawings shall not release the Contractor from his responsibility for their adequacy.

g) Drawings and Schedules

The Contractor shall submit in advance the drawings, showing the order, magnitude and construction joints proposed for the cast-in-place concrete.

The Contractor shall submit in advance, a weekly placing schedule, giving the detailed locations of the placement, the approximate placement volume and the date on which the concrete will be placed.

#### 10.1.4 Standards and Codes

In this Specification, all or part of the standards and recommendations as listed in ACI 301 are applicable. These references include, but are not limited to:

a) American Society for Testing and Materials

ASTM C 31	Standard Method for Making and Curing Concrete Test Specimens in the Field
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ASTM C 33	Specifications for Concrete Aggregates
ASTM C 39	Compressive Strength of Cylindrical Concrete Specimens
ASTM C 40	Organic Impurities in Sand
ASTM C 70	Test for Surface Moisture in Fine Aggregate
ASTM C 88	Soundness of Aggregate
ASTM C 94	Ready-Mix Concrete
ASTM C 109	Test for Compressive Strength of Hydraulic Cement Mortars
ASTM C 117	Test Method for Material finer than 75 mm (No. 200)
ASTM C 127	Test for Specific Gravity and Absorption of Coarse Aggregate
ASTM C 128	Test for Specific Gravity and Absorption of Fine Aggregates
ASTM C 131	Abrasion of Coarse Aggregate
ASTM C 136	Test for Sieve or Screen Analysis of Fine and Coarse Aggregates
ASTM C 138	Unit Weight, Yield and Unit Air Content (Gravimetric) of Concrete
ASTM C 143	Slump of Portland Cement Concrete
ASTM C 150	Standard Specification for Portland Cement
ASTM C 151	Test for Autoclave Expansion of Portland Cement
ASTM C 171	Sheet Materials for Curing Concrete
ASTM C 172	Sampling Freshly Mixed Concrete
ASTM C 191	Test for Time of Setting of Hydraulic Cement by Vicat Needle
ASTM C 192	Making and Curing Concrete in the laboratory
ASTM C 227	Test for Potential Alkali Reactivity of Cement-Aggregate Combination (Mortar-Bar Method)
ASTM C 231	Test for Air Content of Freshly Mixed Concrete by the Pressure Method
ASTM C 233	Testing Air Entraining Admixture for Concrete
ASTM C 260	Air-Entraining Admixtures for Concrete



ASTM C 289	Test Method for Potential Reactivity of Aggregate (Chemical Method)
ASTM C 309	Specification for Liquid Membrane - Forming Compound for Curing Concrete
ASTM C 451	Test for Early Stiffening of Portland Cement (paste method)
ASTM C 494	Chemical Admixtures for Concrete
ASTM C 535	Test for Resistance to Abrasion of Large Size Coarse Aggregate by use of the Los Angeles Machine.
ASTM C 618	Fly Ash and Raw or Calcined Natural Pozzolans for Use in Portland Cement Concrete
ASTM C 881	Epoxy-Resin-Base Bonding Systems for Concrete
ASTM C 979	Pigments for Integrally Coloured Concrete
ASTM C 1017	Chemical Admixtures for Use in Producing Flowing Concrete
ASTM D 75	Sampling Aggregates
ASTM D 412	Test Methods for Rubber Properties in Tension
ASTM D 422	Standard Method for Particle Size Analysis of Soils
ASTM D 792	Test Method for Specific Gravity of Density of Plastics by Displacement
ASTM D 1667	Flexible Cellular Materials-Vinyl Chloride Polymers and Copolymers
ASTM D 1752	Performed Sponge Rubber and Cork Expansion Joint Fillers for Concrete Paving and Structural Construction

b) American Concrete Institute

ACI 211.1	Selecting Proportions for Normal, Heavyweight, and Mass Concrete
ACI 214	Recommended Practice for Evaluation of Compression Test Results of Field Concrete
ACI 221	Recommended Practice for Selecting Proportions of Concrete
ACI 301	Structural Concrete for Buildings
ACI 304	Recommended Practice for Measuring, Mixing and Placing Concrete

ACI 304.2R	Placing Concrete by Pumping Methods
ACI 305	Recommended Practice for Hot Weather Concreting
ACI 308	Recommended Practice for Curing Concrete
ACI 311.1R	Manual of Concrete Inspection
ACI 311.4R	Guide for Concrete Inspection - SP2
ACI 318	Building Code Requirements for Reinforced Concrete
ACI 343R	Analysis and Design of Reinforced Concrete Bridge Structures
ACI 347	Recommended Practice for Concrete Formwork
ACI 350	Concrete Sanitary Engineering Structures
ACI 423.3R	Recommendations for Concrete Members Prestressed with Unbonded Tendons

c) United States Bureau of Reclamation

USBR	Concrete Manual
USBR	
Designation 13	Determination of Clay Lumps Content
USBR	
Designation 22	Method of Slump Test
USBR	
Designation 26	Mixer Performance Test

d) Thai Standards

TIS 985-2533	Concrete Admixtures for Producing Flowing Concrete
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## 10.2 MATERIAL

### 10.2.1 Cement

a) Type and Requirements

All the cement to be used in the Works shall comply with ASTM C 150, "Standard Specification for Portland Cement". In general cement of Type I shall be used. Cement type I with pozzolan may be used pending on type of pozzolanic material. Pozzolanic material shall be fly ash from EGAT's Mae Moh Power Plant only.

All the cement used in the Works shall be from the same manufacturer unless otherwise approved in writing by the Engineer.

The Contractor shall deliver with each shipment of cement a certificate, by which the cement is guaranteed to comply with the requirements of the Specifications.

The certificate shall indicate the date of arrival of each shipment at the concrete plant, the quantity shipped and the identification of the silo, lot or bin at the factory, where the cement originate.

The Engineer reserves the right to take samples soon after delivery or at a later stage and to require the performance of tests of the cement that the Contractor uses or intends to use. No cement shall be used until the Engineer has indicated, that the same is satisfactory. If the tests demonstrate, that the delivered cement is not satisfactory, it shall be replaced at the expense of the Contractor.

The Engineer may require the removal of any concrete produced with cement that does not comply with the requirements of this Specification.

b) Form of Delivery

Cement to be used in the Works shall be delivered in bags or in bulk. The cement type has to be clearly indicated on each delivery.

Cement in bags shall be delivered to the Site in strong paper bags, factory-sealed, unbroken or undamaged and uncontaminated by moisture, oil or others substance.

Cement may be delivered in bulk provided that the Contractor furnishes adequate transportation, weighing devices and all the necessary facilities to warrant the good condition of the material when the shipments arrive at the Contractor's storage bins.

c) Transportation

The transportation of bulk cement shall be performed in trucks with clean weathertight compartments, sealed and adequately constructed to protect the cement from exposure to moisture.

The method of transporting in bags shall equally guarantee their protection against moisture. The rebagging of the contents of broken or damaged bag will not be permitted.

If the cement has deteriorated during transportation, handling or storage, it shall be removed immediately from the Site at the Contractor's expense.

d) Storage and Handling of Cement

The following requirements shall apply to the storage and handling of cement on Site or at any intermediate transfer or storage point.

Cement of different types has to be stored in sufficient quantity not to hamper the construction progress at any time.

Immediately upon arrival on Site the cement shall be stored in approved storage facilities. Cements of different types have to be stored separately and all storage facilities shall be

arranged in a way to avoid mistakes by mixing up different cement types. Storage of a cement type in a silo, which has been used previously to store the other type, will not be permitted.

The temperature of the cement as delivered to Site shall not exceed 60°C. All loading and unloading facilities for cement shall be covered and weatherproof to the satisfaction of the Engineer.

All cement in bags shall be stored at all times up to its use in the Works in completely weatherproof stores, which shall include a suitably raised floor and be adequately ventilated to prevent the accumulation of moisture.

All storage of cement in bags shall be arranged so as to permit easy access for inspection and definite identification of all cement in the storage.

The floor of the stores shall have a wooden deck at least 30 cm above ground and shall be provided with waterproof membranes. Storage of cement in bags on the ground will not be permitted under any circumstances.

Cement in bags shall be stored in stacks not higher than 8 layers.

When necessary, cement shall be properly covered with waterproof canvas with tarpaulins or other effective waterproof coverings.

The bulk cement shall be kept in weathertight silos, which will be emptied for cleaning at regular intervals not exceeding three (3) months.

When cement is handled by pneumatic means, which involve contact of compressed air with the cement, the temperature of air in contact with the cement shall never exceed 38°C. Where necessary, after-coolers or other means shall be provided to cool the compressed air. All compressed air supplies, where the air may come into contact with the cement, shall be fitted with filters for the removal of moisture, oil or any other contaminating substances. These filters shall be regularly inspected and maintained by the Contractor.

The Contractor will not be permitted to set up cement handling facilities, where cement dust may come into contact with the Authority's electrical and mechanical equipment installed and stored in the vicinity and to which cement dust will be deleterious.

Cement of different quality shall be stored in separate sections of the store or in separate silos. For each silo the following items shall be recorded and submitted on a weekly basis to the Engineer:

- the cement quantity in store at the end of the week;
- the quantities, origins and storage locations of the batches delivered to Site during the week;
- the daily quantities used from each silo.

Cement shall be used in the same chronological order as delivered to the Site to avoid storing some stocks for too long. Any cement, which has been stored on Site for more than sixty (60) days, has to be representatively sampled if so instructed by the Engineer, and if the test results

are not satisfactory, the cement shall be removed from the Site at the Contractor's expense. Such retesting will be at the expense of the Contractor.

Cement shall neither contain lumps nor other visible deterioration at the moment of use. Cement, which has become stale or otherwise unsuitable by absorption of moisture from the atmosphere or otherwise, shall be rejected and immediately removed from the Site at the Contractor's expense.

## **10.2.2 Aggregate**

### **10.2.2.1 Fine Aggregate**

Fine aggregate shall be clean, strong, hard, compact, unalterable and without flaky fragments of rock, and shall be free from adherent coating, clay, loam, alkali, organic material or other deleterious substances.

Fine aggregate shall meet the requirements of ASTM C33 except where specified hereafter.

The Organic Impurities of fine aggregate when tested according to ASTM C 40.

The method of testing for surface moisture shall be in accordance with ASTM designation C70.

The maximum quantity of deleterious substances in fine aggregate, at the time of its discharge into the mixing plant, must not exceed the following values:

<u>Material</u>	<u>Maximum % by Weight of Total Sample</u>
Material passing sieve No. 200 (ASTM C 117)	3
Clay lumps (ASTM C 142)	1
Light weight material	1
Total of other deleterious substances (such as alkali, mica, coated grains, soft and flaky particles and silt)	2

The aggregate sum of the percentage of all the deleterious substances must not exceed 5% by weight.

Fine Aggregate will be rejected if:

- It contains organic impurities (ASTM C40);
- It has a specific gravity (on the basis of weight of saturated surface dry basis) of less than 2.60 (ASTM C 128);
- It has a loss of more than 10% by weight of the fraction retained on sieve No. 50 when subjected to five (5) cycles of soundness test using sodium sulfate solution in accordance with ASTM C 88.

The grading of fine aggregate shall also be controlled so that the fineness modulus, in at least nine out of ten test samples of the fine aggregate as delivered to the mixer, shall not vary more than 0.20 from the average fineness modulus of all samples previously taken unless different instructions by the Engineer.

The fineness modulus of fine aggregate shall range between 2.5 and 3.2.

The grading of fine aggregate when tested according to ASTM C 136 procedures shall conform to the following requirements as delivered to the mixers:

Sieve Size	Percentage Passing by Weight
9.5 mm (3/8 inch)	100
4.8 mm (No.4)	95 to 100
2.4 mm (No.8)	80 to 100
1.2 mm (No.16)	50 to 85
0.60 mm (No.30)	25 to 60
0.30 mm (No.50)	10 to 30
0.15 mm (No.100)	2 to 10

Fine aggregate which produces expansion in, or deterioration of concrete through reactivity with alkalis in cement or other causes shall not be used in the works. The test for alkali reactivity shall be in accordance with ASTM C 227.

#### 10.2.2.2 Coarse Aggregate

Coarse aggregate shall consist of hard, strong, clean, compact, unalterable, not flaky rock, with no particles of foreign matters.

It shall have no adherent coating and shall be free of lumps of clay, loam, roots, sticks and other organic matter, alkali or other deleterious substances, and shall meet the requirements of ASTM C 33 except where otherwise specified hereafter.

The percentage of deleterious substances in each portion of coarse aggregate, when delivered to the batching plant, shall not exceed the following limits:

Material	Maximum % by Weight of Total Sample
Material passing No. 200 sieve (ASTM C 117)	0.5

Clay lumps (ASTM C 142)	0.5
Light weight material	1
Other deleterious substances	1

The sum of all percentages of deleterious substances, in each portion to be delivered to the mixer, shall not exceed 2% by weight.

Coarse aggregates will be rejected if they fail to meet the following requirements:

- Abrasion test, Los Angeles type (ASTM C 131); If the loss exceeds either 10% by weight for 100 revolutions, or 40% by weight for 500 revolutions;
- Resistance to the sodium sulfate action (ASTM C 88); If the average loss by weight, after 5 cycles, exceeds 10 %;
- Specific gravity; If the specific gravity of the material (on the basis of surface-dry basis), is below 2.60 (ASTM C 127).

The grading of the coarse aggregate within the separated size groups according to ASTM E 11 and ASTM C 136 shall conform to the following requirements as delivered to the mixer.

Sieve Size U.S. Standard Square Mesh	Percent by Weight Passing Individual Sieves	
	4.8 to 19.1 mm (No. 4 to 3/4")	19.1 to 38.1 mm (3/4" to 1 1/2")
50.8 mm (2 inch)	-	100
38.1 mm (1 1/2 inch)	-	90-100
25.4 mm (1 inch)	100	20-45
19.1 mm (3/4 inch)	90-100	0-10
9.5 mm (3/8 inch)	30-55	0-5
4.8 mm (No. 4)	0-5	-

When crushed and uncrushed aggregates are mixed, they shall be blended uniformly, and the crushing and blending operations, as well as the amount of crushed material blended, shall at all times be subject to the approval of the Engineer.

### 10.2.2.3 Particle Shape

The shape of the particles in the fine and coarse aggregate shall be generally spherical or cubical.

Manufactured coarse aggregates, containing more than fifteen (15) percent elongated or flat particles, shall not be used. An elongated particle is defined as a particle having a maximum length of more than five (5) times its maximum width.

A flat particle is defined as a particle in which its maximum diameter or length is more than five (5) times its maximum thickness.

#### **10.2.2.4 Storage of Aggregates**

Fine and coarse aggregates shall be stored separately in such a manner as to prevent inclusion or intrusion of foreign matters, or the intermixing of various sizes in the bins.

Fine aggregate shall be stored only in covered steel silos or bins or under approved sheds. Fine aggregate must reach the mixing plant with uniform and constant moisture which shall not exceed 6% of its dry weight. Variations in moisture content shall not exceed 0.5 % from hour to hour or 2 % over a ten (10) hours concreting shift.

The method of testing for surface moisture shall be in accordance with ASTM Designation C 70.

Sufficient aggregate shall be maintained on the Site at all times, to permit continuous placement and completion of any lift of concrete started.

Methods of stockpiling, which permit the aggregate to roll down the slope as it is added to the pile, or which permit hauling equipment to operate over one area at the same level repeatedly, or which permit the free fall of material from a stacker, allowing fine material to be separated from coarse material by wind, will not be allowed. Stackers, if used, shall have an adjustable discharge height so that excessive dropping heights can be prevented.

#### **10.2.3 Admixtures**

##### **a) General**

Concrete admixtures shall comply with ASTM Designation C 260, C 494 and C 1017.

For each type of admixture, the Contractor will submit to the Engineer the catalogs and samples of at least three manufacturers with recognized world-wide reputation in concrete admixtures.

The Contractor will execute tests on the samples of admixtures, after their delivery to the site laboratory in order to verify the quality and the proportion.

Admixture containing calcium chloride will not be permitted.

The admixtures which have to be mixed in the same class of concrete must be supplied by the same manufacturer.

The admixtures shall have a uniform quality in the different stocks, and will be supplied along with manufacturer's test certificate.

Liquid or powdered admixtures shall be stored in such a way that the materials are used in the same chronological order as their delivery to the Site.



Admixture which has been in storage at the Site for longer than six months, shall not be used until retest proves to be satisfactory.

b) Water-reducing, Water-reducing-retarding admixture;

A water-reducing or a water-reducing-retarding admixture may be used in all classes of concrete. The final quantity of water-reducing or water-reducing-retarding admixture in the various classes of concrete shall be established by laboratory tests carried out by the Contractor and will reduce the quantity of mixing water not less than 10% and increase the setting time approximately 2 hours.

c) Air Entraining Admixture

The Contractor may use an approved air-entraining admixture in all concrete. The amount of air-entraining admixture used in each concrete mix shall be such as will effect the entrainment of the percentage of air within the specified range.

d) Expanding Agent

The Contractor may use an expanding agent in a small amount of the concrete and mortar used in the Works. The expanding agent shall consist of an approved aluminum powder or other approved material. The amount of expanding agent used in the concrete or mortar shall be as approved by the Engineer.

#### 10.2.4 Mixing Water

The water used for mixing, rinsing and curing concrete and/or processing concrete aggregates, shall be clean and free from oil, salt, alkali, silt, organic matters or other substances deleterious to concrete such as clay and mud, etc. The water turbidity shall not exceed 2,000 parts per million. The water shall conform to the requirement of ASTM C 94.

The aggregate moisture content shall also be considered as mixing water. The content shall be determined in compliance with ASTM C 70.

If water from local natural sources should contain, at certain times, quantities of impurities in excess of these limits, the Contractor will be required to take all necessary measurements for ensuring its purity before use.

#### 10.2.5 Concrete Class

The concrete is classified on the basis of the minimum compressive strength of standard size cylindrical concrete specimens (Ø15 cm and 30 cm height) at twenty eight (28) days, the minimum cement content, the maximum size of aggregate and the maximum slump as shown in the table hereafter. The applications of each class of concrete are shown as well.

Concrete Class	Minimum Compressive Strength at 28 days (kg/cm <sup>2</sup> )	Minimum Cement Type I Content per unit Volume of Concrete (kg/m <sup>3</sup> )	Maximum Size of Aggregate (mm) See Note 3
A	140	180	20 – 80
B	240	330	20
C	280	330	20 - 80
D	350	See Note 2	20

Class A Lean backfill concrete and dental concrete, etc.

Class B Concrete other than Class A, Class C, Class D

Class C Wye Branch and Bifurcation encasement concrete, Penstock encasement concrete, Valve chamber concrete, Powerhouse concrete, Transformer foundation, Tailrace concrete, Tailrace channel concrete, Secondary stage concrete, Bridge, Concrete pavement, Elevated flume and Surge tank (if required)

Class D Prestressed concrete

Note 1 If cement Type I with pozzolan will be used, the Contractor shall submit Cement Type I content and pozzolan content to EGAT for approval.

Note 2 The minimum cement content of Concrete Class D shall conform to the prestressed concrete manufacturer's specification and be approved by EGAT.

Note 3 In no event should the nominal maximum size exceed one-fifth of the narrowest dimension between sides of forms, one-third the depth of slabs, nor three-fourths of the minimum clear spacing between individual reinforcing bars, bundles of bars, or pretensioning strands.

In no case, the maximum size of aggregate shall not be greater than the size specified in the above table.

### 10.3 EXECUTION

#### 10.3.1 General

##### 10.3.1.1 General Requirements

The concrete to be produced and placed according to this Specification shall be of highest quality and uniformity. In all phases of his operations the Contractor will be subject to strict inspection to assure concrete of the best quality. Special emphasis will be placed on the uniformity of the concrete aggregates, water-cementitious material ratios, consistency, air

content and the temperature control of the concrete at the time of placement in the formwork, as well as the density and finishing when placed.

### 10.3.1.2 Tolerances for Concrete Structures

#### a) Construction Tolerances for Concrete

##### i. Variation from vertical:

- In the lines & surfaces of columns, piers, walls and towers
 

In 3 m .....	5 mm
In 6 m .....	8 mm
In 12 m or more.....	16 mm
- For exposed columns control joint grooves and other conspicuous lines
 

In 6 m max .....	5 mm
In 12 m or more.....	10 mm

##### ii. Variation from the level or from the grades indicated on the Drawing :

- In floor, inverts, ceilings, and beam soffits
 

In 3 m .....	5 mm
In any bay or 6 m max ....	8 mm
In 12 m or more.....	16 mm

##### iii. Variation of the linear structure lines from established position in plan and related position of walls

In any bay or 6 m max ...	12 mm
In 12 m or more.....	25 mm

##### iv. Variation in location of sleeves and sizes and locations of floor openings and wall openings

.....	5 mm
-------	------

##### v. Variation in cross- sectional dimensions of columns, beams and in the thickness of slabs and walls

Minus .....	5 mm
Plus .....	10 mm

##### vi. Variation in steps:

- In a flight of stairs
 

Rise .....	3 mm
Tread .....	5 mm
- In consecutive steps
 

Rise .....	2 mm
Tread .....	3 mm

##### vii. Variation in lining concrete:

- In design center line
 

.....	30 mm
-------	-------
- In inner diameter
 

.....	30 mm
-------	-------

#### b) Construction Tolerance for Placing Reinforcing Steel

- ##### i. Variation of protective covering
- |                               |       |
|-------------------------------|-------|
| With 50 mm cover or less..... | 5 mm  |
| With more than 50 mm cover .. | 10 mm |

- ii. Variation from indicated spacing .....25 mm  
(any one bar)

### **10.3.2 Mix Proportion**

#### **10.3.2.1 General**

Concrete shall be composed of cement, fine and coarse aggregates, admixtures and water.

Proportioning shall mean the process of determining the quantities of the various ingredients, to be used to produce concrete of the required strength and in accordance with the other requirements of these Specifications.

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.

To obtain the best results, the type of the structure concerned and the pouring procedure involved shall be taken into consideration for proportioning.

The Contractor shall be fully responsible for producing and maintaining the quality of concrete with especially compressive strength not inferior to the specified one.

After completion of tests, the Contractor shall inform the Engineer on the proportioning of mixtures to be adopted for the various classes of concrete. No concreting will be permitted until the results of these tests are available.

During the progress of the concrete work, additional trials shall be made with the purpose of improving the proportions of the various classes of concrete.

Mix proportions of concrete shall be determined by the Contractor in accordance with the requirements of these Specifications. The results of the tests required have to be submitted to the Engineer prior to concreting.

#### **10.3.2.2 Required Compressive Strength for Mix Proportion**

During proportioning tests the average value of the compressive strength of three cylinders made from that concrete mix shall be as follows:

If a record of at least 30 compressive strength tests of the same concrete mix is available, the serial compressive strength shall exceed the required compressive strength by at least:

- 10% if the standard deviation is less than 7%;
- 15% if the standard deviation is between 7% and 10%;
- 20% if the standard deviation is between 10% and 14%;
- 25% if the standard deviation exceeds 14%.

If above mentioned record is not available, the required average compressive strength shall be 25% higher than the required compressive strength.

Each test shall represent the average of at least three cylinders. (6" x 12")

#### **10.3.2.3 Water-cementitious Materials Ratios**

The net water content of all concrete mixtures shall be the minimum necessary to properly place the concrete.

Mixing water shall include all water present, that is the surface moisture in the aggregate and the water added in the mix. It shall not include the moisture absorbed by the aggregate reaching a saturated surface-dry state.

Surface moisture content in the aggregates shall be determined in accordance with ASTM C 70.

The water-cementitious materials ratios shall be determined by the requirements for specified strength, durability and impermeability. The maximum w/b-ratio shall be 0.45.

To consider the fluctuation of the water content during mixing on Site due to e.g., slight moisture change of aggregates, the w/cm ratio shall be reduced by 0.05 at the batch plant.

Addition of water to overcome stiffening of the concrete before placing will not be permitted.

Once the proportion of a mix including its w/cm ratio has been determined and specified for use in a structure, it shall be maintained constant during the pouring.

#### **10.3.2.4 Consistency and Slump**

Concrete shall be of a consistency and workability suitable for the conditions on the job. For most concrete a "plastic" mix is required, which will not crumble, but will flow sluggishly when vibrated, without segregation.

Tests for compaction factors shall be performed to determine the consistency of concrete, which shall be made in accordance with DIN 1048, "Test Methods for Concrete".

The consistency is defined by the trial compaction according to DIN 1048 and distinguished between the classes C1 (stiff), C2 (plastic) and C3 (soft).

Slump tests shall be performed in accordance with the "Standard Method of Slump Test for Consistency of Portland Cement Concrete", ASTM designation C 143.

Wherever the limits for consistency and/or slump are exceeded, the concrete shall be rejected and removed at the Contractor's expense.

Types of construction	Slump, cm.	
	Maximum+	Minimum
Reinforced foundation walls and footings	7.5	2.5
Plain footings, caissons, and substructure walls	7.5	2.5
Beams and reinforced walls	10	2.5
Building columns	10	2.5
Pavements and slabs	7.5	2.5
Mass concrete	5.0	2.5

Except for the case of Self-compacting Concrete, flow test conforming to ASTM C1611 or DIN 1048 : Part 1 shall be executed. The average diameter of the flow concrete measured in two perpendicular directions shall be greater than 55 cm. Segregation shall not be found.

### 10.3.3 Batching

#### 10.3.3.1 General

The Contractor shall provide automatic batch-type mixing plants, with minimum rated capacity stated by the manufacturer as required to meet the construction schedule of concrete works. The equipment shall be capable of combining the specified proportions of coarse and fine aggregates, cement, admixtures and water into a uniform mixture, without segregation. Plants shall be designed to batch several classes of concrete at the same time, without undue delay.

The Contractor shall install, maintain and operate at his own expense telephone or radio-telephone communications between each concreting site and the batching plant, so that it can be possible to settle quickly any questions arising from the quality or consistency of the concrete, or any other relevant matter.

The plant shall include provisions and devices to facilitate the inspection of all operations, and sampling of materials at all times.

There shall be in the mixing plant, a room to house the control testing equipment, and the Engineer has the right to access the testing equipment at anytime. The recorders, scales and batching plant control equipment shall be installed in a room that will ensure protection against exposure to excessive dust and other harmful elements.

The term "automatic" shall define batching and mixing plant equipped with automatic interlocks to fulfill the following requirements:

- i) A new batch cycle cannot start until all batchers are completely empty, and their discharge gates or valves closed;
- ii) Cement, aggregates, water and admixtures shall be automatically batched and discharged;

- iii) The discharge mechanism for the mixers shall not operate until the required mixing time has elapsed.

### **10.3.3.2 Batchers**

#### **a) General**

Individual weight batchers shall be provided for each material, except the liquid materials which may be batched by volume, in all works requiring the use of more than two separate size groups of coarse aggregates. Cumulative weight batchers may be provided for work requiring the use of not more than two separate size groups of coarse aggregates, provided cement is weighed and batched separately from the aggregates.

The batching plant shall have an automatic control capable of ready adjustment, to compensate for the varying moisture content of the aggregates, and to change the weights of the materials being batched.

#### **b) Weighing Units**

Every delivery point of aggregates and cement into the mixer charging hopper shall have a weighing unit, and shall include a visible, springless, direct reading dial in kilogram units, which shall indicate the scale at all stages of the weighing operation, from zero to full capacity, or shall include an over and under indicator which will show the scale in balance at zero load, and any beam setting. The indicator shall have an over and under travel equal to at least 5% of the capacity of the beam.

The Contractor shall provide standard test weights and any other auxiliary equipment required for checking the performance of each scale, or other measuring devices.

Tests once a month, shall be made in the presence of the Engineer. Upon completion of each check tests, and before use of the measuring or recording devices, such adjustments, repairs or replacements, as may be required to secure satisfactory performance, shall be made by the Contractor.

The weighing devices shall be maintained accurate within 0.5% of the true weight throughout their range of use.

#### **c) Measuring Water**

Water shall be measured by weight or by volume. The mechanism for measuring and delivering water to the mixers shall not permit leakage when the valves are closed. The filling and discharge valves for the water tank shall be interlocked so that the discharge valves cannot be opened before the filling valve is fully closed.

The line bringing water to the mixing plant shall be adequately insulated, to limit the pick-up of heat in hot weather.

#### **d) Dispenser for Admixtures**

The batching plant shall include a dispensing device to measure and deposit the admixtures into each mix. The dispenser shall be interlocked with the batching and discharging controls of the water, so that the batching and discharging of the admixtures will be automatic. The device shall be capable of ready adjustment, to allow varying the quantity of the admixture to be batched.

e) Recording Devices

An accurate autographic recorder shall be provided. The recording units shall be all in kilogram units, and completely housed in a single cabinet which shall be capable of being locked. The recorder shall produce a printed or autographic record on a single visible chart or tape, of the weights of the materials as batched, prior to delivery to the mixer. The chart or tape shall show the time at intervals of not more than five (5) minutes. The chart or tape shall be so marked that each batch may be permanently identified, and so that variations in batch weights can be readily observed.

All printed records shall be delivered to the Engineer.

f) Accuracy Limits

Delivery of materials from the batching equipment shall be within the following limits of accuracy:

Material	Percent
Cement	1 (by weight)
Water	1 (by weight)
Aggregates smaller than 3.81 cm (1 1/2") in size	2 (by weight)
Aggregates larger than 3.81 cm (1 1/2") in size	3 (by weight)
Admixture	1 (by weight)

Sealed bags of cement on which the weight is clearly marked need not to be weighed.

### 10.3.4 Mixing

#### 10.3.4.1 General

The components of the concrete shall be mixed in proven-type mixers.

Mixers shall be mechanically operated mixers, of either the tilting (conical drum) or non-tilting (turbine with mixing blades) type, of a design approved by the Engineer.

Mixers shall not be charged in excess of the capacity recommended by the manufacturer: the Engineer may direct a reduction in the batch size when mixer performance tests indicate that it is necessary. Mixers shall be capable of combining the materials into a uniform mixture without segregation.



If turbine-type mixers are used, they shall provide a scraping and folding action.

#### 10.3.4.2 Mixing Time

The mixing time for each batch shall be as follows: (time shall start when all solid materials are in the mixer drum or cylinder, provided that all of the mixing water shall be introduced before one-fourth of the mixing time has elapsed):

Capacity of Mixer (m3)	Min Mixing Time in Seconds	
	Non-tilting Type	Tilting Type
1 or less	60	90
from 1 to 3	105	120
over 3	120	150

The mixing time will be increased when such increase is necessary to secure the required uniformity and consistency of the concrete, or when test samples of concrete taken from the front, center and back of the mixer show a difference of more than 10% in sand-cement or water-cement ratio. Excessive overmixing, requiring addition of water will not be permitted.

Mixers shall be provided with an acceptable device to lock the discharge mechanism, until the required mixing time has elapsed. Provisions shall also be made to assure that each batch is discharged completely, before the mixer is recharged.

#### 10.3.4.3 Mixing Performance

The Contractor shall perform mixer efficiency tests on each class of concrete, in the presence of the Engineer, as soon as the equipment is in operating condition. At the end of the prescribed mixing time, three samples of concrete shall be taken; one at the one-quarter point, one at the mid-point and one at the three-quarter point of the batch.

These samples shall conform to the following units of uniformity:

- Variation from the average of air content shall not exceed 0.5% ;
- Variation from the average of the water-cement ratio shall not exceed 10% ;
- Variation in the weights of coarse aggregate retained on the number four screen shall not exceed 5%.

Mixer performance test shall be in accordance with USBR Concrete Manual, 8th Edition, Designation 26.

#### **10.3.4.4 Maintenance**

The mixers shall be maintained in satisfactory operating conditions, and mixer drums shall be kept free of hardened mortar. Should any mixer, at any time, produce unsatisfactory results, leak mortar, or cause waste of materials, its use shall be promptly discontinued until it is repaired.

#### **10.3.4.5 Concrete Not Accepted**

The Engineer shall have the right to reject the concrete in any of the following events:

- When mixing operations have not been started within thirty (30) minutes after the cement is added to the aggregates;
- When more than fifteen (15) minutes have elapsed between the discharging of the mixer and the actual placing of the concrete, without agitating the concrete mix;
- When more than one (1) hour has elapsed between the adding of the cement to the aggregates, and the actual placing of the concrete;
- When the mixture does not comply with the Specifications.

The Engineer reserves the right to specify a lesser time, if hot weather or other conditions cause quick stiffening of the concrete.

None of the concrete rejected by the Engineer shall be utilized in any of the permanent works.

The retempering of concrete which has partially hardened, that is, remixing with or without additional cement, aggregate or water will not be permitted.

### **10.3.5 Transportation**

#### **10.3.5.1 General**

Concrete shall be conveyed from the mixer to the place of final deposit, and finally poured as rapidly as practicable by approved methods, which will prevent segregation, loss of ingredients or damage by exposure to the atmospheric agents, and shall be deposited as nearly as is practicable to its final position. Concrete can be conveyed by truck mixers and agitators, buckets, truck or rail cars chutes and pipes, belt conveyors, concrete pumps and other equipment approved by the Engineer. Conveying equipment shall be of such size, design and condition to ensure a practically continuous supply of concrete at the point of placement, and a concrete placing in approximate horizontal layers while the previous layer is still soft. The maximum height from which the concrete shall be dropped shall not exceed one and a half meters, except where the use of suitable equipment to confine and control the falling concrete is specifically authorized by the Engineer.

All conveying equipment shall be supported independently of the forms. The conveying equipment shall be kept free from hardened concrete and foreign materials, and shall be cleaned at frequent intervals.

Should the concrete show signs of segregation when it reaches the placing point, and provided that the maximum permissible time has not elapsed, it shall be remixed by mechanical means in the vicinity of the placing, otherwise it shall be rejected at Contractor's expense.

In particular, the Contractor shall take appropriate measures to avoid excessive loss of moisture by evaporation, during the transportation and placing of the concrete. Addition of water in the mixture to make up for the evaporation losses shall not be permitted.

### **10.3.5.2 Conveying Equipment**

#### **a) Truck Mixers and Agitators**

Truck mixers and agitators may be used for agitating and transporting mixed concrete to the point of delivery. Truck mixers may be employed for mixing concrete to be used for minor works, provided that provisions for the batching and mixing of all concrete ingredients and admixtures specified hereof have been met.

Measuring tanks on truck mixers shall be equipped with water meter for readily and accurately determining the amount of water in the tank.

Truck mixers and agitators shall be capable of discharging the concrete with a satisfactory degree of uniformity.

The concrete mixed in truck mixers, shall not be discharged until at least twenty revolutions performed at the optimum speed are completed.

When concrete is mixed completely in a stationary mixer and a truck mixer or agitator is used for transporting the concrete to the delivery point, the concrete shall be mixed in accordance with the Specifications hereof, and agitating during transport shall be at the minimum speed.

The mixers and agitators shall be operated within the limits of capacity designated by the manufacturers of the equipment.

#### **b) Bottom-Dump Buckets**

Bottom-dump buckets moved by cranes and other similar equipment will be adopted as normal means for placing concrete except where their use is not technically possible. The buckets shall be capable of prompt discharge of low slump, lean mix concrete. The dumping mechanism shall be capable of controlling the discharge at a slow rate, and of discharging a relatively small portion of concrete in one place. Dumping of buckets on the swing, or in any manner which results in separation of ingredients or disturbances of previously placed concrete, will not be permitted.

#### **c) Truck or Rail Cars**

The conveying of concrete by trucks or rail cars, without agitating equipment, will be permitted provided the concrete has a slump of 50 mm (2") or lower and that the equipment has a proper cover when used outdoor.

Trucks and rail cars used for transporting non-agitated concrete shall be of a type specially designed for transporting and discharging concrete unless the trucks or rail cars are used for conveying concrete in approved concrete buckets.

Bodies of non-agitating trucks shall be smooth preferably stream lined, water tight metal containers equipped with gates that will permit control and ready discharge of the concrete.

d) Chutes and Pipes

Chutes and pipes shall be of a design such that segregation of the concrete constituents will not occur. The chutes shall have a smooth, mortar tight lining (preferably metal) and sides sufficiently high to prevent the concrete from falling over. A vertical drop at the end of chutes and pipes shall be provided, preferably in the form of two sections of metal drop chutes, to prevent segregation. Pipes shall be protected from sun, wind and rain, and shall be less than 10 m in total length. Chutes and pipes may be used only when approved by the Engineer.

e) Belt Conveyors

Belt conveyors used for the transportation of concrete, or for pouring shall have such a shape, size and speed as to prevent the loss of concrete on the way, and their slope shall be such as to avoid the displacement or sliding of the coarse aggregates, which would cause the segregation of the concrete. At the ends, such belts shall be furnished with scraper blades to avoid that the finer part of the concrete may remain on the belt conveyor.

Segregation at transfer points and ends shall be avoided by the use of suitable hopper and drop chutes. The conveyors shall be protected from sun, wind and rain.

If necessary, to prevent exposure of the concrete during transportation the belt conveyors shall be furnished with a continuous protective cover.

The maximum transport length shall not exceed 50 m unless otherwise approved by the Engineer.

f) Concrete Pumps

Concrete pumps may be used for the transportation of the concrete on condition that the concrete to be poured is designed with a slump of 100 mm (4") or more and that the use of the pump is approved by the Engineer. Furthermore, the increased cement content generally acquired for pumped concrete, will not be paid for.

Pneumatic pumps, i.e., pumps which need compressed air to move the concrete are not permitted.

Addition of water to the mixture after it has been discharged from the mixer shall not be permitted, neither during the loading of the pump, nor at the outlet of the piping which conveys the concrete.

The joints between the various elements which form the piping shall be perfectly tight, to avoid water leakage and loss of the finer part during pumping operations.

Delivery piping shall be arranged to provide sufficient delivery points, so that segregation caused by flowing of concrete in the forms will not occur.

### **10.3.6 Temperature Control**

The Contractor shall make the necessary provisions in the storage of concrete materials, handling and batching facilities, as required for complying with the hot weather concreting requirements. The proposed method of temperature control shall be approved by the Engineer.

During hot weather conditions, the temperature of the fresh concrete shall not exceed 25 degree Celsius, when placed in its final discharge point. To meet these requirements, the Contractor shall be prepared to undertake any, or all, of the following corrective measures:

- a) Aggregate stockpiles shall be shaded and sprayed as required to reduce the temperature of ingredients prior to mixing,
- b) 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 concrete,
- c) Reinforcement and metal formwork shall be protected from the effects of hot winds and direct sunlight.
- d) Suitable barriers shall be provided to protect the freshly placed concrete from wind until the concrete is sufficiently hard to allow it to be covered according to Sub-paragraph e) below.
- e) The concrete shall be mixed, transported, placed and consolidated, as rapidly as possible and shall then be covered with an impervious membrane or wet hessian until moist curing begins.
- f) Supply cool mixing water, or adding ice to the concrete during mixing;
- g) Cool the fine and coarse aggregates before mixing operations;
- h) Prevent exposures of batching, mixing and conveying equipment to direct sunlight;

Use of ice for mixing water shall be carefully controlled to ensure complete melting before mixing is terminated.

The application of ice water to the fine aggregate will not be permitted.

Refrigerating units, and the cooling plants, shall be planned in such a way as to secure the maximum continuity of service.

### **10.3.7 Forms**

#### **10.3.7.1 General**

Forms shall be used whenever necessary to confine the concrete, and to shape it to the required lines, grades and dimensions shown on the Drawings. Forms shall have sufficient strength to withstand the pressure resulting from placement and vibration of the concrete, and shall provide concrete surfaces conforming to the requirements of the finishes specified. Forms shall be sufficiently tight to prevent the loss of mortar from the concrete. Where re-usable forms are used, the original strength, rigidity, tightness and surface smoothness of the forms shall be maintained throughout their usage.

The form surfaces in contact with the concrete shall be treated or protected to avoid chemical reactions or discoloring of the concrete surface.

The use of forms with bruises, irregularities and to form curst incrustations shall not be permitted.

Should displacement occur in the position of the forms, with a consequent modification of the lines of the structure, as compared with the lines shown on the Drawings, the prescriptions set forth in the subclause 10.3.1.2 and 10.3.12 shall be applied.

Forms shall be placed so that the joint marks on concrete surfaces are, as much as possible, in alignment both horizontally and vertically.

The support for forms shall be such that no deflection occurs under the weight of wet concrete or other loads.

#### **10.3.7.2 Form Requirements for Various Finishes**

The type of form sheathing or lining shall be in accordance with the following minimum requirements for the formed surface finishes as specified in Clause 10.3.11.

Where Finish F1 is specified, forms may be any grade of steel and wood sheathing, free from great surface roughness or irregularities.

When Finish F2 is specified, forms shall be of pressed fiberboard, ordinary lumber, plywood or steel sheathing, free from surface roughness or irregularities.

Where Finish F3 or F4 are specified, forms shall be of at least 20 mm thick plywood, 30 mm thick first class timber or steel sheathing with plate not less than 3 mm thick, with very smooth and uniform surfaces. Steel lining shall not be permitted.

The first class timber used in the forms shall be free from warp, and wooden forms shall be made of dressed lumber of uniform thickness and width, which is free from loose knots, decay, or other defects. Steel sheathing shall be defined as a steel plate supported by structural shaped steel.

### **10.3.7.3 Forms of Curved Surfaces**

Forms for curved surfaces and transition sections shall be constructed to conform accurately to the required curvatures. The critical hydraulic shape or that relating to the performance of the equipment, e.g., approach channel, power intake, draft tube, etc. shall conform strictly to the theoretical curve from manufacturer. Dimensions from horizontal and vertical base lines will be given at several sections throughout the length of the curved or transition sections. The Contractor shall interpolate intermediate sections as necessary for the type of form construction being used, and shall construct and erect the forms so that the curvature will be continuous between sections. Erection templates shall be used on all curved frameworks where necessary to meet the requirements for curvature. The form sheathing shall be built up of laminated splines cut to make tight, smooth form surface. After the forms have been constructed, all surface imperfections shall be corrected, and any roughness and all angles on the surfaces of the forms caused by matching the form material shall be dressed to the required curvatures.

### **10.3.7.4 Cleaning and Lubricating**

At the time of concrete placing, the inner surface of the forms, the contacts and connections shall be free from any incrustation, mortar, grout or other foreign matter that may contaminate the concrete. Prior to pouring, the surface of the forms, with the sole exception of those made of rough wood, shall be smeared with a bond-breaking compound such as emulsified oil, or with refined mineral paraffin oil, designed to prevent sticking of concrete on the form. The treatment of the forms shall not cause harmful effects, or stains, on the concrete surface, or on the reinforcement system. Bond-breaking compounds shall be applied before reinforcement is placed if this procedure is feasible.

Forms made of timber which have been left in place for such a period that they have dried out, shall be wetted prior to concrete placement.

Furthermore, special care must be taken to prevent concrete adhering to the surface of the forms.

Oil treatment shall be made in such a manner as to avoid spillage on previously placed concrete. All excess oil on the form surfaces, and any oil on the concrete, metal or other parts to be embedded in the concrete, shall be carefully removed.

### **10.3.7.5 Form Ties and Bolts**

The design of form ties shall be such that no metal shall be within 20 mm of any exposed surface, except where Finish F1 is specified.

Where Finish F1 is specified, ties shall be terminated within the formed surfaces, or cut off flat with the formed surfaces. Wire ties will be permitted only where Finish F1 and F2 are specified. Sufficient form ties and bolts shall be used on both sides, and within a few centimeters of construction joints, to ensure the forms fit snugly against the concrete previously placed, and shall remain in tight contact during placing operations.

After completion of the concreting the Contractor shall withdraw the bolts and securely fill up the holes with cement mortar patch.

The terminal part of the wire ties, if their use is allowed, shall be shaped in such a manner that cutting and removal will not damage the concrete surfaces exposed to the sight.

Possible damage to the concrete due to the aforementioned operations shall be repaired in accordance with Clause 10.3.12.

#### **10.3.7.6 Chamfering Strips**

Chamfering strips shall be placed in the forms, to produce beveled edges on permanently exposed exterior corners in concrete surfaces and exposed joints except where specifically not required by the Engineer. Re-entering corners on such surfaces will not require beveling, unless requirement for beveling is indicated on the Drawings. Unless otherwise specified, chamfering strips for exterior beveled corners shall be from 30 to 50 mm.

#### **10.3.7.7 Removal of Forms**

The removal of the forms shall be carried out when the concrete has reached sufficient strength, so that no damage will be caused by removing.

No forms shall be removed within the specified time after the end of concrete placing, except for special cases where shorter time is approved by the Engineer.

As a rule, the forms shall be kept in place at least for the time hereunder indicated after concrete has been placed:

Pier and retaining walls	36 hours
Columns and walls	96 hours
Beams and slabs	7 to 14 days

The minimum time which shall elapse between the completion of concreting and removal of the forms for beams and slabs shall be reviewed by the Engineer for any particular structure, according to the design calculations. After authorization for removal, the forms shall be removed as soon as practicable, to avoid delay in specified curing of concrete, and also to enable earliest practicable repair of surface imperfections. Methods of form removal likely to cause overstressing of the concrete, or injury to the concrete surface, shall not be used. Forms and their supports shall be removed in such a manner as to allow the concrete to take the stresses due to its own weight uniformly and gradually. Provisions shall be made by means of suitable wedges, sand boxes or other devices, for the gradual relaxation of the support given by false work and centering.

### **10.3.8 Placing**

#### **10.3.8.1 General**



All concrete placing equipment and methods shall be subject to the review of the Engineer. Concrete placing shall not be started until all formworks, reinforcement, installation of embedded parts, and preparation of the surfaces of rock, and hardened concrete involved in the placement have been inspected by the Engineer. The Contractor shall notify the Engineer at least 24 hours, in advance allow a reasonable time for inspection before placing begins.

Placement schedules shall be submitted at the end of each work week and shall cover all concrete works planned for the following week.

At least twenty-four hours before the start of concreting, the Contractor shall submit drawings and sketches showing embedded parts, shoring and scaffolding.

Concreting of any part of the work will be authorized only after verification and acceptance of the following items:

- i) The characteristics of the concrete mix to be used,
- ii) The concreting program, type and quantity of equipment for placement and compaction, including the hourly placement rates,
- iii) The availability at the site, of equipment and material necessary for finishing, curing and protection of concrete,
- iv) The condition and cleanliness of forms, adjacent concrete or other surfaces, reinforcement and embedded parts,
- v) Conformity of the installation, including shoring and scaffolding, with the formwork drawings,

Concrete placed without prior knowledge and approval of the Engineer may be required to be removed and replaced at the Contractor's expense.

#### **10.3.8.2 Preparation of Foundation and Abutment**

Before placing concrete, all prejudicial materials shall be removed from the places to be occupied by the concrete, and surfaces which will be in contact with the concrete.

The surface of absorptive soils and rock against which concrete is to be placed, shall be moistened thoroughly so that moisture will not be drawn from the freshly placed concrete.

In area where the nature of the soil or rock is such that it will be softened if washed with water, blow pipes and compressed air shall be used.

All water shall be removed from the space to be occupied by the concrete, before the latter is deposited.

Any water flowing over the surface of the excavation shall be diverted through proper drains, to a sump, or shall be removed by other approved methods in order to prevent the washing away of the freshly deposited concrete or any of its constituents.

Before placing the concrete, rock surfaces shall be clean and free of oil, standing or running water, mud, coatings, debris, loose, small semi-detached or unsound rock fragments, and other foreign materials.

Immediately before placing the concrete, all rock surfaces shall be cleaned thoroughly by the use of high pressure air water jets, wet sand blasting, stiff brooms or other approved methods.

Foundations with surfaces of loose material shall be evened out perfectly and compacted by mechanical or manual means, until a solid and homogeneous abutment surface is obtained. All the areas and surfaces containing water, mud, slime and organic substances shall be drained and cleaned by removing such substances, and consequently filling up the cavities with approved material until the prescribed profile is reached.

Levelling concrete or polyethylene sheet may be placed on adjacent surfaces where proposed by the Contractor. The thickness of levelling concrete shall be 10 cm. Polyethylene sheets shall be lapped by 150 mm.

Surfaces of construction joints and surfaces of blockouts shall be washed thoroughly with air-water jets immediately prior to placement of adjoining concrete. Pools of water shall be removed from the surfaces of construction joints before new concrete is placed. Surfaces of contraction joints shall be cleaned thoroughly of accretions of concrete or other foreign material by scraping, chipping or other approved means.

#### **10.3.8.3 Method of Placing**

The concrete shall be deposited generally in horizontal layers in such a manner as to maintain, until completion of the pour, a plastic surface approximate horizontal. The thickness of each layer shall range from 30 to 60 cm and the placement shall be carried out at such a rate that no concrete surface can reach an initial set, before additional concrete is placed thereon.

The maximum lift of pouring shall not exceed 2.00 m.

The Engineer may authorize higher lifts or layers where concrete can be placed or consolidated in thick layers. Concrete shall be deposited as closely as possible, directly into its final position and in such as to avoid segregation or modification of other properties. Bouncing concrete off forms, reinforcing steel or any other obstruction is prohibited. Distributing of concrete with vibrators, or by other means will not be permitted. For locations when direct placement is not possible, and in narrow forms, hopper and trunks must be provided, of a size to allow a proper placing.

Any tendency to segregation shall be corrected by shovelling stones into mortar, rather than mortar into stones.

Concrete that is of excessive slump, segregated, partially hardened, or unworkable, shall not be placed in forms or if placed, shall be removed and dumped as directed by the Engineer, at the Contractor's expense.

Each layer of concrete which shall be placed and compacted with suitable types of equipment, until the concrete is consolidated to the maximum practicable density, is free of pockets of coarse aggregate, and fits tightly against all form surfaces and embedded materials.

Construction equipment used for spreading, vibrating or other operation must absolutely not spatter loose oil, fuel and grease on the concrete.

If a placement is stopped before completion, bulkheads shall be used to make a vertical joint. Any unconsolidated concrete shall be removed before completing the placement. During placement, and until curing has been completed, the concrete shall be protected to the satisfaction of the Engineer, against the harmful effects of exposure to sunlight, wind and rain.

#### **10.3.8.4 Placing Restriction**

##### **a) Reinforced Structures and Embedded Parts**

Where concrete has to be dropped through reinforcement, care shall be taken so that no segregation or displacement of bars occurs. Closed chutes, elephant trunks, or tremies receiving hoppers, shall be used to place concrete in deep forms, around reinforcement, or other places not readily accessible for direct placing.

Extreme care shall be devoted to placing the concrete around the various embedded parts, to ensure that unbalanced loading and impact from placing concrete, will not cause distortion or dislocation of parts. Both during and after placing of a lift, careful checks shall be made by the Contractor to see that the parts requiring accurate setting have not been displaced.

##### **b) Rain**

Outdoor concreting shall not be started during rains unless the Contractor has taken all protective measures including proper shelters so that during transport and placing. The concrete maintains the consistency tested at the mixing plant. Should concreting be already in process, the Contractor will provide proper shelters in order to complete the pouring operation.

In any case, placing operations shall be suspended, if the rain affects the quality of concrete, i.e., when the slump of vibrated concrete is 25 mm (1") or more than the slump tested at the mixing plant for the class of concrete being poured.

##### **c) Water**

No concreting shall be carried out under water, unless it is foreseen on the Drawings or is approved by the Engineer. The "drop-bottom bucket" or "tremie" method shall be used to pour concrete under water.

Concreting shall neither be conducted in running water, nor be exposed to the action of the same, before it is sufficiently set.

##### **d) Blockouts, Recesses, etc.**

The Contractor shall place concrete in blockouts, recesses, etc. constructed as shown on the Drawings, after, e.g., the installation and adjustment of metal work has been completed.

Before concrete is placed in the blockouts, recesses, etc. the surfaces of the concrete previously placed shall be roughened and cleaned. The roughening shall be performed by chiseling or other methods so as not to crack or scatter any other part of the concrete surface. All concrete, which is not hard, dense and durable, shall be removed to the depth required to secure a surface to the satisfaction of the Engineer. The Contractor shall place the concrete in a way to ensure satisfactory bond with the existing concrete, to secure complete contact with e.g., metal work to be embedded and to avoid any displacement. Where approved by the Engineer, concrete placed in recesses, etc. shall contain an approved expanding agent or non-shrink grout. No force or load shall be applied before the concrete reaches its 28 days strength.

#### **10.3.8.5 Consolidation**

Concrete shall be compacted with mechanical vibrating equipment, supplemented by hand spading and tamping, to a maximum practicable density so that it is in complete contact with the forms, reinforcement and other embedded parts.

The vibration shall be carried out by means of immersion type high-frequency vibrators, of the electrically driven or compressed air types, or by means of engine driven vibrators. For the consolidation of concrete where immersion vibrations shall prove impracticable, vibrators rigidly attached to the forms shall be adopted subject to the approval of the Engineer.

The size and number of vibrators, at each pour, shall be sufficient to thoroughly compact concrete, at the rate and conditions of placement.

The total consolidating capacity, in m<sup>3</sup> of concrete 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 concrete is placed in the Works.

For water depths exceeding 1 m, the concrete is to be placed so, that it does not fall freely through the water, that the cement is not washed out and that, as far as possible, no separating layers of laitance are formed.

For components of secondary importance the concrete may be deposited layer-by-layer with bottom-opening skips or traveling tremies on the foundation bed or on the surface of the individual layers of concrete.

The tremies must be constantly and sufficiently far immersed in the concrete already placed for the concrete flowing out of the tremies to displace the earlier concrete.

For every four vibrators in use on the Works, an additional standby vibrator of similar consolidating capacity and in good working order, shall be provided.

When vibrating a layer of fresh concrete, the vibrator shall be held in a near-vertical position. The immersion of the vibrator shall be sufficiently deep to vibrate the entire depth of a new layer: the vibration should penetrate several centimeters into the layer below, to ensure thorough union of the layers.

No new layer of concrete shall be placed, before the underlying one has been thoroughly vibrated. Immersion points for the vibrators shall be adequately spaced, so as to make sure that every part of the concrete has been properly vibrated. Care shall be taken to prevent contact of vibrators against reinforcement steel, especially that starting initial set. Vibrators shall not be allowed to come into contact with form or finish surfaces.

Displacing concrete 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 50 mm clear of the formwork.

Provisions shall be made to ensure that any entrapped air, formed during the placing of concrete, be allowed to escape, by leaving effective air vents in the formwork. Care shall be taken to provide a dense envelope of concrete surrounding the waterstops with no voids or honeycombing.

Excessive vibration, causing segregation and laitance, and tending to bring water to the surface, shall be avoided.

Vibration or disturbance of concrete, which is partially hardened, will not be allowed. Necessary traffic over new concrete shall be on independently supported timber walkways so constructed that the fresh concrete is not disturbed.

#### **10.3.8.6 Green Cutting**

The Contractor shall remove laitance on concrete surfaces, on which another lift of concrete will be placed, by green cutting with a high velocity water jet or air-water jet.

Green cutting shall be performed before concrete 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.

#### **10.3.9 Joints**

##### **10.3.9.1 Construction Joints**

The shape and position of all construction joints shall be proposed by the Contractor and are subjected to the review by the Engineer, if not shown on the Drawings and/or not instructed by the Engineer.

Construction joints shall be sealed by waterstops or other means if so shown on the Drawings or instructed by the Engineer.

After the initial set, but before final hardening of the concrete, the unshuttered surface of the joint shall be washed with water and compressed air jets to thoroughly remove the top layer of mortar and all semi-detached parts from the surface, and to expose the upper half of the big size aggregates, however, without loosening or undercutting them.

If the surface of a lift with reinforcing steel is congested and is relatively inaccessible, or if for any other reason disturbing an unhardened surface is considered undesirable, green cutting by air-water jets will not be permitted and the use of wet sand blasting will be required after hardening of the concrete.

When employed in the preparation of construction joints, wet sand blasting shall be performed immediately before final cleaning for the following lift. The operation shall be continued until all unsatisfactory concrete and all laitance, coatings, stains, debris, and other foreign materials are removed.

Immediately before pouring is resumed, air and water jet cleaning shall be repeated, until the washing water remains quite clear; the Contractor shall deal in a controlled way with the water employed in washing, carefully diverting it from the pouring zone, leaving the surface wet, but without water puddles.

The air pressure used in the jet shall be not less than 0.6 MPa, and the water pressure shall be sufficient for thorough cleaning.

When construction joints are not covered with concrete within twenty (20) days after their formation, the Contractor shall apply wet sand blasting or roughen all surfaces by light jackhammering, when preparing for the next lift. The extent of concrete to be removed will be indicated by the Engineer. The treatment described above shall also be carried out when construction joints have been covered by stagnant water for a period of more than ten (10) days or by foreign materials difficult to remove by normal cleaning operations.

Formed surfaces of construction joints shall be roughened prior to continuing concreting and shall be clean and free from oil, objectionable coatings and loose, semi-detached or unsound fragments. Wherever possible, forms for construction joints shall be made of expanded metal. The period of moistening shall be two days.

Formed surfaces of construction joints to be grouted shall be cleaned of all accretions of concrete or other foreign material by scraping, chiseling or other effective means.

Whenever required by the length and type of structure the Engineer may instruct to carry out compulsory construction joints. At these joints no concrete shall be placed against the joint surface for at least 7 days for structures up to 1.00 m in thickness and for 10 days where the thickness exceeds 1.00 m.

#### **10.3.9.2 Expansion or Contraction Joints**

Joints shall be provided at the locations indicated on the Drawings. In no case shall any fixed metal embedded in the concrete, continue across an expansion or contraction joint.

The expansion or contraction joints can be of the smooth and even or dented type to guarantee the contact of the structures. The opposite faces, which form the joint, shall be completely separate.

Expansion or contraction joints shall be sealed by waterstops and/or joint sealants.

The Contractor shall undertake the pouring of the second surface only after the first one has thoroughly hardened.

When shown on the Drawings, a sheet of plain joint filler or other approved material may be placed in contact with the first pouring before starting the second pouring. The joint filler will not be paid for.

### **10.3.10 Curing and Protection of Concrete**

#### **10.3.10.1 General**

Curing provisions shall be made so that:

- Hydration of cement is developed gradually and completely;
- Concrete does not quickly pass from plastic state to elastic state;
- Concrete is not cracked or damaged by high differential temperatures or rapid changes in temperature;
- Surfaces of concrete are not damaged by traffic, nor discoloured by chemical agents.

The methods and materials used in the curing process shall be at all times, subjected to the approval by the Engineer. All equipment needed for adequate curing and protection of any concrete pour shall be ready to install before actual concrete placement begins.

#### **10.3.10.2 Moisture Control**

The loss of moisture from concrete shall be prevented by water curing or by membrane curing for at least 10 days after placing. Water curing shall start as soon as the concrete has hardened sufficiently to prevent damage and continue during the period, when concrete is protected by the forms. Water curing shall be accomplished by keeping all surfaces of the concrete continuously (not periodically) moist by either sprinkling, ponding, moist sand, moist burlap, or by moist wooden sheathing forms left in place. Water, sand and burlap shall be clean not to discolour the concrete.

Water for curing shall meet the requirements of water for concrete mixing.

Membrane curing may substitute the water curing in locations specifically authorized by the Engineer. Membrane curing shall consist of an application of a sealing compound, which forms a water retaining membrane on the surface of the concrete. The sealing compound shall be white pigmented, except the compound used on surfaces, that will be permanently exposed to view, which shall be grey-pigmented. Sealing compound shall not be used on concrete surfaces, to which additional concrete or other material is to be bonded. Concrete curing compounds shall conform to the requirements of ASTM C 309.

Approved sealing compounds shall be sprayed onto the concrete surfaces in one coat to provide a continuous, uniform membrane over all areas. Coverage shall not exceed amounts given in the manufacturer's instructions; coverage shall be decreased as necessary to obtain the required continuous membrane.

When sealing compound is used on unformed concrete surfaces, application shall commence immediately after pouring. When sealing compound is to be used on formed concrete surfaces, the surfaces 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 sealing compound shall be applied. Special care shall be taken to ensure ample coverage with the compound at edges, corners and rough spots of formed surfaces.

### **10.3.10.3 Protection**

During the curing period concrete shall be protected against any potentially harmful attack, abrasion, vibrations or damage from traffic by independently supported walkways, or an effective cover of sand, or other types of covering. Coverings shall not be applied over membrane-cured surfaces for at least twenty-four (24) hours after the sealing compound has been applied.

Unhardened concrete shall be protected from heavy rain, flowing water, direct sun rays and wind.

### **10.3.11 Finishing**

#### **10.3.11.1 General**

Allowable deviations from plumb or level and from alignment, profile, grades and dimensions shown on the Drawings, as specified in Clause 10.3.1.2, are defined as 'tolerances' and are to be distinguished from irregularities in finish as described herein. The classes of finish and the requirements for finishing of concrete surfaces shall be as shown on the Drawings, or as hereinafter specified. In the event that finishes are not definitely specified herein or on the Drawings, the finishes to be used shall be those specified for similar adjacent surfaces. Finishing of concrete surfaces shall be performed only by skilled workmen. The Contractor shall be advised as to when finishing of concrete will be performed. Unless inspection is waived in each specific case, finishing of concrete shall be performed only in the presence of the Engineer. Concrete surfaces will be tested by the Engineer where necessary to determine whether surface irregularities are within the specified limits.

Surface irregularities are classified as 'abrupt' or 'gradual'. Offsets caused by displaced or misplaced formwork, or by loose knots or otherwise defective form timber will be considered as abrupt irregularities, and will be tested by direct measurements. All other irregularities will be considered as gradual irregularities, and will be tested by the use of a template, consisting of a straight edge or the equivalent thereof for curved surface. The length of template will be 1.5 m for testing of formed surfaces, and 3.0 m for testing of unformed surfaces.

#### **10.3.11.2 Formed Surface**

The classes of finish for formed concrete surfaces are designated by use of symbols F1, F2, F3 and F4. Bag rubbing or sand blasting will not be required on formed surfaces, other than that necessary for the repair of surface imperfections. Unless otherwise specified or indicated on the Drawings, the classes of finish shall apply as follows:



### Class F1 (Sawn)

This finish is generally intended for surfaces against which backfill, concrete or grout will be placed being permanently invisible.

These surfaces shall not be subjected to any special treatment, except for the repair of defective concrete, tie rod holes, etc. Gradual irregularities may be up to 25 mm and abrupt irregularities up to 10 mm.

### Class F2 (Wrought)

This finish is required for structural surfaces permanently exposed to view. Gradual irregularities may be up to 8 mm and abrupt irregularities up to 5 mm.

### Class F3 (Precast Quality)

This finish is required for prominent or important architectural features and for precast concrete units. The surfaces shall be also capable to be subjected to the passage of fast flowing water.

No abrupt irregularities are permitted and the gradual irregularities shall not exceed 6 mm.

### Class F4 (Frigid Accurate)

This finish is required for formed concrete surface when accurate alignment and evenness of surface are essential for prevention of the destructive effects of water action. This surface will be exposed to water flow of high velocity.

No abrupt irregularities are permitted and the gradual irregularities have to be limited to less than 4 mm.

### 10.3.11.3 Unformed Surface

The classes of finish for unformed concrete surfaces are designated by the symbols U1, U2 and U3, defined as follows:

#### Finish U1

This finish concerns surfaces that will be covered by backfill and shall also be used as the first stage of U2 and U3 finishes. Finishing operations shall consist of sufficient leveling and screeding to produce even, uniform surfaces. Gradual surface irregularities shall be such as not to impair the structural properties of the work.

#### Finish U2

This finish concerns surfaces not permanently concealed by second stage of U3 finish. Floating shall be started as soon as the screeded surface has stiffened sufficiently, and shall be done at least to form screeded marks and be uniform in texture. In areas required by the Engineer, a light brooming of the surfaces will be required to provide a non-skid surface. If U3

finish is to be applied, floating shall be continued until a small amount of mortar without excess water is brought to the surface, so as to permit effective troweling. Abrupt surface irregularities are not admitted and the gradual ones shall not exceed 5 mm, Joints and edges shall be tooled where shown on the Drawings.

#### Finish U3

This finish concerns surfaces where an accurate surface is required. When the floated surface has hardened sufficiently to prevent excess fine materials from being drawn to the surface, steel troweling shall be started. Steel troweling shall be performed with firm floated surface and produce a dense and uniform surface free from blemishes and trowel marks. Abrupt surface irregularities are not admitted and the gradual ones shall not exceed 2 mm.

#### 10.3.11.4 Specific Application of Finish

The specific application of the classes of finish to architectural concrete shall be as follows.

##### Building and Houses

structure concrete above ground	F3
structure concrete below ground	F1
structure concrete plastered with mortar	F2 or U2
others	U3

The classes of finish to other concrete than specified above are indicated in Clause 10.4.1.

#### 10.3.12 Repair of Concrete

##### 10.3.12.1 General

Any indentation, irregularity and bulge occurring beyond the specified tolerance, or any voids and honeycombs, fractures or other damages, shall be repaired. Repairs shall be performed by skilled workmen and the Contractor shall inform the Engineer before starting the repair work. Materials, procedures and operations used in the repair of concrete, and also the finished work, shall be done in accordance with the orders and instructions of the Engineer.

In general, the repair work shall be started within 24 hours after stripping of the formwork. Concrete damaged by any cause and concrete that is honeycombed, fractured or otherwise defective, and concrete which, because of excessive surface depressions must be cut back and rebuilt, shall be replaced with mortar, concrete or epoxy resin as specified hereafter or as otherwise directed by the Engineer.

##### 10.3.12.2 Repairs with New Concrete or Mortar

Existing concrete of the portion to be repaired shall be cut back to sound concrete at least to a depth behind the reinforcement, sufficient to provide complete embedment of the reinforcement in the replacement concrete. Voids to be filled shall be provided with anchors, welded wire mesh, and/or dovetail slots whenever necessary to hold the new material securely in place. The edges of the cut shall be sawn normal to the concrete surface and the replacement

concrete adequately doweled to the old concrete as directed by the Engineer. Cut out areas shall be thoroughly cleaned. Holes left by the removal of tie rods shall be thoroughly moistened and filled with dry-pack mortar thoroughly tamped into place. The colour of replacement concrete and patching mortar shall match the surrounding concrete.

Concrete and mortar used for patching and repairs shall be cured in the same manner as specified for general concrete work. Where specifically authorized by the Engineer, bulges may be removed by grinding. Other methods to be followed in carrying out such repair work shall be those detailed in Chapter VII of the Concrete Manual USBR, 8th Edition. Repair of concrete, whenever practicable, shall be completed within thirty six (36) hours after removal of forms.

#### **10.3.12.3 Repairs with Epoxy Resin**

##### **a) Repairs to Depths of more than 6 cm**

Where the depth of damage is more than 6 cm, the repair shall be made by first saw-cutting a groove 4 cm deep around the perimeter of the damaged area. Then the damaged concrete shall be removed by light-weight jackhammer and the resulting surface shall be cleaned by chisel and compressed air to receive the epoxy-bond coat.

Damp or wet areas shall be dried with a propane torch immediately before applying the bonding agent to prepare a surface warm to the touch.

The applicable epoxy bonding agent shall be approved by the Engineer.

After the application on the clean and dry surface, and while still in a tacky stage, the bonding agent shall be overlaid with the repair concrete.

The repair concrete shall be directed by the Engineer.

If the bonding agent has set before applying the concrete, it shall be removed by sand blasting or additional chiseling.

##### **b) Repair to Depths of less than 6 cm**

Where the depth of damage is less than 6 cm the repair shall be made by first saw-cutting a groove 3 cm deep around the perimeter of the damaged area. Then the damaged concrete shall be removed by chisel and the resulting surface shall be cleaned by compressed air to receive the epoxy mortar.

The applicable epoxy mortar shall be approved by the Engineer.

The material shall be applied on the clean and dry surface according to the manufacturer's instructions.

Damp or wet areas shall be dried with a propane torch immediately before applying the epoxy mortar, to prepare a surface warm to the touch.

#### **10.3.12.4 Staining of Concrete**

For concrete surfaces, where Class F3 and Class F4 finishes are specified, care shall be taken that accumulation of foreign materials or staining due to any cause does not occur. Any accumulation or staining shall be cleaned off by the Contractor using a method approved by the Engineer. The Contractor shall not be entitled to any extra payment for this work.

#### **10.3.12.5 Plugging of Form-tie Holes**

Surface holes remaining in formed concrete after dismantling forms shall be cleaned out and neatly plugged with dry pack, as previously specified, except that for tie bolt holes with colour control the dry pack shall be colour-matched with the surrounding concrete.

#### **10.3.13 Dental Concrete**

Dental cavities shall be filled with concrete or shotcrete wherever possible prior to concrete placement.

Where dental concrete is used it shall have the same mix proportion as the concrete covering it, unless otherwise directed by the Engineer.

Dental cavity side surfaces shall be cleaned of all loose and friable materials prior to concrete placement.

#### **10.3.14 Second-stage Concrete**

The work shall be scheduled in conformity with the work as shown on the Drawings, and;

- i) For encasement or mounting of vertical guides for gates and trash rack, limit second-stage concrete placement rate so as not to exceed 30 cm per hour.
- ii) For encasement or mounting the air conditioner or other equipment, the Contractor shall cooperate and coordinate the procedures with the relevant manufacturer.
- iii) The Contractor shall form blockouts, place reinforcement and concrete as shown on the Construction Drawings, and in such manner as to ensure good bond with the existing concrete, to secure complete contact with the metal work to be embedded in the blockout concrete and to avoid displacement of the metal work.
- iv) Blockout concrete excludes concrete designed on the Construction Drawings as second stage concrete.
- v) Expert as otherwise specified the hydromechanical, mechanical, and electrical equipment will be provided and installed by the suppliers in cooperation with the Contractor.
- vi) Before placing concrete, all parts to be embedded shall be checked to ensure that they are firmly fixed in their required position. The surfaces of blockouts or holes shall be thoroughly cleaned and wetted. 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.

- vii) 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.

### **10.3.15 Quality Control**

#### **10.3.15.1 Laboratory Tests**

The Contractor shall construct, operate and maintain the field laboratory as specified in Chapter 3 "Construction Facilities" herein and shall carry out all tests and analyses for determining the mix proportion of each class of concrete including test of aggregates, so as to produce concrete specified in this clause or the approval of the Engineer.

The Contractor shall supply labor, materials and equipment necessary to sample and transport materials to the field laboratory from any part of the project area.

The Contractor shall appoint an engineer experienced in concrete technology, with not less than three years of relevant experience as laboratory supervisor. The laboratory concrete engineer will 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 ASTM Standards specified, or with other equivalent standards approved by the Engineer.

Samples will mainly be of aggregates, and concrete both fresh and cured. Samples shall be representative, taken according to the standard and in a sufficient amount to enable the laboratory to perform any test considered necessary for the Works.

The main tests for controlling the quality of aggregates and concrete shall be as specified in the following table.

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 TESTS FOR QUALITY CONTROL OF AGGREGATES AND CONCRETE
 

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Test	Frequency	Sampling Site	ASTM No.
<b>Fine Aggregate</b>			
Gradation	Once a week	Aggregate stockpile or batching plant	C 136 C 117
Surface moisture	Twice a day	Batching plant	C 70
Organic impurities	As required by the Engineer	Batching plant	C 40
<b>Coarse Aggregate</b>			
Gradation	Twice a month	Aggregate stockpile or batching plant	C 136 C 117
<b>Concrete</b>			
Compressive strength	Once for each 50 m <sup>3</sup> of concrete placed	Placing site and batching plant when required	C 31 C 39
Slump	Once every hour of pouring or as required by the Engineer	Placing site	C 143
Air content	As required by the Engineer	Mixing plant or placing site as directed by the Engineer	C 231
Temperature	Once every hour of pouring	Mixing plant and placing site	

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### 10.3.15.2 Compressive Strength

#### a) Sampling and Testing

Apart from the samples taken from the batching plant to check the uniformity production of the same, all samples taken in the field will be made from concrete at the truck mixer discharge. Each class of concrete shall be represented by at least one test (9 cylinders) for every 50 m<sup>3</sup> of concrete poured, and there shall be at least one test for each day's concreting.

Three cylinders from each set will be tested at an age of seven (7) days; a further three cylinders from each set will be tested at twenty eight (28) days. The remaining three cylinders of each set will be retained as reserve and tested if and when required by the Engineer.

#### b) Use of 7-day Tests

For any mix, a correlation between 7 and 28-day strength may be developed in laboratory. 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 by the Engineer, without waiting for the results of the 28-day tests.

#### c) Basis of Acceptance

The compressive strength of an individual class of concrete placed in the works shall be considered satisfactory if both of the following requirements are met:

- The average of 3 consecutive test strength equals or exceeds the required compressive strength ( $f_c$ );
- No individual test strength falls below 90% of the required compressive strength ( $f_c$ ).

#### d) Non-Conformity

When the results of the tests taken in the field do not comply with the specifications, the Engineer shall have the right to require that one or more of the following measures are taken:

- i) Test the reserve cylinders at fifty six (56) days in order to verify if the strength can be attained;
- ii) Extraction of a sufficient number of concrete samples (core taken with the rotary drilling method) from the structure for which a compressive test, or group of compressive tests, have given unsatisfactory results. These samples shall be taken and tested according to ASTM C 42;
- iii) Performance of load tests, where possible, on the structure whose compressive test were found unsatisfactory;
- iv) Other tests ordered case by case.

If, after carrying out such investigations, the Engineer finds out that the concrete in the structure is not of the specified quality, he may order the strengthening or replacement of all or part of the entire volume of hardened concrete represented by the test failure, or any other part of the Works, whose safety, in the opinion of the Engineer, is prejudiced or whose strength is impaired.

End of Chapter 10

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## **CHAPTER 11 - REINFORCING STEEL**

## TECHNICAL SPECIFICATION

### CHAPTER 11 - REINFORCING STEEL

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#### CHAPTER 11 - REINFORCING STEEL

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## **CHAPTER 11 - REINFORCING STEEL**

### **11.1 GENERAL**

#### **11.1.1 Scope**

The work covered by this chapter is all of the reinforcing steel to be embedded in the concrete structures wherever shown on the Drawings.

#### **11.1.2 Submissions**

At least 60 days prior to fabrication, the Contractor shall submit data showing bar bending details, bar lists, placement drawings, placement schedule and delivery schedule, all prepared in accordance with applicable standards.

At least 60 days prior to installation, the Contractor shall provide the Engineer with representative splice samples for each bar size if mechanical splicing is proposed.

Upon receipt of reinforcing steel onsite, the Contractor shall submit certified copies of mill test reports, including chemical analysis and physical properties of each heat. In case a load contains more than one heat, a list of bar mark numbers by heat shall be included.

#### **11.1.3 Standards and Codes**

American Concrete Institute (ACI):

ACI SP-66	ACI Detailing Manual
ACI 318	Building code Requirements for Reinforced Concrete
ACI 315	Details and Detailing of Concrete Reinforcement

American Society for Testing and Materials (ASTM):

ASTM A615	Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
ASTM A416	Specification for Uncoated Seven - Wire Stress – Relieved Strands for Prestressed Concrete
ASTM A421	Specification for Uncoated Stress – Relieved Wire for Prestressed Concrete

American Welding Society (AWS):

AWS D1.4	Structural Welding Code-Reinforcing Steel
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Thai Industrial Standard (TIS)

TIS 20 - (Latest Version)	Reinforcing Steel	Round Bar
TIS 24 - (Latest Version)	Reinforcing Steel	Deformed Bar

### **11.2 MATERIAL**

The Contractor shall provide materials free of oil, dirt, mud, loose mortar, loose rust, mill scale and coating which may reduce or destroy bond. Tight rust and mill scale or surface irregularities

will be acceptable provided the weight, dimensions, including height of deformations, and tensile properties of wire-brushed test specimens are not less than those required by the applicable specification.

The Contractor shall not use reinforcing steel that is reduced in section, has kinks and visible transverse cracks at bends, or is damaged.

Reinforcing steel shall conform to Thai Industrial Standard and consist of the following grades:

<b><u>Bar Size</u></b> <b><u>(mm)</u></b>	<b><u>Grade</u></b> <b><u>(ksc.)</u></b>	<b><u>Min-Yield</u></b> <b><u>Strength</u></b> <b><u>(kg/cm<sup>2</sup>)</u></b>
6 to 9	SR24	2,400
10 to 32	SD40/SD40T	4,000
	SD50//SD50T	5,000

Prestressing strands and reinforcing steel for use in prestressed concrete shall meet the requirements of TIS 24 (Latest Version), Reinforcing steel: Deformed Bar, ASTM A416, grade 270, latest edition Standard Specification for Uncoated Seven- Wire Stress- Relieved Strands for Prestressed Concrete; and ASTM A421 latest edition, Standard Specification for Uncoated Stress- Relieved Wire for Prestressed Concrete.

Alternatively, the reinforcing and tensioning wire shall conform to the following strength;

Reinforcing shall be of hot – rolled deformed bar with a minimum yield strength of 4,000 kg/cm<sup>2</sup> (Grade SD 40)

The steel tendons for prestressing shall conform to a range of tensile strengths as follows:

<b><u>Nominal Diameter</u></b> <b><u>of Wire, mm</u></b>	<b><u>Stress-Relieved or Hand-Drawn Wire</u></b>	
	<b><u>Min (kg/cm<sup>2</sup>)</u></b>	<b><u>Max (kg/cm<sup>2</sup>)</u></b>
8	14,500	16,000
to	to	to
3.0	18,500	20,000
	<b><u>Hand-Drawn Wire Only</u></b>	
	<b><u>Min (kg/cm<sup>2</sup>)</u></b>	<b><u>Max (kg/cm<sup>2</sup>)</u></b>
2.5	18,500	20,000
2.0	20,000	21,500

### 11.3 EXECUTION

#### 11.3.1 Supply, Storage and Custody

The Contractor shall have the sole responsibility for the safe and proper supply, storage and custody of the reinforcing steel on site.

Reinforcing steel suffering deterioration of quality or damage due to the neglect of the Contractor or steel lost due to theft, shall be replaced with the same quality of reinforcing steel by and at the expense of the Contractor.

The reinforcing steel shall not be placed directly on the ground. Reinforcing steel shall be stored in a warehouse or under suitable cover. Each size of reinforcing steel shall be stored separately.

### **11.3.2 Fabrication**

#### **11.3.2.1 General**

The Contractor shall fabricate reinforcing steel to the dimensions and configurations as shown on the Drawings.

#### **11.3.2.2 Bending**

The Contractor shall prepare reinforcing bar, dowel or pin bending schedules which describe the shape, size and quantities of bars for each portion of the work. The schedules shall be submitted to the Engineer as required in Clause 11.1.2.

Bars shall not be pre-heated for bending without the approval of the Engineer. Once bent, bars shall not be straightened or rebent. Bending of bars protruding from matured concrete for the purpose of clearing embedded items shall be carried out only with the approval of the Engineer. The minimum bending inside diameters for various applications shall be as follows:

##### **a) Standard hooks**

- 180° bend plus 4 Db extension, but not less than 60 mm at free end of bar
  - 90° bend plus 12 Db extension at free end of bar
- (Db= bar diameter, mm)

<b><u>Bar Size (mm)</u></b>	<b><u>Bending Diameter (mm)</u></b>
10	60
12	75
16	100
20	120
22	135
25	155
28	240
32	275

##### **b) Stirrup and Tie Hooks**

- for bar size 16 mm and smaller, 90° bend plus 6 Db extension at free end of bar
  - for bar size 20 mm and size 25 mm, 90° bend plus 12 Db extension at free end of bar
  - for bar size 25 mm and larger, 135° bend plus 6 Db extension at free end of bar
- (Db= bar diameter, mm)

### 11.3.3 Placing

The Contractor shall place reinforcing steel in accordance with the placement drawings and schedules and the tolerances specified herein.

The Contractor shall support reinforcing steel on galvanized or plastic-encased spacers, bolsters, or chairs. For concrete placement on grade, the Contractor shall support reinforcing steel on precast concrete blocks or plastic spacers spaced to maintain required cover. Unless otherwise shown or approved the minimum cover of concrete to reinforcing steel shall be as follows:

- |    |  |       |
|----|--|-------|
| a) | Structures exposed to weather, backfill or submerged but accessible:                   |       |
|    | - DB 20 and larger bars  | 50 mm |
|    | - DB 16 and smaller bars   | 40 mm |
| b) | Structures submerged and not accessible<br>and concrete placed directly against ground | 75 mm |
| c) | Structures exposed to action of moving water   | 75 mm |
| d) | Structures not exposed to weather or not in contact with ground:                       |       |
|    | - beams, girders and columns   |       |
|    | Principal reinforcing steel, ties,<br>stirrups and spirals                             | 40 mm |
| e) | Superstructure of buildings  |       |
|    | - beams, girder, columns and<br>slabs without finishing                                | 30 mm |
|    | - slabs with finishing   | 20 mm |
| f) | Substructure of buildings  |       |
|    | - beams, girders, columns and slabs  | 40 mm |
|    | - footing  | 75 mm |

In addition, the minimum cover of concrete 100 mm shall be used for spillway structure where exposed to action of moving water with high velocity.

The intersections of reinforcing steel shall be securely tied with black annealed wire.

No reinforcing steel partially embedded in concrete shall be field-bent, except specifically permitted by the Engineer.

### 11.3.4 Splicing

#### 11.3.4.1 Lapping

The number of splices shall be kept to a minimum. Location and length of lap splices shall be in accordance with ACI 318.

#### **11.3.4.2 Welded Splices**

The Contractor shall use welded splices only where approved by the Engineer, in accordance with AWS D1.4.

#### **11.3.4.3 Mechanical Splices**

Mechanical splices shall be full tension splicing and shall be performed strictly in accordance with manufacturer's published instructions. All mechanical splicing devices shall be approved by the Engineer before use in the work.

Reinforcing bar couplers, where required or permitted, shall be of an approved type with an ultimate strength at least 25 percent greater than the yield strength of the reinforcing bar.

#### **11.3.5 Quality Control**

The Engineer reserves the right to take samples and to instruct the Contractor to perform tests of the bars that the Contractor intends to supply and to use. The tests shall include, but may not be limited to, tensile and bending tests according to the relevant standards. No reinforcing steel shall be used until the Engineer indicates that the same is satisfactory. If the tests demonstrate that the delivered steel is not satisfactory, it shall be replaced.

The results of tests ordered by the Engineer shall be assessed as follows:

- if two samples out of six samples per diameter show in one or more of all tests performed unsatisfactory results, the reinforcing steel shall be rejected.
- in case one sample fails to meet the required test results in one of the tests, six new samples shall be taken and tested. All tests result of these new samples must turn out to be positive, otherwise the reinforcing steel shall be rejected.

The Engineer may require the removal of any concrete reinforced with steel, that does not comply with the requirements of this Specification.

#### **11.3.6 Inspection**

No placing of concrete shall be permitted without prior inspection by the Engineer for the reinforcing steel.

When the Engineer performs prior inspection and issues conditional approval for the reinforcing steel, the Contractor shall fulfill the said conditions so as to properly complete the reinforcing steel. Unless the said conditions are fulfilled, no placing of concrete shall be permitted.

End of Chapter 11

## **CHAPTER 12 - STRUCTURAL STEEL**



**TECHNICAL SPECIFICATION**  
**CHAPTER 12 - STRUCTURAL STEEL**  
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## **CHAPTER 12 - STRUCTURAL STEEL**

### **12.1 GENERAL**

#### **12.1.1 Scope**

This chapter includes all work in connection with structural steel works including steel frame and steel roof truss as shown on the Drawings and/or as specified hereafter.

The work shall consist of detail design, supply of all materials, fabrication, transportation, storage, erection, painting, inspection, quality control including survey, loading and unloading, protection from damages and other auxiliary works as required.

#### **12.1.2 Submissions**

The following documents shall be submitted to the Engineer for review.

(1) Fabricator

The Contractor shall submit the name of fabricator, official address, list of past practice and brochures showing manufacturing facilities and location of factories.

(2) Schedule

The Contractor shall submit a work schedule indicating time schedule of all works including shop fabrication, transportation, field fabrication, erection at the site and other necessary items related to the work.

(3) Detail Design, Calculation and Shop Drawing

The Contractor shall submit complete shop drawings supported by structural computations, of all structural steel work showing sizes, type and grade of metal, method of assembly, hardware and anchorage or connection with the main structures at least one month before beginning the manufacture of the various items.

The Contractor shall prepare all construction details on the basis of the data contained in the Drawings approved by the Engineer.

Full account shall be made in the design for all temporary loads and stresses which may occur during fabrication, assembly, transportation or erection.

The structural design drawings, specifications and addenda shall be numbered and dated for the purposes of identification.

(4) Erection Procedure

The Contractor shall submit drawings or documents explaining erection procedure including the temporary bracing method and installation equipment or machinery.

(5) List of Materials

Prior to the procurement of materials, the Contractor shall submit list of materials to be used. The name, official address and brochures showing manufacturing facilities of the manufacturer of materials shall be attached with the list.

(6) Mill Sheet and Certificates of Materials

Mill sheets or certificates of materials which are based on the tests performed in the steel maker or an approved independent laboratory shall be submitted to the Engineer.

When Mill Material does not satisfy ASTM A6/A6M or equivalent tolerances for camber, profile, flatness or sweep, the Fabricator shall be permitted to perform correction procedures, including the use of controlled heating and/or mechanical strengthening, subject to the limitations in the AISC specification or equivalent.

### 12.1.3 Standards and Codes

All design, material, execution of work shall comply with the applicable standards and codes listed below, in particular, with the AISC and AIJ codes, the AISC Handbook of Steel Construction, and all local building codes or regulations approved by the Engineer.

AIJ	-	Architectural Institute of Japan "Standard for Design of Steel Structures"  "Technical Recommendations for Steel Construction for Buildings, Part 1 Guide to Steel-rib Fabrications"  "Technical Recommendations for Steel Construction for Buildings, Part 2 Guide to Erection and Construction in Site"
AISC	-	American Institute of Steel Construction "Specification for Structural Steel Building"
AISE	-	Association of Iron and Steel Engineers
AISI	-	American Iron and Steel Institute
ANSI	-	American National Standard Institute
ASCE	-	American Society of Civil Engineers
ASTM	-	American Society for Testing and Materials
BS	-	British Standards Institute
DIN	-	Deutsche Institute for Normung
ISO	-	International Organization for Standardization

JASS - Japan Architectural Standard Specification

JIS - Japanese Industrial Standards

TIS - Thai Industrial Standard

## 12.2 MATERIAL

Except as otherwise specified, all material furnished by the Contractor under this Chapter shall be new, free from defects and imperfections and conform to the following standards or equivalent.

(1) Angle steel, Channel steel, H-steel

- : ASTM A6, A36
- : JIS G3192 SS400
- TIS 1227

(2) Steel plate

- : ASTM A6, A36
- : JIS G3193 SS400
- TIS 528

(3) Steel pipe

- : JIS G3444 STK41
- : ASTM A501
- TIS 107

(4) Round steel bar

- : ASTM A575
- : JIS G3191 SR24

(5) Steel deck plate

- : JIS G3352 SDP2G AL16
- (Galvanized)

(6) Light gage steel

- : JIS G3350
- TIS 1228

(7) High strength bolt

- : ASTM A325
- : JIS B1186 F10T

(8) Medium finished bolt

- : ISO 4014, 4032, 4033 Grade A
- : ASTM A307
- : JIS B1180, 1181 Grade A

(9) Welding rod

- : AWS A5.1, A5.17
- : JIS Z3211, Z3311
- TIS 1549

## (10) Stud bolt

: AWS D1.1  
: JIS B1198

## (11) Anchor bolt

: JIS B1178

## (12) Rust resistant paint

: Red lead paint

**12.3 EXECUTION****12.3.1 Shop Fabrication**

## (1) Measuring Tape

Measuring tapes for shop fabrication and for erection at site shall be of steel, and deviation of each other shall be measured and informed to the Engineer for approval.

## (2) Marking-Off on Material

The positions of bolt hole and shape, dimensions of plate shall be accurately marked on base metal using full size templets.

## (3) Cutting and Forming

In cutting base metal, automatic flame-cut method shall be employed. Base metal shall be accurately cut at right angle to the axis and true to marked line and well-formed to size and shape as marked on. Roughness, burrs or any other irregularity of all edges shall be removed using a grinder or a planer.

## (4) Bending

Except where inevitable, bending of structural steel shall be done cold. In case that it is necessary to employ a heating process, bending of steel shall be done while the steel is red hot with the approval of the Engineer.

## (5) Bolt Hole

Holes shall be drilled with a bit at right angles to the surfaces, and shall not be made or enlarged by burning holes. All bolt holes shall be clean-cut without any burrs or ragged-edges resulting from drilling.

Diameters of holes provided for insertion of bolts shall be as follows:

D	Diameter of bolt hole
More than 20 mm	$D + 1.5 \text{ mm}$
Less than or Equal to 20 mm	$D + 1.0 \text{ mm}$

D : nominal diameter of bolt

When loose bolt holes are employed, the shape of loose bolt holes shall be shown on the drawings or as approved by the Engineer.

#### (6) Welding

##### (a) Welder

Welding shall be executed only by welders who are skillful with welding with all position and experienced in welding of structural steel more than 6 months and approved by the Engineer.

##### (b) Edge Preparation and Assembling

Edge to be welded shall be made into shape in accordance with the approved edge preparation plan, and shall be free from loose scale, slag, grease, paint or other objectionable materials.

Materials to be welded shall be held firmly by an adequate method so as not to move during the welding works. Tack welding shall be performed in such a manner as to minimize residual internal stress. The Contractor shall take other proper means to prevent strain or residual internal stress from welding.

##### (c) Handling of Welding Rod

The welding rod shall be stored in their original packing in a dry place, with appropriate protection against the weather. If the welding rod which seem to have suffered the effects of moisture but do not have any other damage can only be used when they have been dried in satisfactory manner.

Welding rod which has areas where the flux covering is broken or damaged shall be rejected.

##### (d) Common Procedure

###### i) Positioning

Materials to be welded shall be positioned so as to be welded under flat position as far as possible.

ii) Procedure

Welding procedure shall be put in order to minimize residual internal stress.

iii) Preheating

If the temperature at place where welding is performed is between zero (0) degree Celsius and minus fifteen (-15) degrees Celsius the area within 100 mm from the parts to be welded shall be preheated to more than thirty six (36) degrees Celsius.

iv) End tab

End tab shall be employed at the end of weld line.

End tabs employed at invisible part after the beams are installed shall be cut off except the parts 3 mm to 5 mm from root. End tabs employed at visible part after beams are installed shall be cut off all.

v) Removing of slag

Welding of the second layer or thereafter shall be performed after thoroughly removing the slag of the preceding layer.

(e) Full Penetration Butt Welding

i) Back Chipping

When the welding is executed on both sides, the bottom of the weld which is executed first shall be grooved by gas gauging or other adequate means before the back run welding is commenced.

If it is evident that complete penetration can be obtained without back chipping, back chipping may be omitted with the approval of the Engineer.

ii) Backing Strip

When the welding is executed on one side only, the backing strip shall be employed. In this case care shall be taken so that full penetration into the base metal to be welded is obtained by first pass.

iii) Reinforcement of Weld

The reinforcement overlayer of weld shall be less than 4 mm in height, and excessive overlayer of more than 4 mm shall be removed carefully with a grinder.

In the case of tee (T) joint or corner joint, the weld shall be reinforced by fillet weld with more than one-fourth thickness of butting plate.

(f) Fillet Welding

The portion which shall be fillet-welded shall be placed in contact with each other as close as possible.

The height of reinforcing overlayer of weld shall be less than  $0.1 \times S + 1$  mm, where S is the designed size of fillet weld.

(g) Stud Welding

Stud welding shall be executed by electric arc stud welding method. Especially in the case of field welding, when the stud bolts are welded penetrating deck plate, the method shall be proved by adequate field test.

The length of welded stud bolts shall be designed length plus minus ( $\pm$ ) 2 mm.

(h) Correction of Welding Defects

Unless accepted by the Engineer welding defects listed below shall be carefully removed and rewelded, corrected or treated to the entire satisfaction of the Engineer.

- Blow-hole, slag inclusion, and inadequate penetration, pit, overlap, under cut, crack.
- Insufficient throat and leg length of fillet welding.

In this case, the Engineer reserves the right to reject unsatisfactory work.

(7) Permissible Variation

Permissible variation in dimensions of the steel members fabricated at the manufacturer shall be in accordance with the relevant standards specified in the Clause 12.1.3.

(8) Shop Painting

(a) Base Preparation and Treatment

After the completion of fabrication at shop all of the surface to be painted shall be cleaned of all rust, dirt, oil, slag, scale and any other foreign substance. Cleaning of the surface shall be executed with sandblasting or shotblasting and immediately thereafter wash-primer shall be applied to the surface.

(b) Rust-resistant Painting

Rust-resistant paint shall be applied in two coats prior to the shipment.

(c) Contacting Faces for Friction Grip Joint



Contacting faces for friction grip joint of high strength bolt shall be cleaned with sand blasting or shot blasting. Wash-primer, or rust-resistant paint shall not be applied on those faces.

### **12.3.2 Transportation**

The Contractor shall be responsible for all necessary notifications to the concerned office or Authority concerning to the transportation of the member and parts of structural steel. They shall be transported carefully to the site in such a manner as to prevent deformation, corrosion, or other damage to beams.

If necessary, adequate reinforcements, bracing, stiffeners or other means shall be provided.

### **12.3.3 Storage**

The member and parts of structural steel shall be stored under proper covers and placed on supports, so that they are not in contact with the ground or with substances which may cause oxidation and deterioration.

### **12.3.4 Erection**

#### **(1) General**

The contractor shall be responsible for the means and safety of erection of the structural steel structures.

The erection work shall be executed in such a manner that the steel structure do not suffer permanent deformation, and are not subject to stress greater than those considered in the design.

During the erection work the Contractor shall adopt all measures which are necessary to prevent injuries to persons and damage to the neighboring works.

#### **(2) Installation of Anchor Bolts**

Anchor bolts shall be installed accurately to meet the positions shown on the approved Drawings, and the positions of anchor bolts shall be inspected before placing of concrete. When placing concrete, care shall be taken so as not to move the position of anchor bolts.

#### **(3) Friction Grip Joint**

##### **(a) Length of High Strength Bolt**

Standard length of stem shall be obtained by adding respective length tabulated below to the grip thickness.

D (mm)	L (mm)
16	30
20	35
22	40
24	45

Where,

D : Nonimal diameter of bolt  
L : Length to be added to grip thickness

The bolt set shall be stored in their original packing, and care shall be taken so that materials would be free from dirt, damage and corrosion.

(b) Treatment of Contacting Surfaces

The surfaces to become in contact with surface of another steel plate in friction grip joint shall be free from paint, oil and other defects that would decrease friction force.

(c) Tightening

Drifting shall only be performed to bring corresponding parts into proper positions and shall not result in enlargement of holes or distortion of base metal. All out-of-tolerance holes shall be drilled or reamed.

Temporary tightening shall be performed using bolts not less than one third (1/3) of the total number of bolts in each completed joint but never less than two. Bolts for temporary tightening shall be distributed uniformly about the joint.

Tightening shall be done using either the impact wrench method or the "turn-off-nut" method in accordance with the instruction of the bolt manufacturer. The work shall be done by competent and experienced bolting crews.

70 percent of design bolt tension shall be given to the bolts at preliminary tightening and then 100 percent of design bolt tension shall be given to the bolt finally. Excessive tightening of the bolts shall not be permitted.

(d) Calibration of Impact Wrench

If the bolts are tightened by impact wrench method, each impact wrench shall be calibrated prior to the commencement of the work both in the morning and the afternoon.

The impact wrenches shall be equipped with torque indicating scale or calibrating means so that the torque can be measured clearly.

(4) Erection

All steel members shall be installed accurately to meet the positions and level shown on the Drawings, and the positions and level shall be inspected before permanent fixing.

During the erection works, the steel structure shall be ensured sufficiently to withstand all loads such as its own weight, live loads, wind loads and erection loads. All temporary bracing, guys and bolts necessary to ensure safety of the structure shall be provided.

(5) Permissible Variation

Permissible variation shall be in accordance with the standards stipulated in the Clause 12.1.3.

### **12.3.5 Field Retouch Painting**

After installation, all damaged shop coated areas and all bolting, welded and other surfaces left un-painted with rust-resistant paint shall be cleaned of all rust, dirt and any other foreign substances and shall be painted with rust-resistant paint.

### **12.3.6 Inspection**

(1) General

All materials supplied and all work performed shall be subject to inspection by the Engineer at the place of manufacture, fabrication and/or erection. Unless inspection is waived by the Engineer, no material shall be shipped until after such inspection and acceptance of the material has been performed.

Where directed by the Engineer, certified mill- or shop-test reports shall be furnished in lieu of inspection at the mill. Acceptance of material or waiving of inspection thereof shall in no way relieve the Contractor of the responsibility of furnishing the materials and workmanship conforming to the Specifications in all respects.

The Contractor shall submit the records of tests stating the name of test, time and place, results and name of inspector.

The judgement of results of test and inspections shall be made according to the applicable provisions of standards stipulated in Clause 12.1.3.

Tests or inspections may be waived with the approval of the Engineer in case mill sheets or certificates or other appropriate evidences are submitted by the Contractor.

(2) Material Test

Quality of the principal materials to be used, such as rolled steels, bolt and nuts, electrodes shall be tested.

- (3) Qualification Test for Welding Operators, Welders and Welding Procedures:  
- shall be performed in accordance with the applicable provisions of AWS Code.

- (4) Inspection of Edge Preparation;
  - shall be performed in accordance with the approved plan of edge preparation.
- (5) Appearance and Measurement Inspection

The appearance inspection shall be made on welded joints, bolts holes to be bolted in the field, coated surfaces and on other items for defects.

- (6) Inspection of Welded Joint

Welded joint shall be inspected by means of radiographic (X-ray) method and/or ultrasonic method.

The rate of spot inspection shall be not less than 10% of the total welded length.

#### **12.3.7 Quality Control**

The Engineer reserves the right to require independent analysis and tests on the materials by an analyst or testing laboratory selected by him, in order to check the Works, analysis and tests. For this purpose the Engineer may take drillings for analysis and have pieces cut out side by side with pieces subjected to test in the workshops. Should the comparison of the result of any independent analysis or test be unsatisfactory, the materials represented will be rejected.

#### **12.3.8 Auxiliary Work**

Mortar grouting at the baseplate, installation of embedded steel parts in concrete structure shall be included in the work. Shattering needed for these works shall be also included in the work.

End of Chapter 12

## **CHAPTER 13 - METAL WORK**

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## CHAPTER 13 - METAL WORK

### 13.1 GENERAL

#### 13.1.1 Scope

The work to be performed under this chapter consists of furnishing and installing the various metal works including all the auxiliary works in all structures of the Work as shown on the Drawings.

#### 13.1.2 Submissions

At least thirty (30) days prior to commencing the work, the Contractor shall submit to the Engineer the following documents for review.

- Detailed shop and construction drawings which shall include complete details, sections and plans of all parts, assemblies, components, connections and supports, and connections to the work of other items.
- Detailed structural analysis of the proposed metal structures, if required.
- Test certificates proving the physical properties stipulated in the Specifications.

#### 13.1.3 Standards and Codes

Unless otherwise specified the materials to be used for the works shall conform to one of the following international standards and codes with regard to quality, properties and workmanship.

TIS: Thai Industrial Standard  
DIN: Deutsches Institute fuer Normung e.V.  
BS: British Standards  
ASTM: American Standard for Testing Materials  
JIS: Japanese Industrial Standards  
ISO: International Organization for Standardization  
AISC: American Institute of Steel Construction  
AISI: American Iron and Steel Institute

The Contractor shall inform the Engineer of the standards and codes he follows if no particular ones are specified hereinafter. In case the Contractor wishes to follow any other standards and codes, he shall submit sufficient copies of the same to be applied in English to the Engineer for his approval.

Fabrication of metal work shall be performed in accordance with "American Institute of Steel Construction (AISC) Specification for the Design, Fabrication and Erection of Structural Steel for Buildings" or equivalent.

## 13.2 MATERIAL

All materials and structural components to be supplied, erected or installed and, therefore, ultimately incorporated in the structure shall be new and unused. They shall be suitable for their intended purpose and appropriately match each other.

Unless otherwise specified, all materials of metal work shall conform to the following requirements or equivalent:

- Structural steel: ASTM A6/A6M, A36, TIS 1227
- Steel tube and pipe: ASTM A53, A500, A501, A618, TIS 107
- Welding: AWS A5.1, A5.17, TIS 1549
- Steel joints: ASTM A3
- Ladder: Mc Graw-Edison

In the Drawings and the Specifications, the size of steel pipes and shaped steel are indicated in the metric system as a rule. The Contractor will be permitted to use those of inch size which are approximately same or more in size as those indicated on the Drawings or the Specifications.

The crossing of each rail shall include a moving rail head, a steel base plate common to each rail crossing, a water drain for each rail groove connected to an inspection shaft and all necessary fastening and erection materials. Steel joints bars will be as per ASTM A3.

The entire track network shall include anchoring fastening and adequate adjusting material.

The Contractor shall give a five (5) year guarantee on all materials under this chapter for quality and properties as to withstand the climatic weather conditions of the region.

## 13.3 EXECUTION

### 13.3.1 General

Unless specified otherwise in the Drawings, these specifications shall govern.

#### 13.3.1.1 Fabrication and Installation

All works shall be executed by skilled workers in a workmanlike manner.

All members shall be cut in such a manner as not to cause deformation or distortion. Irregularity of cut surface shall be properly finished by planer.

The work shall be shop fitted and shop assembled where possible, and shall conform to the details on approved shop drawings to be provided by the Contractor.

Welding shall be made by arc welding unless otherwise directed by the Engineer.

Where necessary, metals shall be insulated to prevent electrolysis due to contact between dissimilar metals and to prevent corrosion due to contact between metals and masonry or concrete. Insulation shall be by means of bituminous paint or other approved means.



All fastenings, anchors and accessories required for fabrication and erection of the work under this chapter shall be provided by the Contractor. Exposed fastenings shall be kept to an absolute minimum, evenly spaced and neatly set out. Wood plugs shall not be permitted.

Metal work to be embedded in concrete shall be set and fixed in position as shown on the Drawings before placing concrete. If blockouts will be arranged at the locations where embedded parts are set in concrete as shown on the Drawings, the metal work shall be fixed in place by the second stage concrete.

The bond surfaces between the first and the second stage concrete shall be roughened. The cross-section dimensions of the second stage concrete and the locations of embedded anchor bolts shall be as shown on the Drawings.

Where it is impracticable to place anchors or anchor bolts when the concrete is placed, holes will be drilled in the hardened concrete 28 days after placing concrete. Expansion bolts, adhesive anchor bolts or other approved anchors will be installed and fixed in place, and then grouted or backfilled with mortar.

#### **13.3.1.2 Painting and Galvanizing**

All components of the metal works shall either be painted or galvanized against corrosion prior to assembly and/or erection. Any preliminary treatment against corrosion shall ensure a basic protection remaining effective for at least six months.

All steel surface except galvanized surface and embedded parts in concrete shall be painted. Rust-resistant paint shall be applied in two coats and finishing paint shall be applied in two coats. The quality of paint and the painting works shall be performed in accordance with the provisions of Chapter 20 "Painting and Coating". The color of paint shall be approved by the Engineer.

Components to be installed to the exterior shall in any case be hot dip galvanized. Galvanizing of steel shall be in accordance with ASTM A123, A153 and A386 and the zinc coating shall be not less than 610 g/m<sup>2</sup>.

#### **13.3.1.3 Auxiliary Works**

The following auxiliary works and services, shall be deemed to be included in the metal works.

- transport, storing and protection of all structural components on site;
- protection of the executed works from detrimental influences, theft and damages until the time of handover;
- supply of consumable stores;
- removal and making good of all contaminations (building rubbish, refuse and the like) arising from and in connection with the Contractor's works;

### 13.3.2 Steel Pipe

Steel pipes are used for conveying drained water or water for miscellaneous use, or for other purposes.

The Contractor shall furnish and install steel pipes including steel pipes for spring water treatment and for water level measuring devices, drain pipes, water supply pipes, air vent pipe, water gage pipe, water gage connection pipe and embedded steel pipe as shown on the Drawings.

Unless otherwise specified, steel pipes shall conform to the requirements of ASTM A501 or equivalent.

Electric welding of an approved method shall be adopted. The electrodes used shall be of a quality corresponding to the quality of the pipe steel. They shall ensure a tight, poreless weld, according to the rules of a good workmanship. Slag shall be properly removed. In certain cases, a pressure test for the pipes may be required and any imperfect welding shall be corrected at the Contractor's expense.

All associated pieces such as anchors, fixtures, etc. required for appropriate installation shall be furnished and installed.

### 13.3.3 Steel Cover

Steel cover such as steel hatch cover, steel manhole cover and steel trench cover shall be installed at openings and trenches designated on the drawings. The dimension and the number of pieces indicated in the drawings are only approximation and enable the Contractor to establish average prices per square meter.

Steel cover shall be of steel plate, checkered steel plate, or metal sheet, with lifting device as shown on the drawings or as approved by the Engineer.

Frames shall be removable and composed of hot-rolled steel sections conforming to Thai Industrial Standard. The frame shall be adjusted during installation to provide an accurate fit with the cover.

The top cover structure consists of the galvanized steel frame laid on the exterior deck with galvanized wire mesh. The top cover structure shall be installed on the support galvanized steel plate.

The bearing frames or embedded frames of galvanized steel angles, channels or steel shall be anchored to the concrete with steel bolts or straps as shown on the drawings.

In order to ease removal and setting, all covers shall be tapered along the perimeter towards the bottom. The maximum clearance between hatch cover and outer frame shall be 5 mm around and finished floor level.

All structural members and steel plates shall conform to the requirement of ASTM A36 and shall be hot dip galvanized to Category 7.

All steel connection bolts shall be high strength bolt and conform to the requirement of ASTM A325.

Welded spots of wire connected to the frame of the top cover structure shall be treated Category 6 metal work.

The contractor shall submit the detailed drawings, method of fabrication and installation to the Engineer prior to starting the work.

#### **13.3.4 Steel Grating**

The steel gratings will serve as covers for gutter, gutter in invert concrete, sump and trench, and as tread for step ladder etc.

The steel gratings are normally of a rectangular shape. Some are to be provided with openings for the passage of pipes or ducts shown on the Drawings.

Sizes of steel gratings shall be such as to afford easy handling.

Minimum support width shall be the height of the grating but not less than 30 mm.

The bearing frames of steel angles or channels shall be anchored to the concrete with steel bolts or straps as shown on the Drawings.

Before installation the frame shall be adjusted to allow the steel grating to have a continuous support by the frame.

Before ordering the gratings, the Contractor shall check all relevant locations, dimensions and shapes of the openings.

Steel gratings and frames shall be galvanized. Damaged finishing shall be repaired on site as specified by the manufacturer and to the approval of the Engineer.

#### **13.3.5 Metal Stairways, Ladders, Walkways and Platforms**

The Contractor shall furnish and install, metal stairways, ladders, walkways and platforms as shown on the Drawings.

Stair work shall be finished and installed with all stringers, treads, risers, hangers, railings, kick plates, and all appurtenant members. Stair construction, framed to structural steel supports, shall follow the erection of steel work as closely as practicable and shall be securely bolted to the steel framing. The stair treads shall be designed with nosing.

All metal work for metal stairways, ladders, walkways and platforms shall be galvanized in accordance with Chapter 20, Painting and Coating.

### **13.3.6 Steel Handrail**

The Contractor shall position the steel handrails in places as shown on the Drawings. The Contractor shall be responsible for furnishing of materials, fabrication and installation of the handrails.

Steel handrails shall be fabricated and installed in the places as shown on the Drawings. Steel handrails shall be properly anchored to the structures. In general, blockouts shall be provided whenever possible and the blockout shall be filled with the concrete after installation.

All parts shall be rust proof painted after manufacturing but prior to installation.

### **13.3.7 Track System for Sliding Hatch Cover**

The prescribed gauge shall be maintained within  $\pm 1.5$  mm. Leveling of the rail shall be within 2 mm of the theoretical level line. Abrupt changes in elevation of the rail will not be permitted.

The whole track shall be erected on a concrete base and adjusted by means of an adjusting plate under the rail's foot.

After leveling of the entire track, the anchors shall be set in concrete. The mortar under the rail shall be packed by stages between the adjusting plates.

All visible parts shall be coated with bituminous paint (0.120 mm) after erection.

### **13.3.8 Ladder**

Ladder shall be constructed using round bar diameter 25 mm, bent and embedded into concrete as shown on the Drawings.

All metal work for ladder shall be painted with corrosion resistant painting in accordance with Chapter 20, Painting and Coating.

### **13.3.9 Flag Pole**

The flag pole shall be galvanized steel. The pole shall be complete of all fittings shown on the Drawings.

### **13.3.10 Other Metal Works**

Other metal works such as trashrack screen, drain cock, spiral duct, collector ditch, steel weir, stair nosing and hoist rail shall be furnished and installed as shown on the Drawings.

End of Chapter 13

## **CHAPTER 14 - MASONRY**

**TECHNICAL SPECIFICATION****CHAPTER 14 - MASONRY****LIST OF CONTENTS**

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## CHAPTER 14 - MASONRY

### 14.1 GENERAL

#### 14.1.1 Scope

The scope of work covered in this Chapter shall comprise all work, the supply and installation of all materials required in connection with the construction of masonry walls as shown on the Drawings.

It shall also include all appertaining materials and structural parts, scaffolding, transportation, loading, unloading, survey, inspection, test, quality control and all other operations required to complete the masonry work in all respects.

#### 14.1.2 General Requirements

All materials and structural parts incorporated in the permanent work shall be new and unused. Regarding quality and dimensions they shall comply with these Specifications and approved standards.

All masonry shall be carried out in a workmanlike manner at the highest standard and all work shall be coordinated with the work by other Contractors on the Site to allow the performance of all work in the most direct manner.

All materials shall be protected from rain and other deleterious conditions to the satisfaction of the Engineer.

#### 14.1.3 Standards and Codes

All materials and testing shall comply with the standards and codes hereinafter:-

TIS	57	-	Hollow load-bearing concrete masonry units
TIS	58	-	Hollow non-load-bearing concrete masonry units
TIS	20	-	Steel bars for reinforced concrete round
TIS	167	-	Calcium silicate face bricks or sand-line bricks
TIS	168	-	Facing bricks
TIS	77	-	Building bricks
TIS	169	-	Hollow facing bricks
TIS	188	-	Gypsum mortar for construction

## 14.2 MATERIAL

### 14.2.1 General

At least thirty (30) days before ordering any material for masonry, the Contractor shall submit the sample of all materials to the Engineer for reference.

### 14.2.2 Concrete Block

Concrete blocks shall be of the modular, non-load-bearing type and load-bearing and they shall conform to TIS 58, TIS 57 or equivalent standards. The quality of the blocks shall at least reach the quality of the "DETAC" SRIMAKAWALPHUN CO., LTD. or "CPAC" SIAM CEMENT CO., LTD. The thickness shall be as shown on the Drawings or Schedule of Quantities and Prices.

All blocks shall have a minimum compressive strength of not less than 3 N/mm<sup>2</sup> related to the net area in case of hollow blocks. The Contractor shall furnish stretcher, corner, jamb and solid top blocks as required to perform the work as shown on the Drawings.

They shall be machine-made in an approved procedure ensuring an equal, high quality of all blocks and they shall be cured for at least 15 days and left to dry for 30 days.

### 14.2.3 Mortar

#### a) General

The mortar for all masonry work shall consist of cement, admixture for preventing cracks, sand and water.

The mortar for each kind of masonry shall be proportioned as follows.

Wall (Part by Volume)	Cement/Sand Mix Ratio
Concrete block wall, White brick wall	1 : 3
Granite and brick wall	1 : 2

The quantity of water shall be as necessary to obtain a satisfactory workability regarding the use of the mortar.

#### b) Portland Cement

The portland cement shall comply with ASTM C 150, Type I, and all handling shall be in accordance with the provisions set forth in Chapter 10 "Concrete". White portland cement shall be used for white brick, exposed brick and glass block instead of common cement.



## c) Sand

The sand shall comply with the requirements described in Chapter 10, "Concrete". The grading of sand shall be as follows:

US Standard Sieve Passing No	Percentage Passing by Weight Square Mesh %
4	100
8	95-100
16	70-90
30	40-75
50	20-40
100	5-20
200	0-10

## d) Water

Water shall comply with the requirements set forth under Chapter 10, "Concrete".

## e) Mixing, Transporting and Placing

The mortar shall be mixed for a minimum of 2 minutes in a mechanically operated drum-type mixer or equivalent mixer approved by the Engineer.

The mixer shall be rotated at the speed recommended by the manufacturer and the total quantity of material mixed in each batch shall not exceed the rated capacity of the mixer.

The water shall be added gradually to the mixer, partly before the loading of the dry material and partly immediately after loading.

The drum shall be totally emptied before a new batching cycle is started. The drum shall be kept free from hardened mortar and shall be thoroughly cleaned prior to change of mix or on cessation of mixing.

Hand-mixing for small batches may be approved by the Engineer.

However, the mortar shall be mixed up to the degree obtained with a mechanically operated mixer. Prior to adding water to the mix, the fine aggregate, cement and admixture shall be mixed dry in a tight box until the mixture has a uniform colour.

The equipment and tools used for transporting and for placing of mortar shall ensure that contamination or loss of ingredients do not take place.

Mortar shall be stirred or worked at frequent intervals to prevent separation. All mortar shall be placed within thirty (30) minutes after the water has been added to the batch. Except for necessary tempering on the mortar board, retempering of mortar is not permitted.

#### **14.2.4 Reinforcing Steel**

Reinforcing steel for masonry shall consist of plain round mild steel bars and the steel quality shall comply at least with the requirement set forth in TIS 20 for Grade SR 24 steel or with equivalent standards approved by the Engineer.

#### **14.2.5 Anchors and Ties**

All anchors and ties to be used in masonry work shall be of galvanized metal. Wire ties shall be of at least 3.2 mm thickness and hooped on both ends. Wire mesh ties shall consist of at least 1.6 mm wires and a maximum mesh width of 0.015 m.

#### **14.2.6 Bricks**

Bricks for brick wall shall be ordinary red clay brick with nominal size of 40 mm x 65 mm x 140 mm. They shall conform to TIS 77 or equivalent standards.

Brick for exposed brick wall and sunshade shall be special type of red clay brick called "Rachaburi Brick" or equivalent with nominal size of 40 mm x 65 mm x 140 mm. They shall conform to TIS 77 or equivalent standards.

Exposed bricks shall be true to size, without cracks, chips or other defects affecting their strength or durability of the masonry.

Both types of brick, shall be soaked in the water for 10 minutes before placing.

#### **14.2.7 Granite**

Granite for wall, floor, baseboard and lintel finish shall be 20 mm thick. It shall be excellent quality as the product of "Thai Granite" of Thai granite Co., Ltd. or equivalent. The granite for wall and baseboard shall be polished on one side and permissible tolerance on cut shall be 2 mm. of nominal size. The granite for floor shall be of rubbed finish.

#### **14.2.8 Artificial Marble**

Artificial marble for the topping of counter board shall be 1/2" thickness of "2561 DAWN MIST" board the product of FORMICA (THAILAND) Co., Ltd., or equivalent.

#### **14.2.9 Glass Block**

Glass blocks shall be white glass block "Petch Nam Kang or Ploy Meka pattern" or as otherwise approved by the Engineer of dimension 0.10 m x 0.19 m x 0.19 m. It shall be excellent quality as the product of "Bangkok Crystal Co., Ltd." or equivalent.

The glass blocks shall be true to size without cracks or other defects.

## 14.3 EXECUTION

### 14.3.1 Concrete Block Wall

#### a) General

All concrete block walls shall be carried out in a workmanlike manner of the highest quality. The masonry shall be performed in horizontal courses true to line and plumb. The arrangement of headers and stretchers within the walls shall be such as to surely bond the masonry and, unless otherwise specified, the masonry shall consist of alternate headers and stretchers with staggered vertical joints in consecutive joints. For masonry permanently exposed to view, the Engineer may approve bonds other than the above mentioned one.

Concrete blocks at corners and/or wall ends shall have finished return ends. For masonry permanently exposed to view all blocks shall have sharp, undamaged edges and cutting of blocks to required lengths shall be done by saw-cutting only.

Bed joints shall measure between 8 mm and 15 mm, however, the thickness shall be uniform throughout. Vertical joints shall be 10 mm. All joints of walls to be plastered shall be raked out to a depth of approximately 15 mm. Joints of walls permanently exposed to view shall be raked out to 20 mm while the mortar is still fresh and subsequently neatly pointed at a form instructed by the Engineer.

At corners and intersections of walls, the masonry shall be bonded by overlapping blocks at alternate courses. In exceptional cases, the Engineer may permit the use of wire ties thoroughly embedded within the bed joints and anchored in mortar-filled cells. The connection between concrete columns and masonry shall be performed by ties or anchors protruding the concrete.

Immediately after completion of a wall or part thereof the wall or part shall be thoroughly cleaned and watered. The wall or part shall be kept wet for at least 3 days.

#### b) Setting-out

All walls shall be accurately set-out to the dimensions shown on the Drawings by suitable equipment and the deviation between the actually set out walls and their theoretical location shall not exceed the below mentioned tolerances, unless otherwise approved by the Engineer. For vertical dimensions of the masonry a site datum shall be fixed at a convenient position to represent the finished ground floor level of the building. The Contractor shall take care when setting-out the first course of a wall and the combination of stretchers, closers and headers shall be laid "dry" for the approval by the Engineer.

Repeated dimension controls shall be made at short intervals on all lines, levels and plumb throughout all masonry work.

#### c) Permissible Tolerances

The dimensional tolerances of masonry in respect of alignments, length, height, thickness, unevenness, etc. shall comply with the following limits:

## (i) Masonry exposed to view

- all bed joints shall be horizontal and they shall not deviate from a straight, horizontal line by more than 5 mm on a length of 2.50 m;
- the wall surface shall be vertical and it shall at no location deviate by more than 4 mm from the plumb at a length of 2.50 m;
- horizontally the wall surface shall not deviate by more than 4 mm from a straight line on a distance of 2.50 m;
- the deviation of any dimension from the design dimension of walls, openings, recesses, piers, etc. shall not exceed the following values:

<u>respective dimension</u>	<u>maximum deviation</u>
< 1.00 m	4 mm
1.00 m - 2.50 m	5 mm
2.50 m - 10.00 m	8 mm
> 10.00 m	10 mm

- no abrupt irregularities will be permitted.

## (ii) Masonry to be plastered

- the wall surface shall be vertical and it shall nowhere deviate by more than 6 mm from the plumb at a length of 2.50 m;
- horizontally the wall surface shall not deviate by more than 6 mm from a straight line on a distance of 2.50 m.
- the deviation of any dimension from the design dimension of walls, openings, recesses, piers, etc. shall not exceed the following values:

<u>respective dimension</u>	<u>maximum deviation</u>
< 1.00 m	6 mm
1.00 m - 2.50 m	7 mm
2.50 m - 10.00 m	10 mm
> 10.00 m	12 mm

- abrupt irregularities shall not exceed 3 mm.

All masonry exceeding the above stated tolerances shall be corrected or replaced by the Contractor.

## d) Reinforcement

Concrete blocks shall be reinforced. The reinforcement shall consist of vertical and horizontal bars tied at each crossing point and they shall be connected to anchor bars protruding the structural concrete members, or rock surface more than 30 cms.

The vertical reinforcement bars shall have a diameter of 12 mm for 0.15 m and 0.20 m thick walls and they shall be placed at a distance of 0.80 m centre-to-centre. For 0.10 m thick walls the diameter shall be 10 mm placed at above mentioned distance.

At wall ends the first vertical reinforcement bar shall have a distance from the wall end of half of the wall thickness, and at intersections one vertical bar shall be provided in the middle of the intersection.

The horizontal reinforcement shall consist of 10 mm bars regardless of the wall thickness and they shall be placed on every third course.

All cells of the concrete blocks with vertical reinforcement bars shall be totally filled by mortar.

In general, reinforcement bars shall be straight. However, at the wall ends and at intersections with other walls, hooks shall be provided. As far as possible, splices of reinforcement bars shall be avoided. If required due to the length of the wall, splices shall be performed by overlapping measuring at least forty times the bar diameter.

e) Lintels

The Contractor shall construct and install all required lintels to bridge the openings for windows, doors, etc.

The size of the lintels shall be determined by the Contractor according to the clear span and the loads on to the lintels. However, the width of the lintel shall be equal to the width of the respective wall and the height shall measure at least 0.10 m. In case of masonry exposed to view, the lintel height shall correspond to at least one stone height or to a multiple thereof, if required by the results of structural computations.

The length of the lintels shall be equal to the clearance of the opening plus 0.40 m, if no longer supports will be required due to the loads onto the lintel. The cells of the concrete blocks below the lintel supports shall be filled by mortar.

All lintels shall be reinforced by at least 2 bars of 10 mm diameter. In case of masonry exposed to view the surface quality of the lintels shall comply with the finish classes F3 and U3, respectively, according to the stipulations in Chapter 10, "Concrete". The surface finish of lintels for walls to be plastered shall be F1 and U1, respectively.

### **14.3.2 Brick and Exposed Brick Wall**

For the exposed brick wall, the bonding mortar shall be one part of white portland cement, two parts of sand and added the colour powder to make the brick colour mortar.

The masonry shall be performed in horizontal course true to line and plumb. The arrangement of headers and stretchers within the wall shall be surely bonded.

Joints of exposed brick wall shall be raked out to 10 mm while the mortar is still fresh and subsequently neatly pointed at a form instructed by the Engineer.

All exposed brick walls and exposed brick sunshades, after the completion, the wall shall be coated with climate-fungi resistant solution immediately before the wall will be destroyed by fungi and moss.

#### **14.3.3 Granite and Artificial Marble**

Before wall surface will be covered with granite to be set in normal mortar bedding, a sprayed coating of cement mortar stipulated in chapter 17 "Tiling" shall be applied to the base, unless otherwise specified.

Where an adequate bond between the bedding mortar and the base is not ensured by the envisaged mode of execution, such as granite for wall special measures shall apply, e.g., roughening, covering the base by expanded metal, or coarse-plastering of the complete surface.

For the artificial marble counter board, the board of counter surface shall be installed by using special glue instructed by the manufacturer or other method Instructed by the Engineer.

#### **14.3.4 Glass Block Wall**

The mortar for bonding of glass block wall shall be one part of white portland cement and two parts of sand.

Glass block shall be laid in horizontal course and vertical course true to line and plumb. The mortar in the horizontal and vertical joints shall be range from 8 to 15 mm thick.

The Glass block wall shall not carry any load on the vertical axis. For the glass block wall higher than six meter, lintel or beam shall be provided.

The walls may incorporate piers, openings, recesses, block-outs, chases, etc. all as shown on the Drawings.

#### **14.3.5 Tests and Properties**

All materials applied in masonry work shall comply with the relevant standards regarding quality, dimensions, strength, etc. The Engineer may instruct the Contractor to carry out suitability tests on the material proposed to be applied in the Works as well as to perform quality control tests during the progress of the work as described in the relevant standards. Samples for testing will be selected by the Engineer.

End of Chapter 14

## **CHAPTER 15 - WATERSTOP, JOINT SEALANTS AND FILLERS**

**TECHNICAL SPECIFICATION**  
**CHAPTER 15 - WATERSTOP, JOINT SEALANTS AND FILLERS**  
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## CHAPTER 15 - WATERSTOP, JOINT SEALANTS AND FILLERS

### 15.1 GENERAL

#### 15.1.1 Scope

This Chapter covers all works in connection with the supply and installation of sealings and fillers to be used in contraction joints of concrete structures where shown on the Drawings as approved by the Engineer.

### 15.2 MATERIAL

#### 15.2.1 Polyvinyl-Chloride (PVC) Waterstops

The waterstops shall be extruded from an elastometric plastic compound, the basic resin of which shall be polyvinyl-chloride (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 conform to TIS 1239 (Latest Version).

The plastic waterstops shall meet the following requirements:

Requirements	Method of Test
Tensile strength using die "C": not less than 120 kg/cm <sup>2</sup>	ASTM D 412
Ultimate elongation using die "C": not less than 300%	ASTM D 412
Stiffness in flexure, 6 mm span: not less than 28 kg/cm <sup>2</sup>	ASTM D 747
Tear resistance: not less than 30 kg/cm <sup>2</sup>	ASTM D 624
Specific gravity: not less than 1.20	ASTM D 792

#### 15.2.2 Swellable Waterstop

Swellable type waterstop shall be the rubber-type, synthetic rubber (EPDM RUBBER) or Polyurethane reinforced core, expandable when submerged in water and durable for wet-dry cycles. The swellable type waterstop shall be placed in the middle of joint. Edge of membrane shall be continuously placed at distance at least 10 cm. from concrete surface. The waterstop membrane shall be tightly placed on to the surface of 2<sup>nd</sup> stage concrete by using epoxy, sprayed type swellable glue, or other material required by waterstop manufacturer. Installation procedures recommended by manufacturer shall strictly be followed.

The properties of swellable type waterstop are shown as follows.

Material Type	Synthetic Rubber (EPDM Rubber)	Polyurethane Rubber
Hardness	$\geq 70$ Shore A	25-35 Shore A
Tensile Strength	$\geq 8$ MPa.	$\geq 0.5$ MPa.
Elongation At Break	$\geq 180\%$	$\geq 1,000\%$
Volume Increase	$\geq 280\%$ (submerged in clean water at temperature of 23 degree Celsius for 14 days)	$\geq 200\%$ (submerged in clean water at temperature of 20 degree Celsius for 8 days)

### 15.2.3 Joint Fillers

Except as indicated on the Drawing, the bituminous fibre sheet shall be used as the joint fillers. The bituminous fibre sheet shall be 12 mm thick and conformed to ASTM D 1751 for preformed expansion joint fillers for concrete paving and structural construction. The Contractor shall submit a sample of the proposed joint filler to the Engineer.

### 15.2.4 Hot Poured Bituminous Joint Sealant

Bituminous joint sealant shall be composed of a mixture of bitumen, asbestos fibers and a plasticizer that will form a resilient and adhesive compound capable of effectively sealing joints in concrete against the infiltration of moisture and foreign material throughout repeated cycles of expansion and contraction with temperature changes. Mixture will become sufficiently fluid when heated to approximately 150 degree Celsius to 200 degree Celsius to flow without mechanical manipulation.

The material shall maintain its plasticity for temperatures ranging from 10 to 80 degree Celsius.

Joint Sealer shall conform to ASTM D1190 or TIS 479 (Latest Version).

All joint surfaces of the concrete in contact with the sealant shall be primed with a proper and approved bituminous emulsion.

## 15.3 EXECUTION

### 15.3.1 Polyvinyl Chloride (PVC) Waterstop

The Contractor shall supply the Engineer with the manufacturer's affidavit showing that the material supplied meets the requirements specified. The Engineer may direct additional tests. Test specimens, if required, shall be of the shape and dimensions required in the individual test methods.

The extruded waterstop shall be dense, homogeneous, and free from holes, scratches and other imperfections and shall have:

- width: not less than 150 mm (6");
- thickness: not less than 5 mm;

- central shape: bulb or omega shape as required;
- type: as shown on the Drawings or as approved by the Engineer.

#### **15.3.1.1 Splices**

Splices in the continuity or at the intersection of runs of waterstops shall be performed by heat sealing the adjacent surfaces, in accordance with the supplier's recommendations. A thermostatically controlled electric source of heat shall be used to make all splices. The correct temperature at which splices should be made will differ with the material concerned; it should be sufficient to melt but not char the plastic. All splices shall be neat with the ends of the joined materials in true alignment.

A meter-box guide and a proper saw shall be provided and used to cut the ends to be joined, to ensure good alignment and contact between joined surfaces. The continuity of the characteristic corrugations of the cross-sections of the waterstop design shall be maintained across the splice.

The number of splices in the sealings shall be the minimum possible and all splices shall be reviewed by the Engineer; the equipment used for making splices in PVC sealings and the splicing method shall also be reviewed.

The Contractor shall make the splices in such a manner as to ensure that the splices have a tensile strength not less than eighty percent (80%) of that of the unspliced material.

#### **15.3.1.2 Installation**

In order to eliminate faulty installation that may result in joint leakage, particular care shall be taken so that the waterstops are correctly positioned during installation. Adequate provisions must be made to support the waterstops during the progress of work and to ensure their proper embedment in the concrete. The symmetrical halves of the sealings shall be equally divided between the concrete pours adjacent to the joints in all cases where the center axis of the waterstops is to coincide with the joint openings. Maximum density and imperviousness of the concrete shall be ensured by thorough vibration of the concrete to be used in the vicinity of all joints.

Suitable guards shall be provided to protect exposed projecting edges, and the end of partially embedded waterstops from mechanical damage at all times. Waterstops shall be thoroughly cleaned of all foreign materials before concrete is placed.

The PVC waterstops which have to remain exposed for more than ten (10) days shall be protected from the action of temperature and ultraviolet rays.

#### **15.3.2 Swellable Waterstop**

The Contractor shall supply the Engineer with the manufacturer's affidavit showing that the material supplied meets the requirement specified. The Engineer may direct additional tests. Test specimens, if required, shall be of the shape and dimensions required in the individual test methods

Installation of swellable waterstop shall strictly follow manufacturer's procedures.

### **15.3.3 Preformed Joint Fillers**

The Contractor shall furnish and install preformed expansion joint filler as shown on the Drawing.

#### **15.3.3.1 Placing**

The joint filler shall be held securely in place against the surface of the concrete already poured by application of an approved glue capable of holding the material in place during the second phase of concreting.

All joints in the filler material shall be made tight so that mortar of the concrete will not seep through to the opposite concrete surface. Damaged or deformed joint filler shall not be used. Preformed joint filler shall have the thickness specified on the Drawing.

The exposed edges of the filler material placed on joints shall be at a prescribed distance back from the finished surface of the concrete when required on the Drawings.

### **15.3.4 Joint Sealants**

The Contractor shall apply bituminous joint sealant as shown on the Drawings.

#### **15.3.4.1 Placing**

All joint surfaces shall be cleaned, sound and dry. All concrete surfaces shall be fully cured before application.

Mixing and application of sealant compounds shall be in accordance with the manufacturer's recommendations.

End of Chapter 15

## **CHAPTER 16 - PLASTER**

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## **CHAPTER 16 - PLASTER**

### **16.1 GENERAL**

#### **16.1.1 Scope**

The scope of work under this Chapter shall include all work in connection with the preparation and application of plaster or mortar on walls, ceilings and concrete floor, etc. made of whatever material. The work shall include all necessary labours, materials, equipment survey, quality control, test, transportation storage, cleaning and preparation of surface and auxiliary work as required to complete the plaster work as specified. Plaster shall be applied in accordance with the finish given on the Drawings.

The Contractor shall coordinate all plastering work with other works and the works of other Contractors so that all works can be performed in the most direct way.

#### **16.1.2 Standards and Codes**

All materials and testing shall comply with the standards and codes hereinafter :-

ASTM C150	-	Standard Specification for Portland Cement
TIS 80 – 2517	-	Mixed Cements
TIS 133-2518	-	White Portland Cement.

### **16.2 MATERIAL**

#### **16.2.1 General**

Plaster shall consist of a binding agent, sand, water and other admixtures, if any. The binding agent shall be cement, admixture for preventing cracks, gypsum for special applications, a synthetic resin dispersion, admixture for waterproof mortar etc. All binding agents shall be delivered in the original sealed packages or containers, bearing the names of the manufacturer and the brand. They shall be suitably stored on Site and kept dry. The provisions made in Chapter 10, "Concrete", concerning storage and handling shall apply accordingly.

#### **16.2.2 Cement**

Cement shall comply with ASTM C 150, Portland Cement Type I or mixed cements "Tiger products of the Siam Cement Co., Ltd. Reference is made to Chapter 10, "Concrete".

#### **16.2.3 Sand**

The sand shall comply with the quality requirements described in Chapter 10, "Concrete".

#### **16.2.4 Water**

Water for the preparation of plaster shall be in accordance with the requirements stipulated in Chapter 10, "Concrete".

### 16.2.5 Admixtures and Colouring Agents

If the Contractor intends to use any admixtures or colouring agents, he shall submit the manufacturer's detailed technical specifications to the Engineer.

### 16.2.6 Mortar

Mortar for floor and wall shall consist of cement, sand, water and admixture. The mix proportion shall be hereinafter :

#### Mortar shall be proportioned by volume

Location	Base Coat Cement:Sand	Second Coat Cement:Sand	Finishing Coat Cement:Sand:Admixture
mortar for wall	1:2	1:3	1:2.5: as instruction of the manufacturer
mortar for floor	-	-	1:2.5: as instruction of the manufacturer

### 16.2.7 Gypsum Plaster

Gypsum plaster shall consist of gypsum, cement, perlite, silicate sand and vermiculite, etc. and shall be of pre-mixed at the factory.

The material which has elapsed four months since being mixed shall not be used.

The Contractor shall submit the detailed technical specifications of the type of gypsum plaster to the Engineer.

### 16.2.8 Finishing Surface Plaster

Finishing surface plaster for exterior wall shall be based on a dispersion of synthetic resin with titanium dioxide (rutil) or equivalent and a weatherproof admixture. The plaster shall meet the requirement of "TEXSA" wall of S.C.B Engineering Co., Ltd. or equivalent material.

Prior to order the plaster the Contractor shall submit the manufacturer's detailed technical specifications including samples of the plaster to the Engineer.

### 16.2.9 Waterproof Mortar

Waterproof agent shall be approved by the Engineer, and other material, mix proportion shall be as specified in Clause 16.2.6 of the Specifications.

### 16.2.10 Metal Parts

Metal parts to be embedded in the plaster, e.g., corner beads, metal profiles for joints, etc. shall be of manufactured galvanized steel profiles and additionally coated for rust protection.



### 16.2.11 Floor Hardener

Floor hardener for work shop in Powerhouse shall be concrete floor with the addition of a top hardening agent to form the resistant surface. The top hardening agent shall be "CONCRETING" mortar screed product of Diethelm Trading Co, Ltd. or equivalent.

## 16.3 EXECUTION

### 16.3.1 General

Plastering shall be carried out by skilled workman in a workmanlike manner to the highest quality standard for this kind of work.

All surfaces to be covered by plaster shall be thoroughly cleaned by removing loose particles, dust, grease, oil, efflorescence and other foreign matters, shall be roughened if so required and shall be moistened adequately before the plaster is applied. No plastering in any part of the work shall be commenced prior to the surface inspection and respective approval by the Engineer.

Plaster shall be mixed by approved mixers in quantities required for immediate use. All mortar for plastering shall have been applied within one hour after adding cement to the mix. retempering of set mortar will not be permitted. Reference is made to Chapter 14, "Masonry".

The plaster shall be proportioned according to the purpose of the plastering, the suction capacity and the surface roughness of the base material and to the climate in the case of exterior plaster. In general, the following rules shall apply:

- any underlying material, i.e., base material or underlying plaster material, shall have an equal or higher strength than the covering layer.
- the material of the covering layer shall have a higher flexibility than the covered material.

All proportioning of mortar for plastering shall be done by the Contractor. All mix proportions given within this Chapter shall be considered as proposal only and the Contractor shall be solely responsible for the compliance of the plastering with these Specifications.

The Contractor shall perform all required touch-up work and shall repair all cracks, marks and other defects after other Contractors have completed their work, irrespective of the cause, and shall leave the plaster in the best, undamaged condition.

Particular care shall be taken to protect adjacent surfaces, material and equipment from any damage or soiling by plastering. The Contractor shall be responsible for and shall repair any damage to surfaces, material and equipment caused by plaster work.

Plaster having drummy areas and or those of inadequate bond or showing cracks due to unduly fat mixes or improper curing, or plaster being defective in any other respect, shall be removed and replaced.

After completion of the plastering or parts thereof, all working areas shall be thoroughly cleaned.

### **16.3.2 Mortar**

#### **a) Mortar for Wall**

The finished mortar for wall plastering shall have the following thickness:

- 25 mm for outdoor surface;
- 20 mm for indoor surfaces.

In general, the plaster thickness shall be the minimum possible, however, the thickness has to be sufficient to level out all irregularities in the base to be covered and the surface shall comply with the specified finish class and its respectively permitted tolerances.

Three coats consisting of a scratch coat, brown coat and finish coat shall be applied for mortar.

The scratch coat shall be applied with sufficient force to form a good bond with the base material. It shall be cross-scratched and kept moist until it is covered by the subsequent layer.

The brown coat shall be applied after the scratch coat has set. The brown coat shall be slightly scratched and broomed, kept wet or at least 2 days and then be allowed to dry out.

The finish coat shall not be applied before the brown coat has cured for at least two days. The finish coat shall be located to a true and even surface and shall be troweled to leave the irregularities, cracks or other blemishes and within the specified tolerances. The finish coat shall be protected from rapid drying and cured for 10 days.

#### **b) Floor Mortar**

Mortar coating over the floor concrete, where required shall be laid as soon as practicable after the concrete is placed. When mortar is applied over the concrete which has been left for a considerable time, a sufficient quantity of pure cement paste shall be uniformly spread over the surface with broom before coating.

In applying mortar over the floor, the surface shall be cleaned and properly wetted with water, and then stiff mortar shall be placed and tamped by means of proper tools, such as mallet to force out excess water to the surface.

As soon as free water on the surface disappears, mortar shall be laid and spread uniformly with trowel by carefully checking the grade and smoothness with straight edge.

In case the floor space is large, joints of 2m x 2m to 3m x 3m shall be provided. Joints shall be V-shaped.

c) Smooth Mortar

Smooth mortar is the mortar for floor where vinyl tiles or vinyl sheets are applied. The surface shall be finished smooth with steel trowel.

### 16.3.3 Finishing Surface Plaster

The thickness of the plaster shall not be less than 10 mm. The plaster shall be applied only on cleaned and dried surface by trowel.

Handling, storing, mixing and applying of the finishing surface plaster shall be in accordance with the manufacturer's instructions.

### 16.3.4 Floor Hardener

Floor hardener shall be constructed as the plain concrete floor with adding the top hardening agent, the hardening agent shall be used and applied in accordance with the instruction of the manufacturer.

The colour will be as indicated by the Engineer. Tamping and floating for finishing may be applied either by hand or mechanical methods.

### 16.3.5 Permissible Tolerances

The permissible tolerances for unevenness of plaster surfaces on walls, columns, beams, ceilings, and suspended ceilings, as well as the maximum deviations of actual from theoretical dimensions of openings, wall chases, etc. shall be within the following tolerances:

Finish Class	Permissible Tolerances in mm within the Range of			
	< 1.00 m	> 1.00 m	> 2.50 m	> 10.00 m
P1	5	6	8	12
P2	3	4	5	6
P3	2	2	3	4

The finish classes for plaster shall be applied as follows:

- P1 designates the surface finish of plaster on walls and ceilings with lower surface requirements, i.e., walls and ceilings in storage, workshops, machine rooms etc.
- P2 designates the surface finish of plaster on walls and ceilings with average requirements, i.e., office rooms, corridors, entrance hall, meeting room, control room etc.
- P3 designates the surface finish for prominently exposed surfaces and for surfaces, where only very small tolerances are permissible.

The surface finishes shall be as indicated in the Drawings approved by the Engineer.

### **16.3.6 Test and Properties**

All materials supplied shall be tested, placed and installed shall be in accordance with the relevant Standards. Where required due to specific test equipment or due to other reasons, the Contractor shall engage an approved material testing institute to conduct those tests. Sampling for testing will be made by the Engineer.

### **16.3.7 Auxiliary Work**

The work shall include the following:

- pre-moistening of strongly absorbent plaster base and keeping the plaster-background moist until setting;
- providing required gauges and templates;
- execution of all grooves, fillets, edges, expansion joints and the like, including supply and installation of plaster stops and corner beads, where required;
- performance and maintenance of all protective measures for plaster work and finished plaster as well as its curing for a minimum period of 10 days;
- cleaning of plastered surfaces immediately after completion of plastering as well as cleaning of all parts clogged by mortar, such as conduits and the like.

End of Chapter 16

## **CHAPTER 17 - TILING**

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## CHAPTER 17 - TILING

### 17.1 GENERAL

#### 17.1.1 Scope

This Chapter includes all works in connection with tile works for all structures on Site as shown on the Drawings and as specified hereafter. The work shall consist of preparation, curing and maintenance of placing and maintaining tile of tread and riser and non-slip nosing of a stair, and tile of covering floor and wall by ceramic tile, etc. including all accessories, e.g., sealing of joints, separating strips, survey, quality control, test, transportation storage, cleaning and protection of surface shall also be included in the scope of work.

#### 17.1.2 General Requirements

Tiling shall be carried out in accordance with the work shown on the Drawings approved by the Engineer.

All works shall be performed in a workmanlike manner by skilled workmen only and at the highest quality standard for this kind of work.

The Contractor shall maintain all finished areas up to the Final Certificate and shall take all required measures to protect these areas from any damages. The measures shall include, but may not necessarily be limited to, covering the respective areas by saw dust, plastic foils, plywood, etc. Damaged areas will have to be repaired applying methods approved by the Engineer.

#### 17.1.3 Standards and Codes

All materials and testing shall comply with the standard and codes hereinafter:-

TIS 37	-	Floor tiles
TIS 38	-	Mosaic tiles
TIS 378	-	Concrete flooring tiles
TIS 613	-	Glazed ceramic tiles for internal walls
TIS 614	-	Ceramic tiles for external walls
TIS 556	-	Refractory mortars

### 17.2 MATERIAL

#### 17.2.1 General

At least thirty days before ordering any material for tiling, the Contractor shall submit to the Engineer for reference and approval samples of all materials intended to use, including all manufacturers' technical specifications.

The colour, surface texture and pattern of all tiles and accessories shall be subject to the selection by Engineer.

### 17.2.2 Tiles for Floors and Walls

#### a) General

Tiles shall have the following properties:

- sharp, straight, parallel, non-crumbling edges;
- free from soluble salts and other detrimental constituents;
- free from cracks and blisters;
- rough or specially formed rear and lateral surfaces to obtain a good bond to the subbase.
- grade A quality

They shall be free from warps, lamination and any other imperfections or flaws affecting their quality, appearance and strength. Bases, stops, returns and caps shall be supplied as required to provide a complete and neatly finished installation.

#### b) Ceramic Wall and Floor Tiles

The ceramic tiles shall be selected from the following manufacturers' products or equivalent.

"Campana" product of Thai-German Ceramic Industry Ltd.

"Cotto" product of Siam Cement Ltd.

"Duragres" product of UMI Ltd.

#### c) Mosaic Tile

The material shall comply with the following minimum requirement:

- Thickness of Tile : > 5 mm
- Surface Treatment : non-slip, smooth
- Size : 50/50 mm

And they shall be "Cotto" product of Siam Cement Co. Ltd., "Campana" product of Thai-German Ceramic Industry Co. Ltd. or equivalent.

#### d) Local Brick Tile

Local brick tile shall be "Daan Kwean" tile, local product of Nakorn Rachasima Province or equivalent. They shall be the excellent quality of this kind of product.

### 17.2.3 Accessories

Metal edging strips shall be of stainless steel or brass to protect the exposed edges of the floor finish. They shall be fastened with chromium-plated slotted flat head or countersunk screws at spacing not exceeding 0.30 m depending on the thickness of the strips.

In order to separate different kinds of floor finish, a perforated flat bar of brass not less than 30 mm high shall be fixed in position before commencing of flooring. Strip thickness shall be at least 6 mm.



To bridge expansion/contraction joints within areas covered by heavy-duty tiles subject to traffic loads, special stainless steel profiles shall be supplied and installed on either joint side flush with the floor surface. The stainless steel profiles shall be interconnected by a heavy-duty rubber profile clamped to either side.

To cover expansion joints in areas of normal wear and tear, as well as in tiled wall surfaces, continuous aluminum angles shall be attached to either side of the joint and a special PVC-profile shall be pressed into the gap of in general 15 mm width remaining between both angles.

### **17.3 EXECUTION**

#### **17.3.1 General**

All surfaces to be covered by tiling shall be thoroughly cleaned by removing loose particles, dust, grease, oil, efflorescence and other foreign matters, shall be roughened if so required and shall be moistened adequately before placing. No tiling works in any part of the Works shall commence prior to the surface inspection.

The joint pattern of the areas covered by tiles shall be symmetrical with regard to the bordering areas, walls, etc. and Shop-Drawings showing pattern and tile arrangement shall be submitted for the approval of the Engineer prior to the commencement of tiling work. The width of the joints shall be as specified by the manufacturer.

In the lavatories and pantries, tile arrangement shall be coordinated with the location of sanitary fixtures of plumbing system, in order that sanitary fixtures such as faucets, drains, and other pipes can exist at just the joint of tiles.

The Contractor shall perform all required touch-up work and he shall repair all damaged areas after other Contractors have completed their work, irrespective of the causes, and shall leave the tiling and flooring in the best, undamaged condition.

Screeds and/or tiling revealing drummy areas and/or those of inadequate bond or showing cracks due to unduly fat mixes or improper curing, shall be removed and replaced at the Contractor's cost.

#### **17.3.2 Tiling of Floors, Walls and Stairs**

Before wall surfaces covered with tiles set in normal mortar bedding, a sprayed coating of cement mortar shall be applied to the base, unless otherwise specified.

Where an adequate bond between the bedding mortar and the base is not ensured by the envisaged mode of execution, special measures shall apply, e.g., roughening, covering the base by expanded metal, or coarse-plastering of the complete surface.

Where no adequately even surface is available for thin bed tiling, rendering coats and/or screeds shall be applied.

Concrete surfaces to be covered by tiles shall be cleaned by wet sandblasting and/or water jet.

The concrete surface shall be kept thoroughly wet for a period of 24 hours prior to placing of tiles.

Tiles in indoor areas shall be set and laid only after the complete erection of window and door frames and trims, stop rails, plumbing installations and the application of plaster, unless otherwise specified.

All tiles shall be set or laid to the lines, levels and grades shown on the Drawings. If special tiles with textured surfaces are used, projections will be accepted only to the extent allowed by the particular type of tile.

All tiles shall be set or laid in a cement mortar bed or by the thin-bed method as proposed by the Contractor and reviewed by the Engineer.

The mortar shall be proportioned as follows:

Application	Cement/Sand Mix Ratio (Parts by Volume)
Sprayed Coat	1:2 to 1:3
Rendering Coat	1:3 to 1:4
Setting and Laying (indoor)	1:4 to 1:6
Setting and Laying (outdoor)	1:4 to 1:5

The material properties of cement, sand and water, reference is made to Chapter 10, "Concrete".

The thickness of the mortar bed for tiles shall be on average 25 mm unless otherwise shown on the Drawings.

The adhesives to be applied for the thin bed method shall be subject to the approval by the Engineer and shall be applied in accordance with the instructions given by the manufacturer of the adhesive.

Where floor drains are provided, the planes of the finished floor shall be sloped towards the drains. Intersections and returns shall be formed accurately. Cutting of tiles, where necessary, shall be done along the outer edges of the floor and done without miring the tile surfaces. Tiles shall fit closely and neatly around all plumbing fixtures, electrical outlets, pipes, fittings, etc. and the joints shall be properly covered by cover plates or escutcheons.

Upon completion of the work, all surfaces of ceramic tiles shall be cleaned with a soap powder and clean water applied with stiff fiber brushes. After scrubbing, the tile surfaces shall be rinsed with clean water. Hard lumps of mortar shall be removed by using wooden paddles.

The application of metal cleaning tools or metal brushes or acid solutions will not be permitted.

The joint widths between tiles shall depend on their size and the following values shall apply for all ceramic tiles:

- wall tiles      2 mm through 4 mm
- floor tiles      2 mm through 4 mm for ceramic tile and Mosaic tile 8 mm for heavy-duty tile

Where walls and floors are covered by the same material, the same joint width shall apply with both, floor tiles and wall tiles.

Joints shall be raked out and pointed with white cement and/or cement mortar as approved by the Engineer. Pointing shall be carried out by the flushing-in method. Where imperfections occur in pointing, the joints shall be raked out not less than 8 mm and shall be pointed fully and smoothly to match adjoining parts.

All contraction and expansion joints shall extend through the mortar bed and the tiling and shall be sealed at the surface by a suitable elastic sealing compound approved by the Engineer.

The joints between floor and wall tiles, as well as the joints in vertical corners, shall be sealed by an elastic sealing compound.

Special tile-units shall be provided as required to form all corners, returns, caps and off-sets. All tile edges at exterior corners shall be rounded and all visible edges shall be of the same surface properties as the tile surface.

All treads and risers of indoor stairs shall be covered by tiles as shown on the Drawings. The tiles covering the treads shall have non-slip nosing tile approximately 100 mm width. Walls adjacent to stairs shall receive a baseboard of approximately 0.10-0.15 m height measured from the treads and risers. The baseboard shall follow the treads and risers.

### **17.3.3 Tests and Properties**

#### **17.3.3.1 General**

All materials supplied shall be tested placed and installed in accordance with the relevant Standards. Where required due to specific test equipment or due to other reasons, the Contractor shall engage an approved material testing institute to conduct those tests. Sampling for testing will be by the Engineer.

#### **17.3.3.2 Tolerances**

Any abrupt surface irregularity will not be permitted. The permissible tolerances for gradual irregularities of surfaces on floors and walls and for measurements shown on the Drawings shall not exceed the following values:

Finish Class	Permissible Tolerances in mm within the range of:			
	< 1.00 m	> 1.00 m to < 2.50 m	> 2.50 m to < 10.00 m	> 10.00 m
TF1	1	2	3	4
TF2	2	3	4	5
TF3	2	3	6	8

The finish classes for tiling and flooring shall be applied as follows:

- TF1 designates the surface finish of floors and walls with spatula or other fillers.
- TF2 designates the surface finish of floors and walls covered by tiles (ceramic, PVC, terrazzo).
- TF3 designates the surface finish for cement screeds.

#### 17.3.4 Auxiliary Work

The work shall comprise as well, but may not necessarily be limited to, the following:

- pre-moistening of strongly absorbing subbase and keeping the base moist until setting;
- providing required gauges and templates;
- covering of all grooves, fillets, edges, expansion joints and the like, including supply and installation of all specified accessories;
- neat tiling and flooring around doors, windows, pipes, cables, structural parts and the like;
- performance and maintenance of all protective measures for flooring and tiling work and finished surfaces, as well as curing of all screeds for a minimum period of 10 days;
- cleaning of finished surfaces immediately after completion of flooring and tiling as well as cleaning of all parts clogged by mortar, such as conduits and the like;
- joining coverings to adjacently installed structural components, such as frames, trims, stop rails, pipes, columns, sills, and the like;
- wrapping-in of pipes, ducts, etc. to be embedded in cement screed by building paper;
- sealing of all joints and corners in tiling, flooring and skirting by elastic joint sealants, as well as filling of joints between screeds and bordering walls, etc. as specified including supply of all material.

End of Chapter 17

## **CHAPTER 18 - FINISHING WORK**

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## **CHAPTER 18 - FINISHING WORK**

### **18.1 GENERAL**

#### **18.1.1 Scope**

The scope of work covered in this chapter shall comprise all works and the supply and installation of all materials required in connection with the installation of finish works as shown on the Drawings.

It shall also include all appertaining material and structural part, scaffolding, transportation, loading, unloading and all other operation to complete the works in all respect.

#### **18.1.2 General Requirements**

All works shall be performed in a workmanlike manner by skilled workmen only and at the highest quality standard of this kind of work.

All finish works shall be coordinated with the works by other Contractors on Site, that it can be performed in the most direct way. The Contractor shall take into account, that access to and from finished areas will have to be provided for other Contractors and that closing off will be permitted only for the time required for setting and hardening of the material.

The Contractor shall maintain all finished areas up to the final certificate and shall take all required measures to protect these areas from any damages. The measures shall include, but may not necessarily be limited to, covering the respective area by saw dust, plastic foils, plywood, etc. Damaged areas will have to be repaired applying methods approved by the Engineer.

### **18.2 MATERIAL**

#### **18.2.1 General**

All materials for finish works shall be new and unused and of the best grade and quality for the purpose use. All manufactured items shall be standard commercial products of reputable manufacturers. Where material is required, but not specifically covered by a Standard or Specification, the Contractor shall furnish high class commercial grades acceptable to the Engineer.

At least thirty days before ordering any material for finish works, the Contractor shall submit to the Engineer for reference and approval samples of all materials that intended to use, including all manufacturers' technical specifications.

#### **18.2.2 Standard and Code**

All material for finish works shall conform to the standard below;

TIS 298-2522	Acrylic Sheet
TIS 724-2530	Teak Spiced Veneer

TIS 178-2549	Plywood Sheet
TIS 180-2532	Fiberboard : Hard fiberboards (hardboards)
TIS 172-2530	Asphalt adhesive for PVC asbestos floor tiles.

### 18.2.2.1 Vinyl Tile and Vinyl Sheet

The material properties shall be as follows:

- Size of sheet: Approved by the Engineer
- Size of tile: 300/300 mm- 500/500 mm  
or approved by the Engineer
- Thickness of tiles: 2.0 mm (Minimum requirement)
- Electrical resistant value: Approximately  $1 \times 10^9$  ohm

### 18.2.2.2 PVC Static Dissipative Floor Tile

The material properties shall be as follows:

- Size of sheet: Approved by the Engineer
- Size of tile: 300/300 mm- 500/500 mm  
or approved by the Engineer
- Thickness of tiles: 2.0 mm (Minimum requirement)
- Electrical resistant value: Approximately  $1 \times 10^8$  ohm

All adhesives shall have suitable properties to ensure a firm and durable bond. They shall not adversely affect the flooring, shall be odorless once applied and shall be of an approved waterproof type recommended by the manufacturer of the flooring material.

Fillers and leveling compounds shall have a firm and durable bond to the base, shall provide a good bonding surface for the adhesive and shall give an adequate support to the covering. They shall have no adverse effects on bases, adhesives and covering material.

### 18.2.3 Plaster Board

Plaster board for ceiling shall be gypsum board of 9 mm thick. Even edge type shall be used for plaster boards that combine with acoustic rock wool boards. The ceilings that have only normal or moisture resistant plaster board shall use tapered edge type.

The dimension of board shall be 1.20 m x 2.40 m and they shall conform to TIS 219.

Plaster boards shall be new, undefected and of the best grade and quality. All the boards shall be standard commercial products of reputable manufactures.



#### 18.2.4 Acoustic Rockwool Board

Acoustic rockwool board for ceiling shall be mineral fiber board of dimension 0.60 m x 1.20 m and 16 mm thick (minimum), even edge type and conform to JIS A6307 or equivalent.

They shall be thermal insulating and sound absorbing material, and shall be new, unused and of the best grade and quality.

The material shall be "TG ACOUSTIC BOARD" Thaigypsum Co., Ltd., "ARMSTRONG" Siam Gypsum Industry Co., Ltd. or equivalent.

The texture of acoustic rockwool board shall be selected by the Engineer.

#### 18.2.5 Glass Fiber Heat Insulation (Not applicable)

#### 18.2.6 Suspension Ceiling

Suspension ceiling shall be the metal frames of plaster board ceiling, acoustic rockwool board ceiling or the ceiling that comprises both of these materials. The metal frames shall be galvanized steel and conformed to the latest version of TIS 863 Level 1. Frames are attached by adjustable suspension rods, dowels and hooks to the ceiling frames. The height of suspension may vary over a range of 0.50 m to 1.50 m.

#### 18.2.7 Rockwool Insulation

They shall be at least 75 mm thick and have the following properties :

- Thermal Conductivity (k) =  $\leq 0.035 \text{ W/mk at } 20^{\circ}\text{C}$
- Thermal resistance (R) =  $\geq 2.00 \text{ m}^2\text{k/W}$
- Fire resistance material
- Sound absorption material

#### 18.2.8 Carpentry and Joinery

All timber for permanent Works shall be reviewed by the Engineer. For joinery only hardwood shall be used.

All timber for permanent Works, but excluding timber to be oiled or varnished, shall prior to delivery to the Site be pressure impregnated with an approved water solution type preservative. The preservative shall be of a type suitable for the use to which the timber is to be put. Insofar as is possible, cutting and shaping of the timber shall be completed before preservative treatment is carried out. Where any cutting or treatment has to be carried out after treatment, the surfaces so cut or worked shall be given two coats of the preservative.

All timber shall be properly stacked on the Site and allowed to dry out until the correct moisture content is achieved. Should any of the permanent timber work shrink, warp or develop any defects within the Maintenance Period, the same shall be removed and new fixed in its place together with all other work which may be affected thereby.

Glues, nails and screws shall be of the type, material, size and finish suitable for their purpose. Glue shall be suitable for the climatic conditions at the Site. Glue for load-bearing joints or where conditions may be damp, shall be of the resin type.

Mastic where specified for bedding joinery, sills, etc. shall be approved non-hardening, plastic, polysulphide synthetic rubber or butyl composition filler or sealer suitable to the climatic conditions at the Site.

Plywood shall be obtained from an approved manufacturer. All plywood shall be first grade “interior” quality unless otherwise specified. Samples of veneered plywood shall be submitted to the Engineer. Where specified to be “exterior” quality, plywood shall be waterproof in accordance with relevant standards.

### **18.2.9 Coated Galvanized T-bar**

Coated Galvanized T-Bar shall be the frames of plaster board ceiling, acoustic rockwool board ceiling where required by the Engineer or as shown on the Drawings. The T-Bar frames shall be heavy duty type. Main bar and cross Bar shall be conformed to the latest version of TIS 449 and shall be hot-dip galvanized as follow the latest version of TIS 50. The galvanized steel shall be coated with polyester paint. For wall edge bar, the frames shall be rectangular or right angle section. Frames shall be fixed by adjustable clamping devices to allow accurate alignment of the ceiling. Coated Galvanized T-Bar shall be products of Siam Cement Co., Ltd. or equivalent.

### **18.2.10 Aluminum Composite Panel**

Aluminum Composite Panel shall be the exterior wall which consists of anti - toxic polyethylene and non - flammable central panel lined both sides with covered aluminum or alloy plate of 0.5 mm thick. The size of this panel shall be approximate to 1.25 m wide and 6.0 mm thick and it shall conform to BS 476 or ASTM E84 or equivalent.

The material shall be “Alcopanel” the product of Premier Products Company Limited or shall be “Alucobond” the product of Loxley Public Company Limited or equivalent.

### **18.2.11 Aluminum Spandrel Panel**

All the elements for aluminum spandrel panel shall at least meet the quality of “FAMED LINE” aluminum panel of Fame Line Products Company Limited or “LUXALON” product of Hunter Douglas Co., Ltd. or equivalent.

Aluminum spandrel Panel shall be aluminum C-section made of aluminum alloy AA-3003, enamel coating by spray system. Each panel shall be the dimension of 85 mm width, 0.6 mm thick which are fabricated with galvanized steel carrier, LG. 1” x 1” steel section and steel frame hang from roof frame.

## **18.3 EXECUTION**

### **18.3.1 General**

All finishing materials shall be placed or installed neatly, straightly, evenly, planely, accurately, rigidly and free from any movement, damage, gap with other materials unless otherwise it is approved to be unnecessary by the Engineer. The method for the execution of finishing works shall be in accordance with the standards recommended by the manufacturers unless otherwise specified below.

### **18.3.2 Vinyl Tile and Vinyl Sheet**

The installation shall be in accordance with the manufacturers' standard.

The cement base shall have sufficiently dried prior to placing these materials.

After the vinyl tile and sheet have set sufficiently, they shall be thoroughly cleaned by a special cleaner recommended by the manufacturer of the tiles and sheets. On the cleaned surface a coat of an approved water emulsion wax shall be applied, brought to a bright polish by machine buffing.

### **18.3.3 Plaster Board**

Plaster board of the ceiling shall be placed to suspension ceiling by using screw drivers spacing about 0.30 m on center's board line, and about 0.20 m on the edge line.

Screw heads and board joints shall be patch by joint compound plaster and paper tapes or other patching material instructed by the manufacturer to form neat and smooth surface and joints, except the boards that attach to acoustic rock wool boards.

### **18.3.4 Acoustic Rockwool Board**

Acoustic rockwool boards that combine with Plaster boards shall be fixed to the plaster boards by the manufacturer's method. Ordinary acoustic rockwool board shall be laid on the section of suspension aluminum frames, fixed tightly with two clip-locks for each board. The fixing shall allow easy removal of individual board, whenever required for maintenance purposes.

Detail layout, fixing, fastening and hanging method for installation shall be submitted to the Engineer for review.

### **18.3.5 Glass Fiber Heat Insulation (Not applicable)**

### **18.3.6 Suspension Ceiling**

All the frames of suspension ceiling shall be fabricated tightly to the concrete wall and ceiling. Suspension rods shall be used as described in the manufacturer's instructions. They shall be equipped with adjustable clamping devices to allow accurate alignment of the ceiling. Their spacing depends on the weight of the ceiling including all additional loads from lighting

fixtures, outlets for the air-conditioning system, cables, pipes etc. but shall not be more than 1.00 m.

The Contractor shall submit all technical details drawings of suspension ceiling frames system to the Engineer for review before the fabrications.

#### **18.3.7 Rockwool Insulation**

The installation shall be in accordance with the manufacturers' standard. Detail, layout, fixing, fastening and other method for installation shall be submitted to the engineer for approval.

#### **18.3.8 Carpentry and Joinery**

All carpentry and joinery shall be carried out in accordance with the best of workmanship.

Timber shall be as long as possible to reduce joints. Where joints are unavoidable, surface shall be in contact over the whole area of the joints before fastenings are applied.

No nails, screws or bolts shall be fixed in any split end. If splitting is likely, or is encountered in the course of any work, holes for nails shall be prebored at diameters not exceeding 80% of the diameter of the nails. Lead holes shall be bored for all screws.

All joiner's work shall be accurately cut out and properly mortised, tenonend, housed, shouldered, dovetailed, notched, pinned and framed together. All exposed surfaces for joinery work shall be wrought and all arrisses cased off by planning and sand-papering to an approved finish suitable for the specified treatment. All beads, fillets and small members shall be fixed with round or oval brads or nails well punched in and stopped. All larger members shall be fixed with screws, the heads let in and pelleted over with wood pellets to match the grain.

Frames, casings and other joinery and fitting shall be secured for fixing bricks or to hardwood fixing slips built in for the purpose. Doors shall be secured to the frames by three hinges, and the frames shall be tied to jambs with strong galvanized mild steel cramps and have galvanized steel dowels to posts let into the flooring or have at least 100 mm of the frame let into the floor.

Manufactured units to be painted shall be primed at the place of manufacture with an approved wood primer, after inspection and approval. The primer shall be applied by brush in an adequate and uniform coat to all surfaces including those to be bedded in.

Except where work is shown as being to finished sizes, 3 mm tolerance shall be allowed for each wrought face.

All cut ends, shavings and other wood waste from all parts of the Works and the Site generally shall be cleared out as the Work progresses and at the conclusion of the Work to prevent borer infestation and to discourage termites and decay.

### **18.3.9 Coated Galvanized T-bar**

Coated Galvanized T-bar system shall be installed tightly to structural members of wall and ceiling by following the manufacturer's instruction.

### **18.3.10 Aluminum Composite Panel**

The installation of panel shall be in accordance with the instruction or the standard of the manufacturer. Detail, layout, fixing, fastening and other method for installation shall be submitted to the Engineer for review.

### **18.3.11 Aluminum Spandrel Panel**

The panel for walls shall be installed by the method of "Tray panels suspended on pins" and the panel for ceiling shall be installed by the method of "Tray panels screw-fixed" named by Alucobond or equivalent method. The panel of ceiling shall be designed and installed in order that no water leaks throughout the joint. Before fabrication the Contractor shall submit detail layout and all technical details drawing and shop drawings show the method of installation and all necessary components of aluminum panel to the engineer for approval.

End of Chapter 18

## **CHAPTER 19 - DOOR AND WINDOW**

**TECHNICAL SPECIFICATION**  
**CHAPTER 19 - DOOR AND WINDOW**  
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## CHAPTER 19 - DOOR AND WINDOW

### 19.1 GENERAL

#### 19.1.1 Scope

The scope of work described under this chapter consists of furnishing and installation of doors, windows, and glazing, etc. shown on the Drawings.

#### 19.1.2 Submissions

Complete shop and erection drawings, or manufacturer's drawings, supported by structural computation, if so required, of all doors and windows showing sizes, type and grade of metal, method of assembly, hardware and anchorage or connection with the main structures, shall be prepared by the Contractor and submitted to the Engineer for review at least one month before beginning the manufacture of the various items.

Samples of all hardware for doors and windows shall be submitted to the Engineer for review prior to ordering any part and/or prior to start of manufacture of the metal parts the hardware will be attached to.

#### 19.1.3 Standards and Codes

All the materials and testing shall conform to the standards herein after :- (or equivalent)

TIS 54	-	Ordinary Sheet Glass
TIS 218	-	Anodized Aluminum
TIS 593	-	Steel Rolling Shutters
TIS 744	-	Metal Frames and Panel Frames for doors and windows : aluminum windows
TIS 756	-	Cylindrical Lock
TIS 759	-	Hinges for doors and windows : Butt Hinges
TIS 778	-	Frames Sets for adjustable louver window
TIS 829	-	Metal Frames and Panel Frames for doors and windows : aluminum doors
TIS 192	-	Wood - based panel door
TIS 313	-	Aluminum Insect Wire Screening
TIS 724	-	Teak spliced veneer
TIS 192	-	Wood based panel door
TIS 208	-	Galvanized wire netting
TIS 1344	-	Tinted float glass



## 19.2 MATERIAL

### 19.2.1 General

In case that performance such as wind resistance, air tightness and water tightness, etc. is required in this Specification, the Contractor shall submit documents clarifying the required performance for the Engineer's review.

The manufacturer or supplier of the materials of this work shall be selected within following or others approved as equivalent.

- Aluminum door, window and louver : Thai Inter Aluminum Co., Ltd., Alfab Thailand Co., Ltd., International Aluminum Co., Ltd.
- Steel door : Diamond Door Co., Ltd., Safety Steel Industry Co., Ltd., Sun Metal Co., Ltd.
- Steel shutter, stainless steel grille shutter : Safety Steel Industry Co., Ltd., Toyo Shutter Co.,Ltd., Bangkok Shutter Co., Ltd.
- PVC. door : NAPA Co., Ltd., Polywin Co., Ltd., Champ Associate Co., Ltd.

### 19.2.2 Aluminum Door, Window, Louver and Frame

#### (a) Performance

The performance of aluminum door, window, louver and frame facing outside shall conform to applicable ASTM, JIS, DIN, TIS or other international standards.

#### (b) Material

The material of aluminum door, window, louver and frame shall be as following or equivalent.

Aluminum extruded profiles	:	JIS H4100 A 6063S
Aluminum sheet	:	JIS H4000 1.5 mm thick or more
Surface Treatment	:	Colored anodic oxidation of JIS H8602 Class B and 2 coats of clear lacquer
Connectors and anchors	:	Galvanized steel or aluminum alloy
Screw	:	Stainless steel of JIS G4308 SUS 305 or XM7
Slit filler	:	Polyamide fiber and/or neoprene strip
Insect screen	:	Metal mesh
Hardware	:	As Manufacturer's standard and subject to the approval of the Engineer

### 19.2.3 Steel Door

The material of steel door shall be as following or equivalent.

- (a) Steel sheet : JIS G3302 Hot-dip galvanized steel sheet
- Zinc thickness 120 g/m<sup>2</sup> or more
- Door panel : 1.6 mm thick
  - Door frame : 1.6 mm thick
  - Reinforcing rib : 1.6 mm thick
- (b) Shape steel : JIS G3101
- (c) Threshold : JIS G4305 Stainless steel SUS 304  
2.0 mm thickness
- (d) Screw : Stainless steel SUS 305
- (e) Hardware : As Manufacturer's standard and subject to the approval of the Engineer

### 19.2.4 Steel Shutter

(a) Performance

- Operation : Motor drive and manual operation
- Switching : Push button switch of open-stop-close (for inside and outside) and limit switch

(b) Material

The material of steel shutter shall be as follows or equivalent.

- Slat and shutter case : JIS G3302 Hot-dip galvanized steel sheet, 1.6 mm thick Zinc thickness 120 g/m<sup>2</sup> or more
- Guide rail : JIS G4305 Stainless steel SUS 304, 1.5 mm thick (minimum)
- Motor : 1 phase 220 V/50 Hz or 3 phase 380 V/50 Hz

(c) Design

Total overlapping length of the slats and guide rails for both sides shall be more than following.

<u>Width of Shutter</u>	<u>Total Overlap</u>
Less than 3 m	90 mm
3 ~ 5 m	100 mm
5 ~ 8 m	120 mm

### 19.2.5 PVC. Door

PVC. door shall made of strong durable synthetic PVC., self-coloured, fire and chemicle resistant, fungus proof and will not attract termite or insects.

PVC. door shall consist of PVC. panel of 3 mm thick and PVC. frame of 2.6 mm. The surface shall be smooth and no deflection.

The colour and texture of PVC. door shall be subject to the selection by the Engineer.

### 19.2.6 Wooden Door and Wooden Window

Wooden doors shall be of flush construction water-proof type made of two plywood sheets, a cellular structure inside, thick edges, a solid wood frame and fitted with wood stops. The thickness of the doors shall range from 35 to 40 mm.

All the frames of doors and windows fixed in walls shall be hard wood of Teng Wood and shall be installed before the plastering of walls. All door frames and window frames shall be secured in position by means of heavy and approved steel fittings.

### 19.2.7 Hardware

Hardware such as hinge, cylinder lock handle and door-closer shall be of excellent quality, extra heavy duty type, made of stainless steel or approved equal alternate and equal to, or exceeding the product of "Schlage" Skulthai Co., Ltd., "Yale" or equivalent Samples of hardware shall be submitted to the Engineer.

### 19.2.8 Glazing

#### (a) Clear Glass

Clear glass shall have a plane, bright, transparent, clearly reflecting and distortionless surface. Isolated, unobtrusive small bubbles and inconspicuous scratches may be allowable. The deviation of the glass thickness shall not exceed the following values :

Standard Fabrication Thickness (mm)	Permissible Deviations (mm)
4	+ <sub>-</sub> 0.2
5	+ <sub>-</sub> 0.2
6	+ <sub>-</sub> 0.2
8	+ <sub>-</sub> 0.3
10	+ <sub>-</sub> 0.3
12	+ <sub>-</sub> 0.3
15	+ <sub>-</sub> 0.3
19	+ <sub>-</sub> 0.3
21	+ <sub>-</sub> 1.0

In general, crystal plate glass shall be used for all windows, glazed doors, glazed partition walls, etc. where shown on the Drawings and for which no special requirements have been specified.

(b) Tinted Glazing

Tinted glass shall be used for the glass doors and windows facing exterior. They shall consist of tinted glasses, e.g., glasses floated with a bronze tint, body colored float glasses, color to choice, and/or laminated reflective glasses. The tinted double glazing shall meet the following minimum requirements :

- type of glass	:	Panel of crystal plate glass, tinted, thickness acc. to size of pane
- light transmittance	:	40%
- solar radiant heat reflectance	:	10%
- thermal transmission coefficient	:	3.0 W/m <sup>2</sup> /K
- tint	:	light blue green

The glazing of all outer doors and windows of the buildings shall be subject to the selection of colour and type by the Engineer.

### 19.2.9 Sealing Compounds

The elastic sealing compounds applied in all glazing work shall have a good bond to the glass and to the adjoining structural member. They shall not tear or break even under consideration of all possible relative movements between the pane and the structural member due to expansion, shrinkage, etc. and they shall remain permanently elastic without age-hardening, taking into account the prevailing temperature conditions on Site. The compounds shall warrant adequate compatibility with all materials in contact.

### 19.2.10 Sealing Sections and Strips

The quality, dimensions and design of the sealing sections and strips applied in all glazing work shall suit their intended application. They shall be permanently flexible, shall allow all movements between the pane and its appertaining frame and shall seal the gap between the pane and frame, water and air-tight, if so required. The sealing sections or strips shall be capable to bridge all tolerances within the glass rebate which have reasonably to be expected. They shall be aging-resistant, shall maintain their specified properties under the prevailing temperature conditions and shall be of adequate compability with surrounding materials.

## **19.3 EXECUTION**

### **19.3.1 General**

All parts to be manufactured under this chapter shall be installed in a workmanlike manner at the location and to the lines, levels and grades shown on the Drawings. All parts shall be designed in a way that all tolerances normally to be expected can be coped with.

Generally, and unless otherwise specified, the Contractor shall design and dimension all doors, windows and other metal parts specified in this chapter on the basis of the details and layouts shown on the Drawings and/or described within this chapter.

### **19.3.2 Aluminum Door, Window, Louver and Frame**

Manufacture and fabrication of aluminum door and window shall be in accordance with the manufacturer's standard.

The frame of door, window and louver shall be attached to the structural members by anchors or by separate galvanized steel frames of tubular profiles. The steel frames shall be fixed to the surrounding structural members by dowels prior to installation of the window. The anchors shall generally be of non corrodible material and shall allow for tolerances normally to be expected in this kind of work. If required, spacers shall be used to bridge gaps. Drilling of holes through the aluminum profiles of the frames for fixing purposes will not be permitted.

The space between aluminum frame and structure shall be filled with mortar.

### **19.3.3 Steel Door**

#### **(a) General**

Manufacture and fabrication of steel door shall be in accordance with manufacturer's standard.

#### **(b) Installation**

Installation of doors shall be in accordance with approved shop or setting drawings, at the proper elevation and location, plumb, level and in alignment. Frames shall be properly braced to prevent distortion and misalignment. Doors shall be protected against accumulation of cement, lime and other building materials by keeping doors tightly closed and wired to frames.

The joint between the frames and lateral walls or lintels, respectively, shall be sealed by elastic joint sealant.

The joint between the frames and concrete structure shall be filled with mortar.

After installation, the doors shall be checked for operation and with respect to weathering. After they have been installed and before completion or painting, all doors and hardware shall be adjusted to operate smoothly.

Regarding coating of the doors including their frames, reference is made to Chapter 20 "Painting and Coating".

#### **19.3.4 Steel Shutter**

Manufacture and fabrication of steel shutter shall be in accordance with the manufacturer's standard.

The joint between the frames and lateral walls floors or lintels, respectively, shall be sealed by elastic joint sealant ; the joint between the guide rails and concrete structure shall be filled with mortar.

#### **19.3.5 PVC. Door**

PVC. door frames shall be installed by using anchor bolts embedded to concrete wall or as the instruction of the manufacture.

Prior to ordering the doors, the Contractor shall submit respective technical details for review by the Engineer.

#### **19.3.6 Wooden Door and Wooden Window**

The Contractor shall protect all doors against dampness during and after delivery.

The lower ends of the door frames shall be blocked in the floor to the extent of 5 cm when the sill is omitted.

Doors shall not be stored or installed within the buildings until plastering and paintings are reasonably dry. All doors, prior to the delivery at Site, shall be given one shop coat of approved stucco paint.

After the installation, all woodworks shall be finished with painting in accordance with the prescriptions of Chapter 20.

#### **19.3.7 Glazing**

The glass sizes shall be made by actual measurement of installed frames with sufficient clearances to avoid the glass being forced into its lodgement when installed.

Any exterior glazing which allows water seepages into the building shall be removed, the rabbets cleaned and the glass reset without additional charge.

All excess glazing compound shall be cleaned off of the glass and the glazing compound left neatly pointed.

On completion, glass shall be free of scratches, cracks or other defects. Any cracked or broken glass shall be replaced prior to the acceptance of the work.

Upon completion of the buildings, the Contractor shall wash all glass installed leaving same in a clean and acceptable condition.

### **19.3.8 Auxiliary Work**

The following efforts shall among others be deemed to be included as auxiliary work.

- Any corrosion or surface protection of any metal parts until the final coating has been executed on Site.
- All dowels required to be fixed or embedded in walls, slabs, etc. of concrete for fastening metal parts, wherever required.
- Providing block-outs, recesses, etc. and filling of block-outs, recesses, etc. by concrete, mortar, non-shrink grout to fill the joint of frames and building structure after installation of the doors, windows and other metal parts.
- Provision and application of elastic joint sealants, wherever required in connection with doors, windows and other metal parts.

### **19.3.9 Tests and Properties**

All materials to be supplied and installed shall be in accordance with the relevant Standards and shall conform to all requirements laid down therein.

The Contractor shall carry out tests and/or submit certificates issued by approved material testing institutes of tests conducted on the supplied equipment to prove its conformity with the specified quality requirements.

Samples for testing material will be selected by the Engineer.

End of Chapter 19

## **CHAPTER 20 - PAINTING AND COATING**



**TECHNICAL SPECIFICATION**  
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## CHAPTER 20 - PAINTING AND COATING

### 20.1 GENERAL

#### 20.1.1 Scope

This Chapter covers the performance of all work in connection with the preparation of surfaces, the supply and application of paint or varnish for coating and finishing of metal, concrete, masonry and wood surfaces, etc.

#### 20.1.2 Submissions

At least thirty days before ordering any materials for painting and coating, the Contractor shall submit to the Engineer for review the products and name of manufacturers including all manufacturers' technical specifications.

For each color of all kinds of painting, painted pieces of 30 cm x 30 cm in size shall be submitted as sample to the Engineer to its color and glossiness. The paint color samples shall be kept by the Engineer.

#### 20.1.3 Shop and Field Painting

Shop painting refers to paint to be applied in the fabricating shop prior to delivery to the Site for erection or installation. Field painting refers to paint to be applied on Site.

Unpacked black steel items shall be primed at the fabricating shop and finished in the field, while packed steel items shall be primed in the shop and may be finished in the shop or in the field.

Field painting shall be accomplished after erection, except for surfaces to be coated, which will be inaccessible after erection. Touch-up painting to repair marks and scratches and to restore the coating to an unbroken condition shall be carried out in the field on all shop-primed and shop-finished items prior to the final field painting.

#### 20.1.4 Standards and Codes

All the materials and testing shall conform to the Standards hereinafter :- (or equivalent)

TIS 272	- Emulsion Paint
TIS 285	- Methods of Test for paint, varnishes and related materials
TIS 327	- Gloss enamel paints
TIS 401	- Zinc chromate primer
TIS 390	- Aluminum paints
TIS 389	- Red lead based primers for iron and steel surface
TIS 559	- Silicone-based water repellents for masonry
TIS 607	- Vinyl and fouling paint
TIS 618	- Binders for paints and Varnishes : Alkyd resins
TIS 691	- Epoxy paint
TIS 727	- Coal-tar epoxy paint

TIS 1005	- Semigloss enamel
ASTM E-119-95a	- Standard test method for fire test of building, construction and
BS476 Pt21	material

## **20.2 MATERIAL**

### **20.2.1 General**

The paint shall be selected from the following manufacturers products or equivalent

"JOTUN Paint" product of the JOTUN THAI Company Ltd.

"ICI Paint" product of ICI Paint Thailand Ltd.

"SHERWIN WILLIAMS"

"TOA" Products of TOA Paint (Thailand) Co., Ltd.

"ACT Hydratherm IMS"

The product and name of manufacturer shall be submitted to the Engineer for review. The product grade shall be super premium grade of each manufacturer. Colors shall be selected by the Engineer. Other products may be used upon the Engineer's approval.

### **20.2.2 Delivery Conditions**

All coating materials shall be delivered to the Site in original and unopened containers, properly marked with the material designation, the brand name and the name of the manufacturer. The manufacturer's application instructions shall be included with each shipment.

The manufacturer's product identity forms according to relevant Standards shall be supplied with each shipment of material.

## **20.3 EXECUTION**

### **20.3.1 General**

The coating systems shall be applied according to the manufacturer's instructions. No paint shall be extended or modified unless otherwise specified by the paint manufacturer and approved by the Engineer. Dilution of paint shall be carried out with approved solutions only.

Surfaces to be painted shall be thoroughly cleaned and prepared according to the manufacturer's instruction before being coated. All oil, grease, dirt, rust, loose material and other foreign matters shall be removed.

No coating work shall be started before the surfaces to be covered have been inspected by the Engineer.

All coating and painting work including surface preparation shall be scheduled such, that dust, spray, etc. will not deteriorate newly painted surfaces in adjacent areas. All surfaces and equipment not to be painted shall be adequately protected.

Where required, imperfections and holes in surfaces shall be filled by approved material.

Hardware, electrical fixtures and similar accessories shall be removed during preparation and painting and shall be re-installed after completion of all painting.

### **20.3.2 Surface Preparation**

#### **a) Metal Surfaces**

Weld spatter, burrs or any other objectionable surface irregularities shall be carefully removed or repaired before cleaning. Any grit or dust remaining after the cleaning operation shall be completely removed from the surface by brushing, air blowing, suction or other effective means before the surfaces are painted. In the event that rust forms or the surfaces become otherwise contaminated during the period between cleaning and painting, re-cleaning will be required.

Steel surface shall be cleaned of all dirt, oil and other foreign substances by thinner and kerosene, and scraped all rust by sand blasted, sand paper, wire brush or other approved means. After cleaning, the surface shall be coated with rust resistant liquid, left for 3-4 minutes before cleaned with dry cloth.

After sandblasting, dust and spent sand shall be removed from the surfaces by brushing or vacuum cleaning.

The prime coat shall be applied as soon as possible after the surface preparation is finished and always before the surface starts to rust.

Where a period longer than three (3) hours has elapsed since cleaning or where blasted surfaces have, in the opinion of the Engineer, deteriorated, they shall be re-done immediately prior to painting.

Galvanized steel surface to be painted shall be treated with etching primer or other means approved by the Engineer.

#### **b) Concrete and Masonry Surfaces**

Concrete or masonry surfaces shall be prepared by removing all dirt, dust, efflorescence, oil and grease stains or other foreign substances by wire or fiber brushing scrapers, light sand blasting and/or other approved means. Where necessary to provide good adhesion to paint the surfaces shall be roughened. New concrete surfaces shall be allowed to cure for a minimum of thirty (30) days before being painted. Cracks, holes and pock marks exceeding 2 mm diameter shall be repaired by approved patching material.

#### **c) Plastered Surfaces**

Unless otherwise authorized or provided for elsewhere, no paint shall be applied to plastered surfaces cured for less than 20 days. Prior to painting, care shall be taken to ensure that such surfaces are thoroughly dry, clean and free from grease, loose plaster and surface irregularities. Cracks and holes shall be repaired with approved patching materials, properly keyed to the existing surfaces and smoothed by sand paper.

d) Wood Surfaces

Wood surfaces shall be sanded smooth and no tool marks shall show in the finished work. Cracks shall be raked out, filled with wood filler and sanded smooth. Nail holes and minor defects shall be putty stopped and sanded after the priming coat is dry. Where resin or pitch has exuded or caused defects in the finish, the surface shall be scraped and sanded until the defect is removed and the surface shall be refinished.

e) Plaster Board Surfaces

Plaster board surface shall be cleaned free from dirt and other foreign substances. Nail holes and joints of two boards shall be filled with patching materials and sanded smooth before coating.

Cracks and holes shall be repaired with approved patching materials, properly keyed to the existing surfaces and smoothed by sand paper.

### 20.3.3 Paint Application

a) Workmanship

All work shall be of the best quality and performed only by skilled workmen. Paint shall not be applied over a previously applied coat until the surface is dry and hard, has been properly prepared to receive the next coat, and the surface has been inspected by the Engineer.

Materials shall be spread evenly and flowed on smoothly and evenly, without runs, sags, brush marks or skips. Each coat of paint shall have a slight variation in colour to identify it from the preceding coat.

Care shall be exercised during spraying operations to hold the nozzle sufficiently close to surfaces being painted to avoid excessive evaporation of the volatile constituents and loss of material into the air, or the bridging over of crevices and corners. Where coverage rate and numbers of coats are specified, such figures shall be considered as minimum and if a minimum dry film thickness is required, the Contractor shall not be entitled to additional compensation if additional coats are required to obtain such minimum thickness.

Spray equipment shall be equipped with mechanical agitators, pressure gauges and pressure regulators. Nozzles shall be of proper size. Floors, roofs, and other adjacent areas and installations shall be satisfactorily protected by drop cloths or other precautionary measures. Thinnings shall be as approved by the Engineer.

b) Atmospheric Conditions

Paints shall be applied only to surfaces that are thoroughly dry and only under such conditions of humidity and temperatures of the atmosphere, and with surfaces to be painted, which will cause evaporation rather than condensation. A practical test is to wipe a damp cloth on the surface to be painted; if the moisture streak will dry within a few minutes, conditions conducive to evaporation prevail. In no case any paint shall be applied during rainy, misty weather or to surfaces upon which there is moisture condensation and without suitable protection.

All paint when applied shall have approximately the same temperature as the surface onto which it will be applied.

c) Protection of Paint Surfaces

Where protection is provided for paint surfaces, such protection shall be preserved in place until the paint film has properly dried, and removal of the protection is authorized.

Items, which have been painted, shall not be handled, worked on or otherwise disturbed until the paint coat is completely dry and hard.

d) Contacting Surfaces

When riveted contact is to exist between surfaces of metal parts such surfaces shall not be painted. In case of bolted contact, each of the contacting surfaces shall be given one coat of the specified primer. Where an electric potential is apt to exist between metal surfaces of unlike chemical composition in riveted or bolted contact, each of the contacting surfaces shall be cleaned, pre-treated and given one coat of primer, all as specified for the particular metals involved. Where a non-metal surface is to be riveted or bolted and is in contact with a metal surface, the contacting surfaces of the metal shall be cleaned, pre-treated and given coats of the specified primer.

e) Time Between Surface Preparation and Painting

Surfaces, which have been cleaned, pre-treated and/or otherwise prepared for painting, shall be primed as soon as practicable, but in any event prior to deterioration of the prepared surface.

f) Method of Paint Application

Unless otherwise directed or authorized by the Engineer, the first coat on plastered surfaces or concrete surfaces shall be applied by brush. Subsequent coats may be applied by spray or brush. The coats of paint shall be applied by spray to steel surfaces.

g) Coating Progress

Where painting on any type of surface has been commenced on any portion of work, the complete painting operation, including priming and finishing coats on that portion of the work, shall be completed as soon as practicable without prolonged delays. Unless otherwise specified, sufficient time shall elapse between successive coats permitting them to dry for re-coating and this minimum drying period shall be modified as necessary to suit adverse weather conditions.

h) Dry Film Thickness

The protective paint systems shall be applied in continuous films to give, at the minimum, the total dry thickness indicated in the coating schedule, as measured by the agreed methods. Wet thickness gauges shall be used continuously by the applicator during application to ensure that the dry thickness requirements will be met.

An elcometer paint inspector, microtest, or similar approved gauge to be provided by the Contractor, shall be used to measure the thickness of the coats. It must be accompanied by a set of standard shims for calibration at least once per week under normal Site conditions.

### **20.3.4 Coating for Fireproof**

Fireproof coating for steel structure shall have quality meets ASTM E-119, BS476 Pt21 or International Standard equivalents and shall be product of ACT “Hydratherm IMS” of ACT (Thailand) Co., Ltd., or fireproof coating of Sherwind William “B50 (TH) 4W” or product of Anti Fire Engineering Co., Ltd. or equivalents.

#### Surface Preparation

The surface should be cleaned by abrasive blast-clean. Coating should be applied before the degradation of the surface take place (normally within 4 hr.). If oxidation takes place the steel must be removed, the surface must be cleaned out of rust, laitance, oil, grease and dust.

#### Primer

The fire protection system’s anti-corrosive primer is recommended (also available from ACT in the name of Hydratherm Primer or equivalent).

#### Application

- Stir thoroughly before use until the coating is homogeneous.
- Apply the coating roller, brush or spray.
- Wait for 16-24 hr. between re-coat (if require).

#### Dilution

The coating is supplied in ready to use, the dilution is normally not required. If necessary, dilute with maximum 5% with xylene and mix it consistency before use.

#### Overcoat

The overcoat can be apply if require the aesthetical or to protect from atmospheric attack (also available from ACT in the name of Hydrarofex, Polyflex 79P, etc. depend on the desired properties or equivalent products).

#### Characteristics

Appearance	:	White
Solid	:	70%
Specific Gravity	:	1.30
Drying Time : Touch Dry	:	4 - 6 hr.
Re-Coat	:	16 - 24 hr.
Full-Cure	:	5 Days

#### Standard

ASTM E-119, BS476 Pt21

#### Storage

In unopened packs, the coating has a shelf life of at least 12 months when stored in warehouse condition below 35°C. However not be stored at very low temperatures, to guarantee a good working consistency.

Precaution

The coating can cause an allergic reaction after prolonged contact with sensitive skin. Therefore avoid contact with skin and use protective equipment. Rubber gloves and protective clothing are recommended. After contact with skin wash immediately with plenty of water and soap. In case of contact with eyes rinse immediately with plenty of water and seek medical advice. Ensure good air circulation in the room.

Cleaning

The working equipment, tools, etc. can be mechanically cleaned by using brushes in combination with xylene or any aromatic solvent. The cleaning should be done immediately after the completion of the work and within the pot life of the material to avoid sediments on the equipments, tools, etc.

**20.3.5 Coating Schedule**

The coating systems shall be carried out according to the coating schedules indicated in the Drawings and herein after this specification.

For coating of aluminum parts reference is made to Chapter 19, "Door and Window".

No painting shall be applied to stainless steel, copper, bronze, chromium, nickel, brass or galvanized surfaces, unless otherwise directed by the Engineer.

The following coating schedule shall be adopted:

Item	Surface preparation and Coating	Material or Equivalent approved
Batteries room (Concrete floor) (EPX 1)	Surface preparation : as specified  Prime coat : Floor epoxy solvent free primer (100 microns)  Finish coat : Floor epoxy solvent free top coat (1,400 microns)  Total Dry Film thickness : 1,500 microns	As specified by the Engineer
Batteries room (Concrete wall and ceiling) (EPX 2)	Surface preparation : as specified  Prime coat : Epoxy primer for concrete (50 microns)  Second coat : Epoxy top coat (50 microns)  Finish coat : Epoxy top coat (50 microns)  Total Dry Film thickness : 150 microns	As specified by the Engineer



Item	Surface preparation and Coating	Material or Equivalent approved
Erection bay (Concrete floor) (EPX3)	Surface preparation : as specified  Prime coat : Floor epoxy primer (50 microns)  Second coat : Floor epoxy polyamide topcoat (50 microns)  Finish coat : Floor epoxy polyamide topcoat (50 microns)  Total Dry Film thickness : 150 microns	As specified by the Engineer
Exterior wall (Exterior Plaster wall) (PA1)	Surface preparation : as specified  Prime coat : Alkali resisting primer (30 microns)  Second coat : Pure acrylic 100% for exterior (35 microns)  Finish coat : Pure acrylic 100% for exterior (35 microns)  Total Dry Film thickness : 100 microns	As specified by the Engineer
Control room Erection bay Switchgear room Storage Corridor (Interior Plaster wall) (PA2)	Surface preparation : as specified  Prime coat : Alkali resisting primer (30 microns)  Second coat : Pure acrylic 100% for interior (35 microns)  Finish coat : Pure acrylic 100% for interior (35 microns)  Total Dry Film thickness : 100 microns	As specified by the Engineer

Item	Surface preparation and Coating	Material or Equivalent approved
Steel item (SC1)	<p>Surface preparation : SSPC-SP10</p> <p>Prime coat : Inorganic zinc with a minimum of 84 percent zinc by weight in the dry film (60-80 microns)</p> <p>Touchup : Organic zinc or modified epoxy Power tool clean damaged surfaces only (60-80 microns)</p> <p>Second Coat : Epoxy coat (110-125 microns)</p> <p>Finish coat : Acrylic aliphatic polyurethane (50-60 microns)</p> <p>Total Dry Film thickness : 240 microns</p>	As specified by the Engineer
Steel (SC2- surface in contact with water)	<p>Surface preparation : SSPC-SP10</p> <p>Prime coat : Inorganic, zinc- rich primer (75 microns)</p> <p>Second coat : Mastic epoxy (200 microns)</p> <p>Third coat : Mastic epoxy (200 microns)</p> <p>Finish coat : Mastic epoxy (color) (200 microns)</p> <p>Total Dry Film thickness : 675 microns</p>	As specified by the Engineer
Steel structure (SC3) (see 20.3.4)	<p>Surface preparation : as specified</p> <p>Prime coat : as specified</p> <p>Finish coat : as specified</p>	As specified by the Engineer

Wooden surface (CLK)	Surface preparation : as specified	As specified by the Engineer
	Prime coat : Oil stain (2 coats)	
	Second coat : Wood sealer (2 coats)	
	Finish coat : Clear lacquer (3 coats) (Flat or glossy finish shall be directed by the Engineer)	
Wooden door, window (ALK1)	Surface preparation : as specified	As specified by the Engineer
	Prime coat : Aluminium wood primer (30 microns)	
	Second prime : Wood primer coat (30 microns)	
	Second coat : Alkyd top coat (35 microns)	
	Finish coat : Alkyd top coat (35 microns)	
	Total Dry Film thickness : 130 microns	
Steel door, window and misc. steel (ALK2)	Surface preparation : as specified	As specified by the Engineer
	Prime coat : Alkyd primer (zinc phosphate) (40 microns)	
	Second prime : Alkyd primer (zinc phosphate) coat (40 microns)	
	Second coat : Alkyd top coat (40 microns)	
	Finish coat : Alkyd top coat (40 microns)	
	Total Dry Film thickness : 160 microns	
Exposed brick Surface (SI)	Surface preparation : as specified	As specified by the Engineer
	Prime coat : Silicone resin(2 coat) (Climate & Fungi Resistant)	
	Finish coat : Ditto (1 coat)	

Surge Tank (concrete inner) surface (EPX4)	Surface preparation : as specified  Prime coat : Floor epoxy polyamide primer (2 coats = 80 microns)  Second coat : Aluminium epoxy mastic (250 microns)  Finish coat : Epoxy mastic (250 microns)  Total Dry Film thickness : 580 microns	As specified by the Engineer
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### 20.3.6 Colour Standard for Pipe Work

For coating of all pipe systems the Contractor shall strictly follow the EGAT Colour Standard.

### 20.3.7 Tests and Properties

All materials applied for painting and coating shall comply with the relevant standards. The Engineer may instruct the Contractor to carry out suitability tests on the paint proposed to be applied in the Works as well as to perform quality control tests during the progress of the work as described in the relevant standards and in this Chapter. Apart from the dry film thickness measurements to be carried out on a routine schedule this may include adhesion tests and tests by pin hole detectors. Sampling for testing will be by the Engineer.

End of Chapter 20

## **CHAPTER 21 - ROOFING**

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## CHAPTER 21 - ROOFING

### 21.1 GENERAL

#### 21.1.1 Scope

This section covers the supply and installation of metal roof panel system, including insulation, flashings, fasteners and appurtenances, as specified herein.

Steel components shall conform to the AISI or TIS Specifications or other standards and codes as specified in Chapter 12 and 13.

#### 21.1.2 Submissions

##### (1) Roof Panel System

Roof panels covered in this section shall be provided as distinct and proven panel system for which catalogs shall be submitted with the Bidder's proposal and shall be defined as follows:

<u>System</u>	<u>Components</u>
Insulated metal roof panel system	Manufacturer's standard to meet the following specification and shall be approved by Engineer.

##### (2) Shop Drawings

Detailed shop and erection drawings and component catalog information shall be submitted to Engineer for review before fabrication in accordance with the requirements of Design Criteria of these specifications. Drawings shall include complete information about materials, sizes, gauges, screw and bolt sizes, system construction, and methods of attachment.

Engineer's review of the shop drawings shall not relieve the Contractor of any responsibility to provide complete roof panel system.

##### (3) Samples

Within 4 weeks after the award of the contract, samples of each panel system shall be submitted to Engineer. Samples shall not exceed 500 mm in any dimension.

The sample panels shall be representative of the typical exterior roof construction, complete with liner panels, subgirts, insulation, face panel, roof panel, flashings, fasteners, and other appurtenances required for the total system. Metal panel fabrication shall not commence until the panels have been examined and accepted by Engineer. The sample panels shall become the standard of comparison for all roof panel work.

Color Samples of the specified finish, measuring 100 mm by 100 mm and showing actual color, sheen, and texture, shall be submitted to Engineer.

#### (4) Instruction of Installation

Within 2 months after the awards of the contract, the instruction (manual) of the installation of the roof pannel system shall be submitted to Engineer for review.

## 21.2 MATERIAL

### 21.2.1 General

The surface of the exterior weathering sheet shall have protection against corrosion on both sides to resist continuous attack of concentrated corrosion elements within the side and end laps.

Component thicknesses specified are minimums. Actual steel metal thickness shall be determined from the detailed design analysis performed by the roof panel manufacturer.

Metal roof panel system with perforated liner panels shall have a minimum noise reduction coefficient of 0.85. Test reports confirming this level of noise reduction shall be submitted for approval.

Exterior face panel and trim shall have a shop applied finish as described in item 21.2.2 Metal Face Panel Finish.

The roof panel system shall be as follows but not be limited to :

- |  |  |
|--|--|
| (1) Exterior face panel  | 0.45 mm minimum base metal (uncoated steel) thickness; metal coated steel, ASTM A653, Grade A; Zincalume coated in accordance with AZ 150 (minimum average 150 g/m <sup>2</sup> coating mass), before forming; metal face panel finish.  |
| (2) Perforated flat liner panel (acoustical) for insulated metal roof panel system | 0.45 mm minimum base metal (uncoated steel) thickness; metal coated steel, ASTM A653 Grade A; hot-dip galvanized in accordance with ASTM A525, designation G90, before forming; Liner panels to be flat with 25 mm minimum of oven baked polyester primer, or Zincalume coated in accordance with AZ 150 |
| (3) Subgirts   | 1.2 mm minimum uncoated metal thickness; metal coated steel, ASTM A653, Grade A; hot-dip galvanized in accordance with ASTM A525, designation G90, before forming; hat shaped.   |



- |                                 |   |
|---------------------------------|---|
| (4) Insulation                  | Rockwool, thickness as required to obtain minimum "R" value specified in Chapter 18, Finishing Work.  |
| (5) Exterior flashings and trim | 0.45 mm minimum base metal (uncoated steel) thickness; metal coated steel, ASTM A653, Grade A; Zincalume coated in accordance with AZ150, before forming; surface texture and finish to match adjacent panel.   |
| (6) Notched metal closures      | Manufacturer's standard to match exterior panel profile, gauge, color, and texture.   |
| (7) Clips, spacers, and shims   | Manufacturer's standard noncorroding.   |
| Flexible closers                | Manufacturer's standard neoprene or acceptable equal to match exterior face panel profile.  |
| (8) Fasteners                   | Material for fasteners shall provide maximum corrosion protection as required by the location and environmental exposure of the fastener. Exterior fasteners shall be stainless steel and shall have separate washers with bonded gaskets or integral self-sealing washers to seal the fastener penetrations. |

### 21.2.2 Metal Face Panel Finish

The interior and exterior finish for all types of the metal roof panels shall be manufacturer standard approved by Engineers. Coatings shall be applied Zincalume coated steel coil stock which has been prepared in accordance with the coating manufacturer's recommended procedures. All coatings applied to external sheets shall comply with the following.

#### (1) Exterior Face Sheet Outer Surface

- |                  |  |
|------------------|--|
| Metallic Coating | Zincalume coated in accordance with AZ150 or equivalent                                    |
| Barrier Coating  | 5 microns minimum, corrosion inhibitive epoxy primer coat                                  |
| Finish Coating   | 20 microns minimum, Custom Formulated System (Polyester), color to be selected by Engineer |
|                  | Total coated thickness excluding Zincalume to be a minimum of 25 microns                   |

#### (2) Exterior Face Sheet Inner Surface

Metallic Coating	Zincalume coated in accordance with AZ150 or equivalent
Barrier Coating	5 microns minimum corrosion inhibitive epoxy primer coat
Finish Coating	10 microns minimum, Custom Formulated Bass, Grey (Polyester)
Total coated thickness excluding Zincalume to be a minimum of 15 microns	

### 21.2.3 Finish Guarantee

The life time of the roof panel is expected about 20 years. However, the roof panel manufacturer and the Contractor shall guarantee the complete system including the finish, for no less than 10 years from the date of Provisional Acceptance of the Works by EGAT, against chalking; against color change; against blistering, cracking, checking, or loss of adhesion; and against corrosion.

If within the guarantee period the finish deteriorates beyond the provisions of this guarantee, the roof panel manufacturer and the Contractor shall promptly correct all defects by repairing or replacing the defective materials. The method of correction shall be acceptable to Engineer. The roof panel manufacturer and the Contractor shall be responsible for all costs associated with correction of the defects, including, but not limited to, shop and field labor and supervision, transportation, materials, parts, supplies, and special tools.

The roof panel manufacturer and the Contractor shall provide an additional guarantee for all repaired and replaced parts furnished under the original guarantee. The additional guarantee shall be for the remaining portion of the original 10 years.

Two copies of the finish guarantee shall be submitted with each proposal. After completion of all work, two additional copies of the guarantee, marked with the date of Provisional Acceptance of the Works by EGAT, shall be submitted to EGAT.

### 21.2.4 Material Tests

The coating system of the external steel sheet for roof has to meet the following performance criteria and test results and must be substantiated and certified by a recognized independent testing organization and submitted with the Bidder's proposal or shall be submitted within thirty (30) days after the bid opening date.

The reports and results of the following tests shall be submitted to Engineer, proving the compliance with the following requirements.

- (1) Color Change and Fade Resistance

A sample shall withstand the EMMAQUA test in accordance with ASTM E-838 or QUV test in accordance with ASTM D-2244 without cracking, peeling, blistering, or loss of adhesion.

(2) Abrasion Resistance Test for Coating System

A flat specimen shall be subjected to ASTM D-965 standard method of test for abrasion resistance of coating by falling sand method.

(3) Coating Systems Integrity Test

A sample shall withstand a salt-fog test for a minimum of 1,000 hours in accordance with ASTM B117, including the scribe requirement in the test. Immediately upon removal of the specimen from the test, the coating system shall show no signs of cracking, peeling, blistering, or loss of adhesion.

(4) Pollution Resistance Test

A flat specimen, with no protected edges, shall be subjected to the 30 cycles of Kesternich testing without blistering, peeling, or any other form of loss of adhesion. The Kesternich test consists of 8 hours of exposure at 40°C with 100 percent relative humidity (condensation) in a controlled sulfur dioxide (SO<sub>2</sub>), carbon dioxide (CO<sub>2</sub>) atmosphere. Atmospheric concentrations of pollutant gasses shall be in accordance with the maximum requirements (2 liters) given in the Kesternich test standards DIN 50018. This is followed by 16 hours of dry time, which concludes one cycle of testing.

(5) Humidity Resistance Test

A sample shall be tested for 1,000 hours at 40° C in accordance with ASTM D2247 with no blistering, peeling, or loss of adhesion.

The above tests shall be applied to the outer surfaces of the external sheeting. For the inner surface of the external sheeting only the humidity resistance tests need to be applied.

## **21.3 EXECUTION**

### **21.3.1 Fabrication**

All metal roof panel systems and their components, including flashings and trim, shall be factory formed and designed, detailed, and fabricated in accordance with these specifications and the details on the drawings to tolerances which, when erected, will assure proper fit and uniform appearance.

Panel system components shall be designed, detailed, and fabricated so that the completed systems shall be resistant to wind, rain, and dust infiltration.

Flat liner panels and flat surfaces of face panels shall have a smooth appearance and shall be free of excessive "oil canning." Panels having excessive "oil canning" as determined by Engineer will be rejected.

Panels shall be provided with internal stiffeners which will make them rigid in service. Side joints of interior panels shall be of interlock construction and shall be caulked full or gasketed at the factory. Side joints of face panels shall be of lap type construction and shall be tape caulked in the field. Panels shall be fabricated in lengths which will minimize horizontal joints in the completed construction. End joints of exterior fluted panels, both insulated and uninsulated, shall provide an overlap of the upper panel over the lower panel of at least 50 mm.

### **21.3.2 Panel Protection**

All panels, copings, flashings, and closures with a shop applied finish shall be properly protected against dents, scratches, abrasions, and surface contamination during shipment, handling, and storage. External sheets shall have plastic interleaving for shipment.

### **21.3.3 Gutter and Downspout**

Eave gutter shall have a cross-sectional area of not less than 220 cm<sup>2</sup>. The gutter apron shall extend under the roof panels to provide positive counter-flashing. The outside face of the gutter shall be supported with 1.5 mm minimum, hot dipped galvanized steel straps attached to the eave member at a maximum spacing of 800 mm.

Downspouts shall be rectangular configuration in the sizes indicated on the drawings. Each downspout shall have a 75 degree elbow at the base and shall be supported with minimum 0.48 mm galvanized steel clincher bands attached to the wall covering at a maximum spacing of 3 m.

Gutter and downspout material shall be stainless steel No. 18. or approved by the Engineer. The use of alternative material shall be subjected to the approval of the Engineer.

### **21.3.4 Flashings**

Flashings shall include all materials adjacent to metal roof panels referred to as flashings, copings, hoods, trim, or closures, and shall be fabricated from the material specified, with finish and color matching the material being flashed. Exposed edges of all flashings shall be hug-edged or hemmed. Both surfaces shall be coated to match the material being flashed.

### **21.3.5 Roof Curbs**

Roof curbs for equipment support shall be made of flashings to match the configuration of the roof panel to allow nesting with the roof panel ribs. The upper side of the flashing shall have a diverter to channel water around the curb. Curbs shall be fabricated as required to make a watertight installation.

### **21.3.6 Panel Joints**

Horizontal panel joints shall be located at the same elevation on all surfaces of the building to the greatest extent possible. Joints shall be located at structural steel girt locations.

### **21.3.7 Shop Applied Caulking**

Where panels are specified to be supplied with shop applied caulking, nonsag caulking shall be applied over the full length of the panel joint and shall be applied in depth sufficient to seal the joint during field erection, but not less than half the joint depth. Panels delivered to the jobsite with insufficient caulking will be rejected and shall be recaulked to the satisfaction of Engineer.

### **21.3.8 Cleaning**

Fabricated galvanized or Zinalume coated steel materials not specified to be otherwise finished shall be cleaned and prepared to receive field applied coatings with no additional cleaning or preparation.

### **21.3.9 Installation**

The installation of the roof panel system shall conform to the instruction of the manufacturer.

End of Chapter 21

## **CHAPTER 22 - ROCK STABILIZATION AND SUPPORTS**

**TECHNICAL SPECIFICATION**  
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## CHAPTER 22 - ROCK STABILIZATION AND SUPPORTS

### 22.1 GENERAL

#### 22.1.1 Scope

This Chapter covers shotcrete, rockbolts and grouted anchor bar including all labor, materials, tests, equipment and services. Shotcrete shall be used as slope protection, support in underground structures and various kinds of thin linings. Rockbolts and grouted anchor bar shall be required to protect, stabilize, or support rock masses uncovered in the course of surface excavation works as well as anchoring of the concrete structures into surrounding or underlying rock.

#### 22.1.2 Definitions

##### 22.1.2.1 Shotcrete

**Shotcrete** is defined as a mixture of Portland cement, aggregates, water, admixtures, and/or reinforcement, if applicable, shot into place by means of compressed air through a spray nozzle.

**Rebound** is defined as the constituents of shotcrete that rebound from the surface during the application of shotcrete.

**Micro Silica** is defined as the finely divided residue resulting from the production of silica or silicon which contains alloys and is carried from the burning surface area of a furnace by exhaust gases.

##### 22.1.2.2 Rockbolts and Grouted Anchor Bar

**Reinforcement Element** is a general term for rockbolts, bars, and rock anchors.

**Rockbolt** is a stressed (or tensioned) reinforcement element consisting of a rod, a mechanical or grouted anchorage, and a plate and a nut for stressing by torque the nut or for retaining tension applied by direct pull. It is synonymous with “active rock anchor”.

**Grouted Anchor Bar** is an untensioned reinforcement element consisting of a rod embedded in a mortar or grout filled hole. It is synonymous with “passive rock anchor” and “rock dowel”.

**Individual Anchoring** refers to the installation of reinforcement elements in localized areas of instability or weakness as determined during excavation. It is synonymous with “spot anchoring”.

**Pattern Anchoring** refers to the installation of reinforcement elements in a regular pattern over the excavation surface.

### **22.1.3 Submissions**

#### **22.1.3.1 Shotcrete**

At least sixty (60) days prior to applying any shotcrete, the Contractor shall submit to the Engineer for his approval, drawings of plant arrangement, details of all equipment, method of operation, type and dosage of admixtures and mix proportions.

At least thirty (30) days prior to applying any shotcrete, the Contractor shall prepare at least three (3) test panels for each admixture to be used.

#### **22.1.3.2 Rockbolts and Grouted Anchor Bar**

The Contractor shall submit the following documents to the Engineer:

a) All pertinent information regarding the type and quality of rockbolts he proposes to use together with manufacturer's instructions and certificates, methods of installations and testing the suitability, testing equipment and for grouted rockbolts and anchor bars, the grouting system.

The contractor may propose alternative types of rockbolts to those described in this Chapter, but acceptance by the Engineer will be subject to full demonstrations of the alternative adequacy.

b) Complete details concerning type, and materials of the post-tensioned rock anchors he proposes to use together with manufacturer's instructions and certifications, methods of installation, corrosion protection, stressing equipment, grouting method and equipment, proposal for testing, stressing tests and equipment.

c) Design, calculations and fabrication details and lagging including size, steel quality, accessories and methods of installation together with certified copies of manufacturer's reports. The Contractor may propose multi-hinged steel supports with appropriate fittings of adaptation of the rib form and its installation as close as possible to the rock surface.

The Contractor shall submit to the Engineer for review his proposed materials delivery schedule. Any amendments to the delivery schedule, proposed by the Contractor as the work proceeds, will also have to be reviewed by the Engineer, and none of the above materials shall be transported to the Site without the Engineer's consent.

Contractor's shop drawing of structural steel supports shall be submitted to the Engineer prior to their installation.

The Contractor shall record the results of all tests performed on the rockbolts and post-tensioned anchors prior, during, and after their installation; and register the readings taken at the load cells installed; and submit these documents to the Engineer.

## 22.1.4 Standards and Codes

Shotcrete	ACI 506R "Guide to Shotcrete"
Rockbolts	TIS 24-(Latest Version) SD40 or equivalent
Grout Anchor Bars	ASTM Specification A615 M, Grade 400 or equivalent

## 22.2 MATERIAL

### 22.2.1 Shotcrete

#### 22.2.1.1 Cement

Cement shall comply with the requirements of Chapter 10 "Concrete" in the Specifications.

#### 22.2.1.2 Aggregates

Fine and coarse aggregate shall comply with the requirements of Chapter 10 "Concrete" in the Specifications, except that the grading of the combined aggregate shall conform to the table below, unless otherwise approved by the Engineer.

Sieve Size U.S. Standard Square Mesh	mm	Percentage by Weight Passing Sieve
3/8"	9.51	100
No. 4	4.76	95 - 85
No. 16	1.19	85 - 45
No. 50	0.30	35 - 10

#### 22.2.1.3 Admixture

The Contractor may use admixtures in shotcrete to enhance certain shotcrete properties. Admixtures shall meet the requirements of the appropriate ASTM specifications below:

Air-entraining admixture	; ASTM C260
Water-reducing admixture	; ASTM C494
Accelerator agent	; ASTM C494
Pozzolanic admixture	; ASTM C618

Micro silica in shotcrete types (VI), (VII) and (VIII) shall be of powder type and meet the following requirements.

SiO <sub>2</sub>	≥ 85%
SO <sub>3</sub>	≤ 1.0%
Loss of ignition	≤ 6.0%

Any admixture shall be added to the batch in solution form as a portion of the mixing water. The concentration of admixture shall be within the tolerance approved by the Engineer.

Any kind of admixture containing calcium chloride will not be permitted.

The 28-day compressive strength with the accelerator agents shall be more than 80% of that without ones.

The Contractor shall demand proof from suppliers of such admixtures for proper use in works.

Under no circumstances shall admixtures be added manually. Only automatic devices shall be used.

When the Wet Mix Method will be applied, no water glass shall be used as accelerator agent.

The costs for admixtures shall be included in the unit prices for shotcrete in the Bill of Quantities.

#### **22.2.1.4 Water**

The mixing water used for shotcrete shall conform to the requirements of Chapter 10 "Concrete" of the Specifications.

#### **22.2.1.5 Reinforcement**

The quality of material of wire mesh netting shall be ST-37 or equivalent approved by the Engineer and the spacing of mesh shall be 10 to 15 cm with the diameter of wires to be 3 to 5 mm.

Steel fibers to be used for shotcrete as a reinforcement shall be 1.0 to 1.5 inches long (25 mm to 38 mm), and steel fiber reinforced shotcrete shall incorporate steel fibers 1.5% by volume of total mixture.

#### **22.2.1.6 Equipment**

All equipment and plant required to perform shotcrete operation shall be subject to the approval of the Engineer.

The Contractor shall be fully responsible for the use of appropriate equipment. This responsibility shall rest with him in case sub-contractors may be engaged for this work.

The Contractor shall make available all and any equipment, machinery, etc. meeting the requirements of the shotcreting procedure, particularly with respect to the workmanlike operation of shotcrete.

The Contractor shall inform the Engineer of the brand names and type, number and capacity of the shotcreting machines he proposes to use, together with all other equipment required to carry out the shotcrete operations.

All equipment required to prepare, mix and place shotcrete shall be kept clean and maintained in good operating condition at all times during the performance of the works.

Batching and mixing equipment shall conform to the requirements of the Specifications. The equipment shall be capable of batching and mixing the specified materials in sufficient

quantity to provide uniform quality of shotcrete mix. Batching by weight shall be used unless otherwise approved by the Engineer.

The shotcreting machine shall have an adequate placing capacity to ensure no delays to excavation and other operations. The equipment shall be such that the admixture can be mixed satisfactorily and immediately before placing. The Contractor shall ensure that adequate air and water is supplied to the machine, as specified by the equipment manufacturer and as directed by the Engineer.

If operation of shotcreting equipment becomes unsatisfactory, the Contractor shall make all necessary repairs or replacement of the equipment.

In all areas where excavation is proceeding, the Contractor shall ensure that sufficient equipment is available to apply shotcrete at any face, as specified herein.

### **22.2.2 Rockbolts and Grouted Anchor Bar**

#### **22.2.2.1 Rockbolt and Anchor Bar**

The following types of reinforcing elements shall be used:

- a) “Perfo” type
- b) Expansion-shell type, ungrouted
- c) Expansion-shell type, grouted
- d) Post-tensioned, cement-bonded type
- e) Resin-grouted type
- f) Swellex-type

#### **22.2.2.2 Cement Grout**

Materials used for cement grout shall conform to materials specified in Chapter 8, Grouting

#### **22.2.2.3 Chemical Grout**

Materials used for chemical grout shall conform to materials specified in Chapter 8, Grouting.

## 22.3 EXECUTION

### 22.3.1 Shotcrete

#### 22.3.1.1 General

Types of shotcreting work in the payment items of the Bill of Quantities are classified below:

APPLICATION	TYPE	THICKNESS (cm)	REINFORCEMENT
Open Surface	0	7	None
Tunnel and Shaft	I	7	None
	II	10	None
	III	10	Wiremesh
	IV	15	Wiremesh
	V	20	Wiremesh
Powerhouse Cavern	VI	8	Steel Fiber
	VII	16	Steel Fiber
	VIII	24	Steel Fiber

Shotcreting is usually classified according to the execution process, wet-mix or dry-mix. The Contractor shall apply the wet-mix process for shotcrete types (VI), (VII) and (VIII). For another types of shotcrete, the Contractor can apply the dry-mix or the wet-mix process as approved by the Engineer.

Attention shall be paid to the adequate storage and transportation of aggregates, and necessary precaution shall be taken against special weather conditions, i.e., heavy rainfall.

Where very poor rock conditions are anticipated, the Engineer may require that shotcrete equipment be available before blasting so that shotcrete can be applied with the minimum of delay.

#### 22.3.1.2 Proportioning

The required mix proportions of cement, aggregates, water and suitable admixture shall be proposed by the Contractor for the approval of the Engineer.

The Contractor shall proportion the mixtures in accordance with the types of shotcrete as specified below.

- a) Shotcrete (0), (I), (II), (III), (IV), (V)

Cement contents : not less than 350 kg/m<sup>3</sup>

Water/cement ratio : 0.40 - 0.45

b) Shotcrete (VI), (VII), (VIII)

Cement contents	:	not less than 420 kg/m <sup>3</sup>
Micro silica	:	8-13% of the weight of cement
Steel fiber	:	1.5% of volume of the total mixture

### 22.3.1.3 Preparation of Surfaces

All loose rock and also all sharp protruding edges as well as dirt, grease, oil, scale and other contamination shall be removed from the surfaces.

The Contractor shall thoroughly clean the surface with water-jet or compressed air, if instructed by the Engineer.

Seepage water entering locally shall be dealt with by suitable means. Water shall be kept free from contact with the fresh shotcrete until it has sufficiently set.

### 22.3.1.4 Installation of Wire Mesh

Wire mesh to be used shall be of an approved type in accordance with the Specifications herein. Wire mesh shall be covered with shotcrete at least 2 cm and shall not be placed in principle at the neutral zone of the shotcrete shell.

It shall be held securely in place by sufficient devices to enable proper fixing of the wire mesh. Fastening bolts/devices shall be placed sufficiently dense to minimize vibration of the wire mesh during shotcretings and the excess volume of shotcrete itself as well.

Minimum overlapping of wire mesh shall be generally 1 mesh in longitudinal direction and 2 meshes in circumferential direction.

### 22.3.1.5 Mixing

The optimum shotcrete mix contains less water than what will cause sloughing, and just enough cement for the desired water/cement ratio.

The non-lift mixing process shall take at least two (2) minutes and the composition of the ready mix shall remain unchanged until it is applied.

During handling, the mixed shotcrete shall be protected against dripping water.

The use of ready mix from transit-mixing plants is allowed for subordinate structural parts only and is subject to the approval of the Engineer.

The maximum time allowed for placing shotcrete after mixing will be determined by the Engineer. Shotcrete charges which are already in condition of hardening shall not be placed and shall not be used in any part of the work.

### **22.3.1.6 Placing**

#### **22.3.1.6.1 General**

Prior to start of shotcreting operations in any area, the Contractor shall establish operating procedures of shotcrete which will produce the best quality product with the minimum rebound. Such establishment of procedures shall include minor variations to mix, if required, and the establishment of acceptable finishes and thicknesses of layers and quantities to be discharged at the nozzle to a unit area of rock or other surfaces, as required by the Engineer.

The quality of the placed shotcrete depends to a large extent on the experience and reliability of the spraying crew, on the proper nozzle spacing and on the correct spray angle. Therefore, only skilled labour having experience of that particular kind of work shall be employed on the work.

The minimum thickness of shotcrete shall be 70% of the designed one and the average thickness of shotcrete shall not be less than the designed one. The minimum coverage over wire mesh netting shall be not less than 2 cm. The minimum coverage over protruding rock surface shall be not less than 3 cm.

In order to easily measure the thickness of shotcrete the Contractor shall embed a certain length of steel pins prior to application, the standard number of which shall be six per one section with 5 m interval in tunnels or shafts, and one per shotcreted area of 25 m<sup>2</sup> in powerhouse cavern or open works.

The flow of the material at the nozzle shall be continuous and uniform and the rate of application over any given area shall be uniform. Slugs, sand spots, wet areas or other defects shall be cut out and corrected as specified herein.

When shotcreting is to be performed near existing structures, the Contractor shall ensure that no damage results to the structure and shall protect the surfaces of structures before shotcreting.

All steel parts such as rockbolts, prestressed rock anchors and steel supports and the like remaining in the shotcrete permanently shall be covered throughout their entire extent by at least 2 cm of shotcrete.

When shotcrete of 15 cm or more in thickness are to be applied to vertical or overhanging surfaces, the shotcrete shall be applied in two or more layers and not more than 10 cm thickness per layer to prevent sloughing of the freshly placed material.

Before a succeeding layer of shotcrete is placed, the preceding layer shall be checked against drumliness, to the satisfaction of the Engineer. The Contractor shall repair all drumly, sandy, cracked or spalled areas and any other areas where, in the opinion of the Engineer, the shotcrete is faulty, by removing the shotcrete to a sound rock or shotcrete, carrying out surface preparation as specified herein and reshooting that area to the satisfaction of the Engineer.



#### **22.3.1.6.2 Detail Operations**

The quantities of shotcrete to be discharged at the nozzle shall be determined on the basis of the average thickness of executing shotcrete taking due account of rebound. Once procedures for the placement of shotcrete are established, subsequent work shall be carried out accordingly.

The water pressure shall be greater than the air pressure in case of the dry-mix process to ensure complete wetting of the materials at the nozzle and to give the nozzle man a quick, positive control. The compressed air shall be dry and water separators shall be installed at compressed air supply pipes.

In case of applying the wet-mix process, the air pressure recommended by the manufacturer's instructions shall be maintained.

Compressed air and pressure water shall be free from oil and shall not be liable to pressure fluctuations.

The distance between the nozzle and the surface to be shotcreted shall be not more than 1.5 m.

Where invert shotcrete has to be placed, all efforts have to be made in order to minimize the amount of rebound. Connection of invert shotcrete to existing side wall shotcrete shall be accomplished by overlapping wire mesh as instructed by the Engineer.

Any adherent rebound and/or loss or clogged material from previous shotcreting shall carefully be removed before shotcreting.

Special lighting shall be provided at the working area.

#### **22.3.1.7 Rebound**

Rebound shall be kept to a minimum, continuously watched, and at the request of the Engineer its kind and quantity shall be ascertained. It shall be entirely removed and under no circumstances may it be sprayed over or even used again as spray material.

#### **22.3.1.8 Drain Holes**

The Contractor shall propose to the Engineer for his approval the length, size and spacing of drain holes to be drilled.

Where drain holes have been drilled and drain pipes have been installed into rock, on which shotcrete is to be placed, the Contractor shall take all necessary precautions to prevent such holes from being plugged or pipes from being damaged.

#### **22.3.1.9 Curing**

During a period depending on local conditions and to be agreed upon with the Engineer, the freshly placed shotcrete shall be protected against sunshine, cold, rain, running water, chemical attack, and vibrations until it hardens, and it shall be kept moist for at least seven (7) days.

If shotcreting is carried out under adverse weather conditions or low temperatures, a protection of placed shotcrete shall be provided.

In case of shotcreting at open works, the surface shall be protected from the direct rays of the sun for the first three (3) days

### **22.3.2 Rockbolts and Grouted Anchor Bar**

Unless otherwise approved by the Engineer, these specifications shall govern.

#### **22.3.2.1 General Requirements**

The type, length, diameter, inclination and pattern of the anchors shall be proposed by the contractor, to be reviewed by the Engineer, except when the dimensions are explicitly shown on the construction Drawings.

Anchors and rockbolts shall be furnished complete with all accessories and other materials necessary for their installation, stressing and grouting.

Bearing plates shall be flat or dished steel plates of minimum dimensions of 150 x 150 x 10 mm, and shall conform to ASTM Specification A 36. The bevel or hemispherical washers shall be made of steel conforming to ASTM Specification F 432. The nuts shall be heavy hexagonal type. Where the above components are to be used with grouted rockbolts, they shall be hot-dip galvanized, with a coating mass not less than 0.6 kg/m<sup>2</sup>.

All surfaces of the bearing plates, nuts, washers and wedged, and threads on the projecting ends of rockbolts shall be protected and lubricated with rust preventive compound.

If approved by the Engineer, the Contractor may supply and install flat steel plates or rolled steel sections to connect together two or more rockbolts. The steel plates and section shall conform to ASTM Specification A 36.

When anchor and rockbolts are used in conjunction with wire mesh, the mesh shall be connected firmly to the bolts by means of extra steel plates and nuts. Wire mesh shall not be placed between rock and the bearing plate for the rockbolt.

Rockbolts shall be provided with devices for load and deformation measurement.

The rock stabilizing and supporting measures to be undertaken during or after the course of excavation work for constructing the Works in a safe manner will be determined by the contractor and reviewed by the Engineer, based on the known or presumed behavior of the rock or ground mass.

In case of emergency or unforeseen exigency, the Contractor is authorized and obliged to undertake independently such supporting measures as he deems necessary without prior consent of the Engineer. In such cases the Contractor shall inform the Engineer of this concern immediately.

The Contractor is responsible for timely (can vary between hours to days) application of stability measures, which shall prevent dilation and corresponding reduction in strength of

the earth or rock mass. In general, each excavation front shall be protected before the next excavation stage proceeds.

Rock stabilization measurement required as permanent feature of the Works (e.g., post-tensioned anchors) shall be installed.

Nothing contained in this Clause shall be construed to relieve the Contractor from sole responsibility for the safety of the Works nor for liability for injuries to, or death of persons or damage to property, nor of any of his obligations under this Contract.

An adequate quantity of rock support materials and equipment shall be stored by the Contractor at the construction sites and be kept ready for immediate use during the whole construction period.

#### **22.3.2.2 Testing and Monitoring of Rockbolts**

The Contractor shall furnish a least 1 sets of testing equipment including hydraulic jacks, fixing device, hydraulic pump with manometer, extensimeter, and all necessary accessories. The testing equipment shall be capable of stressing the largest diameter rockbolt to the yield stress of the bolt.

Prior to the installation of rockbolts in the Works, a series of pull-out test shall be carried out in different rock types designated by the Engineer and which will be representative of the rock expected to be encountered during the excavation, to prove the suitability of the rockbolts proposed by the Contractor. During the pull-out test, both the load applied and movement undergone shall be measured. At least 5 test shall be required for each combination of the rock type/installation condition to be able to assess the suitability of the rockbolt. The pull-out tests shall be carried out sufficiently in advance of the installation of the rockbolts in the Works so that, in the event that the rockbolts proposed by the Contractor do not meet load-strain requirements, the Contractor shall have time to furnish and test rockbolts of a different type. The Contractor shall maintain detailed records of the pull-out tests, the result of which will be used to establish relationships between rock quality and type of rockbolts and tensioning.

During progress of the work the Contractor shall perform pull-out tests, in the presence of the Engineer, on at least 3 per 100 rockbolts installed. The Engineer will determine the bolts to be tested.

Grouted expansion-shell type rockbolts shall be tested before grouting. Other type of rockbolts shall be tested after the mortar or resin have achieved their design strength.

As a part of a monitoring program during the progress of the work, expansion-shell type rockbolts shall be fitted with mechanical read out load cells. Approved load cells which allow to measure the increase or decrease in load in the bolt to an accuracy of 2% shall be supplied by the Contractor, who shall measure the deformation undergone and record the loads registered each load cell nested twice a month and submit the results to the Engineer within 48 hours of taking such readings. Such load cells shall be installed on the ungrouped rockbolts only.

### 22.3.2.3 Drilling Holes and Preparation for Installation

Holes for rockbolts and grouted anchor bars shall be drilled as specified herein.

The diameter of each hole shall be in accordance with manufacturer's recommendations except for grouted anchor bars where the hole diameter shall be at least 1.5 times that of the rod specified for that hole.

The length of drillhole shall be such as to receive the specified rockbolt and to provide for its satisfactory anchorage. The downward holes shall be extended 15 to 20 cm. beyond the length of the rockbolt.

After drilling in compact washable rock, each hole shall be washed out with clean water and cleaned by blowing out all drill cuttings and debris with compressed air. The holes in rock which tend to swelling or is interspersed with clay filled fissures shall be cleaned with compressed air only. The compressed air shall not contain any oil or other material preventing bond.

Prior to installing the rockbolts which will be stressed, the rock surface adjacent to the hole shall be prepared for the bearing plate. When the surface is not perpendicular to the hole axis, bevel washer shall be placed between the bearing plate and the nut, or dished bearing, plate and hemispherical washer used, to ensure uniform bearing.

If a rockbolt is not installed immediately after drilling the hole, the hole shall be washed and cleaned as stipulated above immediately prior to installing the rockbolt.

### 22.3.2.4 "Perfo" Type

A bolt of the "Perfo" type consists of two perforated half round sections of sheet metal, which shall be filled with mortar, wired together and installed in a hole. A deformed steel reinforcing bar is inserted, manually or with a compressed air hammer, into the tube causing the mortar to squeeze through the perforations and bond to sides of the drillhole.

The sheet metal shall have a minimum wall thickness of 1 mm.

The deformed steel bars shall be 20, 25 or 32 mm diameter, as shown on the Construction Drawings, of Grade 400 with a yield strength of not less than 400 N/mm<sup>2</sup> which shall conform to ASTM Specification A 615 M. The bars shall taper at one-end over a length of 50 mm to a point and shall be threaded at the other.

The mortar for filling the "Perfo" tube shall consist of portland cement Type I, water, and washed sand with a maximum size equivalent to that passing a U.S. Standard Sieve No.8 (2.36 mm). The cement to sand ratio shall be 1:1. The mix proportion and accelerator admixtures, if used, shall be reviewed by the Engineer.

The following drillhole/tube/bar diameter relationships shall be maintained if not otherwise recommended by the manufacturer:

Drillhole Diameter	Internal Diameter of Tube	Bar Diameter
32 mm	27 mm	20 mm
38 mm	32 mm	25 mm
45 mm	38 mm	32 mm

“Perfo” type may be used as active as well as passive rock reinforcement. Should stressing of the bar required, it shall be performed according to manufacturer’s instructions.

#### **22.3.2.5 Expansion-Shell Type**

Expansion-shell (or mechanical-anchor) type rockbolts shall be 22 mm diameter as manufactured by Dyckerhoff & Widmann AG (Dywidag) of Germany, or similar as approved by the Engineer, they shall be supplied complete with all accessories required for installation, stressing and grouting.

Rockbolts in underground excavations which will be covered by permanent concrete lining and those in open cuts which will be back-filled later shall be ungrouped. Rockbolts installed as a permanent supports of open cuts or anchoring of concrete structures shall be grouted.

The method and equipment used of installation, to effectively seat, and to stress the expansion-shell rockbolts shall be in accordance with the manufacturer’s instructions.

The rockbolts shall be stressed, immediately after installation in the hole, by torquing or jacking, by means of an approved and regularly calibrated stressing device, to two-thirds (67%) of their yield point stress, unless otherwise specified by the manufacturer on the basis of values established during pull-out tests.

After initial installation, the contractor shall ensure that the rockbolts continue to act as effective supports by periodically testing the rockbolts and, if necessary, retightening to the directed torque or tension.

Grouting, if equipped, of the expansion-shell rockbolts shall be performed without distressing the bolt. Grouting shall be performed as soon as practicable after, but in any case within 21 days, of rockbolt installation. The bearing plate shall be caulked around its perimeter and grout shall be introduced into the hole through a plastic tube fixed to the shaft and extended to ousted through a hole provided in the bearing plate, at a pressure sufficient to fill completely the space around each bolt for the length without any air-pocks remaining inside the hole.

Cracks and fissures adjacent to the rockbolt which the grout is found to be flowing from, during, the grouting operation, shall be plugged or caulked.

No blasting may be performed within 15 m of a grouted rock bolt until 5 days after grouting if no accelerator had been used in the grout.

### 22.3.2.6 Post-tensioned Cement-Bonded Type

For post-tensioned cement-bonded type rockbolts the “GD-TOPAC” cartridges containing accelerator or similar as approved by the Engineer shall be used in the grout.

The deformed steel bars shall be 20, 25 and 32 mm diameter of Grade 300 with a yield strength of not less than 300 N/mm<sup>2</sup> and shall conform to ASTM Specification A 615 M.

In the first step the anchorage zone in the deepest portion of the drillhole shall be filled with plastic mortar on the length of GD-TOPAC cartridge, or cartridges if more than one are used, and the cartridge inserted into it. The rest of the drillhole shall be filled with mortar prior to inserting the steel rod into the hole. The rod consisting of a reinforcing steel bar with one end tapered shall be inserted with a compressed air hammer. The tapered end of the bar will tear the cartridge open and allow mixing of the accelerator with the mortar.

Stressing of the bar shall be carried out after 1 to 3 hours depending on the required stressing load and according to manufacturer’s recommendations.

The following drillhole/bar diameter relationships shall be maintained if not otherwise recommended by the manufacturer:

Drillhole Diameter	Bar Diameter
28 mm	20 mm
36 mm	25 mm
45 mm	32 mm

### 22.3.2.7 Resin-Grouted Type

For resin-grouted type rockbolts the “TITAN” resin cartridges or similar approved by the Engineer shall be used as developed by the Society des Explosives Titanic .

Manufacturer’s directives concerning the time restrictions for utilization of resin cartridges shall be strictly observed. The resin package which shows signs of hardness or other indications of deterioration shall not be used.

The cartridge consist of cylindrical charge made up of a double walled tube of impermeable paper closed at each end. A catalyst is spread uniformly between the two walls and the resin mixed with a mineral is enclosed in the internal envelope.

The cartridges shall be pushed into the drillhole for the full length of the hole. The rod consisting of reinforcing steel bar with one end tapered shall be inserted with a compressed air hammer at the velocity of approx. 1 m per 20 seconds. By rotating the bar the cartridge will be torn and the catalyst mixed with the resin.

The rapidity of the polymerization and hardening of the resin shall be such that the steel bar will not fall out of the upward hole due to its own weight by the time the tapered end of the bar has reached the end of the hole. The bar shall be able to sustain in dry ground the tractive force equal to its yield point strength 15 minutes after inserting the bar into the hole.

Resin-grouted type can be used as active as well as passive rock reinforcement. Should stressing be required, a cartridge containing fast-setting resin for anchoring the bar shall be pushed into the deepest portion of the hole. The rest of the hole shall be filled with cartridges containing slow-setting resin grout which allows the stressing of the bar.

The following drillhole/bar diameter relationships shall be maintained if not otherwise recommended by the manufacturer;

Drillhole Diameter	Bar Diameter
28 mm	20 mm
34 mm	25 mm

#### **22.3.2.8 Swellex-Type**

Swellex rockbolts shall be standard type of 110 kN ultimate load capacity, as developed by Atlas Copco.

The bolt is manufactured from steel tube which has been deformed to assume an outer diameter of 28 mm. Bushes are pressed onto the ends and sealed by welding. One of the bushes holds the washer. Small hole is drilled through this bush for high pressure water injection (up to 300 bar) under which the bolt expands in the drillhole. After releasing the pressure, the rock mass surrounding the bolt contracts around the bolt which results in a mechanical locking effect.

The drillhole diameter shall be as recommended by the manufacturer.

#### **22.3.2.9 Grouted Anchor Bars**

The grouted anchor bars will not be stressed. The rods shall be fully grouted with resin or cement mortar grout.

The rods shall be deformed reinforcing steel bars with the yield strength of not less than 400 N/mm<sup>2</sup> conformant to ASTM Specification A 615 M, Grade 400. The diameter of anchor bars shall be 20, 25 and 32 mm and the length and position shall be as shown on the Construction Drawings.

The surface for anchor bars shall be clean of rust, scale, dirt or other foreign matter.

Holes drilled for anchor bars shall be kept plugged until just prior to commencement of grouting operations. Before grouting each hole shall be thoroughly flushed with water and cleaned with compressed air.

Where possible, water shall be removed from the hole before grouting. If the hole cannot be kept dry during grouting, the grout shall be introduced into the end of the through a pipe which shall be gradually withdrawn as the hole is filled.

Portland cement type I shall be used for the grout mixture. Grout shall have a water to cement ratio of between 0.4 and 0.6 by weight, and a sand to cement ratio of 3:1 by weight or as approved by the Engineer. Admixtures if used, shall be approved by the Engineer.

The anchor bar shall be forced into the grout-filled hole before the initial set of the grout. The bar shall be vibrated or tapped in order to ensure good contact between the steel surface and the grout.

Bar ends to be embedded in the concrete structure shall be provided with hooks welded to the bar to provide a good anchorage. In order to facilitate the inserting of the bar into the hole the bar end shall overlap the hooks by at least 4 cm.

Anchors bars shall be protected after installations in such a manner as to prevent any movement until the grout has hardened. The Contractor shall replace any bars found to be loose after the grout has set.

The depth of holes indicated on the Drawings shall be measured from the effective excavation surface. Should the anchor bars be connected to the reinforcement steel of the concrete structure to be anchored, longer bars shall be provided in case of over-excavation, to maintain the required position in the structure.

End of Chapter 22



## **CHAPTER 23 - PLUMBING**

## TECHNICAL SPECIFICATION

### CHAPTER 23 - PLUMBING

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## CHAPTER 23 - PLUMBING

### 23.1 GENERAL

#### 23.1.1 Scope

The work to be covered in this chapter consists of furnishing and installing of plumbing system as shown on the Drawings.

#### 23.1.2 Submissions

The Contractor shall submit the instruction books on the operation and maintenance of principal equipment furnished and installed by him under this clause two (2) months before the start of installation work.

The following items shall be submitted to the Engineer for review prior to commencement of the work.

- General arrangement of piping, plan and isometric diagram
- Descriptive literature of plumbing fixtures and accessories
- Samples of pipes, fixings, valves, drains, cleanouts and any other items enquired by the Engineer

Those samples shall be used as standard for comparison with installed ones. If needed by the Engineer, catalogues of any sample shall be submitted.

All pipes, fittings, and valves shall be certified or clearly stated by the manufacturer as conforming to specifications noted. Furnish plan indicating location of all inserts, sleeves, drains, cleanouts, etc.

#### 23.1.3 Standards and Codes

The plumbing installation shall be in accordance with the following codes and standards:

- a) E.I.T. 1004-16, 1996 Thai Plumbing Standard.
- b) ANSI A40.8 American Standard National Plumbing Code.
- c) Thai Industrial Standard (TIS)

The applicable TIS for materials used in the plumbing system shall be as follows:

TIS 276-2521	Steel pipes
TIS 277-2522	Galvanized steel pipes with threaded ends
TIS 17-2532	Polyvinyl chloride pipes
TIS 1032-2534	Solvent welding cement for use with unplasticized PVC pipes and fittings

Other materials not covered by TIS shall meet the following standards or as approved by the Engineer:

ANSI	American National Standards Institute
------	---------------------------------------

ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
BS	British Standard Specification
JIS	Japanese Standard Specification
SFS	Standard of Finland Specification

## **23.2 MATERIAL**

### **23.2.1 Water Supply, Soil, Waste, Vent and Drainage Pipe**

Water supply pipe within the buildings, soil, waste and drainage pipe, shall be polyvinyl chlorine (PVC) pipes Class 13.5, conforming to TIS 17-2532, with solvent cement welded PVC fittings or threaded type PVC fittings, where connected to valves or threaded equipment.

Rainwater pipes shall be galvanized steel pipes with threaded ends, medium grade, conforming to TIS 277-2522

### **23.2.2 Valve and Union**

#### **23.2.2.1 Gate Valve**

- 1/4" to 2" shall be forged brass (or bronze) and 2 1/2" to 4" gravity die cast brass
- Non rising stem, solid brass wedge, high quality lubricated packing
- BS 21 Taper Thread
- Pressure (max. working), BS 5154 PN16 Series B, 7 bar at 170°C (hot) and 16 bar from -10 to 100°C (cold)
- Test pressure (hydraulic), BS 5154, shell: 1.5 times Pressure (max. working) at 20°C and seat: 1.1 times Pressure (max. working) at 20°C. The minimum test duration 5 second as per BS 5154.
- Dia. of the water pipe shall not less than full nominal dia. of the valve.

#### **23.2.2.2 Check Valve**

- Lift type
- Horizontal or vertical fixing (upward flow only)
- Metal seat and swing type metal disk, with flow indication arrow
- BS 21 Taper Thread
- Pressure (max. working), BS 5154 PN16 Series B, 7 bar at 170°C (hot) and 16 bar from -10 to 100°C (cold)
- Test pressure (hydraulic), BS 5154, shell: 1.5 times Pressure (max. working) at 20°C and seat: 1.1 times Pressure (max. working) at 20°C. The minimum test duration 5 second as per BS 5154.

#### **23.2.2.3 Pressure Reducing Valve**

- Bronze body with double female ends, LG2
- Provides reliable adjustment between 1.50 and 5.50 bar
- Pressure gauge connection nipple female angled "1/4"
- Stainless steel spring SAE 302

- Nuts and bolts BS 5216

#### **23.2.2.4 Union**

- All unions shall be rated not less than 12 bar water working pressure. For pipes 60 mm diameter and smaller shall be screwed type.
- Sufficient number of unions shall be used to permit readiness and convenience for disassembly of piping.

#### **23.2.3 Miscellaneous Fittings**

##### **23.2.3.1 Water Trap**

A trap shall be provided for each fixture and piece of equipment requiring connection to the sewer system, except fixtures or equipment having an integral trap or seal. Each trap shall be placed to the fixture as close as possible and no fixture shall be double trapped. All traps which are installed in accessible locations shall have cleanout plugs or other approved means for cleaning. Slip joints in traps will be permitted only on the inlet side or in the trap seal.

##### **23.2.3.2 Cleanout**

Cleanout shall be made of polyvinyl chloride (PVC), taper threaded and of same quality and strength as of pipes.

Cleanouts shall be full size of line but not larger than 10 cm except where specifically required. To permit cleaning of all piping, cleanouts shall be provided at all changes of directions and at intervals in straight lengths not more than 15 m on centers, for horizontal drainage lines of 100 mm dia or less, and not more than 30 m apart for larger pipes.

##### **23.2.3.3 Floor Drain**

Floor drain shall be made of polyvinyl chloride (PVC), taper threaded and of same quality and strength as of pipes and shall have trap where indicated. In case the floor has a water proof layer, flange for protection of the waterproof layer shall be provided.

##### **23.2.3.4 Roof Drains**

Roof drains shall be cast iron, dome or scupper type with seepage pan and flashing collar and have bottom outlet threaded connection.

#### **23.2.4 Sanitary Fixture**

Water Closet Water closet shall be white vitreous china syphonic closet type or similar type required by the Engineer with individual water supply tank.

Each water closet shall be complete with pipe, flush valve, high standard brass fittings, "p" trap, hinged plastic seat with cover and toilet paper holder.

Urinals Urinals shall be white vitreous china stall type wall hung wash-out urinal with

high standard brass fittings and strainers.

Lavatory Lavatory shall be white vitreous china with approx dimensions of 60 x 50 cm. Each basin shall be complete with high standard centre set supply and drain fittings and strainers.

Shower Closet Shower closet shall include a white enamel finish stainless steel tray with drain, a shower spray head, flush type, polycarbonate plate closet and sliding door, support bar, soap dish, hot and cold water mixing devices, flow-arm with wall flange, inlet connection screwed female, other relevant accessories.

Sink Sink shall be white vitreous china two basin type having dimensions of approx 100 x 50 cm and fastened to wall by brackets.

Each sink shall be complete with china and waste plug, hot and cold water mixing devices, "s" trap, brackets, coat hook, stop cock and soap-dish.

Mirrors Glass for mirrors shall be 6 mm thick polished plate, first silvering quality. Mirrors shall be genuine electric copper-plated over back of silvering. The mirrors, 50 x 50 cm in size, shall be set in frames designed so that the glass can be replaced without removing the frame from the wall.

Glass shelves, 120 mm wide shall be installed under the mirrors. Edge of glass shall be slightly rounded and polished.

### **23.2.5 Water Supply Pump**

There shall be an automatic water pump operating for a toilet of powerhouse, an emergency eye and face wash in battery room and a toilet of guard house. The pump shall be non-self-priming, horizontal centrifugal pump with mechanical shaft seal and extended pump/motor shaft. The pump shall be equipped with a diaphragm pressure tank keeping uniform water pressure and shall also be supplied with other accessories such as check valve, automatic start/stop switch, pressure gauge, etc. The pump motor shall be single-phase with built-in thermal overload protection. The final schematic arrangement of all equipment shall be designed by the Contractor and submitted to the Engineer for approval.

### **23.2.6 Water Filter**

Water filter shall have the minimum capacity of 1,500 liters/hour and composed of turbidity removal unit and activated carbon unit. The valves, piping and accessories shall be provided. It shall be equipped with backwash system.

### **23.2.7 Water Storage Tank**

Water storage tank shall be made of fiberglass or stainless steel and the minimum storage volume shall be 5,000 liters. The tank level shall be controlled by a float shut-off valve supplied with the tank. A high and low level alarm switch for remote annunciation in the control room shall be supplied.

## 23.3 EXECUTION

### 23.3.1 General

#### 23.3.1.1 Jointing

- a) Pipes shall be cut vertically with a care not to deform the pipes and the cut edge shall be smoothed.
- b) Prior to jointing, all the foreign materials within the pipes shall be cleared.
- c) When suspending piping temporarily, the edge of the pipes shall be protected to prevent foreign materials from entering.

#### 23.3.1.2 Piping

- a) Prior to starting the piping, the gradient of piping line shall be taken into consideration and the position of piping line shall be determined considering location of equipment to be connected with pipes and other pipes run nearby.
- b) As for indoor piping, supporting hardware and necessary sleeves shall be installed without delay as the work proceeds.
- c) Flange joints and unions shall be provided at suitable places of the main line to facilitate disconnection.
- d) Tees shall be used where the main line is to be branched.
- e) The pipe line shall be provided with an air release valve where air deems to gather and with silt discharge valve where silt deems to accumulate.
- f) Horizontal piping should have gradient of 1/250 as a standard, ascending for up-flow water supply and descending for down-flow water supply.
- g) Horizontal and vertical piping for indoor installation shall be supported at the spacing given below. Branches and bends shall be supported as necessary.

Pipe Dia (mm)	Hanger rod (mm)	Spacing (m)	
		Horizontal	Vertical
20	9	1.0	1.2
25	9	1.0	1.2
32	9	1.2	1.8
40	9	1.3	1.8
50	9	1.5	1.8
65	12	1.5	2.0
80	12	2.0	2.0
100	15	2.0	2.0
125	15	2.0	2.0
150	19	2.0	2.0



- h) Underground pipes shall be laid in the trench as shown on the drawing. The shortest route shall be adopted or as approved by the Engineer.
- i) Each branch from main water supply line and water supply piping to and at each plumbing fixture and unit of equipment connected there shall be provided with a shut-off valve and a union which will enable each such branch line, fixture, or equipment unit to be isolated and disconnected without disturbing the supply in the remainder of piping system.

### **23.3.1.3 Water Supply Pump, Water Filter and Water Storage Tank**

The installation of water supply pump, water filter and water storage tank shall conform to the instruction/specification of the manufactures.

### **23.3.2 Drain, Wastewater and Vent Piping**

#### **23.3.2.1 General**

Piping and jointing for the drain, wastewater and vent piping shall comply with the applicable provisions for the water supply piping, except the following.

#### **23.3.2.2 Jointing**

Jointing of PVC pipe shall be done by the bonding agent. The bonding agent shall conform to TIS 1032-2534.

#### **23.3.2.3 Piping**

- a) The junction of main pipe and branch pipe shall be done at an angle of less than 45°. A Y-branch or a 90° Y-branch shall also be used.
- b) Vent pipe from main drain pipe shall be installed vertically and shall not be placed horizontally. When connecting vent pipe on each floor to vent stack, the connection shall be made more than 150 mm above the overflow rim of fixtures on the respective floors. When connecting vent stack to vent stack on the very top floor, the requirements stated above shall also be observed.
- c) Where water supply pipe and drain pipe are embedded in parallel, the horizontal real distance between both pipes shall be over 500 mm, and the water supply pipe shall be embedded closer to the surface than the drain pipe.
- d) The gradient of piping of indoor drainage shall be 1/50 for pipe diameter up to 3 inches and 1/100 for pipe diameters between 3 and 6 inches. Vent pipe shall ascend forward of the vent stack. Care shall be taken so that no reverse grade and irregularities shall be caused to the vent pipe.
- e) PVC pipes to be laid underground shall be provided with sand foundation that shall be approximately 10 cm thick and shall have necessary gradient along the pipe line.

### **23.3.3 Sanitary Fixture**

Prior to installing the fixtures, all the necessary sleeves for setting the fixtures and fittings shall be installed.

Connections between the earthenware of fixtures and the flanges of the drain pipes shall be made absolutely gastight and watertight with closet setting compound or with wax bowl rings. Rubber gaskets or putty is not permitted.

Traps shall be set outlet of fixtures. Provision shall be made for the proper venting of all traps and piping shall be arranged so that horizontal runs or branches are as short as possible.

Exposed supply piping to plumbing fixtures shall be chromium plated brass or copper.

### **23.3.4 Painting**

Exposed rainwater pipe shall be painted. A primer or finishing coat shall be applied according to the manufacturer application procedure.

All surface of materials furnished and installed by the Contractor under this clause shall be painted and executed as specified in Civil Works Technical Specification, Chapter 20, "Painting and Coating", Volume 4 except as listed below.

- 1) Portions to be embedded in concrete or earth
- 2) Plated surface other than zinc plating
- 3) Zinc plated portions to be concealed
- 4) Surface treated with special decorative finish
- 5) Surface where so indicated by the Engineer

### **23.3.5 Disinfection**

a) After the water supply piping system has been installed and successfully tested for pressure and leakage, the Contractor shall disinfect and flush the pipelines.

b) Calcium hypochlorite or any other approved disinfectant shall be used. Suitable quantity of chemical shall be used for disinfection.

### **23.3.6 Foundation of Wastewater Treatment Tank**

Tank shall be placed on adequately designed reinforced concrete slab. The foundation shall be sufficient to withstand weight of the installation and any force to action.

### **23.3.7 Inspection and Test**

Inspection and test for plumbing shall conform to E.I.T. Standard 1004-16,1976 Thai Plumbing Standard.

### **23.3.8 Maintenance**

### **23.3.8.1 Maintenance during Construction**

The sanitary installation and appliances shall be maintained and protected by the Contractor in a satisfactory condition until final acceptance by the Engineer. Defective materials and equipment damaged in the course of installation or testing shall be replaced or repaired by and at the expense of the Contractor in a manner as approved by the Engineer.

### **23.3.8.2 Maintenance during Guarantee Period**

- a) The Contractor shall be responsible for, and shall carry out, all routine maintenance and shall repair or make good at his own expense, all defects or damage that may be discovered or develop in the plant resulting from faulty material, workmanship or design.
- b) The Contractor shall carry out routine maintenance at monthly intervals for the total maintenance guarantee period.
- c) Should the Contractor fail to so carry out maintenance, repair or make good when called upon in writing to do so, the Engineer may do the work at the Contractor's risk and expense, but without prejudice to any other rights which the Engineer may have against the Contractor with respect to such defects or damage.
- d) Routine maintenance shall include supply of chemical agent, etc.

### **23.3.9 Concrete, Plastering and Earth Work**

Concrete, reinforcing, plastering and earth work in this clause shall be performed according to the applicable provisions of the relevant clauses of the Civil Works Technical Specification Volume 4.

End of Chapter 23

## **CHAPTER 24 - SUNDRIES**

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## **CHAPTER 24 - SUNDRIES**

### **24.1 GENERAL**

#### **24.1.1 Scope**

This chapter covers all works in connection with the supply and installation of drainage works, crushed rock, sodding, landscaping, fencing and gate rehabilitation of toe drain outlet as shown on the Drawings.

Drainage works to be constructed by the Contractor shall include the following:

- Gutter
- Drainage Pipe, Manhole and Reinforced Concrete Drain Outlet
- Side Ditch
- Catch Basin

### **24.2 MATERIAL**

#### **24.2.1 Drainage Works**

Materials and components incorporated in the permanent structure which shall be supplied and installed by the Contractor, shall be new and unused unless otherwise specified.

Materials and structural parts not standardized shall be approved by the Engineer prior to be used. Samples and name of manufacturer of such materials shall be submitted for approval.

##### **24.2.1.1 Gutter, Drainage Pipe, Manhole and Reinforced Concrete Drain Outlet**

Concrete for gutters, manholes and reinforced concrete drain outlet shall be class B. Concrete and reinforced steel shall conform to the requirements in Chapter 10 "Concrete" and Chapter 11 "Reinforcing Steel" of these Specifications.

Structural steel for steel grating shall conform to the requirements in Chapter 12 "Structural Steel" of these Specifications.

Drainage pipes shall be reinforced concrete pipe, in accordance with ASTM C76 Class II or TIS 128-2528 Class II and be subjected to an approval of the Engineer.

##### **24.2.1.2 Side Ditch**

Side Ditch shall be the excavated natural earth.

##### **24.2.1.3 Catch Basin**

Catch basin shall be grouted riprap type. Stone for grouted riprap shall consist of rough uneven quarry stone as nearby rectangular in section as possible. The stone shall be sound, tough, durable, dense, resistant to the action of air and water, and suitable in all respects for the purpose intended.

Unless directed otherwise, the stone pieces shall range in weight between 20 – 45 kg. with not less than fifty percent (50%) of the stone weighing more than 35 kg.

#### **24.2.2 Graded Gravel**

This material shall consist of natural gravel or crush rock, clean and well graded from 5 mm to 20 mm in size and may contain up to a total of 10% of particle than 5mm size.

#### **24.2.3 Sodding**

Sods shall consist of an approved grass strongly rooted and reasonably free from pernicious weeds and apparent disease. All sods shall be freshly cut and procured from areas having soil conditions similar to the soils of the areas where they are to be placed. Prior to cutting the sods the grass shall be mowed to a height not exceeding 8 cm. for field-grown sods and 5 cm. for nursery grown sods. Thickness of the sods shall be 5 cm.

Topsoil shall consist of fertile, friable soil of loamy character and shall contain an amount of organic matter normal to the area of the Works. It shall be obtained from well drained arable land and shall be reasonably free from subsoil, refuse, roots, heavy sticks, brush and other deleterious substances. Topsoil shall be capable of sustaining healthy plant life.

Commercial fertilizer shall be uniform in composition, free-flowing, suitable for application with approved equipment and delivered to the Site in unopened original containers each bearing the manufacturer's guaranteed analysis. Fertilizer shall contain the following minimum percentage of plant food by weight:

- 16% available nitrogen
- 20% available phosphoric oxide.

#### **24.2.4 Planting**

The type of the specified tree shall be the Golden Bell with the height of 1.50 m and approximately 25 mm for the trunk diameter. The selected tree shall be strong, healthy without disease and putting out about 5 branches from its stem. The tree grown by seed shall be more required than the one grown by layering.

Commercial fertilizer shall be uniform in composition, free-flowing, suitable for application with approved equipment and delivered to the Site in unopened original containers each bearing the manufacturer's guaranteed analysis. Fertilizer shall contain the following minimum percentage of plant food by weight:

- 16% available nitrogen
- 16% available phosphoric oxide
- 16% available potassium chloride



### **24.2.5 Fencing and Gate**

Wire mesh panel shall be welded fabric steel in accordance with TIS 737. The steel wire shall be 6 mm. thick (minimum) and hot-dip galvanized after welded as wire mesh. The wire mesh shall be installed with the proper hot-dip galvanized post. The welding of wire mesh panel to the post may require as direct by the Engineer.

Gate frames shall be of hot-dip galvanized standard weight seamless steel pipes conforming to ASTM A53, schedule 40.

Gate hinges shall be of hot-dip galvanized ductile iron or malleable iron.

### **24.2.6 Guard Rail**

The rail shall be the steel sheet conforming to TIS 248 and formed to the dimensions as shown on the drawing.

The guard rail post shall be galvanized steel pipe according to ASTM A53. Schedule 40, required bolts, nuts and washers shall be galvanized. The post shall be set to the required depth and shall be held firmly in place by concrete foundation.

### **24.2.7 Sign Board**

Sign Board shall be constructed by the good quality material according to TIS Standard or equivalent. For the best result, the installation of sign board including sand stone work, stainless steel letters and reinforced concrete shall be conformed to the manufacturer's standard and the construction method.

### **24.2.8 Elastomeric Bearing Pads**

#### **24.2.8.1 General**

Bearing Pads shall be of the laminated type consisting of alternate lamination of elastomer and metal or elastomer and fabric bonded together.

The outside laminations shall be metal or fabric. The outside and edges of metal laminations shall be coated over with elastomer not more than 3 mm in thickness.

Laminations of elastomer shall be 10 mm  $\pm$  3 mm in thickness. Variations in thickness and individual elastomer lamination shall not exceed 3 mm 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 thickness of a pad shall not be less than the thickness shown on the Drawings nor more than 6 mm greater than that thickness. Variation of total thickness within an individual pad shall not exceed 3 mm.

Pads containing metal laminations shall be full molded. Cuttings of pads shall be performed in such a manner as to avoid heating of the material and to produce a smooth edge with no

tears or other jagged areas and to cause as little damage to the material as possible. Metal laminations shall be rolled mild steel sheets not less than 1 mm in thickness.

Fabric laminations shall be either a long chain synthetic polymer containing at least eighty five percent (85%) polyester or a long chain synthetic polymeric amide. Each ply of fabric shall have a breaking strength of not less than 50 kg/mm of width in both directions. Fabric laminations shall be single ply at top and bottom surfaces of the pad and either double ply or double strength within the pad.

The sole polymer in the elastomeric compound shall be neoprene and shall not be less than sixty percent (60%) by volume of the total compound.

#### **24.2.8.2 Elastomer**

The elastomer, as determined from test specimens, shall conform to the followings:

Test	ASTM Designation	Requirement
Tensile strength, kg/cm <sup>2</sup>	D 412	150 min
Elongation at break, percent	D 412	350 min
Compression set, 22 hrs at 60 degree Celsius, percent	D 395 (method B)	35 max
Hardness (Shore A)	D 676	60 ± 5
Ozone resistance 20% strain, 100 hours at 38 ± 2 degree Celsius	D 1149	No cracks

#### **24.2.8.3 Certification**

The Contractor shall furnish to the Engineer a certification by the manufacturer that the elastomer and fabric (if 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 tests performed by the manufacturer on samples of the elastomer and fabric to be used in the pads.

## **24.3 EXECUTION**

### **24.3.1 Drainage Works**

#### **24.3.1.1 Gutter**

The Contractor shall construct gutters at service roads, parking area, in accordance with locations, elevations, slopes and dimensions shown on the Drawings or as directed by the Engineer.

#### **24.3.1.2 Drainage Pipe, Manhole and Reinforced Concrete Drain Outlet**

The Contractor shall construct the drainage pipes including manholes and reinforced concrete drain outlet as shown on the Drawings or as directed by the Engineer. The works shall consist of excavation, concreting, reinforcing steel and backfilling.

During manufacturing, transporting, storing and laying of reinforced concrete pipes, the pipes shall not be dropped or handled in a way that might crack the wall or otherwise cause damage. Any length of pipe that, in opinion of the Engineer, is damaged beyond repair shall be removed from the site and replaced by the Contractor.

Reinforced concrete pipe joints shall be mortared to obtain a ring around the pipe having a thickness of 10 cm and a width of approximately 15 cm. The mortar shall be stiff and composed of one part of cement and two parts of sand. Pipe joints under road pavement shall be reinforced concrete having a thickness of 10 cm and a width of 20 cm.

The line, elevation, slope and dimension of the pipes are shown on the Drawings or as directed by the Engineer. Manhole distance shall be within 10 meters.

Reinforced concreted Drain Outlet shall be located in the tailwater channel and shall be able to carry the storm drainage water into the tailwater Channel. Shear key shall be provided to reduce percolation. The location, shape, dimension and elevation of its are shown on the Drawings of as directed by the Engineer.

#### **24.3.1.3 Side Ditch**

The Contractor shall construct side ditches at service roads according to the dimension, elevation and slope as shown on the Drawings or as directed by the Engineer.

#### **24.3.1.4 Catch Basin**

The Contractor shall construct catch basin of grouted riprap type, dimension and the locations shown on the Drawings or as directed by the Engineer.

Stones shall be carefully arranged in relation to one another so as to have a sufficient appearance with empty spaces to be filled with mortar. Mortar shall consist of three parts of clean fine aggregate to one part of Portland cement by volume.

The placing execution for grouted riprap shall conform to the requirements specified in Chapter 7 “Miscellaneous Fills, Backfills, Riprap and Geotextile”.

### 24.3.2 Graded Gravel

Graded Gravel shall be placed in accordance with the alignments, slopes and sections shown on the Drawings.

### 24.3.3 Sodding

Grading of top-soils shall be as specified. All eroded or otherwise damaged areas shall be reinstated prior to placing of sods. Any undulations or irregularities in the surface shall be leveled prior to commencing the placing procedure.

Top soil shall be scattered thoroughly on the area which its surface has been already leveled for sodding. The volume of top soil shall be provided approximately  $3 \text{ kg/m}^3$ .

Fertilizer shall be distributed uniformly at the rate of 2.25 kg per 100 sq.m. over the areas to be sodded.

The fertilizer shall be applied on the area to be sodded. Half of the specified quantity of fertilizer shall be spread prior to sodding. The remaining portion shall be uniformly distributed on the covered area after all placing operations have been completed, but prior to the first watering.

The sods shall be cut into square or rectangular sections. Rectangular sections may vary in length but shall be of equal width and of a size permitting lifting and rolling without destroying the sods. Care shall be taken to retain the native soil on the roots of the sods during stripping, transporting and planting. Sods shall be cut only under favourable soil moisture conditions. When the soil is too dry, the Contractor shall water the area prior to cutting the sods. Dumping from vehicles will not be permitted. The sods shall be re-planted within 24 hours after stripping unless stored in a satisfactory manner. If stacked during transport, sods shall be placed roots to roots or grass to grass. During delivery and while in stacks, sods shall be kept moist and shall be protected from exposure to sunlight. Damaged sods will be rejected.

The sods shall be laid smoothly edge to edge with staggered joints and shall be pressed firmly into contact with the planting bed by tamping or rolling with equipment reviewed by the Engineer to eliminate air pockets, provide true and leveled surfaces, and assure knitting without displacement of the sods or deformation of the surface. After compaction, screened top-soil of good quality shall be used to fill all voids between sods. Excess soil shall be worked into the grass with rakes or other suitable equipment. The quantity of fill soil shall be such as will cause no smothering of the grass. The edges of the sodded area shall be smooth and shall conform to the cross sections indicated. Excess soil from the planting operation shall be disposed of as instructed by the Engineer. On slopes steeper than 2 to 1, the sods shall be fixed to the top-soil by suitable wooden pegs or by other methods approved.

The areas covered by sods shall be watered immediately after placing and in daily intervals for a period of not less than 4 weeks. The quantity of water shall be sufficient to keep the root zone of the sods moist down to a depth of at least 6 cm, however, the application rate

per time unit shall be such that no damages due to erosion will occur. Watering may be interrupted during periods of rainfall.

Sodded areas shall be maintained and watered by the Contractor until the date of Provisional Acceptance of the Works or for a period of not less than 4 weeks whichever come later. When any portion of the surface becomes gullied or otherwise damaged, the affected portion shall be repaired and reinstated. This may include the removal of the sods and of the top-soil within the damaged area and its reinstatement as specified.

#### **24.3.4 Planting**

The hole for growing the tree, which is 1.00 - 1.50 m high, shall be dug at least 0.80 m for the diameter of the width and 0.60 m of the depth.

Top soil, as specified in item 24.2.8 of this chapter, shall be filled into the bottom of the hole approximately 20 percent of the ordinary soil while 10 percent of top soil shall be applied around the bole of the tree. After planting, the stakes shall be used for supporting each tree at least 3 months and the fertilizer shall be added carefully. The planted area shall be soaked immediately after fertilizing.

The plants shall be watered daily intervals for a period of not less than 4 weeks. The quantity of water shall be sufficient to keep the root zone of the plants moist down to a depth of at least 10 cm, however, the application rate per time unit shall be such that no damages due to erosion will occur. Watering may be interrupted during periods of rainfall.

Planted areas shall be maintained and watered by the Contractor until the date of Provisional Acceptance of the Works or for a period of not less than 4 weeks whichever come later. When any portion of the surface becomes gullied or otherwise damaged, the affected portion shall be repaired and reinstated. This may include the removal of the plants and of the top-soil within the damaged area and its reinstatement as specified.

#### **24.3.5 Fencing and Gate**

The Contractor shall furnish and install fencing and gate as shown on the Drawings.

##### **24.3.5.1 Steel Wire**

Wire mesh panel shall be welded fabric steel in accordance with TIS 737. The steel wire shall be 6 mm. thick (minimum) and hot-dip galvanized after welded as wire mesh. The wire mesh shall be installed with the proper hot-dip galvanized post. The welding of wire mesh panel to the post may require as direct by the Engineer.

##### **24.3.5.2 Fencing and Gate Frame**

Posts, brace elements, and gate frames shall be of structural steel conforming to ASTM A 36 and shall have dimension as shown on the Drawings:

##### **24.3.5.3 Chain Link**

Chain link fabric for gates shall be as specified for fences. Each gate leaf shall equip with one pair of heavy hinges that will allow a full gate opening between gate posts. The hinges

shall be designed so as not to twist or turn under gate action and shall allow the gate to swing a full 180°. Hinges shall be of hot-dip galvanized ductile iron or malleable iron.

#### **24.3.5.4 Lock**

Gates shall be equipped with a heavy latching device and cylinder door lock. Locking bars to secure gates in open and closed position shall be provided. Double wing gates shall be provided with on safety stop fixing the wing in its closed position by means of a vertical shaft. The locks and other rotating materials shall be made of brass or bronze.

#### **24.3.6 Guard Rail**

The Contractor shall furnish and install guard rail as shown on the Drawings.

#### **24.3.7 Sign Board**

The work for sign board shall include site preparation, excavation, reinforced concrete, sandstone pavement, sand stone work, the Employer Insignia, Project Name Board, foundation concrete, backfill and all other necessary works as shown on the Drawings or as directed by the Engineer.

The sign board shall be constructed on the location as shown on the Drawing and as directed and approved by the Engineer.

All works shall be executed in accordance with the applicable provisions of the specifications.

#### **24.3.8 Rehabilitation of Toe Drain Outlet**

The Contractor shall carefully execute excavation work for construction of bifurcation and penstock especially in the area where existing toe drain of the dam is located. The contractor shall submit excavation procedure and construction of temporary toe drain outlet to the Engineer for approval.

After completion of the work, the Contractor shall repair rehabilitate toe drain outlet in such a way that the condition of toe drain outlet prior to start of the work is fully achieved.

End of Chapter 24

## **CHAPTER 25 - GABION AND GABION MATTRESSES**

**TECHNICAL SPECIFICATION**  
**CHAPTER 25 - GABION AND GABION MATTRESSES**  
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## CHAPTER 25 - GABION AND GABION MATTRESSES

### 25.1 GENERAL

#### 25.1.1 Scope of Work

The work to be performed under this specification shall include furnishing, assembling, filling, and tying rock-filled wire mesh compartmented gabions and mattresses in accordance with the lines, grades, and dimensions shown on the Drawings or otherwise established in the field by the Engineer or designated representative.

#### 25.1.2 Codes and Standards

American Society for Testing and Materials (ASTM)

- A-313 Standard Specification for Stainless Steel Spring Wire
- A-370 Standard Test Methods and Definitions for Mechanical Testing of Steel Products
- A-641 Specification for Zinc Coated (Galvanized) Carbon Steel Wire
- A-853 Standard Specification for Steel Wire, Carbon, for General Use
- A-974 Standard Specifications for Welded Wire Fabric Gabions and Gabion Mattresses (Metallic-Coated or Polyvinyl Chloride (PVC) Coated)
- A-975 Standard Specifications for Double-Twisted Hexagonal Mesh Gabions and Revet Mattresses (Metallic-Coated Steel Wire or Metallic-Coated Steel with Poly Vinyl Chloride (PVC) Coating)
- B-117 Test Method of Salt Spray (Fog) Testing
- C-535 Standard Test Method for Resistance of Large Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
- D-412 Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers-Tension
- D-638 Test Method for Tensile Properties of Plastics
- D-746 Test Methods for Brittleness Temperature of Plastic and Elastomers by Impact
- D-792 Test Methods for Specific Gravity (Relative Density) and Density of Plastics by Displacement
- D-1203 Standard Test Methods for Volative Loss from Plastics Using Activated Carbon Methods

- D-1242 Test Methods for Resistance of Plastics Materials to Abrasion
- D-1499 Practice for Operating Light and Water Exposure Apparatus (Carbon-Arc Type) for Exposure of Plastics
- D-2240 Test Method for Rubber Property-Durometer Hardness
- D-2287 Standard Specification for Nonrigid Vinyl Chloride Polymer and Copolymer Molding and Extrusion Compounds

## **25.2 MATERIAL**

### **25.2.1 Wire Mesh**

Gabions and gabion mattresses shall consist of rectangular wire mesh formed containers filled with rock.

Gabions and mattresses shall be constructed of galvanized steel wire with polyvinylchloride (PVC) flexible coating. The gabions and mattresses shall be of the construction and sizes specified in the Drawings and shall meet the specifications presented herein. Unless otherwise specified in the Drawings or approved by the Engineer or designated representative, the gabions and mattresses may be constructed of either double twist woven mesh or welded wire mesh.

Gabions shall be furnished in the specified dimensions within a tolerance of  $\pm 5$  percent. mattresses shall be furnished in the specified dimensions within a tolerance of 5 percent for the length and width and 10 percent for the height. For each individual gabion or mattress, the same mesh style shall be used for the base, front, ends, back, diaphragms and lid panels. Each gabion or mattress shall be manufactured and divided into cells of equal length, no greater than 3 feet (0.9 meter), by diaphragm panels.

Twisted-mesh—double twisted, hexagonal wire mesh consisting of two wires twisted together in two 180-degree turns. Twisted-mesh, fasteners, and stiffeners shall conform to the requirements of ASTM A975.

Lacing wire is the standard fastener for twisted-mesh gabions and gabion mattresses. Ring fasteners may be used and shall be made of stainless steel. Ring fasteners must provide the minimum strength per lineal foot that is specified in ASTM A975 for gabions and gabion mattresses.

Welded mesh—Welded mesh with a uniform square or rectangular pattern and a resistance weld at each intersection. Welded mesh and stiffeners shall conform to the requirements of ASTM A974 with the exception that welded mesh may be delivered in component form, either rolled or stacked, for assembly at the job site.

Spiral binders are the standard fastener for welded-mesh gabions and gabion mattresses. Spiral binders shall conform to the requirements of ASTM A974. Alternate fasteners for use with welded-mesh gabions and gabion mattresses, such as ring fasteners or lacing wire, shall be

formed from wire meeting the same quality and coating thickness requirements as specified for the gabions and gabion mattresses. Ring fasteners shall be made of stainless steel. Standard fasteners and alternate fasteners must provide the minimum strength per lineal foot that is specified in ASTM A974 for gabions and gabion mattresses.

### 25.2.2 Rock

Rock—Rock shall conform to the quality requirements in Chapter 7 Miscellaneous Fill. At least 85 percent of the rock particles, by weight, shall be within the predominant rock size range

Gabion basket or mattress height (inch)	Predominant rock size (inch)	Minimum rock size (inch)	Maximum rock size (inch)
12,18 or 36 basket	4 to 8	4	8
6,9 or 12 mattress	3 to 6	3	6

At least 30 days before delivery to the site, the contractor shall inform the engineer in writing of submit in writing the source from which the rock will be obtained. The test data, and other information by which the material was determined by the contractor to meet needed to document that the rock meets the requirements of this specification are included. The Contractor shall provide the engineer free access to the source for the purpose of obtaining samples for testing and source approval.

Bedding or filter material—Bedding or filter material, when specified, shall meet the gradation shown on the plans, or as specified, Aggregates for filter, geotextile shall conform to the requirements specified in Chapter 7 Miscellaneous Fill.

## 25.3 EXECUTION

### 25.3.1 Foundation Preparation

The foundation on which the gabions and gabion mattresses are to be placed shall be cut or filled and graded to the lines and grades shown on the drawings. Surface irregularities, loose material, vegetation, and all foreign matter shall be removed from the foundation.

Gabions, gabion mattresses, and bedding or specified geotextiles shall not be placed until the foundation preparation is completed and foundation the subgrade surfaces have been inspected and approved by the EGAT to meets the requirements in Chapter 7 Miscellaneous Fill.

Compaction of bedding or filter material is required as specified in Chapter 7 Miscellaneous Fill. The surface of the finished material shall be to grade and free of mounds, dips, or windrows. Geotextile shall be installed in accordance with the requirements in Chapter 7 Miscellaneous Fill.

### 25.3.2 Assembly and Placement

### **25.3.2.1 Assembly**

Use ring-type fasteners or lacing wire for the assembly and placement of twisted-mesh panels. Wrap the lacing wire with alternating single and double half-hitches at 4- to 6-inch intervals and secure by tying a double half-hitch at each end. Use spiral or ring type fasteners for the assembly and placement of welded-mesh panels. Where spiral fasteners are used, crimp the ends to secure the spirals in place. Where ring type fasteners are used, install the fasteners at a maximum spacing of 6 inches.

Interior diaphragms are required where any inside dimension exceeds 3 feet. Use the same type fasteners and fastening procedures to install interior diaphragms and lids as used in the panel assembly. Diaphragms are installed to assure that no open intervals are present that exceed 3 feet.

### **25.3.2.2 Placement**

The gabions or gabion mattresses shall be placed on the foundation and use lacing wire to interconnect the all adjacent horizontal and vertical edges adjacent gabions along the top, bottom, and vertical edges using lacing wire. Wrap the wire with alternating single and double half-hitches at 4- to 6-inch intervals. Welded-mesh gabions and gabion mattresses may be interconnected with spiral fasteners, ring-type fasteners, or lacing wire.

Lacing wire will be the only fastener allowed for interconnecting woven mesh gabions. Spiral fasteners, ring type fasteners, or lacing wire. Where spiral fasteners are used, crimp the ends to secure the spirals in place. Where ring type fasteners are used, install the fasteners at a maximum spacing of 6 in are commonly used for the assembly and interconnection of welded mesh gabions.

Spirals are screwed down at the connecting edges then each end of the spiral is crimped to secure it in place. Lacing may be used as needed to supplement the interconnection of welded mesh gabions and the closing of lids

Interconnect each layer of gabions and gabion mattresses to the underlying layer of gabions along the front, back, and sides. Stagger the vertical and horizontal joints between the gabions of adjacent rows and layers by at least half one-fourth of a cell length.

### **25.3.3 Filling Operation**

Twisted-mesh: After adjacent empty twisted-mesh units are set to line and grade and common sides properly connected, they shall be placed in straight line tension and stretched to remove any kinks from the mesh and to gain a uniform alignment. Units may be staked to maintain the established proper alignment before the rock is placed. No stakes shall be placed through geotextile material. Fasteners shall be attached during the filling operation as needed to preserve the strength and shape of the structure.

Internal connecting crosstie wires shall be placed in each unrestrained gabion and gabion mattress unit of more than 18 inches in height, including units left temporarily unrestrained. Two internal connecting wires shall be placed concurrently with rock placement at each 12-inch interval of depth. These crossties shall be evenly spaced along the front face and

connected to the back face. All crosstie wires shall be looped around two mesh openings and each wire end shall be secured by a minimum of five 180 degree twists around itself after looping.

**Welded-mesh**—Welded-mesh units do not require stretching. Units may be staked to maintain the established proper alignment before the rock is placed. No stakes shall be placed through geotextile material. Fasteners shall be attached during the filling operation as needed to preserve the strength and shape of the structure.

Internal crossties or stiffeners shall be placed in each unrestrained gabion and gabion mattress unit of more than 18 inches in height, including units left temporarily unrestrained. Crossties or stiffeners shall be placed concurrently with rock placement at each 12-inch interval of depth. They shall be placed across the corners of the gabions (at 12 inches from the corners) providing diagonal bracing. Lacing wire or preformed hooked wire stiffeners may be used.

**Twisted and welded-mesh**—The gabions and gabion mattresses shall be carefully filled with rock in a manner that will ensure alignment, avoid bulges, and provide a compact mass that minimizes voids. Machine placement requires supplementing with hand work to ensure the desired results. The units or cells in any row shall be filled in stages so that the depth of rock placed in any one cell does not exceed the depth of rock in any adjoining cell by more than 12 inches. Along the exposed faces, the outer layer of stone shall be carefully placed and arranged by hand to ensure a neat, compact placement with a uniform appearance.

The last layer of rock shall be uniformly leveled to the top edges of the cells. Lids shall be stretched tight over the rock filling. The use of crowbars or other single point leverage bars for lid closing is prohibited as they may damage the baskets. The lid shall be stretched until it meets the perimeter edges of the front and end panels. The gabion lid shall then be secured to the sides, ends, and diaphragms with lacing wire, spiral binders, or approved alternate fasteners.

Lacing wire shall be wrapped with alternating single and double half-hitches at 4- to 6-inch intervals. Where spiral fasteners are used, crimp the ends to secure the spirals in place. Any damage to the wire or coatings during assembly, placement, and or filling shall be repaired promptly in accordance with the manufacturer's recommendations or replaced with undamaged gabion baskets materials.

End of Chapter 25

## **CHAPTER 26 - PILE FOUNDATION**

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## CHAPTER 26 - PILE FOUNDATION

### 26.1 GENERAL

The work shall consist of furnishing piles foundation of the type and dimensions specified including cutting off or building up foundation piles when required. This work shall also consist of providing test piles and performing loading tests when required.

### 26.2 SOIL INVESTIGATION AND PILE TESTING

#### 26.2.1 Soil Investigation

EGAT will provide the results of soil investigation of this project, for information only. In case this information is not sufficient for the detail design of the civil works, the Contractor is responsible for carrying out further site surveys, investigation, etc. (if required).

#### 26.2.2 Pile Testing

Dynamic, static axial compressive/tensile, and lateral pile load tests for test piles shall be performed prior to the detail design. The dynamic pile load test shall be performed prior to the static axial compressive pile load test at the same pile. The static axial tensile and lateral pile load test shall be performed on separate test pile. The test piles shall not be used as part of foundation for any structures. The pile capacity, pile section and length shall be determined from soil investigation. Results from this static pile load test and lateral pile load test shall only be used in confirming of the computation.

Test pile for bored pile as the following shall be performed:

Static axial compressive pile load test	Conforming to ASTM D-1143 Standard Test Method, for at least 2 piles for each pile section and length
Static axial tensile pile load test	Conforming to ASTM D-3689 Standard Test Method, for at least 1 pile for each pile section and length
Lateral pile load test	Conforming to ASTM D-3966 Standard Test Method, for at least 2 piles for each pile section and length
Dynamic pile load test	Conforming to ASTM D-4945 Standard Test Method, for at least 2 piles for each pile section and length Dynamic pile load test for bored pile shall be performed by Restrike Test Method.



Proof test pile for bored pile as the following shall be performed:

Dynamic pile load test	Conforming to ASTM D-4945 Standard Test Method, for every 100 piles with the same section and length, any fractions of 100 piles shall be accounted as an additional 100 piles Dynamic pile load test for bored pile shall be performed by Restrike Test Method.
Seismic integrity test	Conforming to ASTM D-5882 Standard Test Method for Low Strain Integrity Testing of Piles shall be performed for all piles
Sonic logging test with cross hole system (for bored pile dia. 800 mm or greater)	Conforming to ASTM D-6760 Standard Test Method for Integrity. Testing by Ultrasonic cross hole Testing, for every 100 piles with the same section and length, any fractions of 100 piles shall be accounted as an additional 100 piles

Toe grout for bored pile can be applied if the load-settlement relationship obtained from pile load test does not meet the civil design criteria. Static axial compressive pile load test shall be done again to determine the ultimate load capacity of bored pile after toe grout process.

Head of bored pile shall be well-prepared and ready to be tested. In addition, pile cap shall be used for testing of pile with diameter of 0.80 m or greater.

If the Sonic Logging Test results of bored piles show the occurrence of pile problems, Core Test along the length of pile shall be performed before commencing of pile repair works. Otherwise, those defect bored piles shall be rejected and foundation modification shall be done. Any expense resulting from Core Test or foundation modification shall be born to the Contractor.

Test pile for driven pile as the following shall be performed:

Static axial compressive pile load test	Conforming to ASTM D-1143 Standard Test Method, for at least 2 piles for each pile section and length
Static axial tensile pile load test	Conforming to ASTM D-3689 Standard Test Method, for at least 1 pile for each pile section and length
Lateral pile load test	Conforming to ASTM D-3966 Standard Test Method, for at least 2 piles for each pile section and length
Dynamic pile load test	Conforming to ASTM D-4945 Standard Test Method, for at least 2 piles for each pile section and length Dynamic pile load

test for driven pile shall be performed by the Initial Driving Test and Restrike Test Method.

Proof test pile for driven pile as the following shall be performed:

Dynamic pile load test

Conforming to ASTM D-4945 Standard Test Method, for every 100 piles with the same section and length, any fractions of 100 piles shall be accounted as an additional 100 piles Dynamic pile load test for driven pile shall be performed by the Initial Driving Test and Restrike Test Method.

Seismic integrity test

Conforming to ASTM D-5882 Standard Test Method for Low Strain Integrity Testing of Piles shall be performed for all piles

For static axial compressive pile load test, 3 cycles of test shall be performed using standard loading procedure for the first and second cycle. The last cycle shall be quick test method. Pile load test shall be performed at 100, 200 and 250 percent of the design load for the first, second and third cycle, respectively.

The static axial compressive pile load test procedure shall be performed in conformity with Clause 22 of Ministerial Regulations No. 6 (B.E. 2527) issued under the provision of the Building Control Act (B.E. 2522).

For static axial compressive pile load test, pile failure shall be concluded in case that the settlement rate and settlement data observed from load-displacement diagram for all cycles conform to Clause 22 of Ministerial Regulations No. 6 (B.E. 2527) issued under the provision of the Building Control Act (B.E. 2522).

Static axial tensile pile load test, 3 cycles of test shall be performed using standard loading procedure for the first and second cycle. The last cycle shall be quick test method. Static axial tensile pile load test shall be performed at 100, 200 and 300 percent of the design load for the first, second and third cycle, respectively.

The lateral pile load test shall be performed by 2 cycles of cyclic load test method. Pile load test shall be performed at 100 and 200 percent of the design load for the first and second cycle, respectively. The limit of horizontal displacement observed from load displacement curve of each cycle not be greater than 25 mm. The allowable lateral load on pile shall be not greater than:

- 50 percent of the maximum test load (200 percent of the design load);, and
- 50 percent of the final load which produces gross lateral movement of 25 mm.

The ultimate pile capacity determined from the dynamic pile load test shall be calibrated with results of the static pile load tests in order to achieve the proper dynamic parameters for matching software.

For driven pile, the number of hammer blows for the last 30 cm. shall be recommended by designer for on-site control of the pile driving. The ultimate load of each pile section and length calculated by Danish Formula for prestressed concrete spun pile and Janbu Formula for prestressed concrete solid square pile shall be compared to the results obtained from test piles by static pile load test. Safety factor for Danish and Janbu Formula shall be calculated based on results of static pile load test. Such comparison result shall be submitted to EGAT for review. The height and weight of ram, type of hammer and other equipment for driving of test piles shall be the same as driving of working piles and shall be proposed to EGAT for approval before pile installation.

For proof test, dynamic pile load test shall be performed by Restrike Test Method. If any load-displacement diagrams of piles simulated from matching software show that the ultimate load is less than 250 percent of the design load, those piles shall be rejected and foundation modification shall be executed at Contractor's expense. In addition, the dynamic pile load test shall be further performed for other piles within 10.0 m radius of the inferior piles. After foundation modification, dynamic pile load test shall be done again at any locations of inferior piles.

The ratio of the pile impedance (or simply cross-section area) at the location of properties change ( $\beta$ ) from dynamic pile load test and integrity test shall not be less than 0.8.

In case that the test results show any deficiencies and pile repair or foundation modification is required, all costs due to pile repair or foundation modification shall be responsible by the Contractor. In addition, after the pile repair is completed, Static Pile Load Test shall be conducted again at the Contractor's cost to confirm the capacity of the repaired pile.

Location of piles to be tested shall be selected by EGAT. The Contractor shall propose the pile load test procedures to EGAT for review before testing.

Test results shall be guaranteed, approved and verified by certified institution and signed by Thai Registered Engineer holding valid Senior Professional Engineer License conforming to the Ministerial Regulations No. 6 issued under the provision of the Building Control Act (B.E. 2522). The results shall be reviewed by EGAT. EGAT does not assume responsibility for any design based on the provided report.

Any cost related to the further site surveys, investigation, etc. (if required) and the pile load test for the detail design shall be born to The Contractor.

### **26.3 EQUIPMENT/STRUCTURE FOUNDATIONS**

In general, all equipment shall be supported by adequately designed mat or block foundations set on piles. Pertinent information about equipment such as the footprints, weights, anchorage requirements, nature of equipment, whether rotating or vibrating, static or dynamic loading criteria or any special recommendations by equipment manufacturers shall be incorporated in the design of foundations.

For equipment inside the buildings, the pads shall project at least 150 mm. The pads for vibrating and rotating equipment shall be isolated from adjacent floor slabs by perimeter joints sealed with flexible joint sealant. All equipment/structure foundations shall be constructed with reinforced concrete. The top surface of the foundation shall be 150 mm minimum above the surrounding ground slab. The top surface shall be finished with slope of 1:100 in outward directions to avoid any water pond on the surface.

## **26.4 PILING**

Bored pile shall be utilized for pile foundations of the following powerhouse and all service buildings and appurtenant structures and etc.

Only wet process bored pile utilizing polymer slurry or bentonite slurry shall be constructed. The polymer slurry or bentonite slurry used for bored piles shall conform to EIT 1019-46. Bored pile shall be constructed in accordance with EIT 1019-46 standard.

Vertical reinforcement as well as spiral reinforcement shall be provided throughout the whole length of pile.

The system shall be designed to accommodate any consequences of future settlement and/or differential settlement of the soft material.

Filled layers shall not be taken into account for friction resistant of pile. Any adverse effect from negative skin friction shall be taken into consideration. In case the tension piles are required, reinforcing steel dowel bars shall be provided and installed during pile manufacture.

The piles shall be designed in such a way that the total settlement, initial settlement and consolidation, shall be limited to 40 mm.

The piling shall be suitably reinforced to resist all loadings. The computation of pile capacity shall be calculated from static theory according to subsoil exploration records and design safety factors for all load cases shall be 2.5 for compression and 3.0 for uplift capacity. The pile subjected to lateral load, the maximum bending moment in pile section occurred from lateral load shall not be greater than cracking moment and design safety factor for all load cases shall be 2.0 for lateral load.

The pile shall be able to withstand earthquakes. The determination of the interaction of the entire structure system (structure and pile) with the movement of surroundings soil shall be performed.

In the design of pile for machine foundation, which subjected to dynamic loads, the response of the foundation, in the form of modal frequencies, deflection, stress, strain, and so on, shall be determined.

The size and length of piles for all structures and equipment foundations shall be proposed to EGAT for approval.

The maximum lateral deviation from the correct location at cutoff elevation up to 5.0 cm will be permitted.

The misalignment along vertical axis of piles shall not exceed 1.5 mm per 100 mm of pile length.

Appropriate flexibility shall be provided for pipe work which passes through the interface between rigid foundation structures and surrounding material that may be susceptible to settlement.

Driven pile, if allowed, pre-boring method shall be utilized for driven pile installation. Pre-bored depth shall be at least 12.0 m.

Prestressed concrete solid square pile shall conform to TIS 396 Standard. In addition to requirements of TIS 396 standards, effective prestress in piles shall not be less than 4.83 MPa for prestressed concrete solid square pile.

Pile splice for driven pile shall be limited to one splice and shall not be in soft soil layer. Splice shall develop adequate strength in compression, tension and moment during installation and in service and be as durable as the pile.

The design of pile splice shall be in accordance with ACI code. Splicing detail and calculation sheet shall be submitted to EGAT for approval prior to manufacturing the test piles. Hexagonal pile shall not be allowed to use for this project.

End of Chapter 26

## **CHAPTER 27 - DRILLING AND WATER PRESSURE TESTING**

**TECHNICAL SPECIFICATION**  
**CHAPTER 27 - DRILLING AND WATER PRESSURE TESTING**  
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## CHAPTER 27 - DRILLING AND WATER PRESSURE TESTING

### 27.1 GENERAL

#### 27.1.1 Scope of Work

The Work under this Section includes all labour, materials, equipment and services required for the execution of drillholes and water pressure testing, at locations shown on the Drawings or where the Engineer may indicate.

Drilling will be required from the surface, from within the dam body and elsewhere and in all directions and inclinations as shown on the Drawings.

Drilling shall include but not be limited to the following:

- Drilling of pilot and exploratory holes for the purpose of extracting rock and soil samples, for conducting water pressure tests and for the determination of rock and soil properties
- Drilling of grout curtain holes / blanket grouting
- Drilling for foundation consolidation grouting
- Drilling of check holes, with or without core recovery, to determine the effectiveness of grouting
- Drilling for installation of instrumentation
- Drilling for crack and joint grouting

The sequence of work shall generally follow the following sequence for any given part of the Works:

- Exploratory or pilot holes with water pressure tests and core recovery.
- Consolidation grouting over entire footprint of all main structures to a 1.5 to 3 m grid.
- Curtain/Blanket grouting in a single row from the grouting galleries or from the rock surface by the split-spacing method, primary holes at 6 m centers, secondary holes in between and so on.
- Additional holes as required, tertiary, quaternary, etc. depending on the cement take.
- Check holes, with or without water pressure tests and core recovery.
- Additional holes as required to achieve final closure criteria.
- Drainage holes from galleries.

Water pressure tests shall be carried out by the Contractor in grout, pilot, exploratory and check holes as requested by the Engineer.

Undisturbed sampling, penetration tests and split barrel sampling shall be carried out by Contractor in drillholes in soils and in soft or completely weathered rock where directed by the Engineer.



The general extent and approximate location of the drillholes are tentatively indicated on Drawings. The actual number of drillholes, size, inclination, depth and location will be adapted to suit the geological and foundation conditions disclosed in the course of the Work, as agreed with the Engineer.

Drilling for installation of rock bolts, grouted anchors bars, and pre-stressed anchors shall be performed in accordance with the provisions in Chapter 22 "Rock Stabilization".

The Drilling and Grouting Subcontractor shall have to prove a minimum experience of three successful grout curtains for dams of similar type and depths within the past 5 years. The responsible staff of the Drilling and Grouting Subcontractor, management, supervisors and foremen shall have to prove a minimum of 10-year experience in deep rock grouting for dams. The Drilling and Grouting Subcontractor shall submit his proposed site organizational structure and CV's at least 45 days before the start of the drilling and grouting works.

### **27.1.2 Submissions**

Within a reasonable time but prior to the start of grouting works, the Contractor shall submit for approval fully detailed proposals and a detailed layout of his proposed arrangements for the drilling, including specifications of all equipment, tools and all grouting materials to be used, drilling report forms, water pressure report forms and qualification and experience of the proposed personnel.

Within 24 hours of completion of any drilling with or without core recovery, the Contractor shall submit, in duplicate, a technical borehole report and log of the drillhole in a form agreed by the Engineer. The log shall include as a minimum the following data:

- a) Date of beginning and end of drilling
- b) Drillhole number
- c) Location, ground surface elevation, co-ordinates, inclination, azimuth, and length of drillhole
- d) Type and diameter of drilling bit and core barrel used, make of drilling rig and length and diameter of casing, if used
- e) Elevation of ground water levels encountered, including dates and times of measurement
- f) Results of leakage tests and other drillhole tests, if any
- g) A record of the drillers observations on progress of drilling, rate of penetration, speed and uniformity of rotation of bit, action of the drill rig such as jerky, smooth, rough, steady, etc.
- h) A record of the drillers' observations on any events encountered such as drill tool drop, voids, water loss, water entry into the borehole (artesian conditions) and any other unusual features
- i) Where pertinent, length of each core run and the length, or percentage, or both of the core recovered and location and cause of core losses
- j) Any changes in the character of the drilling water or mud, and in case the drilling water was lost, the elevation or depth when this happened

- k) A simple driller's interpretation and description of the nature of the formation encountered as the drilling progress
- l) Location and nature of cavities, seams, cracks, soft or broken rock, whether filled or open, and any other observation which could give information in connection with the original purpose of exploratory drilling
- m) Names of drillers and inspectors

Geological logging shall be performed by the Contractor.

Where pertinent, color photographs in minimum A4 size of the boxed cores from each drillhole shall be submitted to the Engineer in 2 copies with electronic file within 10 days from the completion of the drillhole.

The core samples shall be immediately transferred and stored in suitable core boxes. Each core box shall be made of robust construction so as to protect the contents from the elements. See also Subsection 27.2.2 for more details.

The Contractor shall submit reports in duplicate giving the results of each water pressure test performed, within 24 hours of the end of the shift in which the tests were carried out. The reports shall contain the following:

- a) Location and reference number of drillhole
- b) Date and time of test performance
- c) Type of test
- d) Pressure readings and water levels before and after testing
- e) Packer rod characteristics and depth of packer(s)
- f) Total injected water volume and rate per minute and per linear meter of hole for various pressures
- g) Description of all surface water leaks indicating the distance and approximate quantity

The raw data as well as interpretative graphs according to Houlby with analysis (wash-out, dilation etc.) and a representative Lugeon value shall be submitted within 3 days of the test being completed.

The Contractor shall submit reports in duplicate giving the results of each penetration test and split-barrel or thin-walled tube sampling performed, within 24 hours of the end of the shift in which the tests were carried out.

Prior to each phase of drilling, the Contractor shall submit for approval a detailed program and Method Statement for the particular drilling works along with information relating to the methods that are proposed to be used and details of the drilling methods. No drilling work shall be executed without prior written approval by the Engineer.

The drilling and grouting subcontractor shall submit a thorough and detailed works program for the work at least 45 days prior to starting the works. The program shall be prepared in consultation with the Contractor and shall clearly show the critical phases and

paths of the contractors work and their effects on the drilling and grouting. The program shall be regularly updated during the works.

## **27.2 Equipment**

### **27.2.1 General**

Only modern, properly operating equipment approved by the Engineer and operated by trained and experienced crew shall be used for the performance of the Work.

The Contractor shall have sufficient drilling rigs of the necessary type at the Site for the timely completion of the Works. The drilling rigs shall be in good operating condition and adequate for the satisfactory progress of the Work.

Drilling equipment and methods shall be such so as to minimize over-sizing or caving of the holes. Drill casing, where required, shall be of high quality steel, plain or perforated as agreed with the Engineer. The casing necessary for driving through soils shall be of a diameter to take the largest size core barrel or bit to be employed. Auxiliary casing shall be provided where it is necessary to case through formations already penetrated and where no casing has been installed. This shall have a diameter to fit inside the hole and permit the use of the next smaller core bit and barrel. When casing is installed to keep the grout hole open for grouting, equipment and casing shall facilitate the casing removal immediately prior to, or simultaneously with, the grouting process.

The Contractor shall have available at the Site drilling equipment for both rotary and percussion type. The minimum diameter of drilling hole shall be 45mm for consolidation/blanket grouting, 76mm for curtain grouting and 38mm for contact grouting. Other required diameters shall be 48mm, 51mm, 66mm, and 99mm according to the purpose of the drilling as determined by the Engineer.

Drilling equipment shall be capable of drilling at any angle, upward or downward, and at any inclination and shall have capacity to drill up to the depth as shown on the Drawings or as directed by the Engineer.

The Contractor shall keep at the Site an ample and suitable supply of different types and sizes of drilling bits to allow optimal drilling in the different materials to be encountered in the course of work, and sufficient and adequate rods and casings of various diameters to allow proper telescoping and to ensure the stability of drillholes.

An inclinometer for checking the actual inclination of drillholes shall be provided and shall be used on a regular basis in both rotary and percussion drilled holes.

For rotary drilling, only clean water shall be used as the drilling fluid. The drilling fluid delivery shall be sufficient to uplift all the cuttings and to clean the hole. Additives to drilling water, rod dope or excessive rod grease shall not be used. For percussion drilling, compressors of adequate capacity shall be used with suitable air filters and pressure regulators.

### **27.2.2 Drilling with Core Recovery**

Drills for exploratory drilling shall have the following features:

- a) Automatic adjustment or manual adjustment for drill pressure and rate of advance in accordance with the geological condition
- b) Proper working indicator of drilling pressure
- c) Transmission gear to adjust spindle speed

The Contractor shall use swivel type double-tube or triple-tube core barrels.

Drill rods shall be of sufficient diameter to permit adequate flow of the drilling fluid and to provide sufficient upward velocity of the fluid to remove effectively all the cuttings.

### **27.2.3 Water Pressure Testing**

The Contractor shall provide a sufficient number of complete sets of pressure testing equipment (with spares) to allow simultaneous testing at the various drilling and/or grouting locations.

Unless otherwise requested by the Engineer, the pumps shall have a capacity of 120 litres/min at a steady pressure of 10 bars and shall be capable of exerting a pressure from 1 bar to at least 30 bars. The pumping system shall be capable of maintaining any desired pressure without fluctuation and the pressure and discharge must be continuously adjustable throughout the range. The water pumps shall deliver the water smoothly without pulsations or kicks.

Water pressure shall be measured by means of a pressure gauge with an accuracy of 0.5 bar and a range in conformity to the test, so typically a 15 bar pressure gauge for a 10 bar test. Discharge shall be measured with an accuracy of 2 %. The water meter shall measure the discharge from 0.5 l/min. Water meters as well as all pipes, hoses and couplings shall be designed to resist a pressure of 60 bar.

A master gauge shall be provided that has been calibrated and certified by an independent laboratory prior to installation at the Site and shall be subject to periodic verification. The pressure gauges to be used at site shall be checked against this master gauge and any gauge found to be beyond the required accuracy, shall be rejected. Each site gauge shall be indelibly labelled and numbered. The Contractor shall propose a calibration procedure at the start of the Works. If requested, one pressure gauge and one water meter shall, after independent checking, remain at the disposal of the Engineer for further checking purposes. The Contractor will be requested to establish, by way of tests, correction graphs for pressure losses occurring in the pipes. Pressure gauges shall be installed directly at the collar of the drillhole.

The master gauge shall be submitted for calibration by the independent laboratory on a monthly basis.

The flow meters shall be capable of withstanding pressures of up to 15 bar and of metering flows up to 120 litres/min. The accuracy of the meters shall be checked according to a schedule to be agreed with the Engineer and they shall be accurate to within 2%.

Packers shall consist of pneumatically expanded sleeves of rubber or other suitable material, such as type Bimbar or equivalent which can be set tightly in a drillhole at any depth required. Packers shall be generally capable of withstanding pressures of up to 30 bars without leakage or displacement. The Contractor shall keep at the Site an adequate supply of single packers, as well as double packers and spare sleeves and spare parts to allow to isolate a section of a hole, and of sizes to suit the various hole diameters.

For water level measurements, dip meters or electrical probes with an accuracy of 10 mm shall be used. They shall be provided with measuring tapes marked with centimetre gradations.

## **27.3 DRILLING**

### **27.3.1 General**

Rigs shall be capable of drilling holes in all directions, both vertical upward and downward and inclined at depths and the locations specified with a deviation accuracy of less than specified below, as measured at the bottom of the hole (higher accuracy required for pendulums):

- 1% of the length up to 50 m depth
- 2% of the length between 50 and 100 m

An inclinometer for checking the actual inclination of drillholes shall be provided and shall be used on a regular basis in both rotary and percussion drilled holes.

Holes shall be drilled within 10 cm of the positions shown on the Drawings or otherwise agreed with the Engineer.

The diameter specified for any drillhole shall be the minimum diameter. The diameter of the hole as drilled shall equal or exceed the specified diameter over the entire length of the hole.

Sufficient circulation clean water shall be used to flush out all sediments. The use of lubricants such as metallic salts or mineral soaps in the circulating water to help the drilling process or to reduce the wear on the drill bits shall require the consent of the Engineer. These products shall not impair the quality of the grouting or the setting of the grout. The use of grease, oil, or other lubricants or additives shall not be permitted for grout holes. The injection of cement grout to stabilize the drillholes is subjected to the geological condition and duly informed to the Engineer.

Unless otherwise agreed with the Engineer, all holes shall be thoroughly washed out from the bottom with water under pressure immediately after drilling. Water flushing shall continue until the waste water runs clear.

Unless otherwise agreed with the Engineer, all grout holes excluding drain holes drilled through the structural concrete lining or backfill concrete shall be reamed or re-drilled and filled as described in "Closure of Holes and Clean-up" in Chapter 27 "Grouting for Dam".

All surface holes (with drilling completed to any stage), and underground holes (as needed) shall be temporarily capped or otherwise protected.

If the drilling plan is altered to require additional drillholes in any section of the Works, the Contractor shall reinstall the equipment and carry out new drilling in the pattern and lengths as instructed by the Engineer. All such additional drilling shall conform to these Specifications.

No drilling operations shall be permitted within 24 m of another hole being drilled, grouted or water pressure tested. In the foundation and curtain grouting works, no borehole shall be left open un-grouted closer than 12 m from a hole being grouted.

### **27.3.2 Drilling of Exploratory Holes, Sampling and Testing**

#### **27.3.2.1 Drilling and Core Recovery**

The Contractor shall carry out exploratory drilling work before grouting works started or as agreed with the Engineer at the duration of the Contract. The exploratory drilling shall comprise:

- a) Drilling from galleries for geological exploration during excavation and after grouting operations
- b) Drilling from the surface for geological exploration, testing and sampling

The specific location, direction and depth of holes to be drilled shall be as proposed by the Contractor and agreed with the Engineer.

Drilling from galleries or from the surface will generally not exceed 100 m in depth and the Contractor shall drill at any angle or direction agreed with the Engineer.

Exploratory drillholes shall be of 76 mm minimum diameter. However, the Engineer may order exploratory drilling from the surface of larger diameter if it is technically required. Drilling shall be performed with rotary drilling equipment using coring type bits. Unless otherwise agreed with the Engineer, the Contractor shall use a standard ball bearing, swivel type, double-tube core barrel equipped with core bits set with diamonds, tungsten carbide, or similar hard materials and standard core lifters. Core diameter shall be 55mm minimum for 76mm and 76mm for 90mm diameter drillhole.

Coring runs shall be limited to a maximum length of 3 m. The cores shall be removed from the holes immediately if blocking of the bit or grinding of the core is indicated by the drill behaviour regardless of the length of the run which has been made. When less than 80 % percent of core is recovered from a 3 m run, the length of the following run shall be shortened by 50 %, unless otherwise agreed with the Engineer. Where core loss is seen, this shall be clearly marked in the core box with a piece of wood so labelled and with the depth of the core loss.

The length of each run shall be clearly marked in the core boxes with a permanent wooden or other method and similarly the length of each run shall be clearly marked in the bore logs.

Only samples not altered or damaged by the drilling process will be considered as "core". Core must correspond to the depth of origin with an accuracy of 50 mm. The Engineer may at any time check the accuracy of the core runs during drilling operations. Core recovery not representative of the drillhole depth may require partial or total re-drilling of the hole by the Contractor.

Metallic or other hard material hammers shall not be used to assist in the removal of the core from the core barrel nor shall the core barrel be dropped or bounced on the ground to loosen core.

A core recovery of at least 95 % is required in sound rock and 80 % in weathered and fractured rock and in soils of any nature. Drilling shall be stopped and the cores removed from the barrel as often as is necessary to secure the required core recovery. Where a higher core recovery is required, the Engineer may order the use of triple-tube core barrels such as Mazier samplers or similar approved.

Each hole drilled shall be protected from becoming blocked by means of a cap or other suitable device on the collar. Any hole that becomes blocked before completion of operations shall be cleaned out in a manner satisfactory to the Engineer or replaced by another hole drilled by the Contractor.

Where indicated on the Drawings or requested by the Engineer, the cored holes shall be fill-grouted in accordance with the provisions of Chapter 27 "Grouting for Dam". All holes within the grout curtain shall be grouted within a maximum of 72 hours of hole completion unless otherwise explicitly requested by the Engineer, for example if the hole is to be used for long-term water level measurement purposes.

#### **27.3.2.2 Handling and Storage of Cores**

The Contractor shall provide strong core boxes, 1.1 m long, of wood, metal or other robust durable material so that the contents are protected from the elements, subject to approval by the Engineer. The boxes shall be provided with hinged lockable covers, robust handles at both ends and with longitudinal spacers that will form 5 separate compartments so that each box shall hold cores from 5 m of the hole. There shall be sufficient space between the core and box such that core can be easily extracted for inspection but not so much that the core risks damage by excessive movement during transport.

Each core box shall be indelibly marked both inside and outside with the project name, borehole number, borehole details, box number and box number sequence with total number of boxes for that hole, borehole depth contained in that hole, date and location. The borehole number and box number sequence shall be marked at either end of the box.

The core boxes shall be stored in weatherproof sheds of sound construction in the vicinity of the Works, at locations agreed with the Engineer.

The core shall be carefully extracted from the core barrel and stored in core boxes in the correct orientation and sequence. All cores shall be marked with an arrow in the direction of drilling. Wooden blocks which fit between the longitudinal spacers with a clear and durable inscription of the depth shall be placed between each core run. Where core is not recovered, or where samples have been removed by the Engineer, timber blocks of square

cross-section shall be placed in the box. These timber blocks shall be cut to the same length as the missing cores and placed in the corresponding positions. If these positions cannot be determined, the blocks shall be placed at the top of the run.

No box shall contain cores from more than one hole.

Once the logging and photographs are done, all details in the logging shall be checked by the Engineer and the Contractor prior to transfer the core boxes to a secure and protected storage area, with roofing such that the core boxes are protected from the elements. The boxes shall be labeled at each end to allow for easy and practical locating. A shelf or racking system raised off the ground appears to be the most convenient way so that the boxes are not damaged and are easy to extract for inspection.

### **27.3.2.3 Sampling and Testing**

In overburden, soft or weathered rock or when, in the course of drilling, soft materials are encountered which produce less than 50 % recovery, the Engineer may direct the Contractor to perform Standard Penetration Tests and to secure the desired samples by split-barrel sampling and/or thin-walled tube sampling of soils in accordance with the procedures described in ASTM Method D 1586 and in Method D 1587.

The Engineer may request to perform special tests in exploratory holes carried out from galleries and from surface.

### **27.3.3 Drilling of Pilot Holes, Primary Test Holes and Check Holes with Core Recovery**

The Contractor shall propose to the Engineer for approval to drill vertical or inclined holes with core recovery to determine the nature of the rock before grouting, and the effectiveness of the grouting operations. Water pressure testing shall be carried out in each of these holes over their entire length as agreed by the Engineer.

These holes shall be drilled as stipulated for exploratory holes, and shall be drilled from the surface or from grouting galleries as agreed with the Engineer. Primary test holes shall be cored as a minimum two stages deeper than the indicated depth of the grout curtain. However, in the event of high take or collapsing or other anomaly in the lowermost stage, the hole shall be deepened by one stage or as instructed by the Engineer.

Cores shall be stored in core boxes and colour photographs shall be taken as described for exploratory holes.

### **27.3.4 Drilling Through Concrete**

Drilling through concrete shall be by rotary or percussion drilling, as agreed with the Engineer.

In grouting galleries, in order to avoid drilling through concrete containing reinforcement, damageable tubing or other embedded parts, "guide sleeves" shall be installed in the forms prior to placing concrete. These sleeves shall be rigid plastic pipes that do not deform



during the concreting works with an internal diameter suitably sized to accommodate the largest drill bit.

### **27.3.5 Drilling for Foundation Consolidation Grouting**

The Contractor shall drill consolidation grouting holes from the rock surface over the entire footprint of the structures and from grouting galleries, if any, to the lengths and directions indicated on the Drawings or as agreed with the Engineer.

The drillholes shall have a minimum diameter of 45mm. Generally, the foundation consolidation grouting holes shall be drilled to a 3m grid system over the entire footprint and shall be drilled perpendicular to the rock surface in a vertical, inclined, or horizontal direction to 30 m maximum depth. However, in the area with stress concentration, fault, closely spaced joints or other geologic defects, the consolidation grout holes may be drilled to a 1.5 to 3m grid system. Depending on the cement takes, the holes may be extended by one stage. Higher order may be instructed by the Engineer and positioned using the split-spacing method.

It is anticipated that the holes will be drilled and grouted in the ascending or upstage method in stages of 5 m length.

Whenever required for downstage method or descending grouting (as described in Chapter 27 "Grouting for Dam") or depending on the geological conditions encountered and from experience gained at site, the Contractor shall drill the holes in successive stages from the collar of the hole. When the grouting is to be done in a descending arrangement, the drilling shall be interrupted to grout the previous section. After the time agreed with the Engineer the hole shall be washed and the drilling resumed.

The holes may be drilled in rock with percussion, rotary or rotary-percussion drills without core recovery, though it is generally anticipated that percussion drilling will be performed for consolidation grouting holes.

Check holes may be required to verify the effectiveness of the consolidation grouting treatment. These holes may need to be cored with water pressure tests, as described in the Section "Drilling for Exploratory Holes".

Holes drilled in soft rock or fractured formations shall be cased with a perforated or non-perforated steel pipe as agreed with the Engineer. Where practicable, such casing shall be later removed. Casings shall only be allowed to remain permanently in place with the approval of the Engineer considering with the geological condition.

In general, radial deviation from the specified inclination of the drillhole shall not be greater than 1% of the length up to 50 m.

### **27.3.6 Drilling for Curtain/Blanket Grouting**

The Contractor shall drill holes from grouting galleries or from the surface at locations, and to the lengths, and in all directions as indicated on the Drawings or as agreed with the Engineer.

The drillholes shall have a minimum diameter of 76mm, with inclusive of primary test holes and check holes with core recovery.

The Contractor shall drill grout hole through PVC pipe which installed with minimum diameter of 100mm in accordance with inclination of drillhole through the rock foundation. The installation of PVC pipe shall be up to sequence of tertiary grout holes (1.5m spacing) as agreed by the Engineer.

The spacing of primary holes shall tentatively be 6m, and grouting shall be done using the split-spacing method. Depending on the cement takes, the holes may need to be extended by at least one stage. Exploratory or pilot holes shall be tentatively spaced at 36m intervals. The grout curtain shall be a single row grout curtain.

The length of holes is indicated on the Drawings. The drillholes shall be vertical, inclined, or horizontal as indicated on the Drawings.

The holes for grouting may be drilled with percussion, rotary or rotary-percussion drills, and except those for primary test holes, pilot, exploratory and check holes, shall be done without core recovery. However, if so requested by the Engineer, samples obtained from the drilling shall be recovered and stored, which shall be done as far as possible from each linear metre of the drillhole. The samples shall be stored in plastic bags with indicated drillhole number, date and depth of recovery. These samples shall be stored for the duration as required by the Engineer and finally at the same place as the core boxes.

It is anticipated that the holes will be drilled and grouted in the ascending or upstage method in stages of 5 m length. Depending on the geological conditions encountered and from experience gained at site, however, the descending or downstage method may be required. In the event of frequent collapsing over a number of holes, the first three stages of the grout curtain shall be drilled and grouted by the descending method or downstage, thereafter if conditions allow, the remainder of the hole shall be drilled and grouted by the ascending method or upstage.

When the grouting is to be done in a descending arrangement, the drilling shall be interrupted to grout the previous section. After the time agreed with the Engineer the hole shall be washed and the drilling resumed.

Holes drilled in soft rock or fractured formations shall be cased with a perforated or non-perforated steel pipe as agreed with the Engineer. Where practicable, such casing shall be later removed. Casings shall only be allowed to remain permanently in place with the approval of the Engineer considering with the geological condition.

Water pressure testing shall be systematically carried out in downstage or descending in the pilot or exploratory holes and check holes over their entire length, if not otherwise agreed with the Engineer.

All holes drilled through the structural concrete lining of the grouting gallery shall be reamed or re-drilled and filled as described in "Closure of Holes and Clean-up" in Chapter 27 "Grouting for Dam".

### **27.3.7 Drilling of Drainage Holes**

Drainage holes shall be drilled from the rock and dam galleries, if any, in locations and at inclinations and directions recommended by the Engineer and as shown on the Drawings. In addition to use for drainage purposes, the holes may be used as ground water observation wells or to determine groundwater pressures.

Holes for drainage shall be drilled after all holes for all types of grouting in a particular section are complete.

Drainage holes shall be drilled by rotary or rotary-percussion drilling, and shall have a minimum diameter of 76mm and a length as agreed with the Engineer. Core recovery may be required in some holes, in rock or through the concrete.

Where required, drillholes shall be cased. Casing shall be withdrawn after installation of drainage pipes.

PVC pipes (with or without perforation as needed) of a nominal internal diameter of 50mm shall be installed where agreed with the Engineer. The pipes shall be "Schedule 40 PVC" pipes according to ASTM Specification D 1785 or approved equivalent. Pipes shall be provided with couplings to achieve any required length.

Where recommended by the Engineer, selected holes, and in particular those drilled after placing of the concrete lining, shall be equipped with a pressure gauges to measure the water pressure within the rock, in general 1 to 3 m within the hole. An external soft rubber collar shall be fitted around a drainage pipe and together inserted to the appropriate depth. The space surrounding the drainage pipe shall then be filled with non shrink cement grout.

The Contractor shall install pressure gauges, pipes and fittings which will allow the measurement of pressures up to 20 bars with an accuracy of  $\pm 2\%$ . The pressure gauge shall be combined with a pressure relief valve to limit the water pressure to 20 bars.

Pressures shall be recorded as agreed with the Engineer and results shall be made available to the Engineer. When pressure measurements are no longer required, the pressure gauge shall be removed.

### **27.3.8 Drilling for Installation of Instrumentation**

The Contractor shall drill holes with core recovery for instrumentation such as water and uplift pressure cells, standpipe piezometers, inclinometers, etc. where shown on the Drawings or agreed with the Engineer. The holes will be drilled from within the galleries or from the exposed ground surface. Drilling for instrumentation shall be carried out in accordance with the specifications for drilling of exploratory holes, except as amended below.

It is assumed that the majority of holes for instrumentation will be 76 mm diameter holes (55 mm core). However, the Contractor may be requested to drill 90 mm holes (67 mm core), or to such appropriate diameter to suit the instrumentation proposed for installation.

### 27.3.9 Drilling for Crack Grouting

The Contractor shall drill holes for grouting and sealing of cold joints, construction joints, shrinkage cracks, etc. vertical, inclined or horizontal, in structural concrete lining as directed by the Engineer and as stipulated in Chapter 10 "Concrete".

The drilling shall consist of a series of minimum 38 mm diameter drillholes executed within or along the cracks which have been suggested by the Engineer to receive such treatment. However, in case of short hole, the Engineer may instruct to use smaller size to suit with the size of cracks.

Only rotary drilling will be permitted for crack grouting. However, in case of the contractor install PVC pipe (sleeve pipe) during concrete placing to intercept joint, percussion drilling may be accepted as agreed with the Engineer to use for drilling through the sleeve pipe.

## 27.4 WATER PRESSURE TESTING

### 27.4.1 Lugeon Test

The Contractor shall perform water pressure tests by the Lugeon Test Method in grout and exploratory holes or section of holes, as the drilling proceeds or after completion of a drillhole, as and where agreed with the Engineer.

The permeability as measured in the drillholes shall be expressed in Lugeon units, *1 Lugeon unit being equal to a water take of 1 litre per minute per linear metre of hole at a pressure of 10 bars. (1 Lugeon =  $10^{-5}$  cm/sec)*

The hole or section of a hole to be subject to testing shall be sealed generally with single packer placed 5 m above the bottom of the hole when drilling is done descending, or rarely with double packers 5 m apart when the testing is done ascending. The groundwater table, if any, shall be measured and registered before and after each test.

After the packer is installed, the drillhole shall be thoroughly flushed and the Contractor shall check that the flow through the packer is not obstructed.

Water shall be pumped into the hole through a header and pressure shall be applied in stages up to the maximum pressure. The maximum pressure shall be agreed with the Engineer and, where water pressure tests are carried out in grout holes, the maximum pressure shall generally not exceed the maximum grouting pressure to be used. The pressure shall be applied in equal five stages as follows and will depend on the depth of the stage being tested:

Stage	Pressure (bar)
1	Low (e.g., 1-3)
2	Moderate (e.g., 2-6)
3	Peak (e.g., 3-10)
4	Moderate (e.g., 2-6)
5	Low (e.g., 1-3)

Before starting the measurements for any test or test stage, water shall be pumped into the stage until a stable pressure has been established. Care should be taken to not oversaturate the stage or induce excessive washing out. The same procedure shall also be adopted when changing to the next pressure stage. For each stage of pressure, water absorption shall be measured every 1 minute for a 10 minute test interval at each pressure stage. The time for each stage of pressure shall therefore be at least 10 minutes and the total time for a completed Lugeon test comprising 5 stages of pressure will be at least 50 minutes, plus the time for pressure stabilisation.

In the event the required pressure cannot be reached, the test shall be modified such that the maximum pressure that can be reached is the peak, stage 3, the pump shall be operated at its maximum discharge rate and the remaining stages shall be divided equally into that maximum.

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

#### **27.4.2 Lefranc Test**

In the event that the permeability is so high that water under pressure is seeping at rates exceeding the capacity of normal pumps, the Contractor shall carry out permeability tests by the *Lefranc method*.

Prior to starting each test, the drillhole shall be adequately cleaned. A standpipe shall be inserted into the drillhole with appropriate packing, and free-flowing water shall be passed by overflow into the standpipe. By adjusting the rate of flow, the water level in the pipe will be kept constant over a period to be agreed with the Engineer. The flow shall be stopped and the water level measured at regular intervals depending on the rate of change of the water level. The entire test shall not exceed 30 minutes.

End of Chapter 27

## **CHAPTER 28 - GROUTING FOR DAM**

**TECHNICAL SPECIFICATION**  
**CHAPTER 28 - GROUTING FOR DAM**  
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## CHAPTER 28 - GROUTING FOR DAM

### 28.1 GENERAL

#### 28.1.1 Scope of Work

The Work under this Section includes all labor, materials, equipment and operations required for the performance of grouting in the holes within the construction sites and from surface, at locations shown on the Drawings or where the Engineer may suggest.

Grouting operations shall include the following:

- a) Consolidation grouting of the structure's foundations
- b) Blanket grouting in order to reduce permeability of broken or leached rock
- c) Curtain grouting in order to cut off seepage along dam axis
- d) Fill grouting of drainage trenches, conduits and sump pits, and of exploratory drillholes and drain holes
- e) Crack grouting to seal open cracks and joints in structural concrete
- f) Chemical grouting in zones of fine sands and soils, and to control high water inflow and increase the stability and strength of the formation that are too tight to be grouted with a cement grout

The general extent and approximate location of the drillholes of the contact and consolidation grouting are tentatively indicated on the Drawings. The final number, length, location and inclination of the drillholes, as well as the composition and consistency of the grout mixes, grouting pressures, pumping rates and sequence in which the holes are to be drilled and grouted shall be determined according to the results of grouting test panel and will be governed by actual conditions encountered on Site and shall be at all times subject to agreement by the Engineer.

The location, orientation and depth of the drillholes for the grout curtain are shown on the Drawings. This system and the sequencing of the grouting operations shall be adjusted if necessary to suit the actual conditions encountered on the Site and from the test panel.

The extent of crack grouting will be agreed with the Engineer.

No boreholes shall be left open for longer than 72 hours before grouting. Before grouting, the Contractor shall ascertain that the hole is still open and clear of obstructions.

The Drilling and Grouting Subcontractor shall have to prove a minimum experience of three successful grout curtains for dams of similar type and depths within the past 5 years. The responsible staff of Drilling and Grouting Subcontractor, management, supervisors and foremen shall have to prove a minimum of 10-year experience in deep rock grouting for dams. The Drilling and grouting Subcontractor shall submit his proposed site organizational structure and CV's at least 45 days before the start of the drilling and grouting works.

## **28.1.2 Definitions**

### **28.1.2.1 Cement Grout**

Cement grout is defined as a mixture of cement and water with the addition of admixtures, sand, bentonite, if required, which is forced under pressure into prepared holes or pipes in order to fill voids or consolidate the rock mass as a whole.

Cement grouts can be subdivided into stable and unstable mixtures:

- Unstable mixtures are simple suspensions of cement in water. These suspensions are only homogeneous as long as they are in movement and the sedimentation starts as soon as the movement is stopped.
- Stable mixtures are colloidal suspension dissolved in water which grain size is so small that no appreciable sedimentation occurs during the grouting operation. These suspensions are obtained by high speed mixing of cement with addition of additives or bentonite.

Only stable mixtures shall be used for the permanent grouting works.

### **28.1.2.2 Chemical Grout**

Chemical grout is defined as a mixture of two or more solutions which combine chemically and form a gel or a solid matter. The solutions may react either prior to pumping into, or within the void.

The chemicals may be used in combination with cement or clay grouts as determined by testing and agreed with the Engineer.

### **28.1.2.3 Single-Stage Grouting**

The single-stage grouting (nipple grouting) is carried out by introducing the grout at either the collar of the hole through a nipple or by means of a grout supply pipe at the bottom of the hole. The entire length of the hole is grouted in one operation.

This grouting method will in general apply for crack grouting and for consolidation grouting of short holes in stable ground.

### **28.1.2.4 Multiple-Stage Grouting**

This grouting method will in general apply for curtain grouting and consolidation grouting in deep holes.

Multiple-stage grouting is carried out by introducing the grout into a predetermined stage of the hole which is blocked off by a packer. The grouting of the entire length of hole is performed in successive stages either in ascending (upstage) or descending (downstage) arrangement.

The terms ascending or descending arrangement mean the sequence of the grouting stages, and by implication the way the stages are drilled, either from bottom to the collar of the hole or in reverse, irrespective of the effective direction or inclination of the hole.

When grouting is done in ascending arrangement, the hole is drilled to its full depth, washed out, and the packer is set at the top of the deepest stage to be grouted. The stage is then water pressure tested (if the hole is a pilot or exploratory hole or is deemed necessary by the Engineer) and grouted at the required pressure through the grout supply pipe. The packer is allowed to remain in place until there is no back pressure, usually 10 minutes and then withdrawn to the top of the next stage to be grouted. The grouting is repeated successively stage by stage until the entire length of the hole is filled with grout.

When grouting is done in descending arrangement, the Work is accomplished in stages from the collar of the hole. The hole is drilled to a limited depth, washed out and the packer is set just above the stage to be grouted. The stage is then water pressure tested (if the hole is a pilot or exploratory hole or is deemed necessary by the Engineer) and grouted at the required pressure. The grout within the hole is either washed out before it hardens or is allowed to reach final set and then drilled while the grout surrounding the hole is allowed to obtain its initial set. The whole process is then repeated by successively drilling, water pressure testing if necessary and grouting at various depths until the entire length of hole is completely drilled and grouted.

Grouting stages, in general, shall be 5 m. Shorter stages may be necessary depending on the conditions encountered, hole collapsing, voids and so on. If stage grouting for the consolidation grouting is required, stages of 3 m length are anticipated.

#### **28.1.2.5 Water-Cement Ratio**

The water-cement ratio (W/C) is the proportion by weight of water to cement in a water-cement mixture.

#### **28.1.3 Submissions**

By latest 45 days prior to the start of grouting works, the Contractor shall submit for approval fully detailed proposals and a detailed layout of his proposed arrangements for grouting, including specifications of all equipment, tools, test panel details (see section "Test Panel") and all grouting materials to be used, grouting report forms and qualification and experience of the proposed personnel.

An overall grouting program shall be drawn up jointly between the Contractor and the Engineer. Grouting mixes, pressures, pumping rates, and sequencing will be selected, subject to modifications, to meet local conditions encountered during the performance of the Work. Grouting works shall be planned in such a manner that they can be carried out according to the approved plan concurrently with other activities. Modifications to the grouting program shall be implemented as agreed with the Engineer. These initial points shall be confirmed during the execution of the test panel phase.

Prior to each phase of grouting, the Contractor shall submit for approval a detailed program and Method Statement for the particular grouting works along with information relating to the methods that are proposed to be used and details of grout mixes. No grouting work shall be executed without prior written approval by the Engineer.

At least 45 days prior to the start of the grouting works, the drilling and grouting Contractor shall propose a methodology for the grout trial mix campaign. In this proposal, the Contractor shall, from his experience in similar projects and similar geological

conditions, propose a range of grout mixes that should be tested. The proposal shall include the additives, test equipment and testing location where the trials shall be conducted. The aim of the trial is to identify several stable grout mixes of varying consistencies that will be used for the grouting works.

During the performance of the grouting works, the Contractor shall keep complete daily records of all grouting operations which shall include the following:

- a) Drillhole Number
- b) Location, ground surface elevation, co-ordinates, inclination, direction, and length of drillhole
- c) Results of water pressure tests
- d) Grouting method
- e) Date and time of commencement and of each change in grouting operations
- f) Rate of pumping
- g) Pressure quantity and flow curves from the automatic grout recorders shall be submitted
- h) Grouting pressures and gauge reference number
- i) Water-cement ratio and its variations
- j) Quantities of cement, sand, bentonite, admixtures and chemicals used
- k) Connections, if any, with other holes as well as any surface leakage of water or grout. The location, caulking method and the success of caulking shall be described. The approximate station and offset of each surface leak shall be recorded where it occurs in the foundations.
- l) Number of holes and depth of holes left for redrilling
- m) Time of completion
- n) Name of the foreman in charge

Grouting reports in an approved form shall be compiled from these records and submitted weekly to the Engineer. Results of grout takes shall be presented graphically.

The Drilling and Grouting Subcontractor shall submit a thorough and detailed works program for the Work 60 days prior to starting the Works. The program shall be prepared in consultation with the Contractor and shall clearly show the critical phases and paths of the Contractors work and their effects on the drilling and grouting. The program shall be regularly updated during the Works.

At least 60 days before the start of grouting and the trial mix campaign, the Contractor shall submit the details of source, detailed specifications, method of delivery and storage of all materials to be used in the Works.

The Contractor shall obtain and submit manufacturer's certificates from the suppliers for each consignment of materials to be used in the Works.

## 28.2 SAMPLING AND TESTING

The Contractor shall prepare and test the trial mixes as agreed with the Engineer in good time before commencement of any grouting. Materials for use in grout mixes shall be tested for compliance with the applicable requirements stipulated in "Materials" of this Section.

During the trial mix campaign, done well before the production grouting starts, and production grouting, the grout mixes shall be subjected to frequent and comprehensive quality control tests. The following tests are required:

- a) Laboratory tests (in the grout mix campaign stage):
  - Grain size distribution and moisture content of sand
  - Atterberg's limits
  - Chemical analysis of water and solids
  - Blaine test and other tests on cement as specified in the "Materials" section
- b) Laboratory tests, to be done on a weekly basis:
  - Compressive strength in cube or cylinder form
  - Viscosity (by fan-viscosimeter and Marsh cone)
  - Rheometer test (by Rheometer)
  - Density (by mud balance)
  - Decantation, shrinkage or bleeding (by transparent 1 litre cylinder)
  - Setting time, initial and final (by Vicat needle)
- c) Field tests, to be done on every few batches at site:
  - Density
  - Decantation or bleeding
  - Viscosity (by Marsh cone)
  - Temperature of grout and water (by thermometer)

Sampling and testing will be supervised by the Engineer.

All chemical grouts shall be tested in the laboratory at the Site, under conditions identical to those to which they will be subjected in the field, in order to determine the suitability of various chemicals and proportion of the ingredients to satisfactorily complete the Work.

During the actual grouting operations, the Contractor shall carry out tests on grout mixes at the same time as grouting, and shall plot values of viscosity, sedimentation limits, compressive strength, and maximum viscosity possible for the grouting. The frequency of testing will be determined at site but indicatively it will be every few batches for the site tests and weekly for the laboratory tests.

In the event the cement type or additives change, the Contractor shall be obliged to conduct another series of trial mixes. The acceptance criteria will be determined by the Engineer.

## **28.3 GROUTING MATERIALS**

### **28.3.1 General**

The following kinds of grout mixes may be needed:

- a) Neat cement grout, with admixture
- b) Cement-sand grout, possibly with admixture
- c) Chemical grout such as polyurethanes, one or two component type
- d) Cement-bentonite grout with sand

The quantities of sand, bentonite, and admixtures will depend on the permeability of the rock and the size of the voids to be grouted.

Cement, sand, water, admixtures, and fly ash for use in grout mixes shall conform to the requirements of Chapter 10 "Concrete", except as specifically amended hereafter.

Indicatively the grout mix properties shall be:

- Bleeding below 5% after 2 hours
- Viscosity between 30-50 seconds
- Compressive strength higher than 12 MPa at 28 days
- Grout mix temperature, mixed, below 35° C.

### **28.3.2 Cement**

Cement shall have a minimum specific surface of 3,500 cm<sup>2</sup> per gram as determined by the Blaine air-permeability method (ASTM C 204). No cement particle shall be retained on (100% passing) 0.08 mm sieve and at least 98% of any sample shall pass 0.04 mm sieve. The cement shall be standard Portland cement. Only fresh lump-free cement shall be used.

Cement storage and handling shall confirm to the requirement of Chapter 10 "Concrete". Cement shall be stored and used in silos and/or in bags located at the main batching or in mixing plants. Cement in bags can be used but the Contractor is to ensure that a sufficient quantity of cement shall be stored at or near the site of the Works to make sure that grouting operations will not delay or be stopped by shortage of cement.

### **28.3.3 Sand**

Sand in grout might be required for parts of the Work in highly fissured or fractured rock zones or where there is high takes. Sand shall have the following grading:

U.S. Standard Sieve	Square Mesh Sieve Opening	Percentage Passing (by weight)
No.8	2.360 mm	100
No.16	1.800 mm	95-100
No.30	0.600 mm	60-85
No.50	0.300 mm	20-50
No.100	0.150 mm	10-30
No.200	0.075 mm	0-5

Sand for grout should consist of hard and sound particles containing no more than five percentages of deleterious substances. Sand shall not contain more than 3% of flat or elongated particles having a maximum dimension in excess of four times the minimum dimension. Either natural or manufactured or a combination thereof can be used, but the source and gradation shall be subjected to the Engineer's approval.

#### 28.3.4 Water

The water used in the grout shall be fresh, clean and free from sewage, oil acid, alkali, salts, organic matter, or any deleterious or undesirable matter. Water shall not contain more than 2,000 mg/l of suspended colloidal solids and no particles larger in size than the cement particles. It shall not be aggressive. The chloride content shall be less than 50 mg/l and the sulphate content less than 100 mg/l.

The specifications covering the batching of water for concrete which is given in Chapter 10 "Concrete" shall also apply to the preparation of grout.

The temperature of water used for the preparation of grout shall not exceed 30°C.

#### 28.3.5 Admixtures

Admixtures shall be added to grout mixes to lower the water content, to optimize the strength, viscosity, density, decantation, setting time and shrinkage.

Only admixtures proved by testing prior to the start for grouting in the trial mix campaign may be used. Manufacturer's certificates or guarantees will not be accepted as relieving the Contractor of his responsibility for the suitability of any admixture.

#### 28.3.6 Bentonite

Bentonite shall be as specified by the American Petroleum Institute as follows:

Type	Sodium Montmorillonite
Wet screen analysis residue on sieve No. 200	max. 2.5%
Moisture	max. 13%
Fan reading	min. 30 at 600 rpm
Yield point	max. 3 x plastic viscosity
Filtrate	maximum 13.5 cc
Liquid limit	not less than 350
Plastic limit	not less than 28

### **28.3.7 Polyurethanes**

Polyurethanes shall be used for consolidation of the sheared or disturbed rock, loose material, and for sealing against high water inflow even under high pressure. Polyurethanes are synthetic materials which penetrate even the thinnest fissures and are able to expand up to 30-40 times of the original volume even in the presence of water.

### **28.3.8 Chemicals**

When chemicals are required or proposed, they shall be accompanied by the manufacturer's certificates that they have been commercially used with satisfactory service in similar type of work. The storage, handling and usage shall strictly adhere to the manufacturers printed instructions.

The use of toxic chemicals such as acryl amide shall not be permitted for use in the Works.

## **28.4 GROUT MIXTURES**

### **28.4.1 General**

The type of grout and products for each mixture will be agreed with the Engineer according to design requirements and the purpose of the Work. The mix will be determined from the grout mix trial campaign done well before the start of the grouting works and shall be proven during the test panel. The Contractor shall test and submit for approval a range of mixes that can be used during the grouting works as conditions dictate.

The proportions of various constituents in the grout mixtures shall be agreed with the Engineer in consultation with the Contractor.

The Contractor shall be required to prepare and inject the following grout mixes:

- a) Cement/water mix, with the addition of an additive, for consolidation grouting and for the grout curtain
- b) Cement/sand mix with admixture for cases of large grout takes and void filling
- c) Cement/water mix with admixture, possibly with addition of polyurethanes for crack grouting

Any grout mixture not used within one hour after mixing shall be discarded.

The Contractor shall take particular care regarding the disposal of grout with additives or chemicals that they do not enter the water table and that they disposed of in an environmentally-friendly way.

### **28.4.2 Stable Cement Mixtures**

Stable mixtures shall consist of cement, with addition of an additive and as the Engineer may suggest. In modern grouting practice, it is common to use one fairly thick grout with a suitable additive that will be used for the majority of the Work. Typically the water-cement ratio (W/C) of such a mix shall vary from 0.60 to 0.8.



The Contractor will make additional tested and approved mixes available, both thicker and thinner, to be used depending on the conditions encountered at site.

The preparation of cement-additive grout mixture shall be as follows:

Phase 1: Mix water and the lump-free cement in a high-speed colloidal mixer. The grout is mixed for 2 minutes. The pre-measured quantity of additive is slowly added to the mix, the grout is mixed for 1 minute.

Phase 2: Transfer the grout to an agitator where the mix is slowly turned and kept ready for delivery to the grout hole.

In the event bentonite is used for the grouting works, the bentonite slurry shall be prepared at least 24 hours before it is used for full hydration and kept in a holding tank under agitation. Under no circumstances shall the same mixer be used for both bentonite and grout mix preparation.

Water used for the preparation of the grout or bentonite slurry shall not contain any suspended cement particles.

#### **28.4.3 Grout Mixtures for the Grout Curtain**

It is anticipated, that the proposed grout mix will be in the range of water-cement 0.6-0.8 with 0.5%-A further thicker mix shall also be required as will a sandy mix for cases of very high uncontrolled grout take.

If the grout pressure develops up to 80% of specified pressure with the initial grout mix, the hole shall be grouted to refusal point. If there is a pressure drop or if there is no pressure, the grout mixture shall be thickened to obtain the development of the desired grout pressure. In the event there is still no pressure development after a pre-determined volume has been injected, a sandy mix may be used.

The cement/pozzolan blend shall contain 20% pozzolan to improve mechanical properties of the slurry and the resistance of the grout to dissolution by soft water.

In areas of known high permeability, as interpreted by the Engineer, or where detectable water loss during drilling occurs, the starting grout mix shall be the thicker water-cement mix with plasticizer.

If the grout take exceeds a pre-established amount the mix shall be switched to a thicker mix or a sandy mix in order to fill the open seams with mortar composed of one part sand (i.e. 20% of cement), cement/pozzolan and water (i.e. 1:1.2) with plasticizer as required. Mortar shall be pumped to refusal.

All the grout mixes used shall have been tested in the grout mix trial campaign completed well before the start of production grouting.

## **28.5 EQUIPMENT**

### **28.5.1 General**

Only modern, properly operating grouting equipment approved by the Engineer and operated by trained and experienced crew shall be used for the performance of the Work. This shall be specifically observed when dealing with chemical products.

Grouting equipment shall consist of grout pumps, weighing scale for additives and cement, silos for cement storage with screw delivery or proper cement bag storage, grout mixers, water meters, agitators, pressure gauges, packers, pipelines and fittings, and miscellaneous tools specifically designated for grouting purposes.

Grouting equipment shall be capable of effectively mixing and stirring the grout and forcing it into the grout holes or grout connections in a continuous, gradually increasing, uninterrupted flow at any specified pressure up to a maximum of 35 bars, and of accurately measuring the grout take. It shall maintain the specified pressure for at least 10 minutes after the hole refuses to accept further grout. High pressure capacity up to 50 bar may be required if several grout holes are simultaneous grouted from the main grout line. The equipment shall be capable of accurately controlling grout flows and pressures and shall be suitable for neat cement, cement-sand, and chemical grouts.

Spare gauges, shall be prepared to suit the pressure used (e.g., 0-7 bar, 0-16 bar, 0-35 bar) valves and fittings shall be kept available at the Site.

Standby equipment which can be activated immediately shall be furnished to ensure continuity of work in the event of main equipment breakdown. The standby equipment shall be able to operate at pressures up to 25 bars.

Graduated water discharge meters shall be accurate to  $\pm 2\%$ .

Equipment for proportioning grout mixing of cement from bulk silo or from cement bags and dosing of bentonite and water shall maintain dosing accuracies of 2 and 5%, respectively.

Prior to commencement of the Work, during the Work as specified or as requested by the Engineer, and at the end of the Work, all pressure gauges, recorders and discharge meters shall be checked and calibrated. A calibration schedule shall be agreed in advance with the Engineer.

The grouting equipment shall always be well maintained in order to guarantee continued and efficient performance during grouting work.

### **28.5.2 Cement Storage / Cement Bag Storage**

Cement shall be stored in silos or in cement bag storage with firm foundations placed above the main grouting stations and shall be easily accessible by delivery trucks. The storage shall have sufficient cement capacity to ensure uninterrupted grouting for 10 days. Cement shall be transferred from the storage to the mixer with a screw conveyor as required. The quantity of cement to be delivered per batch shall be controlled by either

weighing pads under the mixer or by a timer system that controls the amount of time the conveyor should be activated for. Only lump-free fresh cement shall be used.

### **28.5.3 Grout Mixers and Agitators**

Grout mixers for mixing the stable mixtures shall be of the mechanically operated, high speed colloidal type of sufficient size and operating at 1,500 to 2,000 rpm to ensure complete dispersion and activation of the mix with electric or pneumatic drive. Grout mixers shall be approved by the Engineer.

Hand-powered mixers or concrete mixers shall not be permitted for preparation of grout mixtures.

Mixers shall be provided with equipment for measuring weight and volume of mix components with an accuracy of 2%, and a water meter calibrated in litres with a reset switch for zeroing after each delivery.

After mixing, the grout shall be discharged through a 5mm mesh screen into an agitator equipped with stirring paddle to prevent settling and to remove any air bubbles from the mix. The maximum rotation speed of the agitator blades or paddle shall be in between 80-100 rpm to avoid that the mix is over-heated. The stirring paddle shall be of such arrangement to guarantee a complete circulation of the entire agitator content. The agitator sump shall have at least 1.5 times the capacity of the mixer so that one batch of grout can be pumped while the next batch is being mixed to ensure uninterrupted grouting.

The mixers shall be capable of mixing sandy mixes and mortars.

### **28.5.4 Grout Pump**

Grout pumps shall be capable of delivering a flow of 50 litre/minute of thick grout (W/C = 0.5) at the specified pressure and shall be able to achieve and hold a pressure of up to 35 bar. They shall deliver grout at constant pressure and flow, from 1 bar and 1 litre/minute, without pressure or flow surges.

Pumps shall be of the duplex double acting piston-type or a single or double acting plunger type, or other similar type approved by the Engineer. Pumps that induce excessive “kicks” or “jerks” in the line with pressure surges during the grouting will not be approved. The pump body shall be of high wear and shock resistant material. The plunger unit shall be of stainless steel, highly resistant to abrasion.

The pumps shall have either pneumatic drive or electro-hydraulic drive.

The pumps shall be equipped with precise pressure and capacity control valves which allow the independent setting of both maximum pressure and flow. The pumps shall automatically stop whenever the pre-set pressure is reached, and shall maintain that pressure without fluctuation.

For works requiring a small volume of grout such as crack grouting or rock bolts grouting, the Contractor may use hand operated grout pumps if agreed with the Engineer. These pumps shall be able to achieve a pressure of up to 10 bars.

The pumps shall be capable of pumping sandy mixes and mortars.

#### **28.5.5 Grout Recorders**

Grout recorders shall be provided to measure the grout flow, quantity and pressure in each grout line. The sensor of the recorder shall be set up not further than 5 m from the borehole collar being grouted.

The recorder shall be of an approved type by the Engineer. The data shall be collected in electronic form on a removable chip card for subsequent conversion into an Excel table or printed directly with permanent ink onto paper with P-T graph and Q-T graph. The recorders shall be capable of measuring flows as low as 2 litres/min and pressures within the range of the pumps. Overall precision shall be better than 5%.

The pressure, flow and quantity curves shall be submitted on a daily basis together with the drilling and grouting reports.

#### **28.5.6 Pressure Gauges**

The Contractor shall provide pressure gauges for both low and high pressure ranges (0-7 bar, 0-16 bar and 0-35 bar). Two gauges for the appropriate range shall be provided in each grout line, one at the pump for the use of the pump operator, the other at the hook-up connection directly at the collar of the hole. The required pressure for each particular hole shall be measured on the hook-up pressure gauge, not at the pump.

The pressure gauge adapted to the stage being grouted shall be chosen such that the maximum pressure of the gauge is less than 2 x the refusal pressure of the stage.

Pressure gauges shall have an accuracy of 2%. A minimum of a master gauge and two standardized pressure gauges for each range shall be calibrated and certified by an independent laboratory prior to the commencement of grouting works. One gauge for each range shall remain at the disposal of the Engineer, and the other shall be used by the Contractor for checking and calibration of working gauges. Working gauges shall be regularly cleaned preferably at every 2 shifts and recalibrated at least once a month. All working gauges shall have reference numbers for identification, which shall be quoted in the grouting reports to be submitted to the Engineer.

#### **28.5.7 Connections to Grout Holes and Packers**

Supply and return lines equipped with hydraulic fittings shall be able to withstand an internal pressure twice (x 2) that of the maximum grouting pressure and greater than the maximum pressure produced by the pump, whichever is higher. The internal diameter of the lines shall be such that no appreciable settlement of grout will take place when pumping at the minimum discharge capacity of the pump.

Grout lines equipped with quick release couplings may only be used for low pressure grouting. Quick release couplings shall be equipped with a safety clasp for safety reasons and fresh gaskets to ensure no leakage.

Valves shall be provided at the pump, in the supply line and at the collar of the hole being grouted. Suitable screens shall be incorporated in the supply line for removing oversize particles and foreign matter before injection into the grout hole.

Packers shall be the same as used for water pressure testing as specified in Chapter 27 "Drilling and Water Pressure Testing".

### **28.5.8 Embedded Pipes and Fittings for Grouting**

Standard mild steel or rigid plastic pipes and fittings for grouting shall be set in the rock and concrete as the Engineer may suggest, or where shown on the Drawings. The pipes and fittings embedded in concrete shall be cleaned thoroughly of all dirt, grease, grout and mortar immediately before embedment and shall be firmly held in position and protected from damage or displacement while the concrete is being placed. A standard coupling and nipple wrapped to facilitate eventual removal shall be attached to the grout pipe where embedded in concrete. No portion of the pipe shall be allowed to remain within 50mm of the concrete surface and the resulting recess, after removal of the pipe or fitting, shall be filled with dry-pack mortar.

"Tube-à-manchette"-type pipe shall be provided by the Contractor for cases where repeat grouting is required or chemical grouting operations or where closing the gap between two different concrete stages caused by the shrinkage is required and as shown on the Drawings. The pipe shall have an internal diameter of not less than 50mm and shall be perforated every 30 to 40cm. Each series of holes shall be covered externally by the rubber sleeve, called "manchette", to allow the grout under pressure to flow out but not to re-enter. In the drillhole the pipe shall be embedded by means of a cement-bentonite mixture which shall be injected into the space between the "Tube-à-manchette" and the temporary hole casing while this is being withdrawn. The grout supply pipe shall have a double packer to allow the grout to flow out only from one series of holes that coincides with the "manchette".

Care shall be taken to avoid premature blockage of pipes. Any pipe that becomes blocked before completion of operations shall be cleaned out in a satisfactory manner or replaced by the Contractor.

## **28.6 GROUTING OPERATIONS**

### **28.6.1 General**

All pressure grouting operations shall be subject to the prior approval by the Engineer. No grouting operations shall be permitted within 24 m of another hole being drilled grouted or water pressure tested. In the foundation and curtain works, no borehole shall be left open closer than 12 m from hole being grouted.

### **28.6.2 Grout Test Panel**

The main purpose of the test panel is to allow the Drilling and Grouting Subcontractor to verify the initial grouting design, pressures, depths, mixes and to verify the effectiveness of the equipment and procedures.

At least one area of the permanent grout curtain in compatible with the geology encountered at site shall be termed the Test Panel. Typically the test panel shall cover 5 primary holes and the panel will be executed as per the production grouting procedures as described in the approved Method Statement. As it is the test panel, more exploratory may be performed than would otherwise be necessary in the production grouting. The Contractor shall consider for the application of GIN method as agreed with the Engineer.

Once the test panel is completed, a summary and analysis report shall be written by the Contractor and on the basis of the results obtained, the design for the remainder of the Works shall be determined. As is common in grouting works, the grout curtain design is however constantly evolving depending on the results obtained and geological conditions encountered.

In the test panel, several of the mixes tested in the trail grout mix campaign will be tested to determine which are the most suitable for the site geological conditions.

### **28.6.3 Consolidation Grouting for Surface Structures**

Consolidation grouting shall be performed underneath surface structures at the following locations:

- a) Over the entire footprint of all major structures (spillway and powerhouse), if need, drilled perpendicular to the rock surface
- b) In any other zone within the construction sites where conditions so dictate and as the Engineer may suggest

Consolidation grouting shall be performed depending on the geological conditions. The grouting pressure for each stage shall be agreed with the Engineer. Consolidation grouting at foundations of surface structures shall generally be performed before starting concrete placement. However, the Engineer may request that consolidation grouting be carried out after the first layers of concrete have been poured, when necessary to assure a sufficient grouting pressure. In such cases, grouting shall only be carried out after the structural concrete already in place has been cured for a period of 7 days minimum. Consolidation grouting of the foundations shall extend over the full area of the footprint. The grout pressure will be agreed with the Engineer based on the structural capacity of the foundation. Consolidation grouting shall be performed in areas by drilling and grouting several holes according to the sequence or as directed by the Engineer. Grouting shall be done in a continuous operation avoiding disturbance of zones grouted within the previous 24 hours. Consolidation grouting shall be performed before commencing the grout curtain, and shall be done using the split spacing or "closure method". Generally, the grouting holes shall be arranged in a 3 m grid system. However, in the area with stress concentration, fault, closely spaced joints or other geologic defects, the blanket grout holes may be drilled to a 1.5 to 3m grid system.

*The permeability of the grouted area shall not be more than 5 Lugeons.*

Drilling shall be performed through sleeve pipe which be installed during concrete placing. The Contractor shall install sleeve pipe up to at least tertiary grout holes, in such of risky area quaternary sequence may be needed as agreed by the Engineer.

Drilling shall follow the specifications contained in Chapter 27 "Drilling and Water Pressure Testing".

Immediately before grouting the grout holes shall, rock characteristics permitting, be thoroughly washed out under pressure until the returning water is clear, and then as the Engineer may direct, pressure tested as specified in Chapter 27 "Drilling and Water Pressure Testing".

Where, during grouting of any hole, grout is found to be flowing from adjacent cracks of any kind, such openings shall be capped temporarily by plugging or caulking.

When performing the multiple-stage grouting in descending arrangement, the grout that is within the hole shall be removed from each stage except the deepest one, by washing, or by the use of a chopping or a "fishtail" bit before it takes a hard set.

Grouting operations shall be temporarily halted in the event of a sudden drop in pressure or a sudden increase in grout take until the crack or opening causing the loss is located and caulked. During this time the drillhole shall be continuously washed to avoid a premature grout set which would inhibit grouting when resumed.

If surface grout leaks cannot be located and successfully caulked, or the cause for the pressure loss cannot be determined, within 1 hour, the washing of the drillhole will be stopped and the grout in the rock formation shall be allowed to set for 24 hours. After setting, the drillhole shall be hooked onto again and grouted. If the hole, or stage, does not accept grout the hole shall be re-drilled or a replacement hole shall be drilled.

If, during grouting, there is a communication between holes the Contractor shall set packers in the communicating holes, which shall be bled of accumulated air and water frequently until grout emerges from the holes. The communicating holes shall then be grouted simultaneously using thicker grout.

Grout injection will be deemed to be completed when the grout take has reduced to 30 litres or less per stage of hole being grouted during 10 minutes at the specified grouting pressure and mixture.

After completion of grouting, the packers shall remain in the hole for a minimum of 10 minutes and the pressure shall be maintained until the grout has attained its initial set.

The results of water pressure testing and all information obtained during the performance of grouting will be used for the determination whether the grouting in each section of the Works under consideration is completed in a satisfactory manner, or whether additional grouting in separate drillholes is required.

#### **28.6.4 Curtain / Blanket Grouting**

Curtain grouting shall be performed for the foundation of all headwater retaining structures, embankment dam, as shown on the Drawings, from grouting galleries at locations indicated on the Drawings and as agreed with the Engineer. Hole depths, inclinations, sequence of grouting, method of grouting, whether single or multi-stage, in ascending or descending arrangement will be adapted as necessary based on information

from exploratory drilling or current operations, from the test panel and from the design. The holes shall be drilled and grouted by the closure method involving split-spaced holes.

The closure method shall involve drilling and grouting primary holes at 6 m spacing followed by secondary holes located midway between the primaries at 3m. The split-spacing pattern may need to be extended further with tertiary quaternary and quinary holes depending on the grout takes and whether closure is being achieved. The Contractor shall consider for the application of GIN method as agreed with the Engineer. The grout curtain is arranged along a single row as shown on the drawings.

Selected primary grout holes or pilot holes shall be cored and water pressure tested before grouting. Based on the results, the grout mix shall be agreed as well as the pressures to be used.

Normal sequence of grouting shall be ascending from bottom to top of hole in stages determined from water pressure tests done in the primary test holes. Where the permeability exceeds 20 Lugeons or where geological conditions dictate such as collapsing loss of drilling fluid and so on or where previous experience dictates, grouting shall generally be performed in descending arrangement.

When performing multiple-stage grouting in descending arrangement, the grout that is within the hole shall be removed from each stage except the deepest one, by washing, or by the use of a chopping or a "fishtail" bit before it takes a hard set.

Stage lengths shall be a maximum of 5m or shorter according to the conditions, and grout mixtures shall be in accordance with this specification.

The grout pressures shall be determined from the test panel but indicatively and unless otherwise directed by the Engineer, air, water and grout pressures shall not exceed 2 bar plus 0.25 bar per linear meter of vertical depth measured from the collar of the hole to the bottom of the packer at depth. Grout pressures shall not be released nor packers removed until the grout in each successive stage has achieved an initial set or as directed by the Engineer.

The curtain grouting shall be performed from one or several grout stations. If several such stations are used, each shall be completely equipped with mixers, agitators, silos, pumps, gauges, measuring devices and qualified personnel and shall have a sufficient supply of grouting materials.

In cases where the required pressure is not reached even when injecting maximum volumes of thick grout, the grouting suspension or changing to thick grout mix with suitable accelerator or sand shall be decided according to approved grouting criteria together with the Engineer.

Where grout is found to be flowing from adjacent holes or cracks of any kind, such openings shall be capped temporarily by plugging or caulking. If this does not bring satisfactory results, further grouting shall be interrupted and the injected material left to harden.



Grouting injection will be deemed to be completed when the take has reduced to 30 litres or less per stage of hole being grouted during 10 minutes at the specified grouting pressure and mixture.

After the completion of each section or every 2 pilot holes of the grout curtain, the Contractor shall submit "as-built" drawings of the grouting and water pressure results and based on this the necessity for further holes will be determined. Check holes as stipulated in Chapter 27 "Drilling and Water Pressure Testing" will be required once a section or panel or curtain reaches the criteria, Lugeon value and cement take per meter. Unless otherwise directed, these check holes shall be drilled to intersect areas of high grout take or Lugeon value and they may be cored and water pressure tested. On completion they will be pressure grouted. Based on the results obtained in the check holes, the Engineer may order additional grout holes or a new row of grout holes to be executed according to approved criteria and grouting analysis for the particular section or panel.

*The general target of permeability of the grouted dam foundation is 5 Lugeons.*

#### **28.6.5 Closure of Holes and Clean-up**

Upon completion of grouting work each hole shall be filled with thick grout and connections not embedded in the concrete shall be removed. The holes drilled in concrete shall be reamed or re-drilled to a minimum depth of 20 cm, and filled with dry-pack mortar, as stipulated in "Repair of Defective Concrete" in Chapter 10 "Concrete", flush with the concrete surface.

After completion of the grouting works the internal surface of the concrete or steel lining shall be cleaned and restored to its original condition.

#### **28.6.6 Crack Grouting**

Crack grouting shall be performed to seal the cold joints, construction joints, shrinkage cracks, honeycombs, poorly closed grout holes etc., in the structural concrete as agreed with the Engineer and as stipulated in Chapter 10 "Concrete".

Crack grouting shall consist of injecting a stable, cement-water mix with admixture through holes specially drilled into cracks or joints. Preventive measures shall be taken by plugging the joint with wooden wedges, cardboard, cement-gypsum mortar or other suitable means to prevent the grout from flowing out of the crack.

#### **28.6.7 Grouting behind Steel Structures**

Where shown in the Drawings or specified or directed by the Engineer, following the concrete placing behind and around steel structures such as steel liners, draft tubes, etc., all voids between the steel structure and concrete shall be filled with non-shrinking grout, generally injected at low pressure from holes pre-prepared in the steel elements.

Grouting between the steeling and the back-filled concrete in any section shall not commence until the backfill concrete has been placed for at least 28 days.

Only stable, cement-water mixtures with plasticizing agent shall be used for this grouting. Pre-tapped holes for grouting, completed with threaded steel plugs, shall be provided by

the lining supplier in the steel lining. The Contractor shall provide threaded pipes to protect the thread of the grouting hole during the drilling and grouting operation. Low pressure grouting shall be carried out until all voids between the steel lining and backfill concrete are thoroughly filled. The maximum pressure shall be 3 bars or as agreed with the Engineer. The strength of grout material shall not lower than the characteristic strength of the embedding concrete. Only hand pumps shall be allowed for this operation. After grouting completed, the Engineer and the Contractor will inspect the effectiveness of the grouting together to check void remaining by tapping (wooden hammer tapping). If remaining voids are found, the additional holes (grout holes and release holes) shall be drilled through remaining area until all voids are completely filled.

After completion of grouting, the Contractor shall clean the thread holes and screw the plugs back into its position. The plugs will be welded permanently into the steel lining and stub heads cut off by lining supplier. When this work is completed the Contractor shall thoroughly clean the whole steel lining surface of all grout remnants and other debris, and shall assist the lining supplier in restoration of the pre-applied corrosion protection.

End of Chapter 28