

Maha Metro



Tender Documents

**UGC-02: DESIGN AND CONSTRUCTION OF UNDERGROUND STATIONS AT
BUDHWAR PETH, MANDAI AND SWARGATE AND ASSOCIATED TUNNELS**

PART II – EMPLOYER’S REQUIREMENT

SECTION VIII - OUTLINE CONSTRUCTION SPECIFICATIONS

June 2018



PUNE METRO UNDERGROUND SECTION

CONTRACT UGC-02

TENDER DOCUMENTS

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PUNE METRO UNDERGROUND SECTION

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Tender Documents

**UGC-02: DESIGN AND CONSTRUCTION OF UNDERGROUND
STATIONS AT BUDHWAR PETH, MANDAI AND SWARGATE
AND ASSOCIATED TUNNELS**

PART II – EMPLOYER’S REQUIREMENT

**SECTION VIII - OUTLINE CONSTRUCTION SPECIFICATIONS
S.01 Civil and Structural Works**

June 2018

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1. GENERAL

1.1 INTRODUCTION

These specifications contained herein shall be read in conjunction with other Contract Documents.

The Outline Construction Technical Specifications as follow are based on latest edition of “Specifications for Road and Bridge works” of Ministry of Road Transport & Highways (MORTH) as published by Indian Roads Congress, Indian Railway Standards and CPWD/ PWD Government of Maharashtra specifications – latest editions with correction slips & amendments up to date to the extent they are applicable to the Works covered under scope of works. However, the provisions of MORTH specifications take precedence over CPWD/Maharashtra PWD specifications. Further the specifications contained herein will supersede the provisions of the MORTH & CPWD/Maharashtra PWD specifications to the extent of their applicability.

The Indian and International Standards as scheduled below has been used as base for the specifications.. The Contractor shall be responsible for detailing in his specifications submitted to the Engineer/Employer, as part of the Definitive Design Submission, the standards on which his materials and workmanship will be based. These shall be of similar or higher standard than those listed below. The Contractor is required to notice in the first instance the Indian Standards, and base the specifications prepared by him on Indian Standards to the extent that they are applicable.

Alternative or additional codes and standards proposed by the Contractor shall be internationally recognised codes and shall be equivalent to or better than, Indian Standards issued by the Bureau of Indian Standards or any other Indian professional body or organization, subject to being, in the opinion of the Engineer/Employer, suitable for incorporation or reference into the specifications. The specifications have been divided into different sections / sub-heads for convenience only. They do not restrict any cross-references. The Contractor shall take into account inter-relations between various parts of works/trades. No claim shall be entertained on the basis of compartmental interpretations.

1.2 Reference to the Standard Codes of Practice

Legend:

ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing Materials
BS	British Standard
CPWD	Central Public Works Department
DIN	Deutsches Institut für Normung e.V.
IRC	Indian Road Congress

IRCEM	Institution de Retraite Complementarie des Employes de Particular
IRS	Indian Railway Standards
IS	Indian Standards
MORTH	Ministry of Road Transport and Highways
	Public Works Department Government of Maharashtra
UIC	International Union of Railways

The detailed list of Standards referred to is mentioned in Section 1.3 below

1.3 Applicable Codes, Standards & Publications for Structural & Architectural Work

The important Codes, Standards and Publications to Contract are listed here under

Standard No.	Specifics
A	General
IS:875 (Part 3)	Code of practice for design loads (other than earthquake) for buildings and structures
IS:1322	Bitumen felts for water proofing and damp-proofing
IS:1893	Criteria for earthquake resistant design of structures
IS:2572	Code of Practice for construction of hollow concrete block masonry
IS:2974(Part 1)	Code of Practice for Design & Construction of machine Foundation
IS 414	Code of practice for design and installation of joints in buildings Excavation Work- Code of Safety
IS:6408 (Parts 1,2)	Recommendations for modular co-ordination in building industry – tolerances
IS:10958	General check list of functions of joints in building
IS:11817	Classification of joints in buildings for accommodation of dimensional deviations during construction
IS:11818	Method of test for laboratory determination of air permeability of joints in buildings
IS:12440	Precast concrete stone masonry blocks
CPWD	Specifications 2009.
BS:476 (Part 7)	Method for classification of the surface spread of flame of products
BS:476 (Part 20)	Method of determination of the fire resistance of elements of construction (general principles)
BS:476 (Part 22)	Methods for determination of the fire resistance of non-load bearing elements of construction
BS:5215	Specification for one-part gun grade polysulphide-based sealants

Standard No.	Specifics
BS:5606	Guide to accuracy in building
BS:6093	Code of practice for the design of joints and jointing in building construction
BS:8200	Code of practice for the design of non-load bearing external vertical enclosure of building
ASTM C 332	Specification for light weight aggregate for insulating concrete
SP 7	National Building Code of India
SP 23 (S&T)	Hand Book on Concrete Mixes
B	Bitumen
IS:702	Industrial Bitumen
IS:3384	Specification for bitumen primer for use in waterproofing and damp-proofing
C	Building Construction Practices
IS:1838 Parts I and II.	Specifications for preformed fillers for expansion joint in concrete pavements and structures.
IS:1946	Code of Practice for use of fixing devices in walls, ceilings, and floors of solid construction.
IS:6509	Code of Practice for installation of joints in concrete pavements.
IS:11134	Code of Practice for setting out of buildings.
IS:11433	Parts I and II. Specifications for one part Gun grade polysulphide based joint sealant.
IS:12200	Code of Practice for provision of water stops at transverse contraction joints in masonry and concrete dams
D	Cement
IS:269	33 grade ordinary Portland cement
IS:455	Portland Slag Cement
IS:650	Specification for standard sand for testing cement.
IS:1489 (Part 1)	Portland pozzolana cement: Flyash based
IS:1489 (Part 2)	Portland pozzolana cement: Calcined clay based
IS:3535	Method of Sampling Hydraulic Cements
IS:4031	(Parts 1 to 13) Methods of physical tests for hydraulic cement.
IS:4032	Method of chemical analysis of hydraulic cement.
IS:6925	Methods of test for determination of water soluble chlorides in concrete admixtures.
IS:8042	White Portland Cement

Standard No.	Specifics
IS:8112	Specification for 43 grade ordinary Portland cement.
IS:12269	Specification for 53 grade ordinary Portland cement.
IS:12330	Specification for sulphate resistant Portland cement.
E	Concrete
IS:456	Code of practice for plain and reinforced concrete.
IS:457	Code of practice for general construction of plain and reinforced concrete for dams and other massive structures.
IS:460 (Parts I to II)	Specification for Test Sieves
IS:516	Methods of test for strength of concrete.
IS:1199	Methods of sampling & analysis of concrete.
IS:1200	Method of measurement of building and civil Engineering
IS:1343	Code of practice for prestressed concrete
IS:1607	Method of Test Sieving
IS:2386	Parts I-VIII. Methods of tests for aggregates for concrete.
IS:2430	Methods of Sampling of Aggregates of Concrete
IS:2438	Specification for roller pan mixer
IS:2514	Specification for concrete vibrating tables
IS:2571	Code of practice for laying in-situ cement concrete flooring
IS:2645	Specifications for integral cement water proofing compounds
IS:2722	Specifications for portable swing batchers for concrete (double bucket type)
IS:2770	Methods of testing bond in reinforced concrete part I pull out test
IS:3025	Methods of sampling and test (physical and chemical) for water & waste water
IS:3370	Code of practice for concrete structures for storage of liquids
IS:3935.	Code of practice for composite construction
IS:4326	Code of practice for earthquake resistant construction of building
IS:6925.	Methods of test for determination of water soluble chlorides in concrete Admixtures
IS:7242	Specifications for concrete spreaders
IS:7251	Specifications for concrete finishers
IS:7861	Parts I & II. Code of practice for extreme weather concreting.

Standard No.	Specifics
IS:7969	Safety code for handling and storage of building materials
IS:8989	Safety code for erection of concrete framed structures
IS:8142	Methods of test for determining setting time of concrete by penetration resistance
IS:9103	Specifications for admixtures for concrete
IS:9013	Method of making, curing and determining compressive strengths of accelerated cured concrete test specimens
IS:9284	Method of test for abrasion resistance of concrete
IS:10262	Recommended guidelines for concrete mix design.
MORTH	Specifications for Road and Bridge Works, Ministry of Road Transport and Highways (Roads Wing)
IRS : CBC	Concrete Bridge Code
IRC 112	Code of Practice for Concrete Road bridges
ASTM - C - 94 IS 4926	Ready Mix Concrete Ready Mixed Concrete – Code of Practice
ASTM – C - 1240	Specifications for Silica Fume for use in Hydraulic Cement and Mortar
F	Construction Plant and Machinery.
IS:1791	Specification for batch type concrete mixers.
IS:2505	General requirements for concrete vibrators: Immersion type.
IS:2506	General requirements for screed board concrete vibrators.
IS:3366	Specification for pan vibrators.
IS:3558	Code of Practice for use of immersion vibrators for consolidating concrete.
IS:4656	Specifications for form vibrators for concrete.
IS:4925	Specification for concrete batching and mixing plant.
IS:11993	Code of Practice for use of screed board concrete vibrators.
G	Formwork
IS:4990	Specifications for plywood for concrete shuttering work.
IRC:87	Guidelines for the design and erection of false work for road bridges.
IS:806	Code of practice for use of steel tubes in general building construction.

Standard No.	Specifics
IS:1161	Specification of steel tubes for structural purposes.
IS:1239	Specification for mild steel tubes. Tubulars and other wrought steel fittings.
H	Gypsum and Gypsum Board
IS:2095	Gypsum plaster boards
IS:2542 (Part 1/Sec 1 to 12)	Methods of test for gypsum plaster, concrete and products: plaster and concrete
IS:2542 (Part 2/Sec 1 to 8)	Methods of test for gypsum plaster, concrete and products: Gypsum products
IS:2547 (Part 1)	Gypsum building plaster: Excluding premixed lightweight plaster
IS:2547 (Part 2)	Gypsum building plaster: Premixed lightweight plaster
I	Handling and Storage
IS:4082	Recommendation of Stacking and Storage of construction materials
IS:8348	Code of practice for stacking and packing of stone slabs for transportation
J	Instruments For Testing Cement and Concrete
IS:5513	Specification for vicat apparatus.
IS:5514	Specification for apparatus used in Le-Chaterlier test.
IS:5515	Specification for compaction factor apparatus.
IS:7320	Specification for concrete slump test apparatus.
IS:7325	Specification for apparatus to determine constituents of fresh concrete.
IS:10080	Specification for vibration machine.
IS:10086	Specification for moulds for use in tests of cement and concrete.
IS:10510	Specification for vee-bee consistometer.
K	Joint Fillers
IS:1838 (Part 1)	Preformed fillers for expansion joint in concrete pavements and structures (non extruding and resilient type): Bitumen impregnated fibre
L	Paints and Coatings
IS:102	Ready mixed paint, brushing, red lead, non-setting, priming
IS:109	Ready mixed paint, brushing, priming, plaster, to Indian Standard Colour No. 361 and 631 white and off white.

Standard No.	Specifics
IS:347	Varnish, shellac, for general purpose.
IS:2074	Ready mixed paint, air drying, red oxide-zinc chrome, priming
BS:6496	Specification for powder organic coatings for application and stoving to aluminum alloy extrusions, sheet and preformed sections for external architectural purposes, and for the finish on aluminum alloy extrusions, sheet and preformed sections coated with powder organic coatings
BS:EN:10152	Specification for electrolytically zinc coated cold rolled steel flat products. Technical delivery conditions
ASTM A 164-71	Specification for electrodeposited coatings of zinc on steel
M	Pigment for Cement
BS:1014	Specification for pigments for Portland cement and Portland cement products
N	Reinforcement & Structural Steel
IS:280	Mild steel wire for general Engineering purposes
IS:432	Part I. Mild steel and medium tensile steel bars. Part II Hard-drawn steel wire.
IS:814	Parts I & II. Electrodes for metal arc welding of structural steel.
IS:815	Classification coding of covered electrodes for metal arc welding of structural steels
IS:816	Code of Practice for use of metal arc welding for general construction in mild steel.
IS:1566	(Part I) Specifications for hard-drawn steel wire fabric for concrete reinforcement.
IS:1786	Specification for high strength deformed steel bars and wires for concrete reinforcement.
IS:2502	Code of Practice for bending and fixing of bars for concrete reinforcement.
IS:2629	Recommended practice for hot-dip galvanising of iron and steel.
IS:2751	Code of Practice for welding of mild steel plain and deformed bars for reinforced concrete construction.
IS:4759	Hot-dip zinc coating on structural steel and other allied products.
IS:5525	Recommendations for detailing of reinforcement in reinforced concrete works
IS:9417	Recommendations for welding cold-worked steel bars for reinforced concrete construction.
IS:14268	Uncoated stress relieved low relaxation steel class 2 for Pre-stressed concrete

Standard No.	Specifics
IS:226	Structural steel (Standard Quality)
IS:800	Code of practice for use of structural steel in general building construction.
IS:813	Scheme of symbols for welding.
IS:814	Covered electrodes for metal arc welding of structural steel. (Part I & Part II)
IS:816	Code of practice for use of metal arc welding for general construction in mild steel.
IS:822	Code of practice for inspection of welds.
IS:961	Structural steel (High Tensile)
IS:1024	Code of practice for use of welding in bridges and structures subject to dynamic loading.
IS:1161	Steel tubes for structural purposes.
IS:1182	Recommended practice for radiographic examination of fusion welded butt joints in steel plates.
IS:2062	Structural steel (Fusion welding quality)
IS:3757	Specification for high tensile friction grip bolts.
IS:5624	Specification for foundation bolts.
IS:3600	Code of practice for testing of fusion welded (Part I) joints and weld metal in steel.
IS:4923	Hollow steel sections for structural use.
IS:6227	Code of practice for use of metal arc welding in tubular structure.
IS:801	Code of practice for use of cold formed light gauge steel structural members in general building construction.
IS:811	Specifications for cold formed light gauge structural steel sections.
O	Aggregates
IS:383	Coarse and fine aggregates from natural sources for concrete.
P	Scaffolding
IS:2750	Specification for steel scaffoldings
IS:3696 (Part 1)	Safety Code of scaffolds and ladders: Scaffolds
IS:3696 (Part 2)	Safety Code of scaffolds and ladders: Ladders
IS:4014 (Part 1)	Code of practice for steel tubular scaffolding: Definition and materials
IS:4014 (Part 2)	Code of practice for steel tubular scaffolding: Safety regulations for scaffolding

Standard No.	Specifics
IRC:87	Guidelines for the design and erection of falsework for road bridges
Q	Sealants
IS:10959	Glossary of terms for sealants for building purposes
IS:11433 (Part 1)	One part grade polysulphide base joint sealant: General requirements
IS:11433 (Part 2)	One part grade polysulphide base joint sealant: Methods of test
IS:13055	Methods of sampling and test for anaerobic adhesives and sealants
BS:5889	Specification for one part gun grade silicone-based sealants.
R	Wood
IS:303	Plywood for General Purposes
IS:848	Synthetic resin adhesives for plywood (phenolic and aminoplastic)
IS:1141	Seasoning of Timber - Code of Practice
IS:1328	Veneered decorative plywood
IS:1659	Block Boards
IS:2046	Decorative thermosetting synthetic resin bonded laminated sheets
IS:2202 (Part 1)	Wooden flush door shutters (solid core type): Plywood face panels
IS:2202 (Part 2)	Wooden flush door shutters (solid core (type): Particle face panels and hardboard face panels
S	Bearings
IRC:83 Part-II	Standard specifications and code of practice for road bridges Elastomeric Bearings
IRC:83 Part-III	Standard specifications and code of practice for road bridges Pot Bearings
T	UPVC Pipe For Drainage
IS 4985	Unplasticized PVC Pipes for portable water supplies
U	PILING
IS :2911 PART-I	Bored Cast in-situ Concrete Piles
IRC:78	Standard specifications and code of practice for road bridges Foundation And Substructure
V	Indian Railway Standards (IRS)
	IRS- Bridge Rules for loading (Ministry of Railways)
	IRS- Code of practice for steel bridges.

Standard No.	Specifics
	IRS- Code of practice for plain, reinforced and pre-stressed concrete for general Bridge construction.
	IRS- Code of practice for the design of substructures and foundation of bridges.
W	Indian Roads Congress Standards (IRC)
IRC 5	Standard Specifications and Code of Practice for Road Bridges, Section I- General Features of Design
IRC 6	Standard Specifications and Code of Practice for Road Bridges, Section II – Loads and Stresses
IRC 10	Recommended Practice for Borrow pits for Road Embankments Constructed by Manual Operation
IRC 11	Recommended practice for the design of layout of cycle tracks
IRC19	Standard Specifications and code of Practice for Water Bound Macadam
IRC 112	Code of Practice for Concrete Road bridges
IRC22	Standard Specifications and Code of Practice for Road Bridges, Section VI – Composite Construction
IRC24	Standard Specifications and Code of practice for Road Bridges, Section V – Steel Road Bridges
IRC36	Recommended Practice for the Construction of Earth Embankments for Road Works
IRC37	Guidelines for the Design of Flexible Pavement
IRC45	Recommendations for Estimating the Resistance of Soil below the maximum Scour Level in the Design of Well Foundations of Bridges
IRC48	Tentative Specifications for Bituminous Surface Dressing Using Pre-coated Aggregates
IRC75	Guidelines for the Design of High Embankments
IRC78	Standard Specifications and Code of Practice for Road Bridges, Section VII (Parts 1 and 2), Foundations and Substructure
IRC83	Standard Specifications and code of practice for Road Bridges, Section IX - Bearings Part I & II: Bearings (Metallic and Elastomeric)
IRC87	Guidelines for the Design and Erection of False Work for Road Bridges
IRC89	Guidelines for Design and Construction of River Training and Control Works for Road Bridges
IRC: SP11	Handbook of Quality Control for Construction of Roads and Runaways

2. EARTHWORKS

2.1 Excavation

Excavation works shall comply with the relevant requirements of the Outline Design Specification and of this Specification as indicated below:

2.1.1 Site Clearance

- (1) The Contractor shall clear the Site as required by demolishing all building structures and the likes and removing vegetation, debris, trees along with their roots and the like to location agreed with the Engineer on or off the site
- (2) Stumps and major roots shall be grubbed up and disposed of off the site or burnt as directed. The Contractor shall take precautions to protect all adjacent public and private property during these operations and shall be responsible for all and damage arising from such.
- (3) The Contractor shall prevent erosion of all cleared excavation and fill areas by providing suitable protection.
- (4) The Contractor shall also prevent siltation of all areas adjacent to the Works as a result of fines being transported from the Works by provision of suitable silt fences.

2.1.2 Top Soil Stripping

Top soil shall be removed as required, deposited in separate heaps at locations agreed with the Engineer.

2.1.3 Removal of Unsuitable Material

Unsuitable material are defined in Clause 2.2.2 of this section.

The Contractor shall remove all unsuitable material as agreed with the Engineer, and shall dispose of it on or off the site as stipulated in Contract conditions. . Boulders, stones and other materials of value or usable again on the works shall be neatly stacked and graded as directed by the Engineer.

2.1.4 Excavation - General

- (1) Excavation shall be carried out to the lines, levels and profiles shown on the Drawings having Notice of No Objection from Employer/Employers Representative. The work shall be carried out by the Contractor in such a way as to avoid soil erosion, ground water pollution accidents in habitational or frequented places, disturbance to the surrounding ground or Structures, accident to workmen and any other untoward incident. Particular care shall be taken to maintain stability when excavating in close proximity to existing works. Fencing, caution signages with red lights and other safety measures shall be employed to avoid accidents. Where necessary, signal men shall be employed to guide the movement of people, vehicles and equipment.
- (2) The work shall be carried out in a careful manner to ensure that the exposed surfaces are as sound as the nature of the material permits and that no point shall protrude inside the lines shown on the Drawings except as otherwise specified or agreed by the Engineer. In soft soil excavation which is to remain open permanently, exposed faces shall be formed accurately to the required slopes and profiles and

properly protected by turfing or pitching as required by the Engineer.

- (3) The Contractor shall dispose of all material arising from excavations either off the site or to approved tips on the site, as required.
- (4) The Contractor shall be responsible for keeping all excavations free from water from whatever cause arising and shall provide such pumping capacity and other measures as may be necessary for this purpose.
- (5) The Contractor shall properly support the sides of excavations and shall be responsible for their safety. In case of any slips or blows in the excavation, the same shall be cleared by the Contractor at his own cost.
- (6) The Contractor shall notify the Engineer without delay of any permeable strata, joints, faults, fissures or unusual ground conditions encountered during excavation instability and/or collapse.
- (7) The contractor shall ensure that no air pollution takes place during excavation, storage and transportation of earth by providing suitable measures such as appropriate cover and the like.
- (8) The Contractor shall provide to the Engineer full details of the proposed rock excavation methods for Notice of No Objection. Excavation should be carried out by controlled blasting where feasible and permitted by the Employer duly controlling the noise, dust and vibration levels to be within the acceptable limits. However there may be certain stretches on the alignment where blasting shall not be permitted and at such locations appropriate excavation methods such as mechanized or manual or by expansive chemical agents shall be employed duly complying with all other stipulations of the Contract in this respect. Similarly, the Contractor shall submit his plans for methods for monitoring ground stability, noise and vibration adjacent to residential area and sensitive structures including heritage structures.
- (9) The Contractor shall carry out ground stabilization measures without delay before and/or after excavation, the Contractor may request the Engineer to accompany him when inspecting structures and excavated rock surfaces revealed after excavation operations.

2.1.5 Excavation beyond True Lines and Levels

If from any cause whatsoever excavations are carried out beyond their true line and level other than as per noticed drawings then the Contractor shall make good at his own cost to the required line and level with the appropriate grade of filling to be contained in the true excavation, or with concrete or other approved material in such a manner as the Engineer shall require.

2.1.6 Notice of Excavation

When excavations have been taken out accurately to the profiles or dimensions required for the Works, the Contractor shall inform the Engineer for his Notice of No Objection.

The Contractor shall carry out additional excavation to such new profiles or dimensions as the Engineer may give Notice of No Objection.

2.1.7 Excavations for Structures

- (1) Open excavation to lay a foundation for a structure shall be carried out to the lines and dimensions necessary to permit the proper construction of the structure.
- (2) Where a structure is to be founded on soft ground, the excavation shall be taken down until the required suitable soil formation is exposed and prepared to the Notice of No Objection from Engineer.
- (3) Prior to any construction within excavation the bottom of the excavation shall be re-compacted to achieve a dense smooth and level surface longitudinally and transversely or stepped. Subject to the Notice of No Objection from Engineer, layer of granular fill not exceeding 200 mm loose thickness shall be placed and compacted to 95% of the maximum dry density.
- (4) Where required, filtered under drainage pipes shall be placed within the granular fill layer in accordance with the noticed designs
- (5) In the event of excavation having been made deeper than that shown on the drawings or as give Notice of No Objection by Engineer, the extra depth shall be made up with concrete or masonry of the foundation grade at the cost of the Contractor. Ordinary filling shall not be used for the purpose to bring the base of foundation to required level.
- (6) Surfaces of excavations or filling on which plane (unreinforced) or reinforced concrete will be formed shall be prepared with a blinding layer of concrete as shown on the Drawings or in such other manner as will provide a suitable surface at the correct lines and levels to the Notice of No Objection of the Engineer.

2.1.8 Trench Excavation for Utilities and Services

- (1) Trench excavation shall be performed by the use of suitable equipment, in such manner as to minimise disturbance to the required finished sides and bottom of the excavation.
- (2) Trenches for pipes shall be excavated to a sufficient depth and width to enable the utility or services and the specified joint, bedding, haunching and surrounding to be accommodated and for all loose material placed to be compacted to the required standards.

2.1.9 Trenches

- (1) The Contractor shall carry out excavation in a safe manner such that the sides of the trench are adequately supported and stable till the completion of work.
- (2) The Contractor shall leave a clear adequate space between the edge of the excavation and the inner toes of the spoil banks.
- (3) Trenches shall be excavated to the lines and levels shown on the Drawings.
- (4) Trenches shall not be excavated too far in advance of pipe laying and shall be sufficiently wide to allow proper and efficient jointing to be carried out in clean and dry conditions. Due allowance shall be made for bedding and surrounds where these are specified.

- (5) The bottoms of all trenches shall be trimmed to grade and level and compacted before any bedding is placed or utility or services are laid.
- (6) The widths of trenches crossing roads or at other locations, as directed, shall be as narrow as is practicably possible. The maximum width measured between undisturbed soil in the trench sides shall not exceed the outside diameter of the pipe being laid plus 550 mm for pipes up to and including 800 mm in diameter and plus 750 mm for pipes over 800 mm in diameter. The depth of excavation shall be such as to provide adequate cover / cushion to the Utilities or services.
- (7) Trenches for pipes carrying water under pressure shall, except where otherwise described in the Contract or agreed by the Engineer, be excavated to a sufficient depth to ensure a minimum cover of 900 mm to the top of the utilities or services.

2.1.10 Road Crossings

The Contractor shall close-sheet and adequately support all excavations/trenches within and across existing roads. Great care shall be taken by the Contractor to ensure that existing roads and services are not damaged by road crossing operations. The excavation/trenches on roads shall be back filled and roads repaired on utmost priority taking all safety precautions.

2.1.11 Channels

- (1) Channels shall be excavated by methods which do not endanger the stability of the side slopes.
- (2) Existing channels, which are to be reshaped, cleared and trimmed, shall be cleared of all weeds and growth and the beds graded to the required levels. The sides of channels shall be trimmed to the required safe limits of slope and width.
- (3) Side banks of channels shall be trimmed to a neat appearance and even surfaces.
- (4) Any channels, streams, drains or pipes taking water to or from cultivated land shall be diverted so as to maintain their flow before being moved or broken into. All diversions and their subsequent reinstatement shall be carried out to the satisfaction of the Engineer.
- (5) The Contractor shall control the rates of filling and draw-down of water in channels so as not to endanger the stability of Works.

2.1.12 Notice for Excavations

The Contractor shall seek Notice of No Objection from the Engineer for all excavations prior to placing pavement layers, fill or concrete. The Contractor shall maintain open excavations in a safe and stable condition, and shall rectify the effects of deterioration due to weather.

2.2 Fill

2.2.1 Fill - General

Prior to commencement of any filling either as backfill to excavation or in the formation of embankment, the Contractor shall submit in writing to the Engineer for 'Notice of No Objection' his proposals for carrying out the Works such that the optimum use may be made

of excavated material. The proposals shall include details of the compaction plant and methods for adjusting the moisture content of the material.

Filling shall not commence until the 'Notice of No Objection' proposals and the material intended to be used Received from the Engineer.

2.2.2 Fill Material

- (1) Fill material shall be obtained only from a source agreed with the Engineer
- (2) Fill material, other than for roadworks, shall be evenly graded granular material. Material with more than 20% passing a 75 micron sieve or more than 10% in excess of 75 mm size shall be considered as unsuitable for use in the Works. .
- (3) Before compacting the fill material, clods or hard lumps of earth over 75mm in greatest dimension shall be broken up.
- (4) The Following types of material are considered unsuitable and shall not be used for fill or embankment:
 - a. Materials brought from swamps, marshes or bogs;
 - b. Peat, loam, fine silt, log, stump or organic or perishable materials;
 - c. Material susceptible to spontaneous combustion;
 - d. Clay of liquid limit exceeding 80 and plasticity index exceeding 55;
 - e. Materials containing salts prone to inducing leaching in the embankment
 - f. Any contaminated and environmentally unacceptable material.

The Contractor shall carry out the following initial tests on the proposed material . Thereafter, one set of tests shall be carried out for each 2000 m³ of fill, supplied to Site or as noticed by Engineer..

- 1) Wet sieve analysis
- 2) Dry density/moisture content relationship

Fill material shall be obtained only from the approved source.

2.2.3 Backfill - General

Except around structures, excavations shall be backfilled with suitable excavated material and/or noticed material compacted in layers of 300 mm maximum loose thickness to achieve a density of at least 95% of the maximum dry density.

2.2.4 Backfill to Structures

The Contractor shall not backfill around structures until the structural elements have attained adequate strength and the Notice of No Objection obtained from Engineer to proceed for type of fill material has been obtained. Unless otherwise directed, the backfill material shall be selected excavated material or sand, thoroughly compacted in layers not exceeding 200 mm deep to achieve a density of at least 95% of the maximum dry density.

2.2.5 Preparation of Base /Foundation for Embankment

- (a) Prior to placing any embankment upon any area all clearing and grubbing operations

shall have been completed in accordance with Clauses 2.1.1 to 2.1.3 and got Notice of No Objection by the Engineer..

- (b) Where the height of embankment is 1 meter or less all sod, grass and vegetable matter shall be removed from the ground surface and the top 150mm shall be processed as necessary and compacted to 90% of the maximum dry density.
- (c) Where embankments are to be constructed on slopes, the existing slopes shall be loosened by scarifying or ploughing to a depth of not less than 100mm, to ensure a good bond between the embankment and the embankment foundation, or where this is impracticable, steps in vertical and horizontal face shall be cut in the existing slope and the embankment built up in successive layers. Material which has been loosened shall be re-compacted simultaneously with the first level of embankment material placed.
- (d) Where an embankment is to be placed against sloping ground, having slopes steeper than 4 horizontal to 1 vertical, continuous horizontal benches, each at least 300 mm wide, shall be cut in to the existing and the embankment built up in successive layers
- (e) Where existing embankments are to be widened or included in new embankment, the slopes of the exiting embankment shall be ploughed or scarified to a depth of not less than 10 centimetre or, where this is impracticable, steps in horizontal and vertical faces shall be cut in existing slopes and the embankment built up in successive layers to the level of the old road, before its height is increased.
- (f) Unless otherwise shown on the Drawings, where existing unpaved roads are to be covered with less than 300mm of fill, excluding pavement, the top of the old road bed shall be scarified and re compacted with the next layer of the new embankment. The total depth of the scarified and added material shall not exceed the permissible depth of layer.
- (g) Granular material (eg. sand or gravel) shall be used as filling in swamps or waterlogged ground. The Contractor shall submit details of his proposed granular fill material to the Engineer for seeking Notice of No Objection. The Contractor shall first remove all unsuitable material from the base of the proposed fill area and backfill with the agreed granular material, placed and compacted in accordance with the requirements of this Contract. Where deemed necessary the Contractor may place a geo-fabric “separator” fabric to prevent “punching of the fill into the underlying soft material in accordance with Clause 2.2.6 below.
- (h) Fill material shall not be placed against any abutment or wing wall unless Notice of No Objection has been given by the Engineer.

2.2.6 Construction of Embankment

Embankment shall be constructed in accordance with the following requirements:

- (a) General:

Except as otherwise required all embankments shall be constructed in layers approximately parallel to the finished grade of the track/ road bed. During construction of embankment, a smooth grade having an adequate crown or super

elevation shall be maintained to provide drainage. Embankments shall be constructed to the required grade, and completed embankments shall correspond to the shape of the typical sections as shown on the Drawings.

During construction of embankment, it should be ensured that any work, which is to be done during the course of laying the fill material shall not be left out.

(b) Earth Embankment:

Earth embankments shall be defined as those principally of material other than rock, and shall be constructed of approved material brought from designated or other noticed sources.

Except as specified for embankment in swamps, earth embankments shall be constructed in successive layers, for the full width of the cross section and in such lengths as are suited to the compaction and watering methods used.

(c) Placing over swamp ground:

Embankment in or over swamps or in water shall be placed by dumping granular material or sand in a uniformly distributed layer of a thickness not greater than that necessary to support the equipment while placing subsequent layers, after which the remainder of the embankment should be constructed in layers and compacted as specified.

(d) Preparation of subgrade:

The surface of the finished subgrade shall be neat and workmanlike and shall have the required form, super elevation, levels, grades, and cross section. The surface shall be constructed to sufficient accuracy to permit the construction of subsequent layers of material to the thickness, surface tolerance, and compaction specified.

2.2.7 Compaction of Embankments

- (1) When necessary each layer, before being compacted, shall be processed as required to bring the moisture content sufficiently close to optimum to make possible its compaction to the required density. The material shall be worked as to have an uniform moisture content through the entire layer.
- (2) Each layer of material shall be compacted uniformly by use of adequate and appropriate compaction equipment. The compaction shall be done in a longitudinal direction along the embankment and shall generally being at the outer edges and progress towards the center in such a manner that each section receives equal amount of compaction.
- (3) Hauling equipment shall be operated over the full width of each layer in so far as practicable. There should be a minimum overlap of 150 mm between each run of the rollers.
- (4) Embankment or backfill compaction shall be carried out in one of the following two ways:-

Either the top 200mm centimetres of the finished embankment shall be compacted to a dry density equal to at least 95% of the maximum dry density. Other

embankment layers more than 200mm below finished surface or the underside of the lowest layer of base sub-base and shoulder shall be compacted to a dry density equal to at least 90% of the maximum dry density.

OR the embankment shall be compacted to a dry density equal to at least 95% of the maximum dry density. In the case of embankment exceeding 70 cm in height layers more than 500mm. below finished surface or the underside of the lowest layer of base sub-base and shoulder shall be compacted to a dry density equal to at least 90% of the maximum dry density. The method to be adopted shall be given Notice of No Objection from Engineer..

2.2.8 Inverted Filter

An inverted filter comprising of coarse stone aggregates with an appropriate filter layer or geo-fabrice between the filter and sub-grade shall be constructed behind earth retaining structure..

It shall be constructed simultaneously with the filling work to the retaining structure. Care shall be taken during placing of the filter media to ensure that it does not cause damage to structural members or application of excessive pressure against the retaining structure.

2.3 Tests

2.3.1 Testing of Fill - General

Classification tests as per relevant Standards to which the Engineer has given his Notice of No Objection shall be carried out to ensure that true comparisons can be made between in-situ densities, laboratory compaction densities and field trial densities, i.e., that the variations in properties of fill materials can be determined.

Tests shall be carried out on fill to determine the degree of compaction achieved, at the rate of one test for either each 1,200m³ placed or each layer whichever is the more frequent. Compacted layers shall not be covered without Notice of No Objection obtained from Engineer..

The density of individual compacted layers shall be determined by a method acceptable to the Engineer.

The in-situ dry density of fill shall average 95% of the maximum reached in trials. No single result shall be less than 92% and no more than 25% of the results on any one layer shall fall between 92% and 95%. The average shall be computed from the total number of tests on any one layer where the extent of the layer is defined by the Contractor in submitting same for inspection.

2.3.2 Materials for Topmost Layer of Fill

In addition to the general requirements for fill material, the material in the top layer shall not exceed the following test values:

Plasticity Index : 6%

Liquid Limit : 35%

Total fine shall not exceed 15% Uniformity Coefficient (Cu) shall not be less than 4. The

laboratory California Bearing Ratio (CBR) value, at 95% of the maximum dry density achieved after soaking for 96 hours, shall not be less than 30%.

2.3.3 Testing of Top Layer of Fill

Tests shall be carried out on the top layer of fill as shown in following table. Test shall be carried out as required by the accepted test procedures.:

Test	Frequency of test (not less than one test per...)
A. Laboratory tests to monitor the consistency of the approved material during construction:	
Maximum dry density	1500 sq m
Optimum moisture content	1500 sq m
Grading	1500 sq m
Plasticity index	1500 sq m
Linear shrinkage	1500 sq m
CBR Value	3500 sq m
B. In situ tests to confirm that the required degree of compaction is being achieved during construction:	
Dry density	500 sq m
CBR Value	2500 sq m

Tests shall be carried out as required by the accepted test procedures.

2.4 Landscaping

2.4.1 Topsoil

The Contractor shall obtain topsoil from temporary dumps or noticed borrow-pits and shall spread it on level or sloping surfaces, to the specified depth.

2.4.2 Grass

The topsoil shall be lightly and uniformly raked to give a fine graded layer up to 30 mm deep. The surface shall either be seeded or shall be grassed with a local grass with creeping habit, of which the source and variety shall be suitable to the local conditions and given Notice of No Objection from Engineer. Grass sprigs shall be planted at 0.3 m x 0.3 m spacing. The grass shall be adequately watered until such time as the grass becomes established.

Should the growth fail to become established for any reason, the Contractor shall re-cultivate and replant grass as necessary at his own cost in accordance with the above specification, for as many times as necessary for the grass to become established. When established between 50 and 75 mm high, the grass shall be topped by cutting to leave between 25 and 50 mm minimum growth and watering shall be continued as necessary until the grass is firmly established to full satisfaction of the Engineer.

2.4.3 Turfing

Alternatively slopes of banks may be turfed with sods taken from areas approved by

Engineer. The sods shall consists of dense, well rooted growth of permanent and desirable grass indigenous to locality and be free of weeds and other undesirable matter. They shall be placed compacted and watered periodically and kept free of weeds and any erosion as given Notice of No Objection by Engineer.

2.4.4 Plantation for landscape

The plants selected for landscaping at designated areas, after civil works completion, shall be of local flora with shallow roots, easily maintainable and it should not endanger civil works.

3. ROADWORK

3.1 Temporary Traffic Management

3.1.1 Control of Traffic

- (1) The Contractor shall be responsible for designing, and implementing all Temporary Traffic Management (TTM) schemes required for the execution of the Works. The Contractor shall obtain Notice of No Objection from the Engineer and approval from Relevant Authorities for the TTM schemes.
- (2) The Contractor shall take all necessary precautions in co-ordination with and to the requirements of all the relevant authorities concerned to protect the work from damage until such time as the seal coat or surface treatment has developed sufficient strength to carry normal traffic without any damage to it. The new work shall be opened to traffic only after it is authorised by the Engineer
- (3) Prior to the implementation of any works affecting road and pedestrian traffic, the Contractor shall determine the requirements for the TTM schemes and conduct a detailed assessment of the proposed outline TTM schemes for Notice of No Objection by Engineer and for approval by Relevant Authorities. The assessment shall include:
 - (a) a notice of the construction sequence, programme and outline TTM schemes submitted, and the impact on traffic;
 - (b) estimates of the peak volume of construction traffic that will be generated during each phase of construction together with plans showing the proposed routing of construction traffic to and from the Site;
 - (c) additional details of traffic management schemes, including diversion routes, that the Contractor intends to implement for the construction of his Works;
 - (d) traffic impact analyses to demonstrate the impact of construction traffic and the Contractor's proposed traffic management schemes on the surrounding road network;
 - (e) additional field surveys and studies to establish traffic conditions where appropriate;
 - (f) all such additional information as may be required for the detailed design of the traffic management schemes;
 - (g) consultation and liaison with Relevant Authorities with a view to developing a design that causes minimal impact and is acceptable to all affected parties; and
 - (h) Inversion routes' road capacity improvement measures such as parking restrictions, removal of road humps, over head constraints due to wires and trees, road pavement improvement, junction widening for ease of vehicle turning, signal timing change, etc.

- (4) The Contractor shall submit a detailed traffic diversion/or control and regulation plan and diagrammatic representation, taking all safety measures during the course of work permitted by the concerned authorities to the Engineer for his Notice of No Objection before start of work.
- (5) The Contractor shall be responsible for the construction, manufacture, supply, erection, relocation, and subsequent removal of all temporary traffic signs, directional signs, bollards, street furniture, street lights, roads and road markings related to the TTM schemes. All temporary signs required for the implementation of traffic diversions and the Contractor's TTM schemes shall be designed in accordance with the relevant Code of Practice such as the Indian Roads Congress, Ministry of Road Transport & Highways and Indian Standards.
- (6) The Contractor shall note that no traffic signals, traffic signs and road markings in the public roads shall be erected, relocated or removed unless authorized by Engineer Traffic Police and Relevant Authorities. Furthermore, no roads, lanes or footpaths shall be opened or closed unless authorized by Engineer, Traffic Police and Relevant Authorities.
- (7) The Contractor shall protect the Works related to TTM schemes from damage until such time as the Works have developed sufficient strength to carry normal traffic loads without any damage to those works. The Contractor shall also take up the maintenance responsibilities of the TTM schemes.
- (8) The Contractor shall be responsible for the temporary removal of all existing signs (regulatory, warning and information type), bollards, street furniture, street lights, associated ducting, road markings, etc that may affect the TTM schemes.
- (9) Before any existing pedestrian route is severed or diverted, the Contractor shall submit a detailed proposal to the Engineer, for his onward submission to Relevant Authorities for approval. However, obtaining approval of Relevant Authorities on all such Contractor's proposals shall be the responsibility of the Contractor. The detailed proposal shall include:
 - (a) The width of the existing pedestrian route;
 - (b) Pedestrian volumes prior to diversion;
 - (c) The width of the diverted pedestrian route;
 - (d) The anticipated pedestrian volume along the diverted pedestrian route; and
 - (e) Proposed temporary pedestrian direction signs.
- (10) The Contractor shall ensure all existing or diverted pedestrian routes within the Site are paved, protected, sign posted, illuminated, clean and maintained in good condition to Employer'/Engineers satisfaction.
- (11) The Contractor shall be responsible for the relocation, installation, traffic signal time adjustment, and traffic signal design of the traffic signals affected by the TTM schemes. Traffic signals include related posts, cables and equipment necessary for the proper operation of the traffic signals.
- (12) Traffic signs erected shall be in accordance with the IRC Standards and/or as prescribed and approved by the Pune Traffic Police Department.

3.1.2 Reinstatement

The Contractor shall reinstate all signs, bollards, street furniture, street lights, associated ducting, road markings, road, etc that have been removed for the TTM. The reinstatement works shall be of at least the original standards and to the satisfaction of the Relevant Authorities and Engineer.

Unless agreed with Relevant Authorities and Engineer the Contractor shall remove any

traffic signals installed for TTM schemes and reinstate area. The reinstatement works shall be to the original standards and to the satisfaction of the Relevant Authorities and Engineer.

Unless agreed with Relevant Authorities and Engineer, the Contractor shall reinstate any traffic signals removed for TTM schemes. The reinstatement works shall be to the original standards and to the satisfaction of the Relevant Authorities and Engineer.

3.1.3 Special Events

For special public events such as festivals, and as ordered by Engineer or Relevant Authorities, the roads or pedestrian routes being occupied by the Contractor, or where the Contractor's works are being carried out, may have to be opened for public use for a short duration. The Contractor shall proceed with all necessary measures or modify his works to suit this purpose. The Contractor shall note that the Relevant Authorities may suspend the TTM schemes up to 10 days before the date of the special public events.

The Contractor shall take all necessary and sufficiently adequate precautions to protect against accidents, damages or the like that may be deemed caused by construction equipment, tools, materials, bitumen and bituminous material, or any other construction materials, and shall be responsible for any claims arising from such damage.

3.2 Granular Sub-Base (Non-Bituminous)

This work shall consist of laying and compacting well-graded material on prepared subgrade in accordance with the requirements of these specifications or as per IRC standards, as acceptable to Highway authorities. The material shall be laid in one or more layers according to lines, grades and cross-sections shown on the drawings.

3.2.1 Material

The Material to be used for the work shall be natural sand, moorum, gravel, crushed stone, or combination thereof depending upon the grading specified in MOST specifications for Roads and Bridges. The material shall be free from organic or other deleterious constituents.

The material shall be free from organic or other deleterious constituents and conform to one of the three gradings given in Table 3.2.2.1 and 3.2.2.2

3.2.2 Physical requirements

The material shall have a 10 percent fines value of 50 KN or more (for sample in soaked condition) when tested in compliance with BS:812 (Part III). The water absorption value of the coarse aggregate shall be determined by IS: 2386 (Part 3); if this value is greater than 2 percent, the soundness test shall be carried out on the material delivered to site as per IS: 383. CBR Value shall be determined at the density and moisture content likely to be developed in equilibrium conditions, which shall be taken as being the density relating to a uniform air, voids content of 5 percent.

TABLE 3.2.2.1 GRADING FOR CLOSE GRADED GRANULAR SUB-BASE MATERIAL

IS Sieve Designation	Per cent by weight passing the IS sieve		
	Grading I	Grading II	Grading III
75.0mm	100	---	---
53mm	80-100	100	---
26.5mm	55-90	70-100	100
9.50mm	35-65	50-80	65-95
4.75mm	25-55	40-65	50-80
2.36mm	20-40	30-65	40-65
0.425mm	10-25	15-25	20-35
0.075mm	3-10	3-10	3-10
CBR Value (Minimum)	30	25	20

TABLE 3.2.2.2 GRADING FOR CLOSE GRADED GRANULAR SUB-BASE MATERIAL

IS Sieve Designation	Per cent by weight passing the IS sieve		
	Grading I	Grading II	Grading III
75.0mm	100	---	---
53mm	---	100	---
26.5mm	55-75	50-80	100
9.50mm	---	---	---
4.75mm	10-30	15-35	25-45
2.36mm	---	---	---
0.425mm	---	---	---
0.075mm	< 10	< 10	< 10
CBR Value (Minimum)	30	25	20

Note : The material passing 425 micron(0.425mm) sieve for the three grading when vested according to IS:2720 (Pan 5) shall have liquid limit and plasticity index not more than 25 and 6 per cent respectively.

3.2.3 Strength of sub-base

It shall be ensured prior to actual execution that the material to be used in the sub-base satisfies the requirements of CBR and other physical requirements when compacted and finished. In accordance with MOST specification.

3.2.4 Construction Operations

1 Preparation of sub-grade

Immediately prior to the laying of sub-base, the sub-grade already finished or existing surface shall be prepared by removing all vegetation and other extraneous matter, lightly sprinkled with water if necessary and rolled with two passes of 80 – 100 KN smooth wheeled roller. Damage to the subgrade shall be made good before sub base is laid.

2 Spreading and compacting

- a. The approved sub-base material shall be spread on the prepared sub-grade by a grader of suitable type and adequate capacity.
- b. When the sub-base material consists of combination of materials, mixing shall be done mechanically by the mix-in-place method.
- c. The equipment used for mix-in-place construction shall be approved equipment capable of mixing the material to the desired degree.
- d. Moisture contents of the loose material at the time of compaction shall be checked in accordance with IS: 2720 (Part 7) and suitably adjusted.
- e. Rolling procedure shall be as described under Subsection 3.6.3 (7) except stated herein.
- f. Rolling shall be continued till the density achieved is at least 98% of the maximum dry density for the material determined as per IS: 2720 (Part 8).

3.2.5 Control of Traffic

Control of traffic shall be as described under Subsection 3.1.

3.3 Wet Mix Macadam Sub -base/base (Non-Bituminous)

3.3.1 Description

This work shall consist of laying and compacting clean, crushed, graded aggregate and granular material, premixed with water, to a dense mass on a prepared sub grade/sub -base/base or existing pavement as the case may be in accordance with the requirements of these Specifications. The material shall be laid in one or more layers as necessary to lines, grades and cross -sections shown on the approved drawings or as directed by the Engineer.

The thickness of a single compacted Wet Mix Macadam layer shall not be less than 75 mm. When vibrating or other approved types of compacting equipment are used, the compacted depth of a single layer of the sub-base course may be increased to 200 mm upon obtaining Notice of No Objection Engineer

3.3.2 Materials

3.3.2.1 Aggregates

3.3.2.1.1 Physical requirements:

Coarse aggregates shall be crushed stone. If crushed gravel/shingle is used, not less than 90 per cent by weight of the gravel/shingle pieces retained on 4.75 mm sieve shall have-at least two fractured faces. The aggregates shall conform to the physical requirements set forth in Table 3.3.2.1.1 below,

**Table 3.3.2 .1 PHYSICAL REQUIREMENT OF COARSE AGGREGATES FOR
WET MIX MACADAM SUB – BASE/ BASE COURSES**

Sl. No	Test	Test Method	Requirement (maximum)
1.	* Los Angeles Abrasion value, or	IS :2386 (Part-4)	40 per cent
2.	* Aggregate Impact value	IS :2386 (Part-4) or IS: 5640	30 per cent
3.	Combined Flakiness and Elongation Indices (Total)	IS : 2386 (Part-4)	30 per cent

Aggregate may satisfy requirements of either of the two tests.

If the water absorption value of the coarse aggregate is greater than 2 per cent, the soundness test shall be carried out on the material delivered to site as per IS: 2386 (Part-5).

2.3.2.1.2. Grading requirements:

The aggregate shall conform to the grading given in Table. 3.3.2.1.2

IS Sieve Designation	Per cent by weight passing the IS sieve
53	100
45	95-100
26.5	----
22.4	60-80
11.2	40-60
4.75mm	25-40
2.36mm	15-30
660 micron	8-22
75 micron	0-8

Materials finer than 425 micron shall have Plasticity Index (PI) not exceeding 6. The final gradation approved within these limits shall be well graded from coarse to fine and shall not vary from the low limit on one sieve to the high limit on the adjacent sieve or vice versa.

3.3.3 Construction Method

1. Preparation of base:

- a) The surface of the base or existing surface shall be shaped and prepared to the lines, levels, grades, dimensions and cross sections as shown on the Drawings. Damage to or deterioration of sub-base shall be made good before sub-base/ base is overlaid.

- b) Provision of lateral confinement of aggregates:

While constructing wet mix macadam, arrangement shall be made for the lateral confinement of wet mix. This shall be done by laying materials in adjoining shoulders along with that of wet mix macadam layer and following the sequence of operations described in MOST specifications.

2. Preparation of Mix:

- a) Wet Mix Macadam shall be prepared in an approved mixing plant of suitable capacity having provision for controlled addition of water and forced/positive mixing arrangement like pug mill or pan type mixer of concrete batching plant. For small quantity of wet mix work, the Engineer may permit the mixing to be done in concrete mixers.
- b) Optimum moisture for mixing shall be determined in accordance with IS:2720 (Part - 8) after replacing the aggregate fraction retained *on* 224 mm sieve with material of 4.75 mm to 22.4 mm size. While adding water, dup allowance should be made for evaporation losses. However, at the time of compaction, water in the wet mix should not vary from the optimum value by more than agreed limits. The mixed material should be uniformly wet and no segregation should be permitted.

3. Spreading of mix:

- a) Immediately after mixing, the aggregates shall be spread uniformly and evenly upon the prepared sub grade/sub- base/base in required quantities. In no case should these be dumped in heaps directly on the area where these are to be laid nor shall their hauling over a partly completed stretch be permitted.
- b) The mix may be spread either by a paver finisher or motor grader. For portions where mechanical means cannot be used, manual means as approved by the Engineer shall be used. The motor grader shall be capable of spreading the material uniformly all over the surface. Its blade shall have hydraulic control suitable for initial adjustments and maintaining the same so as to achieve the specified slope and grade.
- c) The paver finisher shall be self-propelled, having the following features :
 - (i) Loading hoppers and suitable distribution mechanism
 - (ii) The screed shall have lamping and vibrating arrangement for initial compaction to the layer as it is spread without rutting or otherwise marring the surface profile.
 - (iii) The paver shall be equipped with necessary control mechanism so as to ensure that the finished surface is free from surface blemishes.

The surface of the aggregate shall be carefully checked with templates and all high or low spots remedied by removing or adding aggregate as may be required. The layer may be tested by depth blocks during construction. No segregation of larger and fine particles

should bellowed. The aggregates as spread should be of uniform gradation with no pockets of fine materials.

a) **Compaction :**

After the mix has been laid to the required thickness, grade and cross fall/camber the same shall be uniformly compacted, to the full depth with suitable roller. If the thickness of single compacted layer does not exceed 100 mm, a smooth wheel roller of 80 to 100 kN weight may be used. For a compacted single layer up to 200mm, the compaction shall be done with the help of vibratory roller of minimum static weight of 80 to 100 kN or equivalent capacity roller. The speed of the roller shall not exceed 5 km/h.

Rolling should not be done when the wmm is soft or yielding or when it causes a wave-like motion in the base course or subgrade. If irregularities develop during rolling which exceed 12 mm when tested with a 3 metre straight edge, the surface should be loosened and premixed material added or removed as required before rolling again so as to achieve a uniform surface conforming to the desired grade and cross fall. In no case should the use of unmixed material be permitted to make up the depressions.

Rolling shall be continued till the density achieved is at least 98 per cent of the maximum dry density for the material as determined by the method outlined in IS: 2720 (Part -8). After completion, the surface of any finished layer shall be well closed, free from movement under compaction equipment or any compaction planes, ridges, cracks and loose material. All loose, segregated or otherwise defective areas shall be made good to the full thickness of the layer and recomputed.

4. **Quality Control & Surface evenness:**

The finished sub-base/ base at any point shall not exceed 12mm above the planned grade or adjusted grade with 3m straight edge applied to the surface parallel to the centerline of the road. With the template laid transversely the maximum permissible variation from specified profile shall be 12mm and 8mm respectively. The surface finish of construction shall conform to the requirements of Clause 902, of MOST specification. Control on the quality of material and works shall be exercised by the Engineer in accordance with Section 900. of MOST specification.

3.4 Bituminous Materials

3.4.1 Materials

Materials shall meet the requirements of the relevant IS Codes. These shall be of the following types.

1. **Cut back Bitumen**

Cut back bitumen shall be Rapid Curing (RC), Medium Curing (MC) or Slow Curing (SC) conforming to IS : 217.

2. **Cationic Emulsion**

Bitumen emulsions of the cationic type for roads shall conform to IS: 8887. Emulsified bitumen shall be Rapid Setting (RS), Medium Setting (MS), or Slow Setting

(SS).

The physical and chemical requirements of the three types emulsions shall comply with the requirements specified in Table 1 of IS: 8887.

3. Paving Bitumen

Paving bitumen shall be conforming to IS: 73 and of the following two types:

Type 1 - Paving bitumen from non-waxy crude shall satisfy the requirements given in Table 1 of IS: 73.

Type 2 - Paving bitumen from waxy crude shall satisfy the requirements given in Table 2 of IS: 73.

The temperature at application of bituminous materials shall be maintained as per manufacturer's instructions and/or as directed by the Engineer

3.4.2 Methods of Storage and Handling

Asphaltic material shall be handled and stored with due regard for safety and in such a way that at the time of use in the work the material conforms to the Specifications. Following precautions shall be taken while using these materials:

- 1 Work with these materials shall be carried out in good weather conditions and it shall be carried out in warm and dry weather, and not in wet or extremely cold weather.
- 2 Emulsified asphalt shall be handled with care and not subjected to mechanical shocks or extremes of temperature likely to cause separation of the asphalt. Emulsified asphalt showing sign of separation shall not be used.
- 3 During heating, no water or moisture shall be allowed to enter the boiler.
- 4 Heating of bitumen shall be done to the correct temperature range, as prescribed by the manufacturer for the grade used. The temperature shall be controlled with the use of a suitable thermometer, and the material shall be drawn and used while still at such temperature as is prescribed by manufacturer or in accordance with MOST specifications.
- 5 It shall be ensured that mixing of ingredients is thorough and all particles of aggregates are coated uniformly and fully.

3.5 Prime Coat

3.5.1 Description

This work shall consist of the cleaning and preparing of the surface to be primed to specified lines, grade, and cross-section, booming and clearing thoroughly and applying bituminous material in accordance with these Specifications.

3.5.2 Materials

The choice of the primer shall depend upon the porosity characteristics of the surface to be primed. The primer shall be Medium Curing Cutback (MC) and the particular grade to be used for the work shall have the Notice of No Objection from Engineer. Slow setting Cationic

emulsion conforming to IS : 8887 may also be used. Sampling and testing of bituminous primer shall be as per IS : 217, IS : 454 and IS : 8887.

3.5.3 Construction Methods

1. Weather Limitations

Prime coat shall not be applied at a time when the surface is wet or when the weather is foggy, rainy or windy.

2. Equipment

The equipment used for the work shall include a power broom and primer material distributor spraying it uniformly at specified rates and temperatures. It shall be equipped with self-heating arrangement, suitable pump, adequate capacity compressor and spraying bar with nozzles having constant volume or pressure system. Spraying by manual methods may be allowed for inaccessible or small areas with the Notice of No Objection from Engineer.

3. Cleaning Surface

Immediately prior to applying the prime coat the surface to be primed shall be swept clean from all loose dirt and other objectionable material and shall be shaped to the required lines, grades, cross section.

4. Application of bituminous primer

The primer material shall be applied by means of a distributor at rates usually from 0.8 to 1.4 litres per square metre and at a temperature within the allowable range corresponding to the material used and porosity condition of surface over which it is laid. The temperature of primer at time of application may vary from 40 °C to 60 °C for cutback bitumen and 40 °C to 60 °C for bitumen emulsion

Prime coat shall be allowed to penetrate for at least 48 hours to allow penetration into the base course and aeration of volatile from the primer material, then covered with clean dry sand or stone screening. Areas containing an excess or deficiency of priming material shall be corrected by the addition of sand or primer.

3.6 Tack Coat

3.6.1 Description

This work shall consist of furnishing and applying bituminous material to an existing road surface or to an existing bituminous prime coat surface which has dried out or preparatory to laying another bituminous layer over it.

3.6.2 Materials

The material for tack coat shall be a bituminous or cut back emulsion of suitable type and grade.

3.6.3 Construction Methods

1. Cleaning Surface

The whole surface on which the tack coat is to be applied shall be cleaned of dust

and any extraneous material before the start of application of tack coat by using a power broom or any other equipment/ method.

2. Application of tack coat material

The tack coat material shall be applied uniformly by means of a distributor at controlled rates as per MOST specifications and at the temperature within the allowable range corresponding to the material used. It shall be done with self propelled or towelled bitumen.

Surfaces of structures and trees adjacent to the areas being treated shall be protected in such a way as to prevent their being spattered or marred.

3.7 Bituminous Macadam

3.7.1 Description

The work shall consist of one or more applications of compacted crushed aggregates premixed with bituminous binder (suitable grade) to a primed non-bituminous surface or previously constructed bituminous surface and in conformity with the lines, grades, dimensions and cross-sections shown on the Drawings. This shall comprise of a single course of 50mm to 75mm thickness as specified in the approve or as Directed by Engineer

3.7.2 Materials

1. Bitumen

The bitumen shall be paving bitumen of suitable grade approved by the Engineer and conforming to IS : 73.

2. Additives

Adhesion and Ant-stripping agent shall be added to the bitumen subject to Notice of No Objection from Engineer at the required percentage of additive. The additive shall be thoroughly mixed with the bituminous material in accordance with the manufacturer's instructions.

3. Aggregates

Aggregates shall consist of clean and hard crushed stone free from dust, clay, dirt and any other deleterious matter. The physical requirements shall be as given in Table 3.7.1. Aggregates shall conform to one of the two gradings given in Table 3.7.2 depending on the compacted thickness; the actual grading shall have the Notice of No Objection Engineer.

Table 3.7.1 : Physical requirements of aggregates for bituminous macadam

S.No	Test	Test Method	Requirement (maximum)
1.	* Los Angeles Abrasion value	IS :2386 (Part-4)	40 per cent
2.	* Aggregate Impact value	IS :2386 (Part-4)	30 per cent
3.	Flakiness Index and Elongation Indices (Total)	IS : 2386 (Part-1)	30 per cent
4.	Coating and Stripping of Bitumen aggregate mixtures	AASHTO T-182	Minimum retained coating 95%
5.	Soundness : i. Loss with Sodium Sulphate 5 cycles ii. Loss with Magnesium Sulphate 5 cycles		12 percent 18 percent
6.	Water absorption	IS : 2386(Part-3)	2 per cent

* Aggregates may satisfy requirements for either of the two tests.

Table 3.7.2 Aggregate grading for bituminous macadam

IS Sieve Designation	Per cent by weight passing the sieve	
	Grading 1	Grading 2
45.0mm	100	-
26.5mm	75-100	100
22.4mm	60-95	75-100
11.2mm	30-55	50-85
5.6mm	15-35	20-40
2.8mm	5-20	5-20

Bitumen content for pre mixing shall be 4% by weight of total mix unless otherwise approved by Engineer.

3.7.3 Construction Methods

1. Weather and Control of Work

The work of laying shall not be undertaken during rainy or foggy weather or when the base course is damp or wet, or during dust storm or when the atmospheric temperature in shade is 15°C or less.

The Engineer may order work to cease temporarily on account of adverse weather, unsatisfactory condition of materials, equipment or any conditions which he considers may affect the work adversely.

2. Cleaning and Preparation of Surface

Prior to the application of binder, loose dirt and other objectionable material shall be removed from the surface to be treated by means of the power broom or blower or

both. If this does not provide a uniformly clean surface, additional sweeping shall be done by hand, using stiff brushes or similar brooms. The areas inaccessible to the cleaning means shall be cleaned manually. The sweeping shall extend 200mm beyond each edge of the area to be treated.

Adherent patches of objectionable material shall be removed from the surface by steel scraper or other approved method and where the Engineer so directs the scraped area shall be washed down with water and hand brooms.

No application of bituminous material shall be undertaken until the surface has been cleaned to the satisfaction of the Engineer.

Before application of the bituminous material any necessary preliminary patching of the surface of the road (To fill in potholes.) shall be done to the complete satisfaction of the Engineer.

Tack coat shall be applied in accordance with these Specifications. Prime coat if required, shall conform to Subsection 3.5.

3. Plant and Equipment

All plant used by the Contractor for the preparation, hauling and placing of asphalt mixtures shall be subject to the Notice of No Objection from Engineer and shall minimise smock,dust and noxious emission and odours. These shall generally meet the following requirements :

- a. The mixing plant shall be a batching plant and shall have adequate capacity sufficient to supply the finisher on the road continuously when spreading the asphaltic mix at normal speed and required thickness.
- b. Scale for any weigh box shall be designed to be accurate to within 1% of the maximum load required and shall be fully automatically controlled. The Contractor shall provide and have at hand not less than ten 25 kilograms weights for frequent testing of all scales.
- c. Weigh box or hopper shall include a means for accurately weighing each bin size of aggregate in a weight box or hopper, suspended on scales, ample in size to hold a full batch without running over.
- d. The asphaltic materials shall be stored in storage tanks designed to keep the temperature of the asphaltic material at maximum temperature of 110 degree C. The properties of the asphaltic material kept in that storage tanks shall be in good condition before mixing.

The plant shall be provided with a circulating system to ensure continuous circulation between the storage tank and the mixer.

- e. The plant shall be provided with a cold bin for feeding the aggregates. Bin shall have a calibration gate and a mechanical means to insure uniform feeding of the aggregates into the drier as required by the Engineer
- f. The rotary drier shall be capable of drying and heating the aggregates to the specified temperature.

- g. The plant shall be provided with plant screens capable of screening all aggregates to the specified sizes.
- h. The plant shall include at least 3 hot bins for storing the aggregates fed from the drier after passing through the screen. Each bin shall be provided with an overflow pipe to prevent any backing up of material into other bins.
- i. The plant shall be provided with asphaltic control unit by weighing to obtain the proper amount of asphaltic material in the mix within the tolerance specified for the job-mix.
- j. The batch mixer shall be an approved twin pugmill type and capable of producing a continuous uniform mixture within the job-mix tolerances. The mixer capacity shall not be less than 1,000 kilogram batch.
- k. An armoured thermometer reading from 50 degree C to 200 degree C shall be fixed in the asphaltic feed line at a suitable location near the discharge valve at the mixer unit.

The plant shall be further equipped with an electric pyrometer, or other approved thermometric instrument so placed at the discharge chute of the drier as to register automatically or indicate the temperature of the heated aggregate.
- l. The plant shall be equipped with a dust collector.
- m. The plant shall be equipped with accurate positive means to govern the time of mixing and to maintain it constant. The time of mixing shall be divided into two steps, dry mixing and wet mixing. For dry mixing, the aggregate from hot bins shall be mixed for a period of 5-15 seconds. For wet mixing, the mixing time shall begin with the start of the asphalt spray after dry mixing. The wet mixing shall take about 30-45 seconds. The mixing time shall be extended if in the consideration of the Engineer the material obtained is not homogeneous.

4. Equipment for Hauling and placing

- a. Trucks for hauling asphaltic mixtures shall have tight, clean, and smooth metal beds that have been sprayed with soapy water, thinned fuel oil, or lime solution to prevent the mixing from adhering to the beds (The amount of sprayed fluid shall however be kept to the practical minimum. Each load shall be covered with a canvas or other suitable material of such size as to protect the mixture from the weather). Any truck causing excessive segregation of material by its spring suspension or other contributing factors, or that shows oil leaks in detrimental amounts, or that causes undue delays, shall upon direction of the Engineer be removed from the work until such conditions are corrected.
- b. The equipment for spreading and finishing shall be mechanical, self powered pavers, capable of spreading and finishing the mixture true to the lines, grades, dimensions and cross sections.

The pavers shall be equipped with hoppers and distributing screws of the reversing type to place the mixture evenly.

The pavers shall maintain trueness of grade and confine the edges of the pavement to true lines without the use of stationary side forms. The equipment shall include blending or joint leveling devices for smoothing and adjusting longitudinal joints between lanes. The assembly shall be adjustable to give the cross-section shape prescribed and shall be so designed and operated as to place the thickness or weight per square metre of material required.

Pavers shall be equipped with activated screeds and devices for heating the screeds to the temperature required for the laying of the mixture without pulling or marring.

The term “screed” includes any cutting, crowing, or other practical action that is effective in producing a finished surface of the evenness and texture specified, without tearing, shoving, or gouging.

If, during construction, it is found that the spreading and finishing equipment in operation leaves in the pavement surface tracks or indented areas or other objectionable irregularities, the use of such equipment shall be discontinued and other satisfactory spreading and finishing shall be provided by the Contractor forthwith.

5. Preparation and transport of mix

Bituminous macadam mix shall be prepared in a hot-mix plant either owned by the Contractor or it may be taken from an approved hot mix plant before supply of mix for the work, consent for the use of the mix shall be taken from the Engineer. The hot-mix plant should be of adequate capacity of batch mix type with the features as described under Subsection 3.7.3(3) or otherwise approved by Engineer unless some work specific features are required and capable of yielding a mix of proper and uniform quality with thoroughly coated aggregates. The plant shall meet the overall requirements through stringent quality control practices.

The mineral aggregates shall be dried and heated to a temperature between 150 degree C and 163 degree C. The contractor shall submit a Form or Notice of No Objection the exact temperature to the Engineer. Surfaces of aggregates shall be clean and free of carbon and unburnt fuel oil. The aggregates, immediately after heating, shall be screened into three or more fractions and conveyed into separate bins ready for combining and mixing with asphaltic material.

The dried mineral aggregates prepared as prescribed above, shall be combined in the plant in the amount of each fraction of aggregate required to meet the job-mix formula for the particular mixture. The proper amount of asphaltic material shall be distributed over the mineral aggregate and the whole thoroughly mixed for a period of at least 30 seconds, or longer if necessary to produce a homogeneous mixture in which all particles of the mineral aggregates are coated uniformly. The total mixing time shall be regulated by a suitable locking means.

The mixture shall when emptied from the mixer be at a temperature between 150 degree C and 163 degree C even for tolerances.

The mixture shall be transported from the mixing plant to the point of use in vehicles conforming to the requirements of Subsection 3.7.3 (4) (a) unless otherwise approved by the Engineer.

6. Application of the Pre-mix

The application of the mix shall proceed immediately after application of tack coat. The mix shall be spread immediately by means of self-propelled mechanical paver with suitable screeds capable of spreading, tamping, and finishing the mix true to lines, levels, dimensions and cross-sections specified. Any bare or insufficiently filled areas shall be re-treated by the mechanical spreader or covered by hand as necessary to give uniform and complete coverage. Any aggregate spread in excess of the agreed rate shall be scattered and evenly distributed on the road or otherwise removed and stockpiled.

The temperature of the mix at the time of laying shall be in the range of 120 or 160 degree C.

7. Rolling

After the spreading of the mix, the rolling shall be done by road roller of suitable type and capacity. Rolling shall start as soon as possible after the material has been spread and it shall be completed within limited time frame, and to meet this the Contractor shall deploy a set of rollers. Rolling shall be done with care to avoid unduly roughening of the pavement surface. It shall commence at the edges and progress towards the centre longitudinally except that on super-elevated and unidirectional cambered portions, it shall progress from the lower to the upper edge parallel to the centre line of the pavement.

The speed of the rollers shall not exceed 5 kilometer per hour for steel wheeled rollers and 7 kilometer per hour for pneumatic tired rollers and shall be at all times slow enough to avoid displacement of the hot mixture. Any displacements occurring as a result of reversing the direction of the roller or from any other cause shall at once be corrected with rakes and fresh mixture where required. Care shall be exercised in rolling not to displace the line and grade of the edges.

Rolling shall progress continuously as may be necessary to obtain uniform compaction while the mixture is in a workable condition and until all roller marks are eliminated.

Heavy equipment or rollers shall not be permitted to stand on the finished surface until it has thoroughly cooled or set.

Any petroleum products dropped or spilled from the vehicles or equipment employed by the Contractor upon any portion of the pavement under construction is cause for the removal and replacement of the contaminated pavement by the Contractor.

When the roller has passed over the whole area once, any high spots or depressions

which become apparent shall be corrected by removing or adding premixed material. Rolling shall then be continued until the entire surface has been rolled to 95 % of the average laboratory density, and there is no crushing of aggregates. and all roller marks are eliminated. In each pass of the roller, preceding track shall be overlapped uniformly by at least 1/3rd width. The roller wheels shall be kept damp to prevent premix from adhering to the wheels and being picked up. In no case shall fuel/ lubricating oil be used for this purpose.

Along kerbs, man-holes etc., and at any other locations where proper consolidation by rollers is not practicable, alternative means such as steel rammers shall simultaneously be used to secure adequate consolidation.

3.7.4 Surface Control

1. Surface Regularity

Maximum permissible undulation in longitudinal profile with 3m straight edge shall be as 12mm.

Maximum permissible variation from specified cross profile under camber template shall be as 8mm.

Surface evenness requirements in respect of both longitudinal and cross profiles should be simultaneously satisfied.

Tests for conformity with the specified crown and grade shall be made immediately after initial compaction, and variations shall be corrected by removing or adding materials as may be necessary. Rolling shall then be continued as specified. After final rolling, the smoothness of the course shall be checked again and any irregularity of the surface exceeding the permissible limits corrected as agreed by the Engineer, including removal and replacement.

2. Surface Finish

The bituminous macadam shall be covered with either the next pavement course or wearing course, as the case may be, without any delay. If there is to be any delay, the course shall be covered with the seal coat. The seal coat in such cases shall be considered incidental to the work and shall not be paid separately.

3.7.5 Control of Traffic

This shall be as described under Subsection 3.1 above.

3.8 Open-graded Pre-mix Carpet

3.8.1 Description

This work shall consist of laying and compacting an open-graded carpet generally of 20mm thickness or as otherwise specified in a single course composed of suitable small sized aggregates premixed with a bituminous binder on a previously prepared base to serve as a wearing course.

3.8.2 Materials

1. Binder

Binder shall be a bitumen of suitable grade meeting the requirements of the work and

other environmental conditions. This shall be conforming to the requirements of IS : 73, IS : 217 and IS : 454 or other approved cut back bitumen as applicable.

2. Coarse aggregates

Coarse aggregates consist of crushed stones and shall be clean, strong, durable, and free from organic or other deleterious materials. The aggregates shall be hydrophobic and of low porosity. If hydrophilic aggregates are to be used, bitumen shall preferably be treated with anti-stripping agents of approved quality in suitable doses.

The aggregates shall meet the requirements given in Table 3.7.1 except that the water absorption shall be limited to 1 per cent. The Stone Polishing Value as measured by BS : 812-(Part-114) shall not be less than 55.

3. Proportioning of Materials

They shall comprise of a mix of stone chipping 13.2mm size (passing 22.4 mm sieve and retained on 11.2 mm size) and 11.2 mm size (passing 13.2 mm sieve and retained on 5.6 mm sieve.)

The contractor shall propose material proportions to the Engineer for his to give Notice of No Objection

3.8.3 Construction Methods

1. Weather and Control of Work

This shall be as carried out per Subsection 3.7.3(1).

2. Cleaning and Preparation of Surface

This shall be as carried out per Subsection 3.7.3(3).

3. Tack Coat

This shall be applied as per Subsection 3.6.

4. Preparation and transport of Premix

The binder shall be heated to a temperature appropriate to the grade of bitumen in boilers of suitable design avoiding local overheating and ensuring a continuous supply.

The aggregates shall be dry and suitably pre-heated to the required temperature before they are placed in a mixer. After about 15 seconds of dry mixing, the heated binder shall be distributed over the aggregates at the rate specified. Mixing shall be continuous and thorough to ensure a homogeneous mixture in which all particles are coated uniformly and the discharge temperature shall be within the specified range.

The mixing of binder with chippings shall be continued until the chippings are thoroughly coated with binder. The mix shall be discharged and immediately transported from mixer to the point of use in suitable vehicles or wheel barrows. The vehicles employed for transport shall be clean and the mix being transported should be covered in transit and protected from any kind of damage.

5. Spreading and Rolling

Immediately after the application of tack coat, premixed material shall be spread by

means of mechanical paver finisher truly to lines, levels, dimensions and cross section as specified. The areas not covered by the mechanical means shall be treated with manual means for which the Engineer has given Notice of No Objection.

6. Rolling

This shall be carried out as per Subsection 3.7.3(7)

3.8.4 Control of Traffic

Subsection 3.1 shall be followed.

3.9 Bituminous Concrete

3.9.1 Description

This work shall consist of a surfacing of single-layer bituminous concrete of specified thickness on previously prepared bituminous surface to the lines, grades, dimensions and cross section as shown on Drawings. It shall be 25mm/40mm thick as required by Engineer.

3.9.2 Materials

1. Bitumen

The bitumen shall be paving bitumen of suitable penetration grade within the range S 35 to S 90 or A 90 to IS : 73. The actual grade of bitumen to be used shall be appropriate to the requirements of the work and environmental conditions.

2. Coarse aggregates

The aggregates shall satisfy the physical requirements given in Table 3.7.1. Flakiness index shall not exceed 30% and water absorbed not more than 1%

3. Fine aggregates

Fine aggregates shall be the fraction passing 2.36 mm sieve and retained on 75 micron sieve, consisting of crushed run screenings, natural sand or a mixture of both. These shall be clean, hard, durable, uncoated, dry and free from any injurious, soft or flaky pieces and organic or other deleterious substances.

4. Filler

Filter shall consist of finely divided mineral matter such as rock dust, hydrated lime or cement. The filter shall be graded within following limits :

IS Sieve	Per cent passing by weight
600 micron	100
300 micron	95 – 100
75 micron	85 – 100

The filter shall be free from organic impurities and have a Plasticity Index not greater than 4. The Plasticity Index requirement shall not apply if filter is cement or lime. When coarse aggregate is gravel, 2 per cent of mass of total aggregate of portland cement or hydrated lime shall be added and percentage of fine aggregate reduced accordingly. Cement or lime is not required when the gravel is lime stone.

5. Aggregate gradation

Mineral aggregates, including filler shall be so graded or combined as to conform to gradings set forth in Table 3.9.1 below.

Table 3.9.1 : Aggregate grading

Sieve Designation	Per cent by weight passing through sieve for		
	25mm thick Grade 1	25-40mm thick Grade 2	>40mm thick Grade 1
26.5mm	--	--	100
22.4mm	--	100	75-100
13.2mm	100	80-100	--
11.2mm	90-100	75-95	50-85
5.6mm	60-80	55-75	20-40
2.8mm	40-55	40-55	5-20
710micron	20-30	20-30	--
300micron	15-25	15-25	--
180micron	10-20	10-20	--
90micron	5-11	5-11	0-5

3.9.3 Mix Design

Requirement of Mix

Apart from conformity with grading and quality requirements of individual ingredients, the mix shall also meet the requirements set forth in Table 3.9.2.

Table 3.9.2 : Requirements of Bituminous Concrete Mix

S.NO	Description	Requirements
1.	Marshall stability (ASTM Designation : D-1559) determined on Marshall specimens compacted by 75 compaction blows on each end	820 Kg (1800 pounds)
2.	Marshall flow (mm)	Minimum 2-4
3.	Per cent air voids in mix	3-5
4.	Per cent voids in mineral aggregate (VMA)	Minimum 11-13
5.	Percent voids in mineral aggregates filled by bitumen (VFB)	65-75
6.	Binder content, per cent by weight of mix	Minimum 4.5
7.	Water sensitivity (ASTM : D-1075) loss of	Minimum 75%

S.NO	Description	Requirements
	Stability on immersion in water at 60 deg. C	Retained strength
8.	Swell Test (Asphalt Instt. MS-2, No. 2)	Maximum 1.5%

1. Binder content

Binder content shall be so determined as to achieve the requirements of the mix set forth in Table 3.9.2. Marshall method for arriving at binder content shall be adopted.

2. Job Mix Formula

Before starting work the Contractor shall submit to the Engineer for his consent. The job mix formula for the mixture shall fix a single percentage of aggregate passing each required sieve size, a single percentage of asphalt to be added to the aggregate, and a single temperature at which the mixture is to be delivered on the road, all of which shall fall within the ranges of the composition and the temperature limits. The formula shall give the following details :

- i. Source and location of all materials
- ii. Proportions of all materials as described under :

Binder	- as percentage by weight of total mix
Coarse aggregate/	- as percentage by weight of total
Fine aggregate/	aggregate including mineral filler
Mineral Filler	
- iii. A single definite percentage passing each sieve for the mixed aggregate (Vide Table 3.4.4)
- iv. The results of test enumerated in Table 3.4.5 as obtained by the contractor
- v. Test results of physical characteristics of aggregates to be used
- vi. Mixing temperature and compacting temperature

3. Application of job-mix formula and Allowable Tolerances

The approved job mix formula shall remain effective unless and until modified. Each day as many samples of the materials and mixtures shall be taken and tested considers necessary for checking the required uniformity of the mixture.

All mixture furnished shall conform to the job-mix formula within the range of tolerances set in forth in Table 3.9.3.

Table 3.9.3 : Permissible variations from the job-mix formula

S. No.	Description of Ingredients	Permissible Variation by Weight of Total mix in Percentage
1.	Aggregate passing 13.2mm sieve and larger	± 8
2.	Aggregate passing 9.5mm sieve and 4.75mm sieve	± 7
3.	Aggregate passing 2.36mm sieve & 1.18mm sieve	± 6
4.	Aggregate passing 600 μ sieve & 300 μ sieve	± 5
5.	Aggregate passing 150 micron sieve	± 4
6.	Aggregate passing 75 micron sieve	± 3
7.	Binder	± 0.3
8.	Mixing Temperature (Centigrade)	± 10

When unsatisfactory results or changed conditions make it necessary, a new job mix shall be submitted to the Engineer.

Should a change in a material be encountered or should a change in a source of material be made, a new job mix formula shall be submitted before the mixture containing the new material is delivered.

3.9.4 Construction Operations

1. Weather Limitation

The control over the weather conditions shall be as described under Subsection 3.7.3 (1) above.

2. Progress of Work

No work shall be performed when there is insufficient hauling, spreading or finishing equipment, or labour to ensure progress at a rate not less than 75% of the capacity of the mixing plant.

3. Preparation of Existing Surface

The surface on which the mix is to be laid shall be swept thoroughly and cleaned of all loose dirt and other objectionable material using mechanical broom immediately before start of work. In portions where mechanical means can not reach.

The surface shall be prepared, shaped and conditioned to specified levels, grade and cross-fall (camber).

4. Preparation of Mix

A Hot-mix plant of adequate capacity and capable of producing a proper and uniform quality mix shall be used for preparing the mix. The plant may be either a weigh batch type or volumetric proportioning continuous or drum mix type. The plant shall have co-ordinated set of essential units capable of producing uniform mix as per the job-mix formula.

The temperature of the binder at the time of mixing shall be in the range of 150 to 163 degree C and of aggregates in the range of 155 to 163 degree C. Provided also that at no time shall the difference in temperature between the aggregates and binder exceed 14 degree.C. The Contractor shall submit the exact temperatures and total mixing time for the consent of the Engineer.

Mixing shall be thorough to ensure that a homogeneous mixture is obtained in which all particle of mineral aggregates are coated uniformly.

5. Transportation and Delivery of Mix.

The mix shall be transported from the mixing plant to the point of use in suitable tipper vehicles. The vehicles employed for the transport shall be clean and be covered in transit.

6. Spreading and Finishing

The mix transported from the hot mix plant to the site and shall be spread by means of a self-propelled mechanical paver with suitable screeds capable of spreading, tamping and finishing the mix to specified grade, elevation, and cross-section. However, in restricted locations and narrow widths, available equipment can not be operated, other suitable means shall be employed subject to the Notice of No Objection from the Engineer. The mixture shall be laid upon an approved surface and only when weather conditions are considered suitable. The temperature of the mix, at the time of laying, shall be in the range of 120 degree C to 160 degree C.

The prime coat and tack coat to be applied shall be as per Subsections 3.5 and 3.6 respectively.

Spreading, finishing and compacting of the mix shall be carried out during daylight hours only, unless satisfactory illumination is provided by the Contractor.

7. Compaction of Mixture

Immediately after spreading of mix by paver, it shall be thoroughly and uniformly compacted by rolling with a set of self-propelled rollers moving at a speed not more than 5 km per hour, immediately following close to the paver. Generally with each paver, two steel wheeled tandem rollers and one pneumatic tired roller will be required. The initial or breakdown rolling shall be with 8 to 10 ton static weight smooth three wheeled steel roller and finish rolling with 6 to 8 ton tandem roller. The breakdown rolling shall preferably be followed by an intermediate rolling with a smooth wheel pneumatic roller of 10 to 25 ton having a tire pressure of 7kg/sqcm moving with a speed not more than 7 km per hour and shall be at all times slow enough to avoid displacement of the hot mixture. Means shall be provided for checking and adjusting the tire pressure on the job at all times. All compaction operations, i.e., breakdown rolling can be accomplished by using vibratory roller of 8 to 10 ton static weight. During initial or breakdown rolling and finished rolling, the vibratory shall be switched off. The joints and edges shall be rolled with a 8 to 10 ton three wheeled static roller.

No delays in rolling the paved surface shall be tolerated, the breakdown roller must be right up to the paver at all times and the intermediate pneumatic roller right up to the breakdown roller. The compaction of the asphaltic concrete shall be controlled by temperature as

follows :

<u>Roller</u>	<u>Temperature</u>
Breakdown	120°C - 135°C
Pneumatic	95°C - 115°C
Finishing	< 65°C

Rolling procedure shall be as specified under Subsection 3.7.3 (7).

No delays in rolling the paved surface shall be tolerated, the breakdown roller must be right up to the paver at all times and the intermediate pneumatic roller right up to the breakdown roller. Rolling shall be continued till the density achieved is at least 98% of that of laboratory Marshall specimen. Rolling operations shall be completed in all respects before the temperature of the mix falls below 100 degree C.

8. Joints

Both longitudinal and lateral joints in successive courses shall be staggered so as not to be one above the other. Longitudinal joints and edges shall be constructed true to delineating lines parallel to the centre line of the road. Longitudinal joints shall be offset by at least 150mm from those in the lower course.

Longitudinal and transverse joints shall be made in a careful manner so that well bonded and sealed joints are provided for the full depth of the course.

9. Surface regularity

Surface shall be tested for undulations in longitudinal and cross profiles with 3 m straight edge and crown template respectively. Crown template shall conform to the typical cross section.

Maximum permissible undulation in longitudinal profile with 3m straight edge shall be as 8mm.

Maximum permissible variation from specified cross profile under camber template shall be as 4mm.

Surface evenness requirements in respect of both longitudinal and cross profiles should be simultaneously satisfied.

10. Protection of the pavement from traffic

Subsection 3.7.5 shall apply except as stated below.

Section of the newly finished works shall be protected from traffic of any kind until the mixture has cooled to approximately ambient air temperature and well set.

3.10 Seal Coat

3.10.1 Description

This work shall consist of application of a seal coat for sealing the voids in a bituminous surface laid to the specified levels, grade, and cross fall. Seal coat used shall be of premix type unless otherwise approved by the Engineer.

3.10.2 Materials

1. Binder

The binder shall be bitumen of a suitable grade appropriate to the requirements of the work and other environmental conditions as directed by the Engineer and satisfying the requirements of IS : 73, 217, 454 or other cut back as applicable.

2. Aggregates

The aggregates shall be sand or grit and shall consist of clean, hard, durable, dry particles and shall be free from dust, soft or flaky/ elongated material, organic matter or other deleterious substances. The aggregates shall pass 2.36mm sieve and be retained on 180 micron sieve. The quantity used for premixing shall be 0.06 cum per 10 sq m area.

3.10.3 Construction Methods

1. Preparation of base

The seal coat shall be applied immediately after laying of bituminous course which is required to be sealed. Before application of seal coat materials, the surface shall be cleaned free of any dust or other objectionable matter.

2. Preparation and Application of Mix

Mixtures of approved type shall be employed for mixing aggregates with suitable bituminous binder.

The binder shall be heated in boilers of suitable design, to a temperature appropriate to the grade of bitumen. The aggregates shall be clean, dry and suitably heated to a temperature before the same are placed in the mixture. Mixing of binder with aggregates to specified proportions shall be continued till the latter are thoroughly coated with the former.

The mix shall be immediately transported from the mixing plant to the point of use and spread uniformly on the bituminous surface to be sealed.

3. Rolling

As soon as sufficient length has been covered with pre-mixed material, the surface shall be rolled with 8-10 ton smooth wheeled steel, suitable vibratory, or other equipment.

As regards procedure for rolling it shall be as specified under Subsection 3.7.3 (7).

4. Control of Traffic

Subsection 3.1 shall apply.

3.11 Cement Concrete Pavements

3.11.1 General

This work shall consist of constructing Plain/ or Reinforced Cement Concrete Pavements as required in accordance with these Specification and in conformity with the lines, levels, grades and dimension in accordance with the design.

3.11.2 Materials

1. General

The concrete materials viz. cement, aggregates, water, steel reinforcement, admixtures shall be in accordance with Section 5 on concrete except as specified herein.

2. Dowel and Tie bars

Dowel bars shall be plain round bars. They shall be free from burring or other deformation restricting slippage in the concrete. Before delivery to the Works, one half of the length of each dowel bar shall be painted with one coat of bituminous material.

Tie bars shall be deformed bars free from oil, dirt, loose rust and scale.

These shall conform to the requirements of IS : 432, IS : 1139 and IS : 1786 as relevant.

3. Sleeves

The sleeves for dowel bars of expansion joints shall be of plastic material. This shall be designed to cover the dowels specified by the Designer, with a closed end, and with a suitable stop to hold the end of the sleeve a distance equal to the thickness of joint filler or at least 30mm from the end of the dowel bar. These shall be of such design that they do not deflect or collapse during construction, and the arrangement of sleeves shall be in accordance with these Specifications.

4. Waterproof Membrane

Where Waterproof membrane is to be provided, it shall be an impermeable polythene plastic sheeting. Where an overlap of underlay material is necessary this shall be at least 300mm. Water shall not be allowed to pond on the membrane which shall be completely dry when the concrete is laid.

5. Jointing Materials

a. Joint Filler

The expansion joint fillers shall conform to the requirements of IS : 1838. They shall be punched to admit the dowels where called for as specified by the Designer. The filler for each joint shall be furnished in a single piece for the full depth and width required for the joint. When the use of more than one piece is authorized for a joint, the abutting ends shall be fastened closely together securely and accurately to shape by stapling or other satisfactory positive fastening.

b. Joint Primer

Joint primer shall be fully compatible with the joint sealant and shall be applied strictly in accordance with the manufacturer's instructions.

c. Joint Sealing Compound

The Sealing Compound of hot poured, elastomeric type shall conform to AASHTO M282 and cold applied sealant shall be in accordance with BS 5212 (Part 2).

3.11.3 Equipment and Tools

1. General

The concrete paving shall be carried out by use of mechanized method. Equipment and tools necessary for handling materials and performing the work shall have the Notice of No Objection from Engineer as to design, type, capacity and mechanical, condition shall be at the site of the work before work is started. In special cases like a very short length of road to be laid at a location, other methods may be approved by Engineer.

2. Batching and Mixing Plant

This shall be the fully automatic plants of suitable type, capacity and make meeting the requirements of work.

3. Paving Equipment

The concrete shall be placed with an approved fixed form or slip form paver with independent units designed to (i)spread, (ii)consolidate, screed and float finish, (iii)texture and cure the freshly placed concrete in one complete pass of the machine in such a manner that a minimum of hand finishing will be necessary and so as to provide a dense and homogeneous pavement in conformity with the plans and Specifications.

Vibrators for full width vibration of concrete paving slabs may be either the surface pan type or the internal type. They may be attached to the spread finisher. They shall not come in contact with the joint, sub base or side forms.

The frequency of the surface vibrators shall not be less than 3500 impulses per minute and for the internal type not less than 5000 impulses per minute. The variable vibration setting shall be provided in the machine.

At least two spare vibrators and one generating unit shall be on hand in case of any breakdown of the vibrating equipment being used.

4. Concrete Saw for joint cutting

The mechanical saw for cutting concrete shall be adequately powered to cut rapidly with a water-cooled diamond edge saw blade to the depth required. A water tank with flexible hoses and pump shall be made available in this activity on priority basis. The Contractor shall have at least one standby saw in good working condition.

5. Forms

Straight side forms shall be metal forms having a thickness of at least 5mm and have a depth equal to the prescribed edge thickness of the pavement slab.

Curved forms shall be of the radius called for as specified by the Designer and acceptable flexible forms shall be installed with that radius. Built-up forms with horizontal joints shall not be used. Forms shall be free from kinks, bend or wraps. Forms shall not deflect more than 6 mm when tested as a simple beam with a span of three metres under a load equal to that which the finishers or other construction equipment will exert on them. The top of the form shall not vary from a three metre straight edge by more than 3mm at any point and the side by more than 6mm at any point.

The forms shall contain provision for locking together tightly the ends of abutting from sections and for secure setting.

6. Curing Compounds

The curing compounds shall have a water retention efficiency index of 90% in accordance with BS 7542.

3.11.4 Construction Methods

1. Preparation of Sub-base

The sub-base, which shall generally be of water-bound macadam (WBM) conforming to Subsection 3.3. The sub base shall be wetted adequately or provided with a water proof membrane so that it does not absorb any water from the concrete to be laid over it.

Concrete shall not be placed on any portion of the sub-base until the Notice of No Objection given by Engineer

2. Setting Forms

The sub-base under the forms shall be compacted and cut to grade so that forms, when set to the position are within ± 3 mm of a straight line formed by the top of the forms. If the sub-base is found to be below the required grade at the form line, the grade line shall be lifted by placing lean concrete mix 1:4:8 beneath the form and setting the form when it is set. Imperfections and variations above grade shall be corrected by tamping or cutting to the degree required.

The alignment and grade elevations of the forms shall be checked and the necessary corrections made by the Contractor immediately before and after placing the concrete. When any form has been disturbed or any roadbed has become unstable, the form shall be reset and rechecked.

On final setting of the forms, these shall be checked for at least half the length of pavement to be concreted in a particular day before concreting commences on that day. While concreting long lengths, the setting up of forms to the exact grade and alignment shall be in advance of the concreting operation by at least 60 m.

Forms shall be cleaned and oiled prior to the placing of concrete. The forms shall be removed not earlier than 24 hours after the concrete has been laid.

3. Preparation of Concrete

a. Trial Mix / Mix Design :

Subsection 5.2.1 shall be followed Minimum grade of concrete to be used is M25.

b. Batching, Mixing and Transporting Materials

Subsection 5.2.4 shall apply.

The Ready-Mixed Concrete (RMC) shall conform to Subsection 5.2.4 (5).

4. Placing Concrete

Concrete shall be placed only on a prepared sub-base as specified in Subsection 3.11.4(1). No concrete shall be placed around structures until they have been brought to the required

grade and alignment nor until expansion joint material has been placed around them.

The concrete shall be spread, compacted and finished by a mechanical paver and in accordance with Subsection 3.11.3 (3). The mixing and placing of concrete shall progress only at such a rate as to permit proper finishing, protecting and curing of the pavement.

The truck mixers, truck agitators and other approved hauling equipment shall be equipped with means for discharge of concrete into the hopper of the paver without segregation of the materials. In all cases, the temperature of the concrete shall be measured at the point of discharge from the delivery vehicle.

The acceptance criteria regarding level, thickness, surface regularity, texture, finish, strength of concrete and all other quality control measures for hand laid concrete shall be the same as in the case of machine laid work.

The concrete shall be thoroughly consolidated against and along the faces of all forms by means of vibrators inserted in the concrete. Vibrators shall not be permitted to come in contact with a joint assembly, the sub-base or a side form. In no case shall the vibrator be operated longer than 30 seconds in any location. The vibrator shall be inserted in the concrete and worked along the full length and both sides of a joint.

Concrete shall be deposited as near to expansion and contraction joints as possible without disturbing them, but shall not be dumped from the discharge bucket on to a joint assembly.

Except at construction joints, concrete shall be shovelled against both sides of the joint simultaneously, maintaining equal pressure on both sides. It shall be deposited to a height of approximately 5 cm more than the depth of the joint, and shall be vibrated so that all honeycombing and voids are prevented. The vibrator shall be inserted in the concrete and worked along the full length and both sides of the base

Subsection 5.2.6 shall also apply.

5. Initial strike-off and Placement of Reinforcement

Where the concrete is laid in two layers, the bottom layer of concrete shall be struck off for the full width between longitudinal construction joint true to crown at the required distance below the finished surface elevation, for placement of reinforcement or for placement of a top layer of the required thickness.

The striking-off shall be accomplished by use of the finishing machine, unless some other approved device is allowed. The reinforcement shall be placed as called for by the Designer and pouring of concrete over it shall only be allowed after placement of reinforcement is proper in all respects and approved by the Engineer.

6. Joints

a. General

Joints shall comply with the design approved for the construction.

A strip of the preformed expansion joint filler shall be placed around each structure which extends into or through the pavement before concrete is placed.

b. Transverse Expansion Joints

These shall be formed at the design spacings. The material for a transverse joint shall be assembled at the roadbed, and placed into position as a unit.

c. Transverse Contraction Joints

Transverse Contraction joints shall consist of planes of weakness created by forming or cutting grooves in the surface of the pavement. Transverse contraction joints shall also include load transfer dowel-bars where these are specified by the Designer.

The contraction joints shall be cut as soon as the concrete has undergone initial hardening and is hard enough to take up the load of joint sawing machine without causing damage to the slab. Grooves shall be at right angles to the centreline of the pavement and shall be true to line, subject to a tolerance of 5 mm in the width of the slab.

Any procedure for sawing joints that results in premature and uncontrolled cracking shall be revised immediately by adjusting the sequence of cutting the joints or the time interval involved between the placing of the concrete and cutting of the joints.

Load transfer assemblies for transverse contraction joints shall consist of dowel bars without sleeves and an approved auxiliary spacing and supporting element.

The assembly shall be placed into position so that the dowels are parallel to the centreline and shall be staked into position in such a way as to hold the assembly securely in position throughout construction.

d. .Longitudinal Joints

Longitudinal joints shall be constructed in conformity with the design. Planes of weakness shall be created by forming or cutting grooves in the surface of the pavement in accordance with the applicable provisions of this Section.

When adjacent lanes of pavement are constructed separately, steel side forms shall be used which will form a keyway along the construction joint. The bars may be bent at angles against the form of the first lane constructed and straightened into final position before the concrete of the adjacent lane is poured.

e. Transverse Construction Joint

Transverse construction joints shall be placed whenever concreting is completed after a day's work or is suspended for more than duration permissible for continuous pouring of concrete.

Joints shall be formed by placing installing bars or suitable bulkhead material so that a vertical face with approved key is formed or shall be butt joints formed with suitable material so that a vertical face is formed with no key. No tie bars shall be necessary when key joints are formed but dowel bars of the same dimensions and at the same spacing as for contraction joints shall be necessary at all butt joints.

7. Finishing

a. Machine Finishing

As soon as the concrete has been placed, it shall be struck off and screeded by an approved finishing machine or tools to the grades and cross sections specified by

the Designer and to a level slightly above grade so that when properly consolidated and finished the surface of the pavement will be at the exact level and grade. The machine or tool shall go over each area of pavement as many times and at such intervals as necessary to give the proper compaction and to leave a surface of uniform texture, true to grade and cross section.

Excessive operation over a given area shall be avoided. The tops of the forms shall be kept clean by an effective device attached to the machine and the travel of the machine on the forms shall be maintained true without lift, wobble or other variation tending to effect the precision finish.

After concrete has been placed on both sides of the joint and struck off, the installing bar or channel cap shall be slowly and carefully withdrawn, the concrete shall be carefully spaded and additional freshly mixed concrete worked into any depression left by the removal of the installing bar.

A diagonal finishing machine shall be used if available.

b. Hand Finishing

A portable screed shall be provided for use. The screed shall be at least 60 cm longer than the width of the slab to be struck off and consolidated. It shall be of approved shape, sufficiently rigid to retain its shape and constructed either of metal or of other material shod with metal. (If necessary, a second screed shall be provided for striking off the bottom layer of concrete).

The screed shall then be placed on the forms and slip along them, without lifting, in a combined longitudinal and transverse shearing motion moving always in the direction in which the work is progressing. If necessary this shall be repeated until the surface is of uniform texture, true to grade and contour, and free from porous areas.

8. Edging at Forms and Joints

After the concrete's initial set, the edges of the pavement along each side of each slab, and on each side of transverse expansion joints, planes of weakness except when sawed transverse construction joints, and emergency construction joints shall be worked with an approved tool and rounded to a radius of 5 mm. A well defined and continuous radius shall be produced and a smooth, dense mortar finish obtained. The surface of the slab shall not be unduly disturbed by tilting of the tool during use.

All joints shall be tested with a straight edge before the concrete has set, and correction shall be made if one side of the joint is higher than the other or if they are higher or lower than the adjacent slabs.

9. Surface Texture

The surface of the carriage-way shall be textured by wire brushing in a direction at right angles to the longitudinal axis of the carriage-way. The pavement shall be given this broomed texturing as soon as surplus water has risen to the surface.

The wire brushes shall be either mechanically operated or manual methods may be allowed depending upon the type of paver being used on the Work. In either case the wire broom

shall be not less than 450 mm wide with two rows of spring steel. At least two brooms in working order shall be on the site at all times.

The surface texturing shall be completed before the concrete is in such condition that the surface is torn or unduly roughened by the brooming. The broomed surface shall be free from rough areas, porous areas, irregularities, or depressions.

10. Surface Requirements

After the concrete has hardened sufficiently, the surface shall be given a further test for tureens, using an approved 3 m straight edge laid on the surface. Any portion of the surface, when tested in the longitudinal direction, which shows a variation or departure from the testing edge of more than 3.5mm but not exceeding 7mm shall be marked and immediately ground down with an approved grinding tool until the variation does not exceed 3.5mm.

Whenever the variation or departure from the testing edge is more than 7.0mm the pavement shall be removed and replaced. Such removal shall be of the full depth and width of the slab and at least 3m long.

11. Curing

Immediately after the surface texturing, the surface and sides of the slab shall be cured by approved curing method for not less than 7 days. During this period measures shall be taken to prevent the loss of moisture.

The concrete shall not be left exposed between stages of curing.

The surface shall be inspected regularly to ascertain the earliest time at which it is able to withstand the spreading of moisture retaining material. This shall be by ponding of water or spreading and wetting either two layers of burlap or two mats of cotton / jute or a layer of sand or other approved highly absorbent material. Whatever material is used it shall be kept continuously moist for not less than 7 days and to a degree which will ensure that 100% humidity is maintained adjacent to the concrete surface. A membrane curing compound meeting the requirements of BS 7542 may be used subject to the Notice of No Objection from Engineer.

Concrete surfaces which are subjected to heavy rainfall within three hours after the curing compound has been applied shall be resprayed by the method and the coverage specified above.

Concrete surfaces to which membrane curing compounds have been applied shall be adequately protected for the duration of the entire curing period from the pedestrian and vehicular traffic, except as required for joint sawing operations and surfaces tests, and from only other cause which will disrupt the continuity of the membrane. The curing membrane so formed shall be maintained intact for a period of not less than 14 days. The entire surface shall be protected from the effects of solar radiation and in addition by the use of frames covered with material with heat and light reflecting properties.

Concrete liable to be affected by running water shall be adequately protected from the damage during the setting period.

Subsection 5.2.10 shall also apply.

12. Removing Forms

Forms shall be removed only after stipulated period and carefully so as to avoid damage to the pavement.

13. Protection of Pavement

The Contractor shall erect and maintain suitable barricades and shall employ watchmen to exclude public traffic and that of his employees and agents from the newly constructed pavement until opened for use. These barriers shall be arranged as not to interfere with public traffic on any lane intended to be kept open and necessary signs and lights shall be maintained by the Contractor clearly indicating any lanes open to the public.

Where any stipulated public traffic lane is contiguous to the slab or lane being placed, the Contractor shall provide, erect, and subsequently remove a substantial temporary guard fence along the prescribed dividing line, which shall be maintained there and protected by signages until the slab is opened to traffic. The Contractor's plan of operation shall be such as to obviate any need for encroachment on the public traffic lane or lanes under use .

The same shall be approved by the local competent authority.

Any part of the pavement damaged by traffic or other cause prior to its final acceptance shall be repaired or replaced by the Contractor.

14. Joints

Before the pavement is opened to traffic, and as soon after the curing period as is feasible, all joints both longitudinal and transverse, shall be filled with the material approved for use as seal.

Both primer and sealing compound shall be treated and applied strictly in accordance with the manufacturer's specifications/ instruction and by use of approved equipment.

The sealing material shall be poured into each joint opening as directed by the Engineer. The pouring shall be done in such a manner that the material will not be spilled on the exposed surfaces of the concrete. Any excess material on the surface of the concrete pavement shall be removed immediately and the pavement surface cleaned.

3.11.5 Control of Traffic

Subsection 3.1 shall apply.

4. PILING AND DIAPHRAGM WALLING

4.1 General

Piling and Diaphragm Wall Construction shall comply with the relevant requirements of the Outline Design Specification and of this Specification as indicated below:

4.1.1 Piling Plant and Methods

- (1) Not less than 2 weeks before any piling work is commenced the Contractor shall submit to the Engineer for his Notice of No Objection, full details of his proposed piling plant, and detailed method statements for carrying out the Works in the anticipated ground condition including boulders, soft ground, hard ground (soft/hard rock) and below ground table.. Such details shall include wherever applicable a full description of the piling plant, drilling equipment, pilling frame, hammer, helmet and packing, methods of handling, pitching and supporting the piles before and during driving, the proposed driving procedure to obtain the

required penetration, calibration for the type of piling rig or the proposed set and the method of calculation of the specified working load of the piles and means to deal with hard ground conditions and socketing the piles in the rocks duly containing the noise and vibration levels at sensitive locations., and such further information as the Engineer may require.

Details of casings and concreting methods in respect of any driven or bored cast in place concrete piles shall be included in the submission.

- (2) The Contractor shall not commence any piling until the plant and methods which he proposes to use have received a 'Notice of No Objection' from the Engineer but such Notice shall not relieve the Contractor from any of his obligations and responsibilities under the Contract. If for any reason the Contractor wishes to make any change in the plant and methods of working, he shall not make any such change without having first obtained the Employer's/Engineer's 'Notice of No Objection' for such changes.
- (3) Reference shall be made to the following documents regarding matters relating to the safety of piling works

BS8004 Code of Practice for Foundations

BS5573 Code of Practice for Safety Precautions in the Construction of Large Diameter Boreholes for Piling and Other Purposes

4.1.2 Records

The Contractor shall keep complete records of all data as required by the Engineer covering the fabrication, driving and installation of each pile and shall submit two signed copies of these records to the Engineer not later than 24 hours after installation of the piles.

4.1.3 Programme and Progress Report

- (1) The Contractor shall inform the Engineer each day of the programme of piling for the following day and shall give adequate notice of his intention to work outside normal hours and at weekends
- (2) The Contractor shall submit to the Engineer on the first day of each week, or on such other date as the Engineer may decide, a progress report showing the rate of progress to that date and progress during the previous week and/or period of all main items of piling works,

4.1.4 Setting Out

The Contractor shall establish and maintain permanent datum level points, base lines and grid lines to the satisfaction of the Engineer and shall set out with a suitable identifiable pin or marker the position of each pile. The setting out of each pile shall be given Notice of No Objection from the Engineer at least 8 working hours prior to commencing work on a pile and adequate notice for checking shall be given by the Contractor.

Notwithstanding such notice, the Contractor shall be responsible for the correct and proper setting out of the piles and for the correctness of the positions, levels, dimensions, and alignment of the piles.

4.1.5 Tolerances

(A) Piles

- (1) Piles shall be driven or bored accurately vertical or to the specified rake and the permitted deviation of the pile centre from the centre point shown on the setting out plan shall not exceed 25 mm measured at the working level of the piling rig, or other level with a Notice of No Objection by the Engineer. Deviation from the cut of level shall be limited to ± 25 mm.
- (2) The maximum permitted deviation of the finished pile shall be 1 in 200 from the vertical for vertical piles, and for raking piles 1 in 25 from the specified rake.
- (3) Forcible corrections shall not be made to concrete piles and can be made to other piles with the approval of the Engineer .
- (4) Variation in cross sectional dimensions shall be limited to + 50 mm and –10 mm.

(B) Precast Piles :

The manufacturing tolerances for precast concrete piles shall comply with the following requirements.

- (1) The external cross-sectional dimensions shall be within 0mm and +5mm of the specified dimensions.
- (2) The wall thickness of hollow spun concrete piles shall be within 0mm and +25mm of the specified thickness.
- (3) There shall be no irregularity exceeding 6mm in a 3 metre length along the face of the pile measured using a 3 metre straight edge.
- (4) The centroid of any cross-section of the pile shall not be more than 12mm from the straight line connecting the centroids of the end faces of the piles.
- (5) The centroid of any cross-section of a hollow pile shall be determined by assuming that the pile has a solid section.
- (6) The diameter of cast-in-situ piles shall be at least 98% of the specified diameter.

(C) Pile caps

- (1) Variation in dimensions shall be limited to +50 mm and –10 mm.
- (2) Misplacement in plan from specified position shall be limited to 15 mm.
- (3) Surface irregularity measured with 3 meter straight edge shall be limited to 5 mm.
- (4) Variation of levels at the top shall not be beyond ± 25 mm.

4.1.6 Disturbances and Noise

- (1) The Contractor shall carry out the piling work in such a manner and at such times as to minimize noise and disturbance. The Contractor shall employ suitable methods for boring/drilling /driving of piles, particularly in rocky strata (boulders, soft rock and hard rock) so as to limit the vibration (as specified in outline design Specifications) and noise levels as acceptable to the residents of the area and Engineer. The Contractor may have to change his pile boring/drilling/ driving method, if so directed by the Engineer, in case the vibration and noise levels generated are excessive and are objected to by the residents of the area and the Relevant utility/services Authorities/Agencies.

- (2) The Contractor shall take precautions adequate enough to avoid damage to existing utilities and services and adjacent structures.
- (3) The Contractor shall ensure that damage does not occur to any part of completed piling works and shall submit to the Engineer for Notice of No Objection his proposed sequence and timing for driving or boring piles having regard to the avoidance of damage to adjacent piles.

4.1.7 Obstructions

If during the execution of the Works the Contractor encounters obstructions in the ground, he shall forthwith notify the Engineer accordingly, submit to him details of proposed methods for overcoming the obstruction and proceed according to the Engineer instructions.

4.2 Concrete Piles

4.2.1 Materials - General

- (1) Requirements of concrete and reinforcement for precast and cast in-situ piles shall comply with Section 5 of these Specifications. Minimum grade of concrete for piles (other than secant pile walls) shall be M35 subject to provision in Contractors DAAR as accepted by Engineer . For secant pile walls minimum grade of concrete shall be M40.
- (2) Minimum cement content for concrete in cast in place piles shall be 400 kg/m³.
- (3) Precast piles shall be marked at the time of concreting with all relevant information, e.g. date, reference number, length etc.

4.2.2 Reinforcement

- (1) The reinforcement shall be assembled before placing in the moulds and all hoops and links shall be of uniform length firmly wired into position. Ends of helical reinforcement shall be firmly secured. Diagonal fork spacers shall be of a Noticed pattern. In this respect provisions pertaining to DAAR in Outline Design Specifications shall be referred to and complied with by the Contractor.
- (2) The cover to all bars shall be not less than 40 mm but increased cover thickness may be provided where piles are exposed to the action of harmful chemicals (as in the case of concrete in contact with earth faces contaminated with such chemicals), and such increase of cover may be between 15 mm and 50 mm beyond 40 mm as may be given Notice by the Engineer.
- (3) Joints in main longitudinal bars will be permitted only where, each bar cannot be supplied in one complete length. Where permitted, joints shall be provided at agreed centres, designed to develop the full strength of the bar across the joint, provided with adequate links or stirrups and staggered in position from those of adjacent longitudinal bars,
- (4) Welding of cold worked high tensile requirement bars at joints in main longitudinal bars will not be permitted without the agreement of the Engineer in which case the Contractor shall comply with requirements of IS: 9417.
- (5) Welding of hot rolled high tensile steel bars shall be permitted provided the method used for the same will not adversely affect the properties of bars.

4.3 Precast Concrete Piles

4.3.1 Formwork

Formwork shall comply with Section 5 of this Specification except as specified below. The head of each pile shall be square to the longitudinal axis. The corners of the head and pile shaft for a distance of 300 mm from the head shall be chamfered 25 mm x 25 mm. The method of forming hollow cores where required shall be such that a continuous core is formed. The use of previously cast piles as side forms will not be permitted. Holes for toggle bolts shall be at right angles to the faces of the pile and lined with steel tubes or other approved material. Holes for lifting, handling and pitching shall be formed in the positions and according to the requirements of the Designer or otherwise approved by the Engineer, and lined with steel tubes.

Details of all pile shoes shall be submitted to the Engineer for his Notice of No Objection prior to fabrication or supply. All shoes shall be fitted to the reinforcement as shown on the agreed Drawings.

4.3.2 Casting Tolerances

The cross-sectional dimensions of piles shall not be less than those specified or shown on the Drawings and shall not exceed such dimensions by more than 6 mm.

Unless otherwise given Notice of No Objection by Engineer, any face of a pile shall not deviate by more than 6 mm from a straight edge 3 m long laid on the face and the centroid of any cross-section of the pile shall not deviate by more than 12 mm from the straight line connecting the centroids of the end faces of the pile.

4.3.3 Protection of Finished Piles

Protection of finished piles against aggressive soil conditions shall be provided by one of the following methods and as agreed in Contractor's DAAR:-

- a) Using sulphate-resistant cement ASTM or TIS Type 5 or Equivalent Indian Standard's IS: 12330
- b) Increasing concrete cover to the reinforcement

4.3.4 Lengthening Concrete Piles

- (1) Where it becomes necessary to lengthen a pile, the reinforcement at the head of the pile shall be stripped of all surrounding concrete and additional reinforcement shall be spliced or, where approved, full penetration butt welded in position as given notice by the Engineer.
- (2) The length stripped shall be not less than 40 times the maximum diameter of the longitudinal reinforcement in the case of a spliced joint or at least 300 mm for a butt-welded joint. New binders of the same size and spacings as in the original pile head and additional binders as instructed by the Engineer shall be fixed in the extension and the pile extended by concreting between properly formed and supported moulds to the required length. Prior to casting the extension, the existing concrete surface shall be cut to sound concrete square to the pile axis and all loose particles removed by wire brushing. This shall be followed by washing with water

and preparing and coating with Noticed epoxy bonding agent applied in accordance with the manufacturer's recommendation. Care shall be taken to ensure that the alignment of the extended pile across the joint is exactly maintained.

- (3) Prior to carrying out any work for the lengthening of piles, the Contractor shall submit a detailed method statement to the Engineer Notice of No Objection.
- (4) After piles have been lengthened, driving shall not be resumed until the specified characteristic strength of the added concrete has been attained. Subject to the 'Notice of No Objection' from the Engineer in writing, the Contractor may use rapid hardening Portland cement conforming to IS:8041 – 1990 for pile extensions in order to expedite the piling work.
- (5) Driving or Re-driving of concrete piles extended as described above shall not be resumed until the Notice of No Objection is given by Engineer.

4.4 Cast in Place Piles

4.4.1 Bored Piles

- (1) The Contractor shall check and agree with the Engineer the casing position for each pile during and immediately after placing the casing. Piles shall be constructed in a sequence submitted in advance to the Engineer. During boring, the Contractor shall where required by the Engineer take soil, rock or groundwater samples and transport them to an Noticed testing laboratory or carry out soil tests in-situ as directed. A complete record of the construction of each pile shall be kept by the Contractor and made available to Employer/Employers Representative for inspection as and when required.
- (2) Diameters of the piles shall not be less than the diameters specified by the Contractor's Designer and given notice by the Engineer. Where enlarged bases are required, these shall be mechanically formed and concentric with the pile shaft to within a tolerance of ten per cent of the shaft diameter and shall not be smaller than the required dimension. The sloping surface of the frustrum forming the enlargement shall make an angle not less than 55° to the horizontal.
- (3) Where polymer is used in boring for maintaining stability, the level of the fluid in the excavation shall be kept at not less than 1.5 m as per IS: 2911 above the level of the external groundwater or at such other level as will ensure that the fluid pressure is at all times in excess of pressures exerted by the soils and external groundwater.
- (4) An adequate temporary casing shall be used where required for ensuring stability of the strata near ground level until concrete has been placed in the pile. A pile excavation shall be backfilled without delay where a rapid loss of drilling fluid occurs and no further excavation at the location of that pile shall be carried out until Contractor has obtained the Employer's/Engineers Notice of No Objection for the proposed remedial work..
- (5) Pumping from a boring shall not be permitted unless Engineer gives Notice of No Objection.
- (6) Where temporary casings or an alternative method for maintaining stability of a

boring are used, these shall be to Notice of No Objection by Engineer.

- (7) Temporary casings shall be free from distortion and of uniform cross-section throughout each continuous length. During concreting, they shall be free from internal projections, encrusted concrete or other materials to the satisfaction of the Engineer. For minimum standards the length of such casing shall be as per IS: 2911.
- (8) Piles constructed in a stable cohesive soil without temporary casings or other form of support shall be bored and concreted without prolonged delay to the satisfaction of the Engineer.
- (9) On completion of boring, loose, disturbed or remoulded soil shall be removed from the base of the pile and prior to placing concrete, each pile boring shall be inspected and given Notice of No Objection by the Employer/ Engineer. After each pile has been cast, any empty bore which may remain shall be protected and carefully backfilled as soon as possible to the satisfaction of the Engineer.

4.4.2 Concreting

- (1) The method of placing and the workability of the concrete shall be such as to ensure that a continuous monolithic concrete shaft of the full cross section is formed. The method of placing shall be subject to Notice of No Objection from Engineer and shall be carried out after inspection without such interruption as would allow the previously placed batch to have hardened. No contamination of the concrete by spoil, liquid or other foreign matter shall be allowed.
- (2) The Contractor shall take all precautions to ensure that the mix and placing of the concrete does not result in arching of concrete in a casing. Slump measured at the time of discharge into the pile boring shall be in accordance with requirements as specified in IS: 2911 Part I Section 2. Internal vibrators shall not be used to compact concrete unless the Contractor is satisfied that no segregation or arching of the concrete will result and this should be put up to get Notice of No Objection from Employer/ Engineer.
- (3) Where concrete is placed in dry borings, measures shall be taken to avoid segregation and bleeding and to ensure that the concrete at the bottom of the pile is not deficient in grout.
- (4) Concrete placed under water or drilling fluid shall be by means of a tremie unless otherwise instructed by the Engineer. This should also satisfy requirements as per IS: 2911 Part I Section 2 –.

Before concreting is commenced, to the Contractor shall remove any accumulation of silt or other material at the base of the pile or boring

- (5) The hopper and pipe of the tremie shall be scrupulously clean and watertight throughout. The pipe shall extend to the base of the pipe or boring and a sliding plug shall be placed in the pipe to prevent direct contact between the first charge of concrete in the tremie pipe and the water or drilling fluid. At all times during concreting, the tremie pipe shall penetrate the previously placed concrete and shall not be withdrawn from the concrete until completion of concreting. A sufficient

quantity of concrete within the pipe shall be maintained at all times to ensure that the pressure from it exceeds that from the water or drilling fluid.

- (6) The internal diameter of the tremie pipe shall not be less than 200 mm for concrete made with 20 mm aggregate, or as otherwise approved by the Engineer.

4.4.3 Polymer Slurry

- (1) Polymer slurry can be used in stabilizing sides of the diaphragm wall/ secant piles or borehole with acceptance from Engineer. The properties of Polymer used & quality control (using testing manual by API 13B) shall be as per requirement given below

Parameters	Fresh Mix	Reused Slurry	Prior to concrete pour
Viscosity Cone Marsh API(s)	65-140	55-140	50-140
Density	1.00-1.04	< /= 1.05	< /= 1.06
Sand Contents (%)	--	< /= 2%	< /= 3%
pH	11-12	11-12	7-12

- (2) The Contractor shall obtain manufacturers' certificates of the polymer to the Site giving properties of each consignment and shall submit them to the Engineer prior to commencing the work and whenever required.
- (3) The frequency of testing polymer and the method and procedure of sampling shall be proposed by the Contractor and subject to Notice of No Objection from Engineer prior to commencement of piling work. Such control tests on the polymer suspension as are required or agreed by the Engineer shall be carried out during the course of the piling work.
- (4) Before concreting a pile, the Contractor shall take measures to remove any heavily contaminated polymer suspension, which could impair the free flow of concrete from the tremie pipe. A sample of the polymer suspension shall be taken from the base of the boring using an Noticed slurry sampling device Consistency of the polymer suspension shall be controlled throughout the piling as well as concreting operations in order to keep the hole stabilized as well as to avoid concrete getting mixed with the thicker mud suspension.
- (5) All reasonable steps shall be taken to prevent the spillage of polymer suspension on the Site in areas outside the immediate vicinity of boring. Discarded polymers shall be removed from the Site without delay and any disposal thereof shall comply with the regulations of all appropriate Relevant Authorities.

4.4.4 Extracting Temporary Casings

- (1) The plant and methods of extraction shall be subject to the Notice of No Objection from the Engineer. Temporary casings for driven or bored cast in place piles shall be extracted carefully whilst the concrete is sufficiently workable to ensure it is not disturbed or lifted.

- (2) During extraction, a sufficient quantity of concrete shall be maintained inside the casing to overcome the pressure from external water, soil or drilling fluid and to ensure that no reduction in section by way of necking or shearing of concrete and contamination of the pile takes place.
- (3) Concrete shall be placed continuously as the casing is extracted whilst maintaining the required head of concrete. The pile should be formed at least 300 mm above the cut-off level. Guidelines in this regard as mentioned in IS: 2911, shall be followed along with other international standard practices. No payment shall be made for scum concrete beyond the cut off level.

4.5 Pile Testing

4.5.1 General

Load testing of Piles shall be in conformity with IS: 2911 (Part IV).

4.5.2 Safety Precautions

(1) General

When preparing for conducting a pile test the Contractor shall carry out the requirements of the various acts, orders, regulations and other statutory instruments that are applicable to the work for the provision and maintenance of safe working conditions, and shall in addition make such other provision as may be necessary to safeguard against any hazards that are involved in the testing or preparations for testing.

(2) Personnel

All tests shall be carried out only under the direction and in presence of an experienced and competent supervisor conversant with the test equipment and test procedure. All personnel operating the test equipment shall have been trained in its use.

(3) Kentledge

- (A) Where kentledge is used the Contractor shall construct the foundations for the kentledge and any cribwork, beams or other supporting structures in such a manner that there will not be differential settlement, bending or deflection of an amount that constitutes a hazard to safety or impairs the efficiency of the operation.
- (B) The kentledge shall be adequately bonded, tied or otherwise held together to prevent it falling apart, or becoming unstable because of deflection of the supports.
- (C) The weight of kentledge shall be greater than the maximum test load and if the weight is estimated from the density and volume of the constituent materials an adequate factor of safety against error shall be allowed.
- (D) No part of the kentledge support system shall be closer to the pile centre-line than a distance of 2.5 times the shaft diameter of the pile subject to Notice of No Objection from the Engineer.

- (E) The weight of the kentledge shall be transferred in manner so that:
 - (i) the load is transferred symmetrically around the pile head;
 - (ii) the suitability of the kentledge is maintained at all time;
 - (iii) any tendency of the kentledge to tilt or sway is minimized.
 - (iv) Loads shall not be allowed to be applied by supporting the kentledge directly on the pile or pile cap.
- (4) Tension piles and ground anchors

Where tension piles or ground anchors are used the Contractor shall ensure that the load is correctly transmitted to all the tie rods or bolts. The extension of rods by welding shall not be permitted unless it is known that the steel will not be reduced in strength by welding. The bond stresses of the rods in tension shall not exceed normal permissible bond stresses for the type of steel and grade of concrete used.
- (5) Testing equipment
 - (A) In all cases the Contractor shall ensure that when the hydraulic jack and load measuring device are mounted on the pile head the whole system will be stable up to the maximum load to be applied.
 - (B) Means shall be provided to enable dial gauges to be read from a position clear of the kentledge stack or test frame in conditions where failure in any part of the system due to overloading, buckling, loss of hydraulic pressure and so on might constitute a hazard to personnel.
 - (C) The hydraulic jack, pump, hoses, pipes, couplings and other apparatus to be operated under hydraulic pressure shall be capable of withstanding a test pressure of one and a half times the maximum working pressure without leaking.
 - (D) The maximum test load or test pressure expressed as a reading on the gauge in use shall be displayed and all operators shall be made aware of this limit.
 - (E) General requirements for load test equipments shall be :
 - i. Load capacity not less than the maximum required load in the schedule of testing.
 - ii. Adequate enough to accommodate the maximum required pile movement specified in the schedule; plus the displacement of the reaction system that occurs during load test.
 - iii. Fully controlled increase or decrease in test load
 - iv. Fully capable of sustaining the applied load as constant for specified period of time.

4.5.3 Presentation of Results

- (1) Results to be submitted

Results shall be submitted as follows:-

- (a) Unless otherwise directed the Contractor shall submit a within 24 hours of

the completion of the test. This summary shall include as a minimum following information.

- (i) for a proof test by maintained load for each stage of loading, the period for which the load was held, the load and the maximum settlement or uplift recorded
- (ii) for Onstand Rate of Penetration (CRP) or Constant Rate of Uplift (CRU) test the maximum load reached and a graph showing applied load verses penetration (movement) or applied load verses uplift (movement)
- (b) the completed schedule of all recorded data shall be submitted to Employer/ as both hard and soft copy in spreadsheet (excel) format within seven days of the completion of the pile test.

4.5.4 Completion of a Test

- (1) Measuring equipment

On completion of a test all equipment and measuring devices shall be dismantled, checked and either stored so that they are available for use in further tests or removed from the Site.

- (2) Kentledge

Kentledge and its supporting structure shall be removed from the test pile and stored so that they are available for use in further tests or removed from the Site.

- (3) Ground anchors and temporary piles

On completion of a preliminary test, tension piles and ground anchors shall be cut off below ground level, removed from the Site and the ground made good with Noticed material.

- (4) Preliminary test pile cap

- (a) The pile cap, if formed in concrete, shall be broken off and the resulting material disposed of off the Site. If the pile cap is made of steel it shall be cut off and stored so that it is available for use in further tests or removed from the Site.
- (b) For preliminary test piles which are not to be incorporated into the Permanent Works, they shall be broken down to 2 m below ground level or as required and backfilled to the original ground level with suitable material. For preliminary test piles which are to be incorporated into the permanent Works the pile head shall be made good or extended to the cut off level.

- (5) Proof test pile cap

- (a) On completion of a proof test on a working pile, the test pile cap, if in concrete, shall be stripped, the pile left in a state ready for incorporation in the Permanent Works and the resulting material disposed of off the Site.
- (b) If the pile cap is made of steel it shall be cut off and stored so that it is

available for use in further tests or removed from the Site as specified.

4.5.5 High Strain Dynamic Testing of Piles

Dynamic pile testing, which mobilizes all or part of the available pile static capacity, shall be used when specified or required and shall be subject to Notice of No Objection from Engineer.

4.5.6 Lateral Load Tests

Lateral load tests, where required shall be carried out using temporary plant capable of providing an unyielding reaction of at least 1.5 times the maximum lateral load to which the pile is to be tested. Alternatively, where tension piles of the same size and type as the permanent piles are used for providing the reaction system for vertical load tests these may be used for the lateral load test by jacking apart. In this case they shall be provided with sufficient reinforcement to sustain the effects of maximum lateral load.

4.5.7 Pile Integrity Tests

(1) General

Pile integrity testing shall be used when specified or required as a method of proof-testing a pile as work proceeds with the aim of indirectly assessing one or more of the following:

- (a) The structural integrity of the pile.
- (b) The relative shape of the pile shaft and an estimate of the physical dimensions of the pile or both.
- (c) The continuity of the pile

Pile integrity testing, when specified, shall be performed on a sufficient number of piles.

(2) Test Procedure

Where integrity testing is required, the test to be adopted shall be one of the following:

- (a) Sonic impact test (SIT)
- (b) Sonic vibration test (SVT)
- (c) Alternative test as specified

The testing, if done, the scheme shall be got Notice of No Objection by Engineer.

(3) Supervision and recording of results

Pile tests shall be carried out under the direction of a person experienced in the supervision of pile integrity tests who shall record all results in both hard and electronic form in preparation of submission to the Engineer.

4.6 Diaphragm Walling

4.6.1 General

- (1) The recommendations of BS 8004 'code of practice of foundation' and DIN 4126 'cast in situ concrete diaphragm walls : design and construction' shall be followed insofar as they are applicable to diaphragm wall construction. Similar Indian Standards for guidance or adoption are :- IS :9556, IS :4651 and IS : 456.

- (2) The Contractor shall take full account of fact that in some locations the walls may be close to existing structures and/or within a location where headroom is limited. The Contractor shall pay particular attention to safety aspects of the Work, employing barriers and covers as necessary.

4.6.2 Method Statement

The Contractor shall submit a method statement giving the full details of materials, plant and operations involved in the construction of diaphragm walls at least 4 weeks prior to the commencement of construction of diaphragm wall. This method statement shall include but not limited to the following details:

- (a) dimension of walls and lengths of panels;
- (b) design calculation, dimensions and details of guide walls;
- (c) the formation of the joints between panels, including sealing the joints and installation of water stop;
- (d) the sequence of excavation and concreting of panels;
- (e) the methods of monitoring and checking the stability of adjacent buildings, structures, properties, pavements, railways, highways, services, utilities, road furniture, other underground structures and like, all termed EBS.;
- (f) the methods of monitoring and checking the tolerances associated with the diaphragm wall panels;
- (g) the methods of monitoring and checking the stability of the diaphragm wall trench;
- (h) the mixing, transporting and placing equipment for the bentonite/polymer slurry;
- (i) the cleaning and re-use of bentonite/polymer slurry;
- (j) the method of disposal of contaminated bentonite/polymer slurry;
- (k) the type, source, chemical and physical properties of the bentonite/polymer to be used;
- (l) calculations to show that the density of the bentonite/polymer and lowest head of slurry are sufficient to maintain the stability of the trench, in the ground conditions envisaged, to its entire length.
- (m) Methods of protection of any adjacent structure and utilities existing close to the trench.
- (n) Safety precaution and risk assessment.

Construction of diaphragm walls shall not commence until the Contractor's proposals have received a 'Notice of No Objection' from the Engineer.

Unless otherwise received Notice of No Objection by the Engineer, the construction of panels shall be continuous once excavation has commenced. Excavated panels or part panels shall not be left open at night or during weekends.

4.6.3 Levels of Work

- (1) Diaphragm walls shall be concreted to the levels shown on the consented-to drawings.
- (2) If the groundwater table is high, the effective trimmed final wall levels shall normally be taken as 250 mm below top of guide wall when concrete is cast-up to top of trench. If required cut off is low and water table is also at depth, concreting can be stopped at lower level subject to receipt of Notice of No Objection from Engineer.
- (3) Any remaining bentonite/polymer within the trench shall be displaced off using lean mix concrete, which shall be poured to the top of the guide walls.

4.6.4 Length of Panels

The length of the panels to be concreted shall be defined in the Contractor's method statement and shall be subjected to a 'Notice of Proceed' from the Engineer.

4.6.5 Tolerances

Construction shall be carried out in accordance with the following normal tolerances, unless otherwise defined by the Contractor's drawings or procedures.

- (a) For straight or other specified profile panels, the minimum clear distance between the faces of the guide walls shall be the specified diaphragm wall thickness plus 25mm, and the maximum distance shall be the specified diaphragm wall thickness plus 50mm. The guide walls shall be propped as necessary, to maintain these tolerances, and the inner guide wall shall be constructed to the line as shown on the drawings.
- (b) Finished faces of guidewalls towards the trench shall be vertical and shall have no ridges or abrupt changes. Variations from straight line or specified profile shall not exceed 25 mm in 3 m.
- (c) The trench face of the guide wall on the side of the trench nearest to the subsequent main excavation shall be vertical to within 1:200. The top edge of this wall face shall not vary from a straight line or the specified profile by more than +15mm in 3m and shall be without ridges or abrupt irregularities.
- (d) The plane of the wall face to be exposed shall be vertical to within a tolerance of 1:200, relative to a vertical line projected from the base of the guide wall. In addition to this tolerance, 75mm shall be allowed for protuberances resulting from irregularities in the ground excavated beyond the general face of the wall.
- (e) The ends of panels shall be vertical to within a tolerance of 1:100.
- (f) Where recesses are to be formed by inserts in the wall, they shall be positioned within a vertical tolerance of ± 50 mm, a horizontal tolerance measured along the face of the wall of ± 50 mm, and a horizontal tolerance at right angles to the face of the wall as constructed of ± 20 mm measured to the reinforcement cage.
- (g) The tolerance in positioning reinforcement shall be as follows:
 - Longitudinal tolerance of cage head at the top of the guide wall and measured

along the trench: $\pm 50\text{mm}$.

- Vertical tolerance at cage head in relation to the top of the guide wall: $\pm 40\text{mm}$.
 - Lateral tolerance of reinforcement position in the direction across the width of the wall shall be $\pm 20\text{mm}$.
- (h) The tolerance in positioning couplers and starter bars for subsequent structural connections shall be as follows:
- Longitudinal tolerance measured along the trench: $\pm 50\text{mm}$.
 - Vertical tolerance: $\pm 40\text{mm}$.
 - Lateral tolerance in the direction across the width of panel shall be $\pm 20\text{mm}$.
- (i) A minimum cover to main reinforcement of 80mm shall be maintained. Minimum clear distance between reinforcement bars shall be 100 mm.
- (j) Notwithstanding the requirements of this Subsection the tolerances may be aggregated only to the extent that they do not exceed 200mm.

If, during the general excavation, it is detected that the above stated tolerances have been exceeded, the Contractor shall draw up proposals for remedying or compensating for the defects. The Contractor should review his method statement for all subsequent diaphragm wall construction.

4.6.6 Access

The Contractor shall note the restricted access to portions of the Works and shall satisfy himself that his method of excavation, positioning of equipment, spoil handling, placement of reinforcement cages, stop ends, and concreting can be accommodated within these restrictions.

4.6.7 Adjacent EBS

- i) The Contractor shall be responsible for any damage, distortion or movement in to adjacent EBS resulting from his work,
- ii) The Contractor shall be deemed to have made due allowance in his rates and prices (The Contract prices) for all ancillary treatment and all work necessary to ensure the stability/protection of all EBS that may be affected by his work.

4.6.8 Reinforcement

- (1) Reinforcement shall comply with the requirements of Contract Specifications.
- (2) High strength deformed steel bars and wires for concrete reinforcement conforming to IS: 1786 and structural steel sections conforming to IS: 800 shall be used.
- (3) Structural steel sections shall be inserted into the cage where openings shall be made at subsequent stages.
- (4) All reinforcement bars and other structural steel section used shall be clean and free from loose mill scales, dust, rust, oils, grease, paint or other coatings which may reduce the bond with concrete.

- (5) Front and rear of cages shall be marked on Site to identify them during placement, and lifting points and design of lifting lugs shall not cause distortion of the cage.
- (6) Distance spacers shall be of an approved type, capable of resisting displacement during cage placement within the trench and shall not entrap slurry during cage placement or concreting.
- (7) The reinforcement shall be adequately fixed to avoid displacement and to maintain the minimum specified cover during concreting.
- (8) Welding of cold worked high tensile reinforcement bars shall not be permitted as a method of splicing cages. If permitted the requirements of IS: 9417 – 1989 shall be adhered to.
- (9) Welding of hot rolled high tensile steel bars will be permitted provided that a method is used which will not adversely affect the properties of the bars.

4.6.9 Concrete

- (1) Concrete shall comply with the general requirements/specifications. . Structural concrete shall have minimum cement content of various grades of concrete as agreed by the Engineer as part of Contractor's DAAR keeping in view the durability and other requirements.
- (2) Minimum slump of the concrete shall be 150 mm and the mix shall flow easily within the tremie pipe and be designed to produce a dense impervious concrete. Such structural concrete shall have minimum concrete grade of M40 and the water : cement ratio of the mix shall not exceed 0.40 or as required by the design subject to fulfilment of the provisions of DAAR.
- (3) Lean mix concrete as per IS: 456 clauses 5 to 8 shall be employed as backfill above any cut-off level for structural concrete and be taken to the top level of the guide walls.

4.6.10 Test Cubes

Test cubes shall be made and tested in accordance with Subsection 5.2.3. Test cubes shall be taken for each panel constructed. Cubes shall be marked with the wall panel numbers and shall be sub-marked within each panel set to indicate a location within the panel.

4.6.11 Polymer

Polymer for use in the wall support slurry shall be in accordance with the requirements of Subsection 4.4.3.

The Contractor shall institute a programme of regular sampling and testing to ensure that the polymer slurry properties are suitable for the work. In this regard the appropriate IS shall be used for guidance.

4.6.12 Storage of Bentonite/Polymer

It shall be stored in dry cool conditions. Particular care shall be taken with bulk storage to prevent balling together due to damp, or deterioration of properties due to damp and heat. A suitable design of hopper cone and polymer feeding device shall be adopted. IS: 4082 shall

be used for guidance regarding stacking and storage of construction materials and components at site.

4.6.13 Alternative Materials

The Contractor may, subject to other requirements of the Specifications, consider and adopt suitable additional or alternative ingredients and additives for the wall support slurry to that of bentonite/polymer. Samples and full details shall be obtained from the supplier and manufacturer of such ingredients.

Any such materials shall have no detrimental effect upon the stability of the excavation or concreting, or formed concrete immediate as well as long term. Ingredients to counteract the loss of slurry to the surrounding strata shall be deemed covered by this Section.

4.6.14 Placing Concrete by Tremie

- (1) Tremie pipes shall be clean, watertight and with a minimum internal diameter of 200mm.
- (2) The tremie tube shall extend to the bottom of the trench excavation prior to concreting and care shall be taken to ensure that all bentonite/polymer slurry is expelled from the pipe during the initial charging operation. The tremie pipe shall be maintained with a minimum embedment of 2.0m into the concrete to prevent the re-entry of slurry into the pipe.
- (3) The Contractor shall ensure that an adequate supply of concrete to the tremie is available at all times so that placement is continuous until completion of the panel.
- (4) The number of tremie pipes per panel shall be in accordance with the method statement. Where more than one tremie pipe is employed during concrete pouring to any one panel, the charging of concrete into the pipes shall be arranged so that it is evenly distributed between the pipes and so that no differential head exists at the concrete/slurry interface over the length of the panel. This level shall be confirmed by soundings taken during the concrete pour.

4.6.15 Stop Ends

- (1) Stop ends, inserted before placement of concrete in the panel, shall be clean and have a smooth regular surface. Any shutter release agent shall have no detrimental effect on the finished works. Where stop ends are inserted in sections, adequate joint connections must be provided to ensure verticality over the whole length.
- (2) The extraction of stop ends shall be carried out at such a time and in such a manner that no damage is caused to the concrete placed against them, or to the adjacent soil and structures
- (3) Stop-ends shall be adequately restrained to prevent movement during concreting and not be permanently encased in the diaphragm wall.

4.6.16 Inserts

Inserts shall be formed at the locations shown in the Contractor's drawings and in accordance with his method statements and procedures.

4.6.17 Checking and Monitoring

The Contractor shall provide all necessary monitoring instrumentation necessary for the close and continuous checking of the movements and distortion of adjacent ground and EBS.

4.6.18 Safety and Emergency Procedures

The Contractor shall take all necessary precautions to ensure stability of his excavations and guide walls and shall take all necessary precautions and be responsible for the safety of personnel in the area of operation. He shall maintain, available for immediate use, a sufficient quantity of slurry to allow for any sudden loss. Should the loss continue despite the addition of the slurry and the stability of the trench are placed at risk, the Contractor shall backfill with lean mix concrete to preserve the stability of the trench and ensure the safety of adjacent ground and EBS. The cause of the loss of slurry shall be investigated and works shall not recommence until remedial measures have been implemented.

4.6.19 Site Cleanliness

The Contractor shall ensure that the Site is cleared of slurry and that surplus or displaced slurry is disposed of safely and without nuisance. All operations shall be conducted in such a manner as to minimise any spillage of slurry over the Site, or accesses thereto.

4.6.20 Obstructions

An obstruction is defined as material, the excavation of which hinders normal progress and the existence of which could not have been foreseen.

Upon encountering an obstruction, the Contractor shall determine the method to be employed in removing the obstruction. and such method shall be subject to the Notice of No Objection from the Engineer

4.6.21 Disposal of Spoil

- (1) Spoil removed from the excavation shall be separated from the slurry employed in the excavation process. It shall be disposed of as quickly as possible to locations as Noticed to Proceed by the Engineer and in such a manner that spillage and annoyance be minimised.
- (2) Contaminated slurry, not suitable for re-use, shall be removed from the Site and disposed of in accordance with Subsection 4.6.24 below.

4.6.22 Joints

- (1) All joints shall be fitted with a water stop covering the full height of the wall.
- (2) Where concrete is cast against previously completed wall panels, the previously formed concrete shall be cleaned so that solid substances are removed before the joint is formed.
- (3) When the joint is exposed upon subsequent excavation, the Contractor shall immediately repair any joints which permit jetting or spraying of water or within which solid foreign substances greater than 3mm separate the concrete in adjacent panels.
- (4) The walls and joints formed shall satisfy the water-tightness, requirement of this Contract.

4.6.23 Records

The following records shall be maintained and kept for each wall panel and such records shall be available for inspection by the Engineer.

- (i) Name of work
- (ii) Panel No and reference drawing no
- (iii) Date and time of start and finish of panel excavation;
- (iv) Details of any obstructions encountered; time spent and construction method adopted in overcoming such obstructions.
- (v) Date and time of completion of cage placement;
- (vi) Date and time of start and completion of panel concreting;
- (vii) Length of panel and width and depth of panel from top of guide wall
- (viii) Top of guide wall level
- (ix) Top level of wall as cast, in relation to top of guidewall at the edges and at the centre.
- (x) A log of soil/rock type encountered from start to finish of excavation, and of slurry levels and densities;
- (xi) Volume of concrete used and time of any interruptions in concrete supply where these exceed 15 minutes.
- (xii) Volumes of normal and lean mix concrete;
- (xiii) Cut-off level of concrete below top of guide wall level;
- (xiv) Date, place and time of slurry control tests and results recorded;
- (xv) Concrete test cubes, w/c ratio, slump markings, date and results obtained on testing;
- (xvi) Details of reinforcement and cage type;
- (xvii) Quantity of slurry removed from Site and spoil removed from Site recorded by date;
- (xviii) A graph of theoretical and placed concrete volumes with depth.

4.6.24 Disposal of Slurry

Used bentonite/polymer or contaminated slurry not suitable for re-use shall be disposed of in water-tight containers. The Contractor may propose alternative means of disposal which shall be subject to the agreement of the appropriate authorities and Notice of No Objection from Engineer.

5. CONCRETE

5.1 Concrete Materials

5.1.1 General

- (1) Construction of concrete works shall comply with the relevant requirements of the Outline Design Specification and of this Specification as indicated below:
- (2) This work shall consist of the construction of all or portions of structures with Ordinary Portland Cement (OPC) concrete, of the required class or classes, with or without reinforcement, and with or without admixture. Constructed in accordance with Contract and the relevant Standard to the lines, levels, grades and dimensions shown on the Construction Drawings.

- (3) Constituent materials for the concrete mix shall comply with the requirements of IS: 456 or BS: 5328, unless otherwise given Notice of No Objection by the Engineer. Additives such as fly ash, ground granulated blast furnace slag and silica fume may be used in concrete to improve its performance and workability etc., only after the Contractor has obtained Notice of No Objection from the Engineer for the same, in which case the Contractor shall demonstrate the quality control procedure including source of these additives, their properties and handling etc. as per the relevant BIS & International codes. The performance of the concrete mix with additives shall be determined by the field suitability tests.
- (4) Ordinary Portland cement (OPC) of 43 grade and 53 grade conforming to IS 8112 and IS 12269 respectively shall be used. Portland pozzolana cement (PPC) conforming to IS 1486 of grades 43 & 53 can also be used. The Engineer may direct the usage of sulphate resistant Portland cement conforming to IS 12330 for structural elements exposed to soil/ground. In all cases the cement shall meet the 28 day strength requirement of IS 8112 or IS 12269.
- (5) Testing and non-conformances affecting the standard of the concrete shall be notified to the Engineer in-line with the Quality Assurance (QA) procedure such that mitigation may be effected expeditiously within the critically defined timeframes.

5.1.2 Cement

1. General

Unless otherwise described in the Contract, Ordinary Portland Cement, of 43 grade and 53 grade conforming to IS 8112 and IS 12269 or BS 12 or other equivalent standard shall be used.

If soil has soluble salts in excess of 0.5%, sulphate resistant cement shall be used conforming to IS: 12330 or BS 4027. or total chloride content in cement shall in no case exceed 0.05% by mass of cement. Also, total sulphur content calculated as sulphuric anhydride (SO₃), shall in no case exceed 2.5% and 3.0% when tri-calcium aluminate per cent by mass is up to 5% or greater than 5% (but less than 10%) respectively

2. Testing

- a) Cement shall be certified by the manufacturer as complying with the requirements of the relevant Standard. The Contractor shall submit to the Engineer the manufacturer's certificate to affirm that the cement complies with the relevant standard.
- b) Before ordering cement, the Contractor shall submit details of the proposed supplier and information on the proposed methods of transport, storage and certification for the Engineer consent and show that the quantity and quality required can be attained and maintained throughout the construction period.
- c) Representative samples of the proposed cement may be required to be taken and forwarded to an independent laboratory for analysis before the source is approved. If cement is imported, fresh tests as per relevant IS code shall be conducted in the Noticed laboratory.

- d) Subsequent to obtaining the Engineer's Notice of No Objection, the Contractor shall not change the agreed arrangements without the prior Notice of No Objection obtained from Employer/ Engineer. Each consignment of cement shall be accompanied by a certificate which shall be submitted to the Engineer immediately after delivery showing the place of manufacture and the results of standard tests carried out by the manufacturer.
- e) Additionally, the Contractor may be required to take samples of cement and test such samples in accordance with the relevant or equivalent Indian Standard. The Contractor shall store the cement so that separate consignments can be identified and so that they are used in order of delivery (first-in, first-out process). In no circumstances shall cement that has exceeded its 'use-by' date be allowed as part of the concrete mix.

3. Delivery and Storage

- a) Cement shall be delivered in bulk or in the original manufacturer's sealed and marked bags, and shall be protected from the weather by enclosed transfer systems or other approved coverings. The Contractor shall provide approved silos to store sufficient bulk cement for continuity of work, and the cement shall be placed therein upon delivery.
- b) All necessary precautions shall be taken to prevent cement dust causing a nuisance.
- c) On receipt of written notification regarding Cement that, in the opinion of the Engineer, has been damaged or does not comply with the specification shall not be used in the Works and shall be removed from the Site within 3 days of the Contractor's receipt of such opinion notification.
- d) Cement remaining in bulk storage at the factory, prior to shipment, for more than six months, or cement in bags, in local storage such as in the hand of vendor /Contractor for more than 3 months after completion of test, may be retested before use, and may be rejected if it fails to confirm to any of the requirements of the IS codes or this Contract.

5.1.3 Aggregate

1. Aggregate Sources

Prior to commencing any concrete work, the Contractor shall obtain the Engineer's Notice of No Objection to proposed types and sources of aggregate. Sampling of aggregates shall be as per IS: 2430

2. Coarse Aggregate

- a) Coarse aggregate for all classes of concrete shall conform to the requirements of IS: 383. It shall be furnished in two separate sizes; either the 20 mm down and or the 38 mm down to No. 4 as required by the Standards.
- b) Physical tests for suitability of aggregate shall be done in accordance with IS 2386 or British equivalent standards.

- c) Coarse aggregate for concrete shall be clean, free from dust and other deleterious material. For reinforced and Prestressed concrete it shall be well graded with nominal 20 mm sized stones.
- d) Hand-broken stone may be used as coarse aggregate for concrete provided such complies with the Contract requirement..
- e) Water absorption shall be less than 3% by weight (ASTM C 117)

3. Fine Aggregate

Fine aggregate shall conform to the requirements of IS: 383 or as required to meet the design requirements.

Water absorption shall be less than 3% by weight (ASTM C 128)

4. Alkali-Silica Reactivity (ASR)

- a) If aggregates contain materials which have been tested to show chemical reactive with alkalis found in any of the constituents of the concrete mix, or in water which will be in contact with the finished work, then the Contractor shall take samples of these materials every week.
- b) The Contractor shall ensure that the concrete mix complies with the requirements of this Contract regarding "Minimising risk of alkali-silica reaction in concrete", (section 5.1.6).
- c) The results of the Contractor's weekly monitoring ASR tests shall be submitted in writing to the Engineer for obtaining Notice of No Objection..

5. Chloride Content

The chloride content of aggregates shall be within the recommended limits stated in IS: 383 or BS 882 and the chloride content of the concrete mix shall be within the recommended limit of IS: 456 or BS 8110. Chloride levels shall be determined daily in accordance with the methods described in BS 812.

6. Sulphate Content

The total acid soluble sulphate content of the concrete mix, expressed as SO₃, shall not exceed the recommended limit in IS: 456 or BS 8110.

7. Storage

All aggregates shall be stored in such a way that they shall be kept free from contact with deleterious matter. Aggregates of different sizes shall be stored separately in masonry or concrete-based bins or on stages to prevent intermixing and the inclusion of dirt and foreign materials.

All aggregate stockpiles shall be shaded from direct sunlight by means of a roof of sufficient height to enable unimpeded access to plant. Spraying of aggregate stockpiles with water shall be undertaken if necessary. All aggregate hoppers shall be painted white.

Storage bins shall be emptied and cleaned regularly.

5.1.4 Reinforcement

1. Steel for Reinforcement

Only thermos-mechanically treated reinforcing bars of Grade 415/500D with minimum total elongation of 14.5% conforming to IS:1786 shall be supplied and used as steel for reinforcement. Rerolled steel shall not be used under any circumstances.

2. Binding/Tying Wire

Tying wire shall be galvanised iron (GI) 18 gauge binding wire with diamond shape binding of core diameter approximately 1.25mm or as specified by Designer.

3. Testing

- a) The Contractor shall provide copies of the manufacturer's certificates of tests results relating to the steel reinforcement to be supplied, and shall additionally provide independent test results obtained from an approved laboratory in respect of samples taken from reinforcement delivered to the Site.
- b) Every bar shall be inspected before assembling and any defective, brittle excessive rusted or burnt bar shall be removed. Cracked end of bars shall be cut-out.

4. Storage

Steel reinforcement shall be stored in an approved manner above ground, on timber supports or on a concrete slab, under cover and racked as necessary for protection from aggressive elements. Stored still at any time shall not come in direct contact with the ground, floor, slab or racks.

5.1.5 Water

1. General

The Contractor shall make his own arrangements and procure fresh potable water for the manufacture and curing of concrete. Testing of such water shall be in accordance with IS: 3025.

2. Quality

- a) Water to be used for mixing and curing concrete and mortar shall be fresh and free from dissolved or suspended matter which may be harmful and shall comply with the requirements of IS: 456 and/or BS 3148.
- b) Water samples from the intended source of supply shall be taken for analysis before any concrete work is commenced, and at regular intervals throughout the duration of the Contract.
- c) Where potable water supply is not available the Contractor shall obtain confirmation of quality and reliability of a proposed source from the appropriate Water Authority and shall test the water for its chemical and other impurities before its use in the Works. Cost of all such tests shall be borne by the Contractor.

5.1.6 Admixtures

1. General

- a) The Notice of No Objection of the Engineer shall be obtained prior to using any admixture in any concrete mix.
- b) Admixtures containing chlorides or other corrosive agents shall not be used.
- c) Admixtures shall conform to IS: 9103 or BS 5075 and BS 1014.

2. Quality

- a) If admixtures are permitted they shall be used in the correct quantities. Approved equipment and methods shall be used for dispensing and incorporating the admixture in the concrete; the dispensing unit shall be designed so that the discharge of the admixture is visible.
- b) The concrete tests described herein shall be conducted with the admixture incorporated to establish that specified strengths are achieved, and that densities are not reduced. Only polymer based admixtures shall be used.
- c) Set-retarding and water-reducing admixtures shall consist of ligno-sulphonate.
- d) Air-entraining agents shall consist of neutralized vinsol resin.
- e) The manufacturer's declared equivalent acid soluble alkali content and the dosage rate of any admixture or pigment to be incorporated shall be included with details of all concrete mixes
- f) The alkali content of admixtures shall be taken into account when determining the total equivalent alkali content of the concrete mix

5.2. Concrete Workmanship

5.2.1 Grade

1. Mixes General

Concrete shall be provided in accordance with IS: 456 or BS 5328 except where required otherwise by this Contract.

2. Concrete Mixes

The concrete mixes to be used in the Permanent Works shall be tabulated in the form as given in the Table of Concrete Mixes below.

3. Chlorides

The total chloride content of the concrete mix shall be in accordance with the limitations given in IS: 456 or BS 8110

4. Sulphates

The total water soluble sulphate content of the concrete mix shall not exceed the limitations given in IS: 456 or BS 8110

TABLE OF CONCRETE MIXES

(Note: to be completed by the Designer)

Description used on Drawings

Type of MIX

Type of Cement.

Type of Aggregate.

Coarse -

Fine -

Nominal Aggregate maximum size (mm)

Grade

Minimum cement content (kg/m³)

Sampling rate (m³) - 28 day normal curing

- 7 day normal curing

Workability - Slump (mm)

- VB(s)

Compacting

Maximum free water/cement ratio

Maximum cement content (kg/m³)

Special cement

Special aggregate.

Coarse:

Fine:

Fine aggregate (%)

Admixtures.

Specified:

Prohibited:

Amount:

Air content

Temperature of Fresh concrete (°C)

Maximum:

Minimum:

Density of Concrete (kg/m³)

Maximum:

Minimum:

5.2.2 Trial Mixes

1. Laboratory Trials

Concrete shall be proportioned to provide an average compressive strength viz. specified characteristic strength plus a standard deviation factor in accordance with acceptance criteria or MORTH or relevant British Standard

Not less than 35 days before commencement of concreting, the Contractor shall carry out trials jointly with the Engineer to determine the concrete mixes which will satisfy the Design Specifications. The materials and conditions used shall reflect those intended to be used for the Works. Minimum six test cubes shall be made from each of three consecutive batches, three cubes to be tested at 7 days and three at 28 days.

If the average 28 day strength being defined as the measured stress when the cube fails, exceeds the specified characteristic strength by 20 percent or more, and the other requirements of IS: 456 and IS:10262 or BS 5328 are met, then the trial mix proportions may be used to commence the Permanent Works. Otherwise further trials shall be carried out using re-designed mixes until the required strength is achieved.

Additional Requirements of Trial mixes shall be tested to determine the following properties of mixes proposed for initial field tests:-

- (a) Bleeding in accordance with ASTM C232.
- (b) Drying shrinkage in accordance with BS 1881.
- (c) Air content if applicable.
- (d) Free water/cement ratio.
- (e) Workability.
- (f) Wet and dry densities.
- (g) Indirect tensile strength in accordance with BS 1881 including cylinder - splitting and beam tests.

If the values obtained do not satisfy the Contract or design requirements, the mixes shall be re-designed.

2. Initial field tests

Trial mixes shall be prepared under full-scale site conditions and tested in accordance with IS: 10262 or BS 1881.

Samples of concrete incorporating the reinforcing details to be used shall be cast and examined, before hardening using hand tools, and after hardening by coring to assess the mixes. Cores shall be 150mm dia. by 200 mm long.

5.2.3 Quality Control

1. Test Cubes

- (a) Cubes shall be manufactured in an on-site laboratory, specially equipped for the purpose, in controlled conditions. They shall be made, cured, stored, transported and tested to IS: 516 and BS 1881.

- (b) The cube-testing machine shall be housed in a laboratory and calibrated to BS 1610 when delivered; the calibration shall be verified at 3-monthly minimum intervals by an approved testing authority having National Accreditation Board for Testing and Calibration Laboratories (NABL) Certification..

2. Cube Samples

- (a) A sample of concrete shall be taken at random on eight separate occasions during each of the first five days of using a mix. The standard deviation shall be calculated from at least 25 individual cube results each representing separate batches of similar concrete produced by the same plant under the same supervision. The margin for the plant shall be 1.64 times the standard deviation.
- (b) Thereafter one sample shall be taken at random for each class of concrete from every group of 25 batches made by each batching plant, and at least one sample shall be taken each day that concrete of a particular grade is made. Samples shall also be taken and two cylinders cast to determine the indirect tensile strength of the concrete at 7 days and 28 days, as specified in relevant IS code or BS 1881.
- (c) These samples shall be taken from every 100 batches, but at least once a week during concreting operations, and shall coincide with samples taken for test cubes. The frequency of sampling may be required to be varied.
- (d) In addition to the above requirements, at least one sample shall be taken from each individual structural unit, or part of a unit, when the latter is the product of a single pour.
- (e) From each sample two cubes shall be made for testing at 28 days and one for testing at 7 days for control purposes. The 28 day Concrete Cube Strength (CCS) shall be the mean of two cubes. The procedure shall be repeated when materials or design mixes are changes.

3. Cube Strength Results

- (1) The results will be unacceptable if:
 - (i) the average strength determined from any four consecutive test cubes does not exceed the specified CCS by 0.5 times the current margin, or
 - (ii) one or more values in forty is less than 85% specified CCS, or
 - (iii) three or more values in forty are less than specified CCS;and any of the following actions may be instructed:-
 - (a) Changing the mix.
 - (b) Improving quality control.
 - (c) Cutting and testing cores from placed concrete.
 - (d) Load-testing relevant structural units.

- (e) Non-destructive testing of placed concrete.
- (f) Cutting-out and replacing defective concrete.
- (2) If the range of individual cube strength made from the same sample exceeds 15% of the mean then the method of making, curing and testing cubes shall be checked.
- (3) In the event of a result having a range exceeding 20% the Contractor submit his proposed corrective action for Notice of No Objection by the Engineer
- (4) In the event of (c) the Contractor shall cut cores from as-built and locations as may be required by the Engineer/Employer, and test them to BS 1881 as modified by Concrete Society Report TR 11. If the values, reduced by 0.69 N/mm² per week of age in excess of 28 days, are less than 75% CCS, the concrete shall be cut out and replaced unless otherwise agreed with the Engineer..

4. Other Tests

- (a) Concrete shall be tested for drying shrinkage, water absorption and moisture movement as directed for which 102mm cubes and 76mm x 76mm prisms shall be prepared and tested in accordance with BS 1881.
- (b) The acceptable limits are:-
 - (i) Water absorption : 3% absorbed after 10 mins;
 - (ii) 6.5% absorbed after 24 hours.
 - (iii) Drying shrinkage : 0.05%
 - (iv) Moisture movement: 0.03%
- (c) Cubes may be required and trials carried out to determine stripping times for formwork, the duration of curing and to check testing and sampling errors. The air content of air-entrained concrete shall be determined for each batch produced until consistency has been achieved, when fewer batches may be tested.
- (d) During Permanent Works concreting six 150mm dia. 200mm long cores shall be cut through horizontal reinforcement to assess plastic qualities. The qualities shall be equal to those obtained in the initial field tests.
- (e) Compaction factor, slump, or other workability tests shall be carried out as required during concreting of permanent works to control workability at the batching plant at the site of the pour. The degree of workability shall be as for the trial mixes; permitted tolerances shall be in accordance with IS:1199 or BS 5320.
- (f) Tests shall be carried out at least daily for the moisture content and weekly for absorption value of the aggregate. The values for the aggregate at the mixer shall be determined and changes made to the mix to compensate for variations.

5.2.4 Batching

1. Machinery

Batching shall be by weigh-batching machines equipped with accuracy checks for the weighing mechanism. The machines shall be cleaned, checked and adjusted regularly. The water supply to the concrete mixers shall have a metering system to control and record the amount.

2. Accuracy of Batching

Batched materials shall be measured out within the following tolerances and discharged into the mixer without loss:-

Cement	± 2% of the weight of the cement in the batch.
Aggregate	± 2% of the weight of each aggregate in the batch.
Water	± 2% of the weight of water added to the batch.
Admixture	± 5% of the amount to be added to the batch.

3. Calibration of Measuring Equipment

- (a) Measuring equipment shall be checked and calibrated at the start of preliminary concrete tests and at weekly intervals. The necessary test weights and the like shall be kept available on site. Scales shall be checked over their complete range by a specialist every three months.
- (b) A calibrated container shall be used to check the accuracy of admixtures dispensers once each month. The results of these checks shall be notified.

4. Mixing

Concrete constituents shall be thoroughly mixed in batches. The machines shall be capable of discharging while running.

5. Ready-Mixed Concrete

- (a) Ready-mixed concrete shall not be used unless approved, and shall comply with the requirements specified herein and those of IS: 4826 and BS 5328.
- (b) The supply and use of ready mixed concrete shall be subject to the Contractor's Quality Assurance procedures.
- (c) Ready mix concrete shall be obtained from a depot consented to by the Engineer. The concrete shall be transported to the Site in truck type mixers and shall be continuously agitated the concrete mix
- (d) The concrete shall be placed in its final position and compacted within 2 hours of the introduction of cement to the aggregates.
- (e) The ready-mix concrete delivered to the Works shall comply with this Specification. 1 m³ of each mix shall be supplied to site before it is required in the Works to allow the Contractor to carry out workability tests.
- (f) The supply and delivery of the ready-mixed concrete shall comply with the

recommendations of IS: 4826 or BS 5328 Subsection 7.4.

- (g) For plant-mixed concrete the delivery note for each batch shall state the time at which the concrete was mixed and the weight of the constituents of each mix.
- (h) When truck-mixed concrete is used, water shall only be added under supervision either at the Site or at the central batching plant in accordance with the Quality Procedures. In no circumstances shall extra water be added to the concrete after the original mixing is complete.
- (i) Samples for work tests shall be taken as the concrete is placed in its final position.
- (j) The Contractor shall arrange for the supplier to provide the facilities stated in BS 5328 Subsection 7.1 or 13.1.

6. Records

Daily returns shall be provided showing the quantities of cement and the total volume batched of each class of concrete for each section of the Works and temporary works. The Contractor shall submit detailed records of all test cubes and specimens taken and without delay submit the test results for the Notice of No Objection from Employer/Engineer.

5.2.5 Control of Chlorides and Sulphates

1. Chlorides in Concrete

- (a) The levels of equivalent acid-soluble chlorides as NaCl ($Cl \times 1.65 = NaCl$) in the constituents of concrete as stated elsewhere are indicative and are subject to the over-riding limits for the mixes. The total estimated content as a percentage by weight of the cement in the mix shall not exceed the following limits:-
 - (i) For reinforced concrete
 - 0.5% if made with Ordinary Portland Cement (OPC)
 - 0.1% if made with Sulphate Resistant Portland Cement (SRPC)
 - (ii) For mass concrete
 - 1.0% if made with OPC
 - 0.2% if made with SRPC
- (b) The Contractor shall test the constituents of the concrete to establish these contents as provided for elsewhere in this Contract.
- (c) In addition, regular tests to BS 1881: Part 6 for chloride content shall be made on the hardened concrete. The following values are acceptable:-
 - (i) For reinforced concrete made with OPC
 - 95% of the test results less than 0.40% NaCl by weight of cement and no result greater than 0.50% NaCl by weight of cement.

- (ii) For reinforced concrete made with SRPC
95% of the test results less than 0.1% NaCl by weight of cement and no result greater than 0.14% NaCl by weight of cement.
 - (iii) For mass concrete made with OPC
95% of the test results less than 1.0% NaCl by weight of cement, and no result greater than 1.30% NaCl by weight of cement.
 - (iv) For mass concrete made with SRPC
95% of the test results less than 0.2% NaCl by weight of cement and no result greater than 0.25% NaCl by weight of cement.
 - (d) In the event that the SRPC used contains a proportion by weight of tri-calcium aluminate which approaches 4 - 8%, then Notice shall be sought from Engineer for an appropriate adjustment of the relevant chloride content limits.
2. Sulphates in Concrete
- (a) The level of acid-soluble sulphates (SO_3) in the mix shall be no greater than:

Coarse aggregate	$\leq 0.4\%$ by weight
Fine aggregate	$\leq 0.4\%$ by weight
Water	$\leq 500 \text{ mg/l}$
 - (b) The total estimated sulphate content (SO_3) of the mix including that present in the cement shall not exceed 3.7% by weight of cement in the mix.
 - (c) In addition, regular tests to BS 1881: Part 6 shall be made on the hardened concrete to determine the total sulphate content, which shall not exceed 4% by weight of cement in the mix.
3. Permissible Level of Chloride and Sulphates
- The permissible level of chlorides and sulphates quoted in the above Subsections shall not be considered as mean values for the whole of the Works, but shall apply to any concrete used in the Works.
4. Concrete for water-retaining structures shall in addition be as per IS: 3370.

5.2.6 Placing

1. General

- a) Concrete shall be placed in the position and sequence indicated on the Drawings, or as directed. Placing shall not be commenced until the fixing and condition of reinforcement and items to be embedded and the condition of the containing surfaces or formwork has been approved. 24 hours written notification shall be given of the intention to place concrete.
- b) Concrete shall be transported by means which prevent contamination (by dust, rain etc.) segregation or loss of ingredients, and shall be transported and placed without delay.

c) Concrete shall be placed directly in its final position without segregation or displacement of the reinforcement, embedded items and formwork. Where necessary concrete may be placed in water in accordance with the Contract requirement.

d) Concrete shall not be dropped through a height greater than 1m

2. Extent of Pours

a) The limit of individual pours and the height of lifts shall be as approved.

b) For walls, the length of panel placed at one time shall not exceed 6m; adjacent panels shall not be placed within 2 days, but shall be placed as soon as practicable thereafter. Subsequent vertical lifts shall not be poured within 2 days.

i. Floors, roofs and ground slabs shall be placed in a sequence of pours to the approval of the Designer and the Notice of No Objection of the Engineer.

ii. If the use of slip-forms or paving trains is permitted, these limits may be revised.

iii. The sequence of pours shall be arranged to minimise thermal and shrinkage strains.

3. Placing Equipment

Concrete shall generally be placed without segregation by pumping or bottom-opening skips. If chutes are used their slopes shall not cause segregation and spouts or baffles shall be provided.

4. Time for Placing

Concrete and mortar must be placed and compacted within 30 minutes of water being added to the mix or otherwise included via damp aggregates, unless admixtures are in use. Partially-set concrete shall not be used in the Works.

5. Compaction

Concrete shall be compacted during placing by approved internal vibrators. The vibrators shall operate at a frequency of not less than 10,000 cycles per minute, and shall be designed for continuous operation. The performance of vibrators shall suit the working conditions, and they shall generally not be less than 75mm diameter. The radius of influence shall ensure that the mass under treatment is compacted at a speed commensurate with the rate of supply of concrete.

6. Vibrators

(a) Vibrators shall penetrate the full depth of the layer of concrete placed and just into the layer below, and be withdrawn slowly to avoid the formation of voids.

(b) Vibration shall not be applied directly or indirectly to concrete after the initial set has taken place, nor shall it be used to make concrete flow in formwork.

(c) The Contractor shall have a minimum of two spare vibrators available during each concrete pour in case of mechanical breakdowns.

7. Continuity of Placing

Placing in each section of work shall be continuous between construction joints. The Contractor shall make provision for standby equipment. If the placing of concrete is delayed due to breakdown then the Contractor shall erect vertical stop-ends and form a construction joint or remove the concrete already placed and restart after repair of the breakdown, as directed.

8. Placing in Inclement Weather

Placing shall not take place in the open during rains or inclement weather. If such conditions are likely to occur the Contractor shall provide protection for the materials, plant and formwork so that work may proceed. If strong winds are prevalent protection from driving rain and dust shall be provided for. During storms and heavy rain periods only underground or enclosed concrete pours shall be permitted and this shall also be subject to where there is a reasonable level of protection to the concreting work

9. Placing in High Temperature and Low Temperature

- a) The temperature of concrete shall not exceed 32° C nor below 5°C or the temperature stated in the table of Mixes whichever is the lower at the time of placing concrete.
- b) The maximum concrete temperature after placing shall not exceed temperature 50°C or 30°C above the concrete temperature at the time of placing whichever is the lower.
- c) Contractor shall comply with the document entitled "Concrete in hot countries" published by FIP congress at New Delhi 1986. The procedures the Contractor wishes to employ shall be subject to the Notice of No Objection from Engineer
- d) The Contractor shall supply suitable maximum/minimum thermometers and record the shade and sun temperatures at locations where concrete is being placed. Recommendations for cold-weather concreting can be obtained from IS: 7861 (Part 2).

10. Placing at Night

If Notice has been given for placing at night or in dark interiors, adequate lighting shall be provided where mixing, transportation and placing are in progress.

11. Placement Under Water

- a) Underwater concrete shall be placed with minimum disturbance of the water. Running water and wave wash shall be controlled.
- b) The specified concrete grade shall be used and the mix design shall provide for good flowing ability.
- c) Tremie pipes, bottom-dump skips or other approved placing equipment shall be used.
- d) Segregation shall be avoided.
- e) Placing shall be commenced in sections and continued to completion subject to Notice of No Objection from Engineer.
- f) The tremie pipe shall be buried in the concrete for at least 1.5m and the pipe must

not be emptied until the pour is complete.

- g) If a bottom-dump skip is used, the contents shall be covered by canvas or similar before lowering into the water. The doors shall be opened when the skip is resting on the bottom with no tension in the support cable, and the skip shall be lifted gradually so that the concrete flows out steadily.

12. Preparation before Placing

- a) Before placing concrete for reinforced work on the ground, the formation shall be compacted as specified and a screed of blinding concrete shall be applied to form a surface for construction.
- b) Before placing concrete on or against rock, masonry, brickwork or old concrete, loose material shall be removed and the surface washed down; water seepage shall be stopped or channelled away from the Work.
- c) For mass concrete placed against masonry or brickwork the following shall apply:-
 - The mortar joints in the facework shall have fully hardened.
 - The water-cement ratio of the concrete shall be increased to compensate for the absorption of moisture by the existing work.
 - The surface shall be soaked prior to placing.
 - The concrete shall be worked around ties and bond stones and into open joints

5.2.7 Formwork

1. Formwork General

- (a) The Contractor shall obtain consent of the methods and materials proposed. They shall preferably be of steel plates and sections suitably designed.
- (b) Details of formwork for special finishes shall be approved before materials are ordered.
- (c) Formwork shall provide concrete of the shape, lines and dimensions shown on the construction Drawings.
- (d) Formwork shall be constructed from materials of sufficient strength, supported to provide rigidity during placing and compacting concrete without discernible deflection and shall be removable without disturbing the concrete.
- (e) Internal ties shall be metal. Removable ties shall be located so that the specified cover to reinforcement is maintained to all surfaces including that of the tie-holes.
- (f) If ties are left in the cover shall be as specified for the reinforcement or as approved. Tie cavities shall be roughened and filled with approved non-shrink concrete or epoxy mortar.
- (g) Formwork panels shall have true edges for accurate alignment and shall be fixed with either vertical or horizontal joints.
- (h) Where chamfers are required the fillets shall be cut to provide an even line. Joints shall not permit leakage of grout, nor steps and ridges in exposed surfaces.
- (i) Due allowance shall be made for deflection of formwork during concrete placement.

2. Wrought Formwork

Wrought formwork shall be steel, Glass Reinforced Plastic (GRP) or lined plywood to produce a fine finish. Lining to plywood shall be clear-lacquered extra-hard hardboard. Where formwork is required and unless otherwise stated, wrought formwork shall be used to produce a fine finish.

3. Rough Formwork

Rough formwork can be of butt-jointed, seasoned, sawn timber with joints made leak proof.

4. Preparation of Formwork for Concreting

Formwork and supports shall be cleaned; before preparing for concreting temporary openings shall be provided for the removal of rubbish. The formwork shall be coated with an approved release agent and the excess removed. Release agent shall not be allowed to come into contact with concrete already placed or with reinforcement.

Not less than 24 hours notice shall be given for the inspection and consent of the formwork and reinforcement, prior to which concrete shall not be placed.

5. Removal of Formwork

Formwork shall be removed without damage to the concrete, but not until the concrete has sufficient strength to support itself. Centres and props may be removed when the member has sufficient strength to carry itself and any loading with a reasonable factor of safety. External loading shall not be applied until the concrete has reached the 28-day CCS unless as give Notice of No Objection by Engineer/ Engineer. Formwork shall not be removed without prior consent.

The following is a guide to the minimum periods between placing and the removal of formwork:

Concrete Formwork	Time
Vertical sides of beams, walls, columns	
- lift not exceeding 1.2m	24hrs.
- lift exceeding 1.2m	48hr
(but see Curing and Protection Subsection 5.2.10)	
Soffits of main slabs and beams	5 days
- props left under	
Beams and main slabs	
- removal of props	14 to 21 days

After removal remedial work shall not be undertaken until the concrete has been inspected and approved.

5.2.8 Reinforcement

1. Reinforcement General

- (a) Steel rod reinforcement shall be cut, bent and fixed to IS:456 or BS 8110: Part 1.
- (b) Cold bending shall be used which does not damage the material.
- (c) Bending hot at a cherry-red heat not exceeding 840°C may be approved except for bars dependent on cold-working for strength.
- (d) Bars shall not be cooled by quenching.

2. Fixing

- (a) The number, size, form and position of pieces of reinforcement shall be as shown on the Drawings. They shall be held in position in the formwork during the placing of concrete by use of distance pieces and spacer bars.
- (b) Links shall be taut so that bars are braced and the inside of their curved parts shall be in contact with the bars being connected. Binding wire shall be twisted tight with pliers and the free ends shall be bent inwards.
- (c) Reinforcement shall be grit-blasted before use to remove rust, oil, grease, salt and other deleterious matter, and where pitting has occurred the causes and products thereof. Repeated blasting may be required when the reinforcement is in position, or partially cast in. Partially-set concrete adhering to exposed bars during concreting operations shall be removed.
- (d) Reinforcement temporarily projecting from the concrete at joints shall not be bent out of position without consent of Engineer, in which event the reinforcement shall be bent over a suitably sized former to prevent any damage or over-stressing.

3. Bending Schedules

The Contractor will provide drawings detailing the reinforcement required and shall prepare bending schedules in accordance with SP 34 of BIS and IS: 5525 BS 4466. Laps and anchorages shall be as stated in IS: 456 or BS 5400: Part 4.

4. Welding

- (a) Electric arc welding may be used, if approved, for joining bars. Covered-alloy or shielded-arc electrodes shall conform to IS: 814 and/or BS 639.
- (b) Workmanship shall be to IS: 2251 or BS 5135.
- (c) Joints shall be butt-welded with standard double-V or double-U welds.

5. Cover to Reinforcement

- (a) Control of the minimum thickness of concrete cover to reinforcement shall be achieved by the use of approved concrete or plastic spacers. Minimum cover shall be as specified in Contract as part of the Contractor's DAAR.
- (b) If concrete spacers are used they shall be of similar concrete grade to the main concrete, and shall have non-metallic ties. For 30 N/mm² concrete or more, the spacers shall comply with the requirements of this Specification for water

absorption.

- (c) Cover blocks used also should be same mix as the concrete of member and be with roughened faces

5.2.9 Joints

1. Construction Joints

- (a) Construction joints shall be located and the sequence of placing arranged as approved, to minimise shrinkage and thermal strains in the concrete.
- (b) Concrete placing shall not be interrupted except where joints occur, and shall continue after normal hours if necessary to achieve this.
- (c) Joints shall be formed square to the work with keyways included.
- (d) Before placing is resumed at a joint the set surface shall be roughened to remove laitence and expose the aggregate; the aggregate shall not be damaged. If damaging materials have come into contact with the surface of the joint the concrete shall be cut back and the roughened surface cleaned by compressed air or water jets and brushed and watered immediately before placing. If required the surface shall be coated with a layer of stiff cement-grout prior to placing the new concrete.
- (e) Chemical surface-retarders shall not be used.
- (f) Construction joints shall be sealed with an approved sealant at external and liquid-contact faces.
- (g) Construction joints in water-retaining structures and in other structure wherever needed, shall incorporate a noticed water-stop to comply with the water-tightness requirement as stipulated in Contract.

2. Expansion, Contraction and Movement Joints

- (a) Expansion, contraction and other movement joints shall be incorporated in the works as shown on the Drawings, that have Notice of No Objection from Engineer.
- (b) Where shown on the Drawings approved, expansion joint fillers shall be supplied and installed. Filler material shall be stored flat on a dry surface adequately protected from rain or moisture in such a way that the material does not deteriorate. Filler material which has been damaged or has started to deteriorate shall not be incorporated in the Works.
- (c) Movement joints shall be sealed with an approved sealant applied in strict accordance with the manufacturer's instructions to the dimensions shown on the Drawings. The surface of the concrete to which the sealant is to adhere shall be straight and cleaned of all filler material, dirt, oil, grease and other matter. The sealant shall be applied by methods recommended by the manufacturer so that the sealant is brought flush to the surface of structure and a smooth surface is achieved. Excess material and spillage shall be properly cleaned off and removed.

- (d) Dowel bars shall be installed and cast in across the movement joint where shown on the Drawings. The bars shall be straight with clean cut ends of the diameters and lengths as shown on the Drawings or in the Schedules. Cutting and cleaning of the dowel bars shall comply with the requirements of the Contract.
- (e) The bars shall be firmly supported in the positions shown on the Drawings so that they remain accurately parallel and are not displaced during the casting of the concrete in the first part of the structure. After the concrete has hardened and the formwork removed, the projecting ends shall be cleaned of all concrete spillage and painted with two coats of an approved bituminous paint and caps shall be fitted to the free ends of the bars. Dowel bar end caps shall be of cardboard or other material, of correct diameter for the dowel bar and of sufficient length to allow the specified movement of the two adjacent concrete structures. They shall be manufactured expressly for this purpose by an Noticed manufacturer.
- (f) The Contractor shall take care to protect the projecting ends of dowel bars from bending or other damage prior to concreting the succeeding bay. The bituminous paint shall be applied as soon as practicable, but end caps shall not be fitted until immediately prior to the succeeding concreting operations.

3. Water-stops

The layout and installation of the water-stops shall be in accordance with the manufacturer's recommendation and shall be subject to the approval of Designer and Notice of No Objection from the Engineer.

4. Bolts, Inserts and Openings

- (a) All fixing blocks, brackets, built in bolts, holes, chases, etc., shall be accurately set out and formed and carefully sealed prior to the concrete being placed. No cutting away of concrete for any of these items shall be done without the permission of the Engineer.
- (b) Bolts and other inserts to be cast into the concrete shall be securely fixed to the formwork in such a way that they are not displaced during the concreting operations, and that there is no loss of materials from the wet concrete through holes in the formwork.
- (c) Unless shown otherwise on the Drawings or the Engineer has given consent, reinforcement shall be locally moved so that the minimum specified cover is maintained at the locations of inserts, holes, chases, etc.
- (d) Temporary plugs shall be removed and the threads of cast in bolts shall be proved to be free and shall be greased before handing over any part of the Works.

5.2.10 Curing and Protection

1. Curing and Protection

- (a) Concrete shall be protected from sunshine and drying winds by approved

shading and wind-breaks, and from cold, rain or running water, for a period of at least 7 days after placing. During this period or for any extended period as may be required by the Engineer the following measures shall be taken to prevent the loss of moisture and to minimise thermal stresses caused by the difference in temperature between the surface of the concrete and the core of the concrete mass.

(b) Horizontal surfaces.

- (i) Polythene sheeting shall be placed immediately after finishing.
- (ii) After final set has taken place, the polythene shall be replaced by wet hessian covered with polythene; the hessian shall be kept permanently damp.
- (iii) After 7 days the hessian and polythene shall be removed and an approved aluminised or white resin- based curing compound applied unless alternative method is agreed to by Engineer or provided for in Contract. The rate of application shall be as recommended by the manufacturer.
- (iv) Alternative methods of curing must be approved before use where special finishes are required.

(c) Vertical surfaces.

- (i) Polythene over wet hessian shall be secured to the surfaces immediately after removal of the formwork. The hessian shall be kept permanently damp.
- (ii) After 7 days the hessian and polythene shall be removed and an approved aluminised or white resin based curing compound applied. Alternatively, the hessian and polythene shall remain for a further 7 days.

Water used during curing operations shall be fresh water. Curing membranes shall be compatible with waterproofing or other materials that may subsequently be applied to the surface of the concrete. In case of steam curing method the period of curing will be as approved by Engineer.

2. Contamination

Concrete shall be protected from contamination by sea or brackish water, oil, fuel and other deleterious materials for a minimum period of 30 days after placing.

3. Insulating Formwork

Insulating formwork shall be left in place for 72 hours after placing or until the temperature peak of the concrete is reached. The initial curing period in 5.2.10.1 (b)(ii) above may then be reduced in proportion, subject to Notice of No Objection from Employer/ Engineer.

4. Protection of Joints

Rebates formed to receive sealant and the surfaces of construction joints shall be protected from curing compound by wet hessian to ensure proper curing of the joint surface and adjacent concrete. The protection shall remain in place until the joint surface is sealed.

5.2.11 Finishes

1. Finishes - General

- (a) The finished faces of concrete shall be sound, even-coloured, even-textured and free from defects. Arises shall have a 20 x 20mm chamfer. Concrete faces shall not be rendered and defective concrete shall be cut out and replaced or made good. A fine finish shall be provided unless detailed otherwise on the Drawings.
- (b) Any concrete structure for the Platform Screen Doors shall be cast with smooth surfaces, free of blowholes and any raised blemishes. The Contractor shall take into account the requirements of Architectural finishes to ensure that appropriate finish of concrete surface is rendered to accommodate requirements of various Architectural finishes in the stations.

2. Fine Finish

Surfaces defined as having a fine finish shall be rubbed smooth by carborundum stone; small holes shall be stopped with approved mortar of the same final colour as adjacent concrete.

3. Concrete Surfaces without Formwork

- (a) On upward-facing surfaces which do not require formwork or special finish the finish shall be produced by proper placing and compacting operations alone.
- (b) For a fair finish screeding shall be used, carried out by sliding and tamping a screed board running on the top edges of the formwork, or on screeding guides, to give a dense concrete skin.
- (c) For a fine finish screeding shall be used as described, then left until the concrete has stiffened and the film of moisture has disappeared. A steel or wooden float shall then be used for a glossy or sandpaper surface as required. Working shall be the minimum compatible with a good finish. The surface shall be protected from water-drops.

4. Wire-Brushed Finish

After removal of the formwork the surface of the concrete shall be abraded by stiff wire brushes and water to remove the cement laitance and expose the aggregate.

5. Bush-Hammered Finish

- (a) The surface shall be abraded by carborundum stones to remove irregularities. Within 3 weeks, the surface shall be bush-hammered to remove the cement laitance and expose the aggregate. Approved bush hammers shall be worked to within 12mm of corners and arises; the remaining 12mm shall be hand-chiselled to match.

- (b) Bush hammers shall be operated perpendicularly to the surface, and the remaining exposed aggregates shall not be loose or fractured. The treated surface shall be washed with water and stiffly brushed. The exposed aggregate shall be clean and free from film.

6. Chemical Retarders

Chemical surface retarders, if approved by designer, may be used to produce an exposed aggregate finish, and the Contractor shall demonstrate that the durability of the concrete surface is not reduced.

- 7. Carborundum finish shall be achieved by sprinkling carborundum grit on the unset surface and working-in by wooden float. The grit shall vary in size between BS 1.18mm mesh and BS 0.60mm mesh and shall be distributed from a BS 1.18mm hand-screen at the rate of 2.15 kg per m².

8. Specimen Panels of Concrete

If required, the Contractor shall produce specimen panels of finished concrete for the Notice of No Objection from the Engineer.

5.2.12 Special Concrete

1. No-Fines Concrete

- (a) The aggregate for no-fines concrete shall be coarse graded from 10mm to 20mm. A small percentage of fines from 10mm to 5mm may be added to improve the strength if noticed.
- (b) Cement shall be mixed with the aggregate in the proportion of 1 to 8 by volume.
- (c) Segregation of the cement grout shall be prevented.

2. Granolithic Concrete

- (a) Granolithic concrete shall consist of one part by weight cement to three parts of combined coarse and fine aggregate.
- (b) Granolithic concrete shall preferably be laid on top of the unset base concrete, and compacted and worked to the correct levels. The surface shall be floated with a steel float after hardening until water sheen has disappeared. Cement or cement-sand shall not be sprinkled onto the surface. The layer shall be 12 - 18mm thick.
- (c) If a granolithic layer is required to be placed on set concrete, the latter shall be scabbled and cleaned to expose the aggregate, and an approved bonding agent applied. The layer shall not be less than 50mm thick.
- (d) If required, compounds shall be added or applied to give a concrete with improved dust-proof and oil-proof qualities of any desired colouring. The compounds shall be used in accordance with the manufacturer's instructions.
- (e) Granolithic concrete paving shall be placed in panels not exceeding 3m square. Contraction joints shall be provided around the perimeter of each panel.

3. Cement - Mortar, Grout, and Rendering

- (a) Cement-mortar shall consist of one part cement and four parts fine sand by volume with just enough water to achieve work-ability.
- (b) Cement lime mortar shall consist of three parts of sand to one part of mixture comprising one part of cement to one part of hydrated lime.
- (c) Grout shall consist of cement mixed with water in designed proportions. Fine sand may be included in approved quantities.
- (d) Rendering shall consist of three parts fine, sharp sand to one part cement applied in two 10 mm coats and one 5 mm finishing coat. The colour of the finishing coat shall be as approved by the Engineer.
- (e) Acid-resistant epoxy mortar shall be obtained from an approved manufacturer and applied in accordance with the manufacturer's instructions.
- (f) Mortar, render and grout shall be used freshly mixed.

5.2.13 Protective Coatings

1. External Sheet Tanking Membrane

- (a) External protection to concrete substructures where required shall be as approved by the Engineer and fixed to the surface in accordance with the manufacturer's instructions.
- (b) Materials and workmanship shall be in accordance with Contract Waterproofing.

2. External Brush-Applied Tanking Membrane

- (a) Substructures shall be protected externally, where required with an approved membrane applied to the top of the blinding concrete and to the outside surfaces of all buried concrete, and continued where appropriate to 300mm above finished ground level.
- (b) The surfaces shall be cleaned and brought to a fine finish before coating. Each coat shall be applied at the rate specified by the manufacturer. Coating shall be protected by hardboard or similar material during backfilling.

3. Internal Protection to Concrete

Protection to internal concrete faces shall be provided as required.

4. Protection of Concrete Above Ground Level

- (a) All exposed concrete surfaces above tanking membrane tuck-in level shall be coated with an approved two-coat protection level system, subsequently overcoated with an approved compatible two-coat smooth finish acrylic paint system.
- (b) Sample panels, of minimum area 10m², shall be made on finished concrete to prove the finish quality and enable the colour to be selected. Only those panels finally approved may be included in the Works.

5.2.14 Tolerances

Tolerances of Concrete Surfaces

The tolerances of concrete surfaces shall be in accordance with the following:

Precast Concrete Members	:	BS 8110
Foundations and other in situ buried concrete	:	BS 5606
Exposed concrete(including internal surfaces of sewer culverts)	:	BS 5606
Other Surface Concrete:	As shown on drawings/schedule of finishes	

5.3 Precast Concrete

5.3.1 Manufacture off-Site

- (1) Casting of members shall not begin until a Notice of No Objection has been given by Engineer to the shop drawings, required computation, prestressing system (if required) and method of manufacture
- (2) When the drawings and method of manufacture have been approved, no changes shall be made without the Notice of No Objection obtained from the Engineer.
- (3) The Contractor shall inform the Engineer in advance of the date of commencement of manufacture and casting of each type of member. Concrete reinforcement and workmanship shall be as per IS: 456.
- (4) A copy of all cube test results to the work shall be sent to the Engineer as soon as they become available.
- (5) No members to which the tests relate shall be dispatched to the Site until the tests have been satisfactorily completed and noticed by the Engineer.
- (6) All members shall be indelibly marked to show the 'Member Mark' as described in the Contract, the production line on which they were manufactured, the date on which the concrete was cast and, if they are of symmetrical section, the face that will be uppermost when the member is in its correct position in the Works. The markings shall be so located that they are not exposed to view when the member is in its permanent position.

5.3.2 Forms

- (1) The design and engineering of the forms and falsework as well as their construction shall be the responsibility of the Contractor.
- (2) Design of the falsework for all concrete shall be done under the direction of a competent designer.
- (3) All exposed surfaces of each element of the structure shall be formed with similar material to produce similar concrete surface textures, colour, and appearance.
- (4) Forms shall be inspected and prior to authorizing casting operations. Details shown on the Drawings shall be built into the forms. Worn, damaged, or otherwise unacceptable forms shall be repaired before casting of any member will be authorised.
- (5) The forms may be made either of steel or of plywood. If the Contractor elects to use plywood forms, it shall be a high quality plywood, 19mm minimum thickness, marine grade and it shall be subject to the Notice of No Objection of the Engineer.

- (6) Forms shall be structurally adequate to support the members within permissible tolerances. The form design shall incorporate the method and the necessary hardware to adjust and maintain grade and alignment. Details of the hardware and adjustment procedure shall be included in the required plans.
- (7) Forms shall be coated with form release agent prior to use. Form release agent shall be a commercial quality form oil or other equivalent coating which will permit the ready release of forms and will not discolour the concrete. Excess form release agent shall not be allowed to stand in puddles in the forms nor shall coating be allowed to come in contact with reinforcing steel or hardened concrete.
- (8) Anchor devices may be cast into the concrete for later use in supporting forms, provided the arrangement is approved by the designer and given Notice of No Objection by the Engineer. The use of driven or drilled types of anchorages for fastening forms or form supports to concrete will not be permitted.

5.3.3 Curing

- (1) The steam curing shall be at 100% relative humidity to prevent loss of moisture and to provide moisture for proper hydration of the cement. Application of the steam shall not be directly on the concrete. During application of the steam, the ambient air temperature shall increase at a rate not to exceed 22°C per hour until the maximum temperature. Curing shall comply with the requirements of the Contract.
- (2) Steam curing process may be used as an alternative to water curing. The casting bed for any unit cured with steam shall be completely enclosed to prevent steam escaping and exclude outside atmosphere. 2 to 4 hours after placing concrete and after the concrete has undergone initial set, the first application of steam shall be made, unless retarders are used, in which case the waiting period before application of the steam shall be increased to from 4 to 6 hours. Water curing methods shall be used from the time concrete is placed until steam is first applied.
- (3) Where the steam has been raised the maximum temperature shall be held until the concrete has reached the desired strength. In discontinuing the steam application, the ambient air temperature shall not decrease at a rate to exceed 22°C per hour until a temperature has been reached 10°C above the temperature of the air to which the concrete shall be exposed. The maximum curing temperature shall be from 60°C to 67°C.
- (4) If the Contractor elects to cure by any other special method, the method and its details shall be subject to the Notice of No Objection by Employer/ Engineer.

5.3.4 Storage

When members are stored, they shall be firmly supported only at the points specified by the Designer. The accumulation of trapped water and deleterious matter in the units shall be prevented. Care shall be taken to avoid rust staining and efflorescence.

5.3.5 Handling and Transport

- (1) Members shall be lifted or supported only at points specified or otherwise give a Notice of No Objection by the Employer/ Engineer and shall be handled and placed without

impact.

- (2) The method of lifting, the type of equipment and transport to be used, and the minimum age of the members to be handled shall be subject to the Notice of No Objection from the Engineer.

5.3.6 Assembly and Erection

The method of assembly and erection described in the Contract shall be as practicable and be strictly adhered to on site. Immediately after a unit is in position, and before the lifting equipment is removed, temporary supports or connections between members, as necessary, shall be provided. The final structural connections shall be completed as soon as possible.

5.3.7 Forming Structural Connections

- (1) No structural connections shall be made until the Notice of No Objection obtained from Engineer's
- (2) Unless otherwise noticed by the Employer/ Engineer, the composition and water/cement ratio of the in situ concrete or mortar used in any connection and the packing of joints shall be in accordance with the assembly instructions.
- (3) Levelling devices shall only be released or removed with the Notice of No Objection from the Engineer.

5.3.8 Epoxy Grout for Structural Connections (if required)

(1) Description

Epoxy shall be furnished as 2 components mixed together at the Site.

(2) Sampling and Testing

All tests will be conducted in accordance with the latest test methods of the American Society for Testing and Materials, Federal Test Method Standard No. 141 or equivalent British Standard.

(3) Packaging, Labelling and Storing

- (a) Each component shall be packaged in steel containers not larger than 20 litres in volume. When the components are to be mixed at a ratio of 2 parts A to one part B, by volume, the container containing component B shall be one half the volume of the container containing component A. T
- (b) The containers shall have lug type crimp lids with ring seals, shall be new, not less than 0.6 mm nominal thickness, and shall be of such character as to resist any action by the components.
- (c) Each container shall be clearly labelled with the designation (Component A or B), type (Standard or Rapid) if applicable, manufacturer's name, date of manufacture, batch number (a batch shall consist of a single charge of all components in a mixing chamber), lot number, all directions for use specified elsewhere and the following warning in Kannada and English

"CAUTION"

"This material will cause severe dermatitis if it is allowed to come in contact with the skin or eyes. Use gloves and protective creams on the hands. Should this material contact the skin, wash thoroughly with soap and water. Do not attempt to remove this material from the skin with solvents. If any gets in the eyes, flush for 10 minutes with water and secure immediate medical attention."

- (d) Attention is directed to the characteristic of some epoxy components to crystallise or thicken excessively prior to use when stored at temperatures below 2°C. Any material which shows evidence of crystallisation or a permanent increase in viscosity or settling of pigments which cannot be readily re-dispersed with a paddle shall not be used.

(4) Directions for Use

- (a) At the time of mixing, components A and B shall be at a temperature between 16°C and 29°C, unless otherwise specified. Any heating of the adhesive components shall be done by application of indirect heat. Immediately prior to mixing, each component shall be thoroughly mixed with a paddle. Separate paddles shall be used to stir each component. Immediately prior to use, the 2 components shall be thoroughly mixed together in the specified ratios. When mixed, all adhesives shall have a uniformly gray colour without black or white streaks. No solvent shall be added to any epoxy.
- (b) After mixing, all epoxies shall be placed in the work and any overlaying or inserted be cleaned and it shall have moisture content of not more than 0.50% when tested. The maximum size of the aggregate shall not exceed that of material which is to be bonded to the work by the epoxy. It shall also be placed before thickening of the epoxy has begun. Surfaces upon which epoxy is to be placed shall be free of rust, paint, grease, asphalt, moisture and loose and deleterious material. When epoxy is used as a binder to make epoxy concrete or grout, the 2 components of epoxy shall be thoroughly mixed together before the aggregate is added and, unless otherwise specified, the mix proportions shall consist of one part of binder to approximately 4 parts of aggregate, by volume. Aggregate for use in epoxy concrete and grout shall be one-fourth of the thickness of the joint to be grouted. All surfaces against which epoxy concrete and grout are to be placed shall be primed with a coat of the epoxy used just prior to placing the grout.
- (c) No more material shall be mixed than can be used within 20 minutes from the time mixing operations are started. Pot life of the epoxy mixture shall be at least 45 minutes.

(5) Epoxy Grout Strength Requirements

The compressive strength of 38 mm cubes of epoxy grout tested in accordance with ASTM C39 after 10 hours of curing at 20°C shall be not less than the design strength of the precast member.

5.3.9 Protection

At all stages of construction, precast concrete units and other concrete associated therewith shall be properly protected to prevent damage to permanently exposed concrete surfaces, especially arises and decorative features.

6. PRESTRESSED MEMBERS

6.1 Prestressing Tendons

6.1.1 Materials

(1) Steel Wire

Steel wire shall comply with BS 5896.

(2) Cold worked high tensile alloy bar

Cold worked high tensile alloy steel bars for prestressed concrete shall comply with the requirements of BS 4486.

(3) Stress-relieved seven-wire strand

Stress relieved seven-wire strand shall comply with the requirements in TIS 420, Grade 1860, nominal diameter 12.7 mm or have properties that are not inferior. The characteristic breaking load shall not be less than that specified by the Contractor.

(4) Sampling and Testing

When it is proposed to use super strand complying with BS 5896 Table 6 or other than the lowest strength 3,4,5,6 or 7 mm diameter wire complying with BS 5896 Tables 4 or 5 the following shall apply:

- (i) A sample shall be taken from each reel of material proposed for use in the Works in the presence of the Engineer.
- (ii) A reel shall only be accepted if both the breaking load and the 0.1% proof load of the sample exceeds the specified characteristic loads given in Tables 4 or 6 of BS 5896. In the case of Table 5 this requirement shall apply to the breaking load and the load at 1% elongation.
- (iii) These requirements shall be additional to any other requirements of the Contract.

Where directed by the Engineer, the Contractor shall arrange for samples of the steel intended for use in the Works to be tested at an approved laboratory.

6.1.2 Handling and Storage

- (1) Care shall be taken to avoid mechanically damaging, work-hardening or heating prestressing tendons while handling. All prestressing tendons shall be stored clear of the ground and protected from the weather, from splashes from any other materials, and from splashes from the cutting operation of an oxy-acetylene torch, or arc-welding processes in the vicinity.
- (2) In no circumstances shall prestressing tendons after manufacture be subjected to any welding operation, or 'on-site' heat treatment or metallic coating such as galvanising.

This does not preclude cutting as specified in this Contract.

- (3) All wires, strands or bars stressed in one operation shall be taken, where possible, from the same parcel. Each cable shall be tagged with its number from which the coil numbers of the steel used can be identified. Cables shall not be kinked or twisted. Individual wires and strands for which extensions are to be measured shall be readily identifiable at each end of the member. No strand that has become unraveled shall be used.

6.1.3 Surface Condition

Prestressing tendons anchorages, blocking devices and internal and external surfaces of ducts shall be clean and free from pitting, loose rust, loose scale and chloride contamination at the time of incorporation in the work. If any surface cleaning is required it shall not heat, damage or polish the surface, or coat it with oil, grease or any other material.

6.1.4 Straightness

- (1) Wire

Unless otherwise given Notice of No Objection by the Engineer, low relaxation and normal relaxation wire shall be in coils of sufficiently large diameter to ensure that wire pays off straight.

- (2) Strand

Prestressing strand, however manufactured, shall be in coils of sufficiently large diameter to ensure that the strand pays off reasonably straight.

- (3) Bars

Prestressing bars as delivered shall be straight. Any small adjustments for straightness that are necessary on site shall be made by hand under the supervision of the Employer/ Engineer. Bars bent in the threaded portion shall be rejected. Any straightening of bars shall be carried out cold but at a temperature of not less than 5°C. Any necessary heating shall be by means of steam or hot water.

- (4) Reinforcement mesh or wire

Mesh or wire shall be delivered in sheets or coils. Any straightening shall be carried out cold but at a temperature of not less than 5°C. Any necessary heating shall be by means of steam or hot water.

- (5) Cutting

All cutting of wire, strand or bar shall be carried out using either:

- a) a high-speed abrasive cutting wheel, friction saw at not less than one diameter from the anchor or any other mechanical method Noticed by the Engineer, or
- b) an oxy-acetylene cutting flame, using excess oxygen to ensure a cutting rather than a melting action not less than 75 mm from the anchor whilst the temperature of the tendon adjacent to the anchor shall not be greater than 200°C. Care shall be taken that neither the flame nor splashes come into contact with either the anchorage or other tendons or reinforcement.

6.2 Pre-cast Construction

Care shall be exercised in the set-up of each member. All materials to be encased within the concrete of the member shall be properly positioned and supported. Provisions for all projections, recesses, notches, openings, blockouts and the like shall be made in accordance with the Drawings.

6.3 Stressing Tendons

6.3.1 General

- (1) It shall be the obligation of the Contractor to provide a technician skilled in prestressing systems to supervise or provide appropriate surveillance of the work and give the Engineer such pertinent information as he may require for inspecting the work. Such a representative shall be available full-time on all days during which the stressing and grouting of tendons is in progress.
- (2) All post-tensioning steel shall be tensioned by means of hydraulic jacks so that the force of the prestressing steel shall not be less than the value shown on the approved working drawings. The maximum temporary tensile stress (stressing stress) in prestressing steel shall not exceed eighty (80%) percent of the specified minimum ultimate tensile strength of the prestressing steel.

6.3.2 Tensioning Apparatus

The tensioning apparatus shall meet the following general requirements:-

- (a) The means of attachment of the tendon to the jack or tensioning device shall be safe and secure.
- (b) Where two or more wires or strands are stressed simultaneously, they shall be approximately of equal length between anchorage points at the datum of load and extension measurement. The degree of variation shall be small compared with the expected extension.
- (c) The tensioning apparatus shall be such that a controlled total force is imposed gradually and not dangerous secondary stresses are induced in the tendons, anchorage or concrete.
- (d) The force in the tendons during tensioning shall be measured by direct-reading load cells or obtained indirectly from gauges fitted in the hydraulic system to determine the pressure in the jacks. Facilities shall be provided for the measurement of the extension of the tendon and of any movement of the tendon in the gripping devices. The load-measuring device shall be calibrated to an accuracy within $\pm 2\%$ and checked at intervals to obtain the Notice of No Objection from the Engineer. Elongation of the tendon shall be measured to an accuracy within 2% or 2 mm, whichever is the more accurate.
- (e) The tensioning equipment shall be calibrated before the tensioning operation and at intervals of the months or as Noticed by the Engineer.
- (f) Any indication in the loss of strength in tendons during the tensioning operation shall be brought to the attention of the Engineer. Any corrective measures which may be required in procedures and/or material shall be noticed by the Engineer.

- (g) When friction must be reduced, water soluble oil may be used subject to the Notice of No Objection of the Engineer. This oil may be flushed from the duct as soon as possible after stressing is completed by use of water pressure. These ducts shall be flushed again just prior to the grouting operations. Each time the ducts are flushed, they shall be immediately blown dry with oil-free air.
- (h) Loss in strength of tendons may occur from wedge pull-in, bond failure tendon slippage or concrete elastic shortening, and these shall be separately identified by methods agreed with the Engineer. Immediate loss in strength must also be identified from relaxation loss for the purposes of design and testing.

6.4 Testing by Contractor

- (1) For the purpose of accurately determining the tendon elongations while stressing, the Contractor shall bench test two samples of each size and type of strand tendon to determine the modulus of elasticity prior to stressing the initial tendon. The bench should be at least 6 metres long, with concrete anchorage blocks having a constant area end section of at least four times that of the anchorage assembly area. The tendon shall be straight and centered on the cross-sectional area of the bench.
- (2) The test procedure shall consist of stressing the tendon at an anchor assembly with the dead end consisting of a load cell. The test specimen shall be tensioned to 80 percent of ultimate to 0 in 10 increments.
- (3) For each increment, the gage pressure, elongation and load cell force shall be recorded. The data shall be furnished to the Engineer. The theoretical elongations shown on the post-tensioning working drawings shall be revaluated by the Contractor using the results of the tests and corrected as necessary.
- (4) Revisions to the theoretical elongations shall be submitted to the Engineer for getting is Notice of No Objectionl. Apparatus and methods used to perform the tests shall be proposed by the Contractor and be subject to Notice of No Objection from the Engineer. After the initial testing, five (5) more tests shall be performed. These tests shall be spaced evenly through the duration of the Contract.

6.5 Pretensioning

Where pretensioning methods are used, the tension shall be fully maintained by some positive means during the period between tensioning and transfer. The transfer of stress shall take place slowly to minimize shock.

- (1) Straight Tendons
 - (i) In the long line method of pretensioning, sufficient locator plates shall be distributed throughout the length of the bed to ensure that the wires or strands are maintained in their proper position during concreting.
 - (ii) Where a number of units are made in the line, they shall be free to slide in the direction of their length and thus permit transfer of the prestressing force to the concrete along the whole line for the grouted tendon. In the individual mould system the moulds shall be sufficiently rigid to provide the reaction to the prestressing force without distortion.

- (2) Deflection Tendons
 - (i) Where possible the mechanisms for holding down or holding up tendons shall ensure that the part in contact with the tendon is free to move in the line of the tendon so that frictional losses are nullified. If, however, a system is used that develops a frictional force, this force shall be determined by test and due allowance made as agreed by the Engineer.
 - (ii) For single tendons the deflector in contact with the tendon shall have a radius of not less than 5 times the tendon diameter for wire or 10 times the tendon diameter for a strand, and the total angle of deflection shall not exceed 15°. Where the radius is less than 5 times the diameter of the tendon and the angle of deflection exceeds 15°, the loss of strength of the tendon shall be determined by test and due allowance made.
 - (iii) The transfer of the prestressing force to the concrete shall be effected in conjunction with the release of hold-down and hold-up forces as given Notice to Proceed by the Engineer.

6.6 Post-tensioning

- (1) Arrangement of Tendons

Where wires, strands or bars in a tendon are not stressed simultaneously, the use of spacers shall be in accordance with the recommendations of the system manufacturer.
- (2) Anchorages
 - a) Anchorages shall be tested in accordance with the requirements of BS 4447.
 - b) For each anchorage system used in the Works, the characteristic value for anchorage efficiency shall be not less than 90%.
 - c) Proprietary anchorages shall be handled and used strictly in accordance with the manufacturer's instructions and recommendations.
- (3) Deflected Tendons

The deflector in contact with the tendon shall, have a radius of not less than 50 times the diameter of the tendon, and the total angle of deflection shall not exceed 15 degrees unless otherwise given Notice of No Objection Engineer.
- (4) Tensioning Procedure
 - (i) Before tensioning, the Contractor shall demonstrate that all tendons are free to move in the ducts unless the geometry of the ducts makes this impracticable as agreed by the Engineer. Tensioning shall be carried out in such a manner that the stress in the tendons increases at a gradual and steady rate.
 - (ii) Unless otherwise described in the Contract, concrete shall not be stressed until it has reached at least the age at which 2 test cubes taken from it attain the specified transfer strength. The test cubes shall be made and tested as described in BS 1881. They shall be cured in similar conditions to the concrete to which they relate in a manner noticed by the Engineer.
 - (iii) The Contractor shall cast sufficient cubes to demonstrate that the required

strength of the concrete at transfer has been reached.

- (iv) The Contractor shall ensure that those carrying out the stressing are provided with particulars of the required tendon loads, order of stressing and extensions. Allowance shall be made during stressing for the friction in the jack and in the anchorage, although the former is not necessary when using load cells.
- (v) Any allowance for draw-in of the tendon during anchoring shall be in accordance with the Employers/Engineer's instructions.
- (vi) Stressing shall continue until the required extension and tendon load are reached or are noticed by the Engineer.
- (vii) The extension shall allow for any draw-in of the tendon occurring at the non-jacking end, but measurement shall not commence until any slack in the tendon has been taken up.
- (viii) Immediately after anchoring, the forces in the prestressing tendons shall not exceed 70% of their characteristic strength. During stressing the value may exceed 70% of their characteristic strength, with the Notice of No Objection by the Employer/ Engineer, but shall not exceed 80%.
- (ix) After the tendons have been anchored, the force exerted by the tensioning apparatus shall be decreased gradually and steadily so as to avoid shock to the tendon or the anchorage. Full records shall be kept of all tensioning operations, including the measured extensions, pressure-gauge or load-cell readings, and the amount of draw-in at each anchorage. Copies of these records shall be supplied to the Engineer within 24 hours of each tensioning operation.
- (x) Unless otherwise agreed by the Engineer tendons shall not be cut less than 3 days after grouting.

6.7 Prestressing Tendons - Protection and Bond

- (1) The prestressing tendons shall be protected in their permanent positions from both mechanical damage shall be applied to all unbonded prestressing tendons within 28 days of installation of the tendon in the duct. The tendon protection compound applied to the and corrosion as described in the Contract and the following sub-clauses.
- (2) The exposed tendons at the anchorages and the anchorages themselves shall be sealed within a closed box and protected from both mechanical damage and corrosion. Suitable access shall be left for jacking equipment for the later removal of the strands of unbonded tendons. The means of protection shall be designed by the prestress supplier and given Notice of No Objection by the Engineer.
- (3) A tendon protection compound tendons shall be a micro-crystalline wax (petrolatum) base material containing additives to enhance the corrosion inhibiting, wetting, and moisture displacing properties, as well as the ability to form a polar bond with the tendon steel.
- (4) The compound Manufacturer shall provide test data verifying that the following properties are met for the service life of 120 years and temperature range of 0°C to

50°C:

- (a) freedom from cracking and brittleness;
 - (b) continuous self-healing film over the coated surfaces;
 - (c) chemical and physical stability;
 - (d) non reactivity with the surrounding and adjacent materials such as concrete, tendons, and ducts;
 - (e) moisture displacing characteristics.
- (5) Additionally it shall remain flexible to allow removal and replacement of the tendons. The tendon protection compound and its method of installation shall be noticed by the Engineer.
 - (6) Provision shall be made for expansion of the tendon protection compound during the lifetime of the structure.
 - (7) Before installing the tendon protection compound it shall be demonstrated that the ducts, U-bend anchorage and anchorages are clean and free of water and chlorides.
 - (8) The tendons, internal face of the steel u-bend anchorage, stressing anchorages and any other metallic components of the prestressing system shall additionally be pre-treated with a protection compound before delivery to site. The protection compound shall be applied to each strand of the tendon and shall be compatible with the tendon protection compound injected into the ducts. The protection compound shall be Notice of No Objection by the Engineer.
 - (9) The supplier of the tendon protection compound shall submit for the Employers/Engineer's notice proposals which shall describe how the tendon protection compound can be removed and re-injected into ducts, including buried ducts, within the permanent works.
 - (10) All materials used in the prestressing systems shall not give off toxic fumes at temperatures below 50°C and shall not support combustion.

6.8 Ducts for Bonded Tendons

6.8.1 Ducts

- (1) Ducts for longitudinal, transverse or vertical tendons embedded into the concrete may be of flexible, semi-rigid, or rigid galvanized, ferrous metal capable of withstanding concrete pressures without deforming or permitting the entrance of cement paste during casting of the member.
- (2) They must retain their shape and be capable of transferring bond stresses. The semi-rigid duct must be rigid enough to remain straight when supported at 1200 mm maximum intervals but flexible enough to allow 3600 mm radius curves. Flexible duct shall be secured or supported at not more than 300 mm intervals.

6.8.2 Grouting of Prestressing Tendons

- (1) General

The Contractor shall undertake grouting trials when required by the Engineer.

(2) Materials

- (a) Unless otherwise directed or agreed by the Engineer as a result of grouting trials, the grout shall consist only of Ordinary Portland Cement (OPC)
- (b) Cement and water. The water/cement ratio shall be as low as possible consistent with the necessary workability, and under no circumstances shall the W/C ratio exceed 0.45 by weight.
- (c) The grout shall not be subject to bleeding in excess of 2% after 3h or 4% maximum when measured at 25°C or such other temperature as may be noticed by the Engineer, in a covered cylinder approximately 100 mm diameter with a height of grout of approximately 100 mm, and the water shall be reabsorbed by the grout during the 24h after mixing.
- (d) Admixtures may be used with Notice of No Objection of the Engineer and shall be applied strictly in accordance with the manufacturer's instructions. Admixtures shall not contain chloride ions in excess of 0.25 percent by weight.
- (e) Dry materials shall be measured by weight.

(3) Ducts

- (a) Air vents shall be provided at any crests in the duct profile and elsewhere as specified.
- (b) All ducts shall be thoroughly clean before grouting. Ducts formed without metal sheathing shall be provided with effective drainage and, unless otherwise directed by the Engineer, shall be flushed with water before grouting.
- (c) All surplus water shall be removed by compressed air injection.
- (d) All anchorages shall be sealed or fitted with grouting connections.

(4) Grouting Equipment

- (a) The mixing equipment shall produce a grout of homogeneous consistency and shall be capable of providing a continuous supply to the injection equipment.
- (b) The injection equipment shall be capable of continuous operation with little variation of pressure and shall include a system for recirculating the grout while actual grouting is not in progress. Compressed air shall not be used.
- (c) The equipment shall have a sensibly constant delivery pressure not exceeding 1 N/mm². All piping to the grout pumps shall have a minimum of bends, valves and changes in diameter. All baffles to the pump shall be fitted with 1.18 mm sieve strainers. All equipment, especially piping, shall be thoroughly washed through with clean water after every series of operations and at the end of use for each day. The interval between washing shall not exceed 3hrs.
- (d) The equipment shall be capable of maintaining pressure on completely grouted ducts and shall be fitted with a valve that can be locked off without loss of pressure in the duct.

(5) Mixing

Water shall be added to the mixer first, then the cement. When these are thoroughly mixed, the admixture, if any, shall be added. Mixing shall continue until a uniform consistency is obtained. Mixing shall not be by hand.

(6) Injecting Grout

- (a) Grouting shall be carried out as soon as is practicable after the tendons in them have been stressed and anchors trimmed and the Employers/ Engineer's Notice of No Objection has been obtained.
- (b) Injection shall be continuous, and it shall be slow enough to avoid producing segregation of the grout. The method of injecting grout shall ensure complete filling of the ducts and complete surrounding of the steel. Grout shall be allowed to flow from the free end of the duct until its consistency is equivalent to that of the grout injected. The opening shall then be firmly closed. Any vents shall be closed in a similar manner one after another in the direction of the flow. After an appropriate time, further injections shall be carried out to fill any possible cavities.
- (c) The injection tubes shall then be sealed off under pressure until the grout has set.
- (d) The filled ducts shall not be subjected to shock or vibration within 1 day of grouting.
- (e) Not less than 2 days after grouting, the level of grout in the injection and vent tubes shall be inspected and made good as necessary.
- (f) The Contractor shall keep full records of grouting including the date each duct was grouted, the proportion of the grout and any admixtures used, the pressure, details of any interruptions and topping up required. Copies of these records shall be supplied to the Engineer within 3 days of grouting.
- (g) Where required by the Engineer, the Contractor shall provide facilities and attendance for the radiographic testing of duct.

(7) Strength of Grout

The compressive strength of 100 mm cubes made of the grout shall exceed 17 N/mm² at 7 days. Cubes shall be cured in a moist atmosphere for the first 24h, and subsequently in water.

6.9 Ducts for Unbonded Tendons

- (1) Unless shown otherwise on the Drawings, ducts and injection tubes in the superstructure and substructure shall be formed from high density polyethylene (HDPE) which shall incorporate a stabilizing agent to prevent Ultra Violet Light (UVL) degradation.
- (2) The minimum wall thickness of the ducts shall be such that the ducts are capable of resisting the pressures developed during installation of the protection compound. The ducts shall be smooth bore.
- (3) Ducts with external diameters greater than 70 mm shall be transported and stored in straight lengths. The distance between supports shall be limited to 3m and the height

of storage to 1.5 m. Alternatively ducts may be transported and stored in coils provided that they are fixed to the tolerances required by the Designer. Damaged ducts shall not be used in the Works.

- (4) No boring of any No boring holes in the ducts shall be permitted once the tendons are installed.
- (5) U-bend anchorages shall be formed from smooth-bore unwelded steel tubes and shall comply with the requirements of BS 4360.
- (6) Joints between ducts, ducts and anchorages and ducts and U-bend anchorages shall be formed by a coupling device using thermo-fusion techniques which shall provide a watertight seal to the ducts and shall be capable of resisting the pressure developed during installation of the tendon protection compound. The inner surfaces of the joints shall form a smooth transition between ducts and U-bend anchorages to allow satisfactory installation of the tendons. All coupling devices shall be give Notice of No Objection by the Engineer.
- (7) Injection tubes shall be provided at the U-bend anchorages, the stressing anchorages and at any other positions on the length of the ducts which are required to achieve satisfactory installation of the tendon protection compound. The injection tubes at the U-bend anchorages shall also be used as drainage points for the U-bend. The connection between the ducts and the injection tubes shall be watertight and capable of resisting the pressure developed during installation of the tendon protection compound.
- (8) All injection tubes shall be sealed after use to prevent the ingress of water to the satisfaction of the Engineer.
- (9) After completion of all duct joints and before completion of the insitu joints between precast segments and before installation of the tendons, all ducts shall be air tested to an equivalent 100 mm water gauge unless otherwise given Notice of No Objection by the Engineer. The test shall be performed in accordance with BS 8301 Section 5.
- (10) Any ducts which do not contain tendons shall remain empty and shall be sealed at each end to prevent the ingress of water.

6.10 Prestressing Tendons - Trial Construction-Unbonded Tendons

- (1) Before commencing construction of the precast segments a trial shall be carried out which shall demonstrate the satisfactory installation, removal and replacement of a prestressing strand together with the proposed techniques for duct jointing, duct testing and installation of the tendon protection compound.
- (2) The tendons shall be stressed in accordance with this Specification.
- (3) The ducts shall be filled with a tendon protection compound in accordance with sub-Section 6.7.4 and the tendon extension and anchorage shall be protected as if they were to be included in the permanent works.
- (4) The trial shall demonstrate that any one strand may be destressed, removed, inspected, replaced and restressed and that no voids are created within the tendon protection compound, all to the satisfaction of the Engineer.

- (5) The trial shall also demonstrate that all of the strands in a duct may be removed and that the tendon protection compound can be removed from the ducts and U-bend anchorage to the satisfaction of the Engineer.
- (6) The trial shall be undertaken using the prestressing system to be used in the permanent works and shall be Noticed by the Engineer.

6.11 Prestressing Tendons - Temporary Tendons

- (1) Temporary tendons may be re-used as temporary tendons elsewhere provided special precautions are incorporated at the anchorages to ensure tendons are not damaged. These precautions shall be give Notice of No Objection by the Engineer.
- (2) The tendons shall be enclosed within a duct throughout their length.
- (3) The tendons shall be pre-treated in accordance with Sub-Section 6.7.7 and the protection compound shall be applied to the outer surfaces of the tendon after each use.
- (4) The maximum jacking force for the re-usable temporary tendons shall not exceed 70 percent of their guaranteed minimum breaking load.
- (5) After removal of the tendons the ducts shall be sealed at each end to prevent the ingress of water.

6.12 Preparation for Casting

- a) The Contractor shall submit for approval, in accordance with the provisions of the Employer's Requirements, working drawings of the prestressing system proposed for use. For initial review, 3 sets of such drawings shall be submitted.
- b) After review, between 6 and 12 sets, as requested by the Emploeyr/Engineer, shall be submitted for final approval and for use during construction.
- c) The working drawings of the prestressing system shall show complete details and be accompanied by substantiating calculations of the method and materials the Contractor proposes to use in the prestressing operations, including any additions or rearrangement of reinforcing steel from that shown on the Drawings. Such details shall outline the method and sequence of stressing and shall include complete specifications and details of the prestressing steel and anchoring devices, working stresses, anchoring stresses, type of ducts, and all other data pertaining to the prestressing operation, including the proposed arrangement of the prestressing steel in the members.
- d) Working drawings shall be A1 size and each drawing and calculation sheet shall include the job site, name of the structure as shown on the Contract Drawings and Contract name.
- e) Working drawings shall be submitted sufficiently in advance of the start of the affected work to allow time for review by the Engineer and correction by the Contractor of the drawings without delaying the work. Such time shall be proportional to the complexity of the work but in no case shall such time be less than eight (8) weeks.
- f) At the completion of each structure, one set of reproducible mylars of the corrected original tracing of all working drawings for said structure shall be furnished to the Engineer. Drawings which are common to more than one structure shall be provided for each structure. An index prepared specifically for the drawings for each structure containing sheet numbers and titles shall be included.
- g) Reinforcing steel shall be fabricated and placed in accordance with the Drawings and as required herein. No reinforcing steel shall be cut and removed to permit proper alignment of stressing ducts. Any bar that cannot be fabricated to clear the conduits

shall be replaced by additional bars with adequate lap lengths and shall be submitted to the Engineer for his Notice of No Objection. In the plane of the steel parallel to the nearest surface of concrete, bars shall not vary from plan placement by more than 12 mm or one-tenth (1/10) of the spacing between bars, whichever is less.

- h) All prestressing steel shall be protected against physical damage and rust or other results of corrosion at all times from manufacture to grouting or encasing in concrete. Prestressing steel that has sustained physical damage at any time shall be rejected. The development of visible rust or other results of corrosion shall be cause for rejection, when ordered by the Engineer.
- i) Prestressing steel shall be packaged in containers or shipping forms for the protection of the steel against physical damage and corrosion during shipping and storage. A corrosion inhibitor which prevents rust or other results of corrosion shall be placed in the package or form, or shall be incorporated in a corrosion inhibitor carrier type packaging material, or when given Notice of No Objection by the Engineer, may be applied directly to the steel. The corrosion inhibitor shall have no deleterious effect on the steel or concrete or bond strength of steel to concrete. packaging or forms damaged from any cause shall be immediately replaced or restored to original condition.

The shipping package or form shall be clearly marked with a statement that the package contains high-strength prestressing steel, and the care to be used in handling; and the type, kind and amount of corrosion inhibitor used, including the date when placed, safety orders and instructions for use.

- k) Prestressing steel for post-tensioning which is installed in members prior to placing and curing of the concrete, shall be continuously protected against rust or other corrosion, until grouted, by means of a corrosion inhibitor placed in the ducts or applied to the steel in the duct. The corrosion inhibitor shall conform to the requirements specified herein.
- l) When steam curing is used, prestressing steel for post-tensioning shall not be installed until the steam curing is completed.
- m) All water used for flushing ducts shall contain either quick lime (calcium oxide) or slaked lime (calcium hydroxide) in the amount of 13g. per litre. All compressed air used to blow out ducts shall be oil free.
- n) When acceptable prestressing steel for post-tensioning is installed in the ducts after completion of concrete curing, and if stressing and grouting are completed within 10 calendar days after the installation of the prestressing steel, rust which may form during said 10 days will not be cause for rejection of the steel. Prestressing steel installed, tensioned and grouted in this manner, all within 10 calendar days, will not require the use of a corrosion inhibitor in the duct following installation of the prestressing steel. Prestressing steel installed as above but not grouted within 10 calendar days shall be subject to all the requirements in this section pertaining to corrosion protection and rejection because of rust.
- o) Any time acceptable prestressing steel for pretensioning is placed in the stressing bed and is exposed to the elements for more than 36 hours prior to encasement in concrete, adequate measures shall be taken by the Contractor, as Notice of No Objection by the Engineer, to protect said steel from contamination or corrosion.
- p) All ducts shall be located within 5 mm of the locations given on approved fabrication plans. Method and spacing of supports for ducts shall be shown on the working drawings. After installation in the forms, the end of the ducts shall at all times be sealed to prevent entry of water and debris. Following each pour of concrete, the Contractor will be required to demonstrate that all empty ducts are free of water and are

unobstructed and undamaged. Immediately prior to installation of the prestressing steel, the Contractor shall again demonstrate to the satisfaction of the Engineer that all ducts are unobstructed and that they are free of water and debris.

Where tendons are described in the Contract as de-bonded from the concrete they shall be covered with sleeves as noticed by the Engineer. The ends of the sleeves shall be taped to the tendon to prevent the ingress of grout.

- q) Concrete shall not be deposited into forms until the entire set-up of the forms, reinforcement, ducts, and anchorage has been thoroughly inspected and checked. The placing of concrete will not be permitted until the Engineer is satisfied that the rate of producing and placing concrete will be sufficient to complete the proposed pour and finishing operations within the scheduled time, that experienced concrete finishers are available where required for finish work and all necessary finishing tools and equipment are on hand at the site of the work and are in satisfactory condition for use.
- r) Conveying equipment shall be of a size and design that will permit the placing of concrete within the time limits specified. Conveying equipment shall be cleaned at the end of each operation or work day and just prior to reuse shall again be checked and cleaned of hardened concrete and foreign materials. Belt conveyors shall be horizontal or at a slope which will not cause excessive segregation or loss of ingredients. Concrete shall be protected against undue drying or rise in temperature. An approved arrangement shall be used at the discharge end to prevent aggregate segregation. Mortar shall not be allowed to adhere to the return length of the belt. Concrete shall be discharged into a hopper or through a baffle.
- s) The concrete shall be first placed in the web forms followed by placement at the bottom slab and then in the top form. Any alternate sequence shall be submitted to the Engineer for his Notice of No Objection.
- t) All concrete shall be consolidated by means of approved vibrators together with any other equipment necessary to perform the work as specified. Internal vibrators shall have a minimum frequency of 8,000 vibrations per minute and sufficient amplitude to consolidate the concrete effectively. At least two (2) stand-by vibrators in working condition shall be provided for emergency use in case of malfunction. The use of external vibrators for consolidating concrete will be permitted and may be required when the concrete is inaccessible for adequate consolidation. When external vibration is used, the forms shall be constructed sufficiently rigid to resist displacement or damage. Vibrating of concrete shall be done with care and in such a manner as to avoid displacement of reinforcing, conduits, and other items to be fixed in place

7. STRUCTURAL STEELWORK

7.1 General

Workmanship and materials shall be generally in accordance with BS 5400 Part 6 or other relevant code of practice noticed by Engineer.

7.2 Material Properties

- (1) Steel for rolled sections, plates and bars shall normally comply with IS:226/IS:2062 or BS 5950, Part 2 Grade 43, or a special steel as per design requirement.
- (2) Dimensional properties, tolerances and rolling margins shall comply with the relevant Standards.
- (3) The condition of steel for fabrication shall be to IS:2062 or Swedish Standard 05 5900, Grade C unless otherwise detailed.

- (4) Bolts and nuts shall comply with design requirement.
- (5) Washers shall comply with BS 4320.
- (6) Stainless steel shall be grade 316 S31 to BS 970 : Part 1, unless detailed otherwise.

7.3 Testing

- (1) The Contractor shall perform tests and submit test certificates for the materials to be used in the work. The tests shall include the following in accordance with IS:226/IS:2062 or BS 5950, Part 2 or applicable Indian Standard.
 - a) Chemical analysis
 - b) Tensile tests
 - c) Bend tests
 - d) Flattening tests
- (2) The tests shall be carried out by a noticed testing authority and notice shall be given of the intended execution of any such test. The specimen for testing shall be random sampling of steel work to be used for the Project.
- (3) If any sample fails a test, the consignment it represents may be rejected in part or in whole. Alternatively it may be possible to either :
 - a. retest the consignment using another sampling set or;
 - b. notice the criteria for acceptance of this particular consignment, should the Employer/ Engineer allow an acceptance for a particular use justified by the design requirements
- (4) In no way do these specific qualifications provide a precedent for future acceptance of any failed consignment.

7.4 Fabrication

- (1) The work of fabrication shall comply with the requirements of IS:800 or BS 5950, Part 2 or other relevant code of practiced noticed by Engineer., in accordance with BS-EN 1993 or ASTM. Fabrication accuracy shall be within the limits detailed in BS 5400, Part 6.
- (2) All parts assembled for bolting shall be in close contact over the whole surface and all bearing stiffeners shall bear tightly at top and bottom without being drawn or caulked. The component parts shall be so assembled that they are neither twisted nor otherwise damaged. As specified cambers if any shall be provided. Drilling done during assembling shall not distort the metal or enlarge holes. The butting surfaces at all joints shall be so cut and milled so as to butt in close contact throughout the finished joints.
- (3) Cutting shall be done automatically. Hand flame cutting will not be permitted.
- (4) The edges and ends of all cut/sheared flange plates, web plates of plate girders, and all cover plates, and the ends of all angles, tees, channels and other sections forming the flanges of plate girders, shall be planed/ground.
- (5) Holes for bolts shall be drilled to conform to clause 10 of IS:7215 . Punching of holes will not be permitted. All drilling shall be free from burrs. No holes shall be made by gas

cutting process.

- (6) All welding for the works shall be carried out by first class welders and shall be in accordance with IS:816, IS:819, IS:1024, IS:1261, IS:1323 and IS:9595. The Employer/Engineer may at his discretion order periodic tests of the welder and/or of the welds produced by them. All such tests shall be carried out by the Contractor at his cost.
- (7) Safety requirements shall conform to IS:7205, IS:7273 and IS:7269 as applicable and shall conform to safety, economy and rapidity.
- (8) As much work as possible shall be welded in shops. The pieces shall be manipulated to ensure down hand welding for all shop joints as far as possible. All parts to be welded shall be arranged so as to fit properly on assembly. After assembly and before the general welding is to commence the parts are to be tack welded with small fillet or butt welds as the case may be. The tack welding must be strong enough to hold the parts together but small enough to be covered by the general welding. The welding procedure shall be so arranged that the distortion and shrinkage stresses are reduced to a minimum.
- (9) All joints required in structure to facilitate transport or erection shall be shown on the drawings. The lengths of structural members shall be the maximum normally available in the market and the jointing of shorter length in order to make up lengths required shall not be permitted.
- (10) Each piece of steel work shall be marked distinctly before delivery, indicating the position and direction in which it is to be fixed. Three copies of a complete marking plan shall be supplied to the Engineer before erection commences.
- (11) In the case of welded fabrication any distortion remaining in the member after welding operations are completed shall be rectified by the Contractor.
- (12) All members of trusses and lattice girders shall be straight throughout their length, unless shown otherwise on the drawings, and shall be accurately set to the lines shown on the drawings. Sheared edges of gussets or other members to be straightened and dressed where necessary.
- (13) Templates and jigs used throughout the work shall be all steel. In cases where actual materials have been used as templates for drilling similar pieces, the Engineer's notice shall be obtained to use as parts of the finished structure.
- (14) Apart from the requirements of welding specified under the above sub clauses, sections above, the Contractor shall ensure the following requirements in the welded joints.
 - a. Strength-quality with parent metal.
 - b. Absence of defects
 - c. Corrosion resistance of the weld shall not be less than that of parent material in an aggressive environment.
- (15) No gasket or other flexible material shall be placed between the holes. The holes in parts to be joined shall be sufficiently well aligned to permit bolts to be freely placed in position. Driving of bolts is not permitted. The nuts shall be placed so that the

identification marks are clearly visible after tightening. Nuts and bolts shall always be tightened in a staggered pattern and, where there are more than four bolts in any one joint, they shall be tightened from the centre of the joint outwards

7.5 Detailing of Connections

- (1) Detailing of connections shall ensure that inaccessible pockets/gaps are avoided. In this respect, back-to-back angles with spacers and similar details which would prevent full accessibility for painting are not acceptable.
- (2) Where cope holes are required to allow completion of butt welding they shall be of adequate size to allow fillet welding to seal the connection, while still allowing full accessibility for subsequent painting.
- (3) Snipping of stiffeners at the root radii of rolled members is not acceptable. Stiffeners shall be cut to the required profile to fit closely into all such radii, and seal welded.
- (4) High-strength friction grip (HSFG) bolts shall be used only on mating surfaces as specified herein.
- (5) HSFG bolted connections, slip-bolted connections and welded connections shall not be used interchangeably or in tandem with each other. The use of each of these types of connections shall be separate and distinct.

7.6 Submissions

- (1) The Contractor shall submit two initial copies of each shop drawing and subsequently four copies of the noticed/final shop drawings for retention by the Engineer. Materials shall not be ordered nor fabrication commenced until shop drawings are noticed.
- (2) The Contractor shall submit for notice, the details of erection procedures. The procedure should contain details of safety precaution to be taken during erection refer - IS:7205.
- (3) In submitting drawings and erection procedures for notice the Contractor shall allow sufficient time for checking and making amendment(s) and re-submission(s) prior to obtaining notice.

7.7 Welding

- (1) Metal-arc welding of steel shall be in accordance with the requirements of relevant IS, BS-EN or ASCI Standards.
- (2) Run-on/run-off plates shall be used during butt welding.
- (3) Fillet welds shall be continuous to form a complete seal where two members join or abut.

7.8 Electrodes

The Contractor shall get Noticed the types of electrodes proposed for use. Welding electrodes shall be suitable for the type of steel and position of welding and shall give a weld deposit with mechanical properties not less than the minimum specified for the parent metal. Hydrogen-controlled electrodes shall be used for butt welding of steel over 25mm

thick.

7.9 Welders

Welders employed on the work shall be tested to BS 4871 and BS 4872 : Part 1. Welding shall be carried out under the supervision of a competent welding technologist and the test pieces shall be tested to BS 4870.

7.10 Testing

- (1) The Contractor shall make radiographic examination of butt welds in accordance with Section 8 of American Petroleum Industry (API) Standard 1104 and shall carry out dye-penetrant tests in accordance with BS 6443.
- (2) Not less than 10% of the length of each butt weld shall be radio-graphically inspected and 10% shall be tested using dye-penetrant method.
- (3) Not less than 10% of the length of each fillet weld shall be tested using dye-penetrant testing. The locations of lengths to be tested shall be as notified by the Engineer.

7.11 Site Welding

- (1) The Contractor may, subject to prior notice, use site welding as an alternative to bolted connections.
- (2) Site-welded joints shall be inspected by radiography in accordance with Section 8 of API Standard 1104. Initially 100% of each butt weld shall be inspected. At the notice of the Engineer, the number of inspections may subsequently be reduced.
- (3) Finished welds shall comply with Section 6 of API Standard 1104. Defective welds shall be cut out, remade and retested as noticed.

7.12 Erection of Steelwork

- (1) Erection of steelwork shall comply with the requirements of BS 5950, Part 2. Stanchions shall be plumbed using steel packs and wedges and restrained while the spaces beneath the base-plates are filled with an noticed non-shrink cementitious grout. Packs and wedges shall be protected by grout to a minimum thickness of 50mm.
- (2) The Contractor shall be responsible for checking the alignment and level of foundation and correctness of foundation bolt centres, well in advance of starting erection work, and shall be responsible for any consequences for non-compliance thereof. Discrepancies if any shall immediately be brought to the notice of the Engineer.
- (3) The structure should be divided into erectable modules as per the total scheme. This should be pre-assembled in a suitable yard/platform and its matching with members of the adjacent module checked by trial assembly before erection.
- (4) Immediately prior to erection any rust in the paint area shall be removed by power wire brushing to a standard equivalent to SA3.
- (5) During erection the rough handling of fabricated materials such as bending, straining or pounding with sledges shall be avoided. Any damage to the structure during transportation or erection shall be immediately rectified by the Contractor at his own cost. The straightening of bend edges of plates, angles and other sections shall be done

by methods which will not cause fracture.

- (6) Following the completion of the straightening, the surface of the member shall carefully be inspected for damage before further use.
- (7) The Contractor shall be responsible for accurately positioning, levelling and plumbing of all steelwork and placing of every part of the structure in accordance with the noticed drawings and to the satisfaction of the Engineer. All stanchion base, beam and girder bearings etc. shall be securely supported on suitable steel packs. All reference and datum points shall be fixed near the work site for facilitating the erection work.
- (8) All equipment used by the Contractor shall be sufficient for the purpose and for the erection of the steel work, in the time specified in the Contract. Any lifting or erecting machinery shall be noticed to be removed from the site if the Engineer considers such appliances dangerous or unsuitable for their functions. The Notice of No Objection from the Engineer shall not relieve the Contractor of the responsibilities for the loads to which the erection equipment shall be called upon to carry. Adequate arrangement shall be made to resist wind loads and lateral forces arising at the time of erection.
- (9) The Contractor is entirely responsible for the stability of the structure during erection and shall arrange that sufficient tack bolts, braces or guy ropes are used to ensure that work will remain rigid until final bolting, riveting or welding is completed. The Contractor shall supply and fix, without extra charge, any temporary bracing which may be necessary.
- (10) All steelwork shall be erected in the exact position as shown on the Drawings. All vertical members shall be truly vertical throughout and all horizontal members truly horizontal, fabrication being such that all parts can be accurately assembled and erected. No permanent bolting, welding or grouting shall be done until proper alignment has been obtained and checked.
- (11) At stanchion splices and at other positions where concrete cover to the steel is liable to be restricted, bolts will be placed with their heads on the outside of the members.
- (12) All field assembly bolting and welding shall be executed in accordance with the requirements for shop fabrication excepting such as manifestly apply to shop conditions only. Where steel has been delivered painted the paint shall be removed before field welding for a distance of at least 50mm on either side of the joints. The number of washers on permanent bolts shall not be more than two for the nut and one for the bolt head.

7.13 Tolerances

The tolerances for erected steelwork shall be as shown on the Drawings. In-lieu of other information the tolerances from BS-EN 1993 shall be adopted.

7.14 Bolted Connections

- (1) Bolts shall be threaded only over the length of shank which is outside the parts bolted together. The bolt shall protrude by at least two complete threads and not more than four complete threads beyond the outer face of the tightened nut.

- (2) Holes shall not be distorted or enlarged by the use of drifts.
- (3) High strength friction grip bolts shall be fitted in accordance with BS 4604: Part 2.
- (4) Load-indicating washers shall be installed in accordance with the manufacturer's recommendations.

7.15 Transportation and Storage

Steelwork and protective coatings shall be protected from damage during packing, handling, transportation and storage. The Contractor shall ensure that members are not subjected to greater stresses than those allowed in BS 5950, Part 2 during fabrication, transportation, storage and erection.

Stored items shall not be in contact with each other and shall be clear of the ground.

7.16 Damaged Material

Steelwork deemed to be damaged during the Contract period shall be replaced. The Contractor shall obtain notice from Engineer for remedial work to damaged material if repairable. The method of repair and final repaired condition shall have Notice of No Objection from the Engineer.

7.17 Galvanising

- (1) Galvanising of steelwork, if required, shall be carried out after fabrication is complete. Steelwork required to be galvanised shall be pickled in dilute hydrochloric acid, washed, fluxed and stoved, then coated with zinc by dipping in a bath of molten zinc. Components shall be immersed in the bath only for a period sufficient to attain the temperature of the bath and shall be withdrawn at a speed which ensures that a coating of 610 grams/sq. m of surface is achieved (85 microns minimum Dry Film Thickness(DFT)). Components shall be covered evenly on all surfaces. Items shall not be galvanised in more than one dip event due to potential warping or additional stresses that may be induced in the metal.
- (2) Items described as heavily galvanised shall be grit blasted prior to galvanising and shall receive a minimum coating of 1000 grams/sq. m of surface (140 microns minimum DFT).
- (3) Lightweight gauge metalwork shall be galvanised by the hot-dip process as specified in BS 3083 or BS 2989.
- (4) Contact between galvanised steel members and aluminum surfaces or between galvanised and ungalvanised steel members shall be prevented by means of approved insulating washers and grommets.
- (5) Galvanised steelwork shall be cleaned, degreased and etch primed before application of the specified paint treatment.

7.18 Preparation of Steelwork for Protective Treatment

- (1) Surfaces shall be cleaned to BS 7079 before any protective treatment is commenced.
- (2) Steelwork shall be degreased and shot or grit blasted to Sa 2.5 quality standard with a surface amplitude of 50 to 75 microns to remove rust and mill scale. Dust and debris shall be removed by vacuum cleaner, compressed air or brush. Site welds and adjacent steelwork shall be blast cleaned and similarly prepared. Surface defects shall be removed in accordance with BS 5950. Other reliable method may be as well used after

getting Notice of No Objection from Employer/ Engineer under special circumstances.

- (3) Regular mill scale detection tests shall be made using the Copper Sulphate method.
- (4) Blasting operations and painting processes shall be segregated.

7.19 Painting Generally

- (1) Paint shall be applied by brushing or spraying in accordance with the manufacturer's instructions. When permitted, thinners shall be added to paint in strict accordance with the manufacturer's permitted percentages.
- (2) Brushes stored in thinners shall be worked out to remove thinners before re-use.
- (3) Painting shall not be carried out when the steelwork temperature is below 4 degrees C, above 50 degrees C, less than 3 degrees C above the dew point, or when the relative humidity is above 80%.
- (4) Stripe coats shall be applied to welds and steel edges before painting.
- (5) Strong paint films shall be achieved on all cleats, arrises, bolt holes, bolt heads and the like.
- (6) Protective treatment, other than the site-applied coatings, shall be applied under factory conditions in an enclosed shop. Completed coats shall be checked for continuity by a low-voltage wet sponge holiday detector and for thickness by an Elcometer. The colour of each coat shall be sufficiently different to permit detection of incomplete application.
- (7) If a required film thickness is specified, it shall be the minimum dry film thickness (DFT) as measured by an noticed gauge. The gauge shall be calibrated for each coating by the use of a shim of known thickness placed on the shot blasted blank or on the underlying coat. The shim shall correspond to the theoretical film thickness of the coating to be measured. Otherwise, a full coating shall be applied in accordance with the rate of coverage recommended by the manufacturer, having regard to the surface profile of the steel and the conditions of application.
- (8) Sample plates shall be prepared for approval and shall thereafter be adopted as the standard to be achieved in the finished work.
- (9) The Contractor shall prevent dust and dirt coming into contact with freshly painted surfaces.
- (10) Before the site painting coats are applied, the surfaces shall be lightly abraded, if required by the manufacturer's instructions, and washed with clean water to remove salt and other impurities.
- (11) Paint shall not be applied to the embedded portions of metal items except those within 75mm of the finished concrete surface.

7.20 Application of Protective Layers

Blast cleaned surfaces shall be kept dry and shall receive the first coat within 4 hours of the start of cleaning (2 hours for outdoor blast cleaning). They shall be treated in accordance with the protective treatment schedule, except the faying surfaces for high strength friction grip bolt connections.

7.21 Protection of Bolts etc.

Bolts, including high strength friction grip bolts, nuts and washers shall be hot-dip spun-galvanised or as approved by the Designer. The threads of nuts may be re-tapped as provided for in BS 729.

7.22 High Strength Friction Grip Connections

Faying surfaces of high strength friction grip connections shall be blast cleaned to Sa 2.5 quality standard, masked within two hours to exclude air and exposed just before bolting-up. Paint and other contaminants shall not be allowed on faying surfaces. Each consecutive coat of paint shall be stepped back from the edge of the faying surface by 15mm.

7.23 Protective Treatment

Damaged paintwork shall be blast cleaned if bare metal is exposed or corrosion is present. If the first coat is intact the surface shall be prepared by power wire brushing. The prepared surface shall be protected with the full paint system.

Submerged steelwork shall, in addition, be coated with a compatible chlorinated rubber based anti-fouling paint to a DFT of 75 microns.

7.24 Paintwork Executed on Site

- (1) Following erection, the exposed parts of galvanised nuts, washers and bolts (except chain fixing bolts) shall be degreased, etch-primed and painted to the specification for adjacent steelwork. Freshly galvanised surfaces shall be abraded and washed before application of the etch primer.
- (2) After the preceding operations, and prior to the erection of cladding, if any, the Contractor shall apply to the superstructure steelwork the finish coat(s) as specified. Cladding shall not be erected until the paintwork has been approved. Any damage to shop coats will be made good on site prior to application of the site coats. If steel has been exposed then the area shall be blast cleaned primed and receive all shop coats to the required standard.
- (3) Before the site painting coats are applied, the surfaces shall be lightly abraded, if required by the manufacturer's instructions, and washed with clean water to remove salt and other impurities. Paint shall not be applied to the embedded portions of metal items except those within 75mm of the finished concrete surface.

7.25 Earthing and Bonding System

Earthing and bonding system shall comply with EN-50122-1 Railway applications fixed Installations-Part I: provisions relating to electrical safety and earthing and BS 7430 Code of Practice for Earthing.

8. FORMWORK

8.1 General

These specifications shall be read in conjunction with the MORTH specifications and CPWD/Maharashtra PWD specifications with correction slips/amendments up to date, and other relevant specifications described in the Contract.

8.2 Material

Formwork shall be of timber, plywood (including marine plywood), steel or any other suitable material capable of resisting damage to the contact faces under normal conditions of erecting forms, fixing steel and placing concrete. The selection of materials suitable for formwork shall be made by the Contractor based on the quality consistent with the specified finishes and safety. The entire responsibility of planning, designing, erecting, dismantling, shifting and safety of false work lies with the Contractor.

All formwork and formwork supports (centering, props, scaffolds, ladders etc.) shall be in structural steel only and preferably of pipes conforming to IS:806, IS:1161, IS:1239, IS:2750. Wooden ballies shall not be permitted as props/formwork supports.

All props shall be properly braced using x & k bracings. Ladders to be used at site should have treads and shall be fabricated from structural steel. Wooden/bamboo/aluminium/pipe ladders shall not be permitted.

8.8.1 Timber

Timber used for formwork shall be easily workable with nails without splitting. It shall be stable and not liable to warp when exposed to sun and rain or wetted during concreting.

8.8.2 Plywood

Plywood used for formwork shall be minimum 12mm thick. Shuttering quality plywood complying with IS:4990. Suitable stiffeners and walers shall be provided depending on the shuttering design.

8.8.3 Steel

Steel formwork shall be made of minimum 4mm thick black sheets stiffened with angle iron frame made out of M.S. angles 40mm x 6 mm supported at suitable spacing.

8.3 Design & Drawings

- (1) The permissible stresses in materials in all Temporary Works such as formwork, falsework, staging, launching and the like shall be the same as for the Permanent Works. The Contractor's checked and verified calculations and drawings of the same including construction sequence (along with soft copy in CD ROM) shall be submitted to the Engineer for obtaining Notice of No Objection.
- (2) All constructed Temporary Works shall be also inspected by the Contractor's Design Checker and an inspection report shall be submitted to Engineer. All Temporary Works shall be robust, safe and constructed in such a way that the concrete can be properly placed and thoroughly compacted to obtain the required shape, position and level subject to specified tolerances. It is the responsibility of the Contractor to obtain the results required by the Engineer, whether or not some of the Work is sub-contracted. Agreement of the temporary works by the Engineer shall not diminish the Contractor's responsibility for the satisfactory performance of the same, nor for the safety and co-ordination of all operations.
- (3) The design of false work should be such as to facilitate easy and safe access to all parts for proper inspection.
- (4) Methodology for removal of form should be planned as a part of total formwork design process.
- (5) In case of pre-stressed concrete work, careful consideration shall be given to re-

distribution of loads due to pre-stressing.

8.4 Formwork for Exposed Concrete Surfaces

The facing formwork, unless indicated otherwise in drawings, shall generally be made with materials not less than the thickness mentioned below for different elements of the structure:

1. Plain slab soffit, and sides of beams, joists and ribs and side of walls, , parapets, etc shall be made with:
 - a. Steel plates not less than 4mm thick of specified sizes stiffened with a suitable structural framework and fabricated true to plane
 - b. Timber planks of 20mm actual thickness and of specified surface finish, width and reasonable length,
 - c. Plywood not less than 12mm thick (IS:4990 - Specification for Plywood for Concrete Shuttering Work) stiffened with a suitable timber frame work or 3mm thick plywood with a 20mm timber plank backing, of specified sizes stiffened with a suitable timber framework and bracing. At joints 6mm/10mm sponge to be provided.
2. Bottoms of beams, sides of columns shall be formed using the following materials.
 - a. a.Steel plates not less than 5mm thick of specified sizes stiffened with a suitable structural framework, and fabricated true to plane
 - b. Timber planks of 35mm actual thickness and of specified surface finish, width and reasonable length,
 - c. Plywood not less than 12mm thick (IS:4990), of specified sizes stiffened with a suitable timber framework.
3. For precast segments, portals, tunnel connections and the like, suitable steel formwork shall be used.

8.5 Formwork for Sloped Surfaces

- 1 Forms for sloped surfaces shall be built so that the formwork can be placed board-by-board immediately ahead of concrete placement so as to enable ready access for placement, vibration, inspection and finishing of the concrete.
- 2 The formwork shall be built in such a way so that the boards can be removed one by one from the bottom up as soon as the concrete has attained sufficient stiffness to prevent sagging. Surfaces of construction joints and finished surfaces with slopes steeper than 2 horizontal 1 vertical shall be formed as required herein.

8.6 Formwork for Curved Surfaces

- 1 The Contractor shall interpolate intermediate sections as necessary and shall construct the forms so that the curvature will be continuous between sections. Where necessary to meet requirements for curvature, the form lumber shall be built up of laminated splices cut to make tight, smooth form surfaces.
- 2 After the forms have been constructed, all surface imperfections shall be corrected and all surface irregularities at matching faces of form material shall be dressed to the specified curvature.

8.7 Erection of Formwork

The following shall apply to all formwork:

- 1 Before fabricating the forms the Contractor shall submit for seeking Engineer's Notice of No Objection, the design of forms and the types of material to be used. (Ref. ACI 347 Formwork for Concrete or equivalent I.S. Code).
- 2 All shuttering planks and plates shall be adequately backed by a sufficient number and size of walers or framework to ensure rigidity during concreting. All shutters shall be adequately strutted, braced and propped to prevent deflection under deadweight of concrete and superimposed live load of workmen, materials and plant, and to withstand pouring rate and vibration.
- 3 Vertical props shall be supported on wedges or other measures shall be taken so that the props can be gently lowered vertically during removal of the formwork. Props for an upper level shall be placed directly over those in the level immediately below, and the lowest props shall bear on a sufficiently strong area. Care shall be taken that all formwork is set plumb and true to line and level or camber or batter where required.
- 4 Provision shall be made for adjustment of supporting struts where necessary. When reinforcement passes through the formwork care shall be taken to ensure close fitting joints against the steel bars so as to avoid loss of fines during the compaction of concrete.
- 5 If the formwork is held together by bolts, these shall be so fixed that no iron will be exposed on surfaces against which concrete is to be laid and within the concrete cover to the steel reinforcement. In any case wires shall not be used with exposed concrete formwork. If the Contractor elects to use tie-bolts running through the concrete then the Contractor shall define the location and size of such tie-bolts and submit his proposals for obtaining Notice of No Objection from the Engineer. The tie-bolts shall be so designed that their removal on de-shuttering does not leave any embedment within the concrete cover to steel reinforcement. Holes left in the concrete by these tie-bolts shall be filled by the concrete repair material and the methodology set out in the Contractor's noticed proposal.
- 6 Provision shall be made in the shuttering for beams, columns, and walls for a port hole of convenient size so that all extraneous materials that may be collected could be removed just prior to concreting.
- 7 Formwork shall be so arranged as to permit removal of forms without jarring the concrete. Wedges, clamps and bolts shall be used wherever practicable instead of nails.
- 8 The formwork for beams and slabs shall be so erected that forms on the sides of the beams and the soffit of slabs can be removed without disturbing the beam bottoms or props under beams.
- 9 Surfaces of forms in contact with concrete shall be oiled with a mould oil of noticed quality form releasing agent. The use of mould oil which results in blemishes of the surface of the concrete including diesel, burnt oil and any other lubricating oil shall not be allowed. mould oil shall be applied before reinforcement has been placed and care shall be taken that no oil comes in contact with the reinforcement while it is being placed in position. The formwork shall be kept thoroughly wet during concreting and the whole time that is left in place.

- 10 Immediately before concreting is commenced, the formwork and other related arrangements shall be carefully examined to ensure the following.
 - a. Removal of all dirt, shavings, sawdust and other refuse by brushing, washing and compressed air/vacuum cleaning.
 - b. The tightness of joints between panels of sheathing and between these and any hardened core.
 - c. The correct location of tie bars, bracing and spacers, and especially connections of bracing.
 - d. Adequate cover blocks are in place
 - e. Straightness and plumbness of the form work
 - f. Side supports/restraints for the form work are enough and robust
 - g. Construction joint (wherever applicable) is properly prepared
 - h. That all wedges are secured and firm in position.
 - i. That provision is made for traffic on formwork not to bear directly on reinforcing steel.
 - j. Pouring platform along with its approach from ground is robust and safe for workers movement.
 - k. Arrangement for vibrators for compaction of concrete
 - l. Sequence of concrete pouring is well defined and is agreed upon by the Engineer and is explained to concrete pouring team
 - m. The Pouring area is well lit.
 - n. Curing arrangements are well planned and agreed upon by the Engineer.
 - o. The concrete protection measures in accordance with this Specification are in place.
- 11 The Contractor shall ensure dimensional accuracies of the Work and for the general arrangement of propping and bracing. (IS:3696 - Safety Code of Scaffolds and Ladders, IS:4014 Steel Tubular Scaffolding I & II). All scaffolding and staging shall be either of steel tubes or built up section of rolled steel with adequate bracing at several levels in each perpendicular direction connecting each prop. In addition to this diagonal bracing should be provided in elevation ideally at 45 degrees or between 30 degrees and 60 degrees. The Contractor shall be entirely responsible for the adequacy of propping, and for keeping the wedges and other locking arrangements undisturbed through the de-centering period. (IS:8989 Safety code for erection of concrete framed structures)
- 12 Formwork shall be continuously watched during the process of concreting. If during concreting any weakness develops and formwork shows any distress the Work shall be stopped and remedial action shall be taken.

8.8 Concrete Finishes

This section deals with the surface of concrete on which forms had been fixed while concreting.

8.8.1 Formed Surface

- (1) Allowable deviation from plumb or level and from the alignment profile, grades and dimensions shown on the drawings is defined as "tolerance" and is to be distinguished

from irregularities in finishes as described herein. Tolerances in concrete construction are specified elsewhere.

- (2) The classes of finish and requirements for finishing of concrete surface shall be as shown on the drawings or as hereinafter specified.
- (3) Completed concrete surface shall be tested, where necessary to determine whether surface irregularities are within the limits specified hereinafter.
- (4) Surface irregularities are classified as "Abrupt" or "Gradual". Offsets caused by displaced or misplaced form sheathing, or form sections or by loose knots or otherwise defective timber form will be considered as abrupt irregularities, and shall be tested by direct measurements. All other irregularities shall be considered as gradual irregularities and will be tested by use of template, consisting of a straight edge or the equivalent thereof for curved surfaces. The length of the template shall be 150 cm for testing of formed surfaces and 300 cm for testing of unformed surfaces.
- (5) The classes of finish for formed concrete surfaces are designated by one of the symbols F1, F2, F3 and F4. Unless otherwise specified or indicated on drawings, these classes of finish shall apply as follows:
 - (a) **Finish F1** : This finish applies to surfaces where roughness is not objectionable, or surface that will otherwise be permanently concealed. Surface treatment shall be the repair of defective concrete, correction of surface depressions deeper than 25 mm and filling of tie rod holes. Form sheathing will not leak mortar when concrete is vibrated. Forms may be manufactured with a minimum of refinement.
 - (b) **Finish F2** : This finish is required on surfaces permanently but not prominently exposed to public view for which other finishes are not specified except F1. Forms shall be manufactured in a workmanlike manner to the required offsets or bulges. Surface irregularities shall not exceed 5mm for abrupt and 8mm for gradual irregularities measured with a 1.5 m template.
 - (c) **Finish F3** : This finish is required for coarse textured concrete surfaces intended to receive plaster, stucco or wainscoting. Surface irregularities shall not exceed 5mm for both abrupt and gradual irregularities.
 - (d) **Finish F4** : This finish is designated for surfaces prominently exposed to public view where appearance is also of special importance.. To meet with requirements for F4 finish, forms shall be manufactured in a skilful, workmanlike manner, accurately to dimensions. There should be no visible offsets, bulges or misalignment of concrete. At construction joints, the forms shall be rightly set and securely anchored close to the joint. Abrupt and gradual irregularities shall not exceed 3mm. Irregularities exceeding this limit shall be reduced by grinding to a level of 1:20 ratio of height to length. Jute bag subbing or sand blasting shall not be used.

8.8.2 Unformed Surfaces

- (1) The classes of finish for unformed surfaces are designated by symbols U1, U2, U3 and U4. Unless otherwise specified or indicated on drawings, these classes of finish shall apply as follows:
 - (a) **Finish U1**: This finish applies to unformed surfaces that will be concealed permanently or otherwise where a screeded surface finish meets the functional requirements. Finish U1 is also used as the stage of finishes for U2 and U3. Finishing operations shall consist of sufficient levelling and screeding to produce an even uniform surface. Surface irregularities shall not exceed 10mm.
 - (b) **Finish U2** : This is floated finish, and used on all outdoor, unformed surfaces.

Finish U2 is also used as the second stage of finish for U3. Floating to be performed manually or mechanically on stiffened screed surface shall be minimum to produce textured surface. If finish U3 is to be applied, floating shall be continued till a small amount of mortar without excess water is brought to the surfaces so as to permit effective trowelling. Surface irregularities shall be removed.

- (c) **Finish U3 :** This is a trowelled finish and shall be used for tops of parapets, etc prominently exposed to view. When the floated surface has **hardened** sufficiently, steel trowelling shall be started. Steel trowelling on hardened, floated surface shall be performed with firm pressure to produce a dense uniform surface free from blemishes and trowel marks and having slightly glossy appearance. Surface irregularities shall not exceed 5mm.
 - (d) **Finish U4 :** This is a steel-trowelled finish, similar to finish U3, except that light **surface** pitting and light trowel marks such as obtained from the use of machine trowelling will be acceptable, provided that surface irregularities do not exceed the limits specified for finish U3.
- (2) Unformed surfaces which are nominally level shall be sloped for drainage as shown on drawings unless the use of other slopes or level surface is indicated on drawings. Narrow surface such as tops of parapets, walls and kerbs shall be sloped approximately 10mm per 300mm of width. Broader surface such as roadways platform shall be sloped approximately 5mm per 300mm of width. Finishes of floor and roof slabs shall be sloped Exposed Concrete Work
 - (3) Exposed concrete surfaces shall be smooth and even, originally as stripped without any finishing or rendering. The surface shall be rubbed with carborundum stone immediately on striking the forms. The Contractor shall exercise special care and supervision of formwork and concreting to ensure that the cast members are made true to their sizes, shapes and positions and to produce the surface patterns desired. No honeycombing shall be allowed. Honeycombed parts of the concrete including the other surface defects in the concrete shall be removed by the Contractor as per the methods, which do not affect the strength of adjoining concrete.
 - (4) Part of defective concrete thus removed shall be re-cast using fresh concrete of same grade or noticed quality concrete repair material depending upon the size, location, thickness of the defective concrete and structural behavior of the member having defective concrete. Contractor shall ensure that no air bubbles are formed on the exposed surface. Concrete pouring sequence, vibration methodology etc shall be planned to avoid air bubbles.

8.9 Age of Concrete at Removal of Formwork

In accordance with CPWD/Maharashtra PWD Specifications or IS:456. Immediately after the forms are removed, they shall be cleaned with a jet of water and a soft brush.

8.10 Stripping of Formwork

The work of formwork removal should be planned and a definite scheme of operation worked out. Formwork shall be removed carefully without jarring the concrete, and curing of the concrete shall be commenced immediately. Concrete surfaces to be exposed shall be rubbed down with carborundum stone or bush-hammer to obtain a smooth and even

finish. Where the concrete requires plastering or other finish later the concrete surface shall be immediately hacked lightly all over using noticed methods.

8.11 Reuse of Forms

The Contractor shall not be permitted reuse of timber facing formwork brought new on the works for more than 5 times for exposed concrete formwork and 8 times for ordinary formwork. 5 or 8 uses shall be permitted only if forms are properly cared for, stored and repaired after each use. Use of different quality boards or the use of old and new boards in the same formwork shall not be allowed. If any other type of special or proprietary form work is used, the number of times they can be used shall be given a Notice of No Objection from the Engineer.

8.12 Formwork for Precast / Pre-stressed Concrete

(1) The provisions in this section shall be considered supplementary to the general provisions stated above and additional Technical Specifications for pre-cast segments. Pre-cast concrete members and panels shall be made in accurately constructed moulds, on a properly prepared casting bed.

The Contractor shall submit detailed drawings of formwork to the Engineer for obtaining his Notice of No Objection. Finishing with cement mortar shall not be allowed.

(2) The formwork should be so designed that it does not restrain the shrinkage movements and possible shortening due to pre-stress of the concrete. The formwork shall be of sturdy construction with special considerations to shutter vibrators when used. All edges and joints of the formwork should be designed and sealed so that no cement grout can escape and there is no wedging or keying to the concrete. The effect of curing on the formwork should be given special consideration. Depending on care, curing, erection and maintenance of the formwork after stripping, the number of uses that can be made with different types of formwork shall be such that the quality of structural element is maintained to the required standards.

(3) Stripping

As soon as the pre-cast units have attained sufficient strength, the formwork shall be stripped. The pre-cast unit shall be lifted uniformly out of the formwork without being subjected to tilting or restraint effects.

8.13 Special Architectural Finishes

Special noticed architectural finishes like grooves, logos, engravings/projections in inset and out set as per the noticed design shall be provided by fixing monolithic rubber forms or any other noticed material fixed on the entire surface of the formwork. The shore hardness of the rubber shall be appropriate to ensure strength, flexibility and elasticity. The rubber shall be cold-cured (preferably polyurethane based) and fixed to the formwork under controlled conditions in shade and air temperature not exceeding 28°C.

The form liners shall be shrinkage free, solvent free and shall be impervious to abrasion by Concrete, resistant to concrete pressure and heat resistant up to 70°C dry heat. Formwork liner fixation shall be factory made under close tolerances and stage inspections.

If proprietary system of formwork is used, detailed information as given in Appendix A herein shall be furnished to Engineer for obtaining Notice of No Objection before use.

Appendix –A

Information to be Supplied by Manufacturers of Proprietary Systems of form Work

1. General

- 1.1 The information which the manufacturer is required to supply shall be in such detail as to obviate unsafe erection and use of equipment due to the intention of the manufacturer not having been made clear or due to wrong assumptions on the part of the user.
- 1.2 The user shall refer unusual problems of erection/assembly not in keeping with intended use of equipment, to the manufacturer of the equipment.

2. Information Required

- 2.1 The manufacturers of proprietary systems shall supply the following information;
 - a. Description of basic functions of equipment.
 - b. List of items of equipment available, giving range of sizes, spans and such like, with manufacturer's identification number or other references.
 - c. The basis on which safe working loads have been determined and whether the factor of safety given applies to collapse or yield.
 - d. Whether the supplier's data are based on calculations or tests. This shall be clearly stated as there may be wide variations between results obtained by either method.
 - e. Instructions for use and maintenance, including any points which require special attention during erection, especially where safety is concerned.
 - f. Detailed dimensional information, as follows :
 - i. Overall dimensions, depths and widths of members.
 - ii. Line drawings including perspectives and photographs showing normal uses.
 - iii. Self weight.
 - iv. Full dimensions of connections and any special positioning and supporting arrangements.
 - v. Sizes of members, including tube diameters and thicknesses of material.
 - vi. Any permanent camber built into the equipment.
 - vii. Sizes of holes and dimensions giving their positions.
 - viii. Manner of fixing including arrangements for sealing joints.
 - ix. Method of de-stripping, storing & shifting.
 - g. Data relating to strength of equipment as follows:
 - i. Average failure loads as determined by tests.
 - ii. Recommended maximum working loads for various conditions of use.
 - iii. Working resistance moments derived from tests.
 - iv. Working shear capacities derived from tests.
 - v. Recommended factors of safety used in assessing recommended loads and deflections based on test results.
 - vi. Deflections under load together with recommended pre-camber and limiting deflections.
 - vii. If working loads depend on calculations, working stresses should be tested. If deflections depend on theoretical moments of inertia or equivalent moments of inertia rather than tests, this should be noted.
 - viii. Information on the design of sway bracing against wind and other horizontal loadings.
 - ix. Allowable loading relating maximum extension of bases and/or heads.
 - x. Any restrictions regarding usage of any component or full assembly with regard to spans, heights and loading conditions.

9. CUT AND COVER CONSTRUCTION

9.1 GENERAL

- (1) Cut and cover construction shall comply with the relevant requirements of the Contract (Outline Design Specification and this Specification) for temporary ground support including elements to be incorporated into Permanent Works.
- (2) Temporary ground support including elements to be incorporated into the Permanent Works : are described in Sections 2, 4, 5 of this Specifications.
- (3) Support by bracing, ties or anchors: are described in Sections 4 and 7 of these Specifications.
- (4) Excavation and backfilling: are described in Section 2 of these Specifications.
- (5) Reinforced concrete construction: are described in Sections 5 of these Specifications.
- (6) Vibration recording devices shall be provided to monitor for vibrations which may cause damage to the proposed constructions and EBS. These devices shall be installed at intervals and locations to provide comprehensive coverage of the Works. Unless otherwise directed by the Fire/Life Safety Authorities/Agencies, these devices shall record ground accelerations generated by the Works to ensure that these accelerations do not exceed the values set by the Relevant Authorities or those determined by the Contractor for the stability and safety of the Temporary and Permanent Works and adjacent EBS and as accepted by the Engineer.

9.2 WATERPROOFING`

9.2.1 General

- (1) Submission, Requirements, Method Statements and Working Drawings
 - a) The Contractor shall include details of his intended waterproofing methods in his design submissions and obtain Notice of No Objection by the Engineer.
 - b) The water-tightness standards to be applied to all underground water tight structures shall be in accordance with the requirements given in this Contract
 - c) Manufacturer's literature shall be provided where necessary to confirm the suitability of the proposed details.
 - d) The Contractor shall produce and submit comprehensive Working Drawings showing all details and procedures for waterproofing of the Works including membrane stops, injection tube systems, details at penetrations including King Post
 - e) The proposed waterproofing material shall be suitably resistant to all chemicals with which they are likely to come into contact.
 - f) Test report to demonstrate that the specified properties are met
- (2) Waterproofing Application
 - a) Waterproofing material shall be installed only by the manufacturer of the products or his noticed applicator. The Contractor shall submit a method

statement, prepared in conjunction with the applicator and endorsed by the manufacturer of the material, describing the details of the waterproofing works including protective measures at all stages.

- b) Waterproofing material shall be stored in a cool place. The materials which are subsequently exposed to sunlight shall not be affected by atmospheric conditions or ultra violet light as stated by material manufacturer.
- c) All cracks on exposed surfaces of external structural membranes shall be effectively sealed in accordance with this Contract before applying any waterproofing system. Inside rendering shall not be acceptable as a method of making the joint water tight.
- d) No material shall be used which is beyond its manufacturer's expiry date.
- e) The Engineer may require the Contractor to carry out a trial application of the waterproofing materials for the proposed waterproofing system.
- f) No waterproofing works shall commence without the written consent of Engineer.
- g) Damages or non-compliant section of membrane shall be repaired in accordance with the manufacturer's recommendation and as accepted by the Engineer.

9.2.2 Structural Concrete Works

(1) Concrete Joints

- a) Notwithstanding the provision of waterproofing membranes, the Contractor shall be designed as undrained Structures i.e, the ground water shall not be allowed to drain into the structures (refer to Section 2, Outline Design Specification). Before placing new concrete against concrete that has already hardened, the face of the old concrete shall be treated in accordance with Section 5 of this Specification.
- b) Concrete shall be cast watertight between construction joints. Should such concrete be found to leak or to have moist patches, the affected concrete shall be rectified by injection of resin material, breaking out and recasting, or other methods of sealing within the concrete. Inside rendering will not be accepted as a method of making watertight.
- c) In top surface of base slab and roof slab at junction with diaphragm walls, a 25 X 25 mm recess will be cast in the slab and subsequently filled with a high performance water stop grout of the crystalline growth type.
- d) All construction joint in external slabs and walls shall be cast with 25 X 25 recess on the outer face (except the base slab where it will be provided on upper face). The recess shall be filled with a high performance water stop grout of the crystalline growth type.

(2) Water-stops

All water-stops used in the Works shall be of swelleble water bar PVC material and of a type appropriate to the location. All joints shall be made with moulded or prefabricated intersection pieces properly jointed in accordance with the manufacturer's instructions. The water-stops shall be installed so that they are

securely held in their correct positions whilst the concrete is being placed. No holes shall be made through any water-stop except where provided for by the manufacturer.

(3) Piles and Pilecaps

Where the waterproofing membrane is discontinuous to permit structural connections to piles and pile caps, water tightness shall be achieved by use of a concrete additive in accordance with the manufacturer's recommendations.

(4) Fillers and Sealant to Expansion Joints

- a) All materials used to fill expansion joints shall be such that they will accept the calculated movements of the joints without extrusion and shall not shrink away from either surface of the joints. Consented-to backing strips and fillers shall be used in accordance with the manufacturer's recommendation.
- b) Where joints are required to be filled with consented-to polysulphide or polyurethane sealant, the material shall comply with BS 4254 or BS 5212.
- c) The appropriate sealant grades shall be used for horizontal and vertical joints, and the joints shall be thoroughly cleaned and primed with the appropriate primer before applying the sealant. The sealant shall be of a colour to match as nearly as possible the colour of the adjoining surfaces where it is to be permanently exposed.
- d) The sealing material shall be used and applied strictly in accordance with the manufacturer's instructions. The Contractor's attention is drawn to the undesirability of the sealant being smeared over the adjacent surfaces, and appropriate precautionary measures, including the use of masking tape, shall be taken to avoid this.

9.2.3 Cleaning and Preparation of Surfaces

No laying shall be commenced until all rough edges and excrescencies have been removed from the surfaces to receive the membrane. Surface depressions shall be filled in accordance with consented-to procedures and the filling allowed to set. The surface to be waterproofed shall be thoroughly cleaned, dried and swept, and kept clean and dry at all stages until the Work is complete.

The surfaces of structures which are to be waterproofed are to be primed with the appropriate primer to ensure good adhesion between the structure and the waterproofing medium.

9.2.4 Waterproofing Underground Structures

The following requirements are applicable to all underground structures built by cut and cover methods from the surface where bonded membranes have been specified. A complete method statement for the Works together with relevant shop drawings and details shall be submitted to the Engineer for obtaining Notice of No Objection prior to application of the system. The method statement shall include all QA/QC procedures required to ensure the integrity of the system. Proposed manufacturers and applicators should have similar experience on previous Metro Projects in India..

9.2.5 Base Slabs with Bonded Membranes

1. Waterproofing shall consist of a pre-applied, flexible, CE Marked, fully-bonded HDPE membrane system loosely laid to a blinding concrete layer but designed to intimately bond to liquid concrete placed against it (i.e Base Slab) to prevent lateral water migration between membrane and Base slab, membrane . Membrane shall consist of a thick white HDPE carrier film, a highly aggressive pressure sensitive adhesive, trafficable, weather and dirt resistant non absorbent protective coating which bonds integrally to poured concrete of base slab & final layer of clear PE Release liner as a protection (Release liner to be removed before laying reinforcement). The membrane along with ancillaries shall be BBA certified or equivalent for basement grades 1,2 & 3 to BS 8102:2009. The membrane shall be chemically resistant in all types of soil or water, has a zero permeance to moisture, is solar reflective to reduce heat gain while exposed, does not activate prematurely due to wet conditions and is unaffected by ground settlement beneath slabs. No primer required enabling membrane application in damp conditions, No protection screed required enabling faster construction. concrete with waterproofing admixture or other similar system with a Notice of No Objection from by the Engineer.
2. Blinding concrete shall be a minimum of 75 millimetres thick. Where ground conditions are such that there would be risk of localised settlement of this blind layer during or after subsequent construction operations, the concrete thickness shall be increased and reinforced as necessary to avoid such localised settlement. A drainage layer shall be provided beneath the blinding concrete where necessary to ensure that the blinding concrete is not damaged by hydrostatic pressures prior to casting of the structural slab.
3. The waterproofing membrane shall be laid by the manufacturer's applicators strictly in accordance with the recommendations of the manufacturer and with accepted good practice in the trade. All detailing components of the system has to be compatible with the proposed waterproofing membrane and has to be manufactured and supplied by the manufacturer of waterproofing membrane. Original manufacturer's MTC (Manufacturer Test Certificate) should be submitted prior to start of the work for traceability of the product. .
When laying the membrane, no other works shall be carried out in the vicinity which may cause personnel or equipment to intentionally or accidentally come into contact with the membrane before the base slab has been casted directly over the membrane without providing protective screed, membrane is designed to receive direct reinforcement . Concrete rebar supports (i.e cover blocks) are recommended when the membrane is installed over a compacted earth or stone substrate and they shall be 75 mm away from the lap joints. Expanded polystyrene boards/Shuttering Plywood or similar shall be used to protect the extended membrane for further overlapping and beyond the limits of concrete pour The membrane needs to be protected from direct sunlight/UV exposure by placing a tarpaulin sheet in case the base slab cannot be casted in 56 days (42 days for hot climatic conditions).
4. Where openings must be left in the membrane for structural continuity of piles or for other items projecting below the soffit of the base slab, the size of opening in the membrane must be kept to a minimum. The opening shall be sealed all round by asphalt modified urethane liquid membrane. .
5. Where external wall above the base slab are to be constructed in open cut, the membrane laid beneath the base slab can be turned vertically (i.e placing the membrane inside the removable or permanent shuttering) and minimum 150

millimeter overlapping with wall membrane. Blinding concrete beneath the membrane need not to be extended 500 millimetres beyond the limits of the structural slab.

6. Where the structural base slab will be cast against diaphragm walls, piled walls, or rock faces, the membrane shall be turned up against the face of the wall by a minimum of 100 millimetres and then turned horizontally into a 20 millimetres by 20 millimetres chase cut into the wall face, and sealed with a bituminous compound or sealant. The wall surface shall first be leveled by the application of a steel trowled mortar coat where there is any risk that its roughness may cause the membrane to be punctured. The construction joints shall form a sealed compartment for which general arrangement shall be indicated in the drawings.
7. Concrete waterproofing admixture shall be the crystalline growth type. The admixture shall have a proven track record of successful application in similar conditions. The admixture shall be applied to the full thickness of the base slab and extend to the sidewalls of sumps and similar depression of the base slab so as to form a continuous watertight surface.
8. Prior to construction, trial mixes are to be conducted under the supervision of the Engineer and with the manufacturer present to confirm that the proposed mix conforms to strength, w/c ratio, slump and other requirements. The trial mix concrete shall further have an average water permeability coefficient when tested at 28 days of not greater than 5×10^{-13} m/s under 5 kgf/cm^2 and an average penetration depth not greater than 10mm as measured by DIN 1048.

9.2.6 External Walls to Structures Built in Open Excavation

1. Waterproofing shall be provided and shall conform to the requirements of this Contract. Concrete surfaces to be waterproofed shall be prepared where necessary by grinding and local filling with mortar having a steel troweled finish to provide a smooth surface free from voids, loose aggregate and sharp protrusions. A brickwork protection layer or heavy duty puncture resistant protection boards shall be provided to the membrane system to ensure that no damage is suffered to the membrane during backfilling operations. Backfilling to be done in stages with proper compaction and within 2-3 days of membrane application.
2. Where pipe penetrations are required through the wall, these shall be formed as sections of galvanized steel pipe of the required diameter, with 36 millimetre welded flange plates having outside diameter 300 millimetres greater than the diameter of the pipe. The waterproofing membrane shall be fitted into the pipe penetration to maintain the integrity of the waterproofing system as per a recommended detail which shall be proposed by the waterproofing manufacture and with a Notice of No Objection from the Engineer.

9.2.7 External walls Built against Diaphragm Walls

- (1) Where in-situ concrete lining walls are cast against diaphragm walls having water bars at panel joints, no waterproofing membrane is required at the interface between the diaphragm and in-situ walls. At base and roof slab levels, two bentonite/polymer based sealing strips 100mm either side of the slab center line shall be provided horizontally along the joint.
- (2) In all cases where slabs are cast against diaphragm walls an injection grouting system shall be provided in each diaphragm wall panel joint at the base and roof slab level, sufficient to enable the joint to be grouted between the inner face of the diaphragm

wall and the innermost water bar across the panel joint. After completion of the base slab but before concreting of the in-situ lining wall, if any, the base slab level grout injection shall be carried out.

- (3) After the grout has set the ground water level beneath the joint shall be allowed to rise to 1 meter above slab level and left for 7 days. The panel joint shall be inspected for water leakage or dampness and if present the joint shall be re-grouted and re-tested. Grout injection at roof slab level shall be carried out after completion of the roof slab.

9.2.8 External Walls Built Against Pile Walls Or Rock Or Soil Faces

- (1) Where in-situ concrete walls are cast against temporary pile walls, rock or soil faces, or any other material, a pre-applied, flexible, CE marked, fully bonded HDPE membrane system shall be provided. The face against which the in-situ wall is to be cast shall be built up by with a steel-trowelled finish, to provide a smooth surface free from voids, loose aggregating and sharp protrusions. Where the thickness of mortar would be excessive, concrete shall be cast as primary filler.
- (2) Material and application requirement for the waterproofing membrane shall be in accordance with this Contract for base slabs. The membrane shall be lapped to the base slab membrane and continued upwards to 300 millimetres above roof slab level, or to the limit of the face against which the in-situ wall is to be cast if this is lower. In such cases suitable provision shall be made for continuity of the membrane with the water-tightness provisions to the wall above. Unless it is to be bonded to the structural wall the membrane shall be protected by suitable geofabric (fleece) sheeting hung from above and left in place.

9.2.9 Roof

- (1) Waterproofing shall be provided by a two component, fast setting, fully bonded liquid membrane system of hybrid polyurea type and shall conform to the requirements of this Specification.
- (2) Where external walls above the base slab are to be constructed in open cut or cast directly against diaphragm walls, piled walls and the like, the roof/top slab membrane shall be extended and turned down the wall and welded to the external water-bar across the roof slab/wall construction joint to form the sealed compartment to comply the Contract water-tightness requirements.
- (3) A 75 millimetre thick concrete protection layer shall be applied over the membrane system for protection during backfilling operations. A 200 gsm non woven geotextile fabric with 75 mm end & side overlaps shall be used as an isolation/separation layer before laying final protective screed.

9.2.10 Waterproofing of Below Grade Construction Joints

- (1) All below-grade construction joints shall incorporate a re-injectable hose which shall be capable of performance in the following manner:
 - (a) The hose should be of a re-injectable nature and be capable of re-injection several times over the life of the structure.
 - (b) Installation should be seamless and without cuts and joints when installed at multiple bends/corners/circular paths in congested heavily reinforced

- concrete.
- (c) The hose shall be capable of following infinite changes in direction and turn corners with ease without impeding the path of grout injected through the hose.
 - (d) Valves shall be enclosed in a retaining mesh to avoid displacement of these during pressure testing and injection.
 - (e) The injection resin should be of a re-sealable type made of an acrylate hydrogel, capable of being vacuumed out of the hose with water (not flushed), before it gels.
 - (f) The injection resin should be of a low viscosity (<50 Centipoises) to enable maximum penetration of very narrow fissures.
- (2) The system shall be placed in 10 to 12 metre lengths with entry port and vent ends terminating in a junction box and shall offer the user the option of vacuuming and re-injection should this be necessary. The junction box shall be placed in vertical elements adjacent to the joint. Should this not be possible the junction box and its cover should be installed flush with the floor level and should be able to tolerate vehicular traffic.
 - (3) The system should be used to seal off the construction joints permanently thus providing protection to the steel reinforcement.
 - (4) Where indicated, all construction joints (vertical and horizontal) shall have the re-injectable hose installed. The re-injectable hose system shall be injected at least once, prior to switching off the dewatering with a vinyl ester methacrylate based injection resin of appropriate viscosity.

9.2.11 Waterproofing To Surface And Partially Underground Structures

(1) Ground Slabs

Waterproofing to ground slabs shall be similar to that specified in clause 9.2.4, and elsewhere in this Contract for base slabs for underground structures.

(2) External Walls Below Ground Level

The requirements of Clauses 9.2.4, 9.2.5, 9.2.6, 9.2.7 and 9.2.8) shall apply, along with any other requirement given in Contract shall apply to all external walls at depths greater than 500mm below finished ground level.

9.2.12 Stray current collectors

These shall be provided as per the Contract.

9.2.13 Warranty

All waterproofing systems shall be warranted against all defects for a minimum period of ten (10) years from the date of Completion of Works. The warranties shall cover the whole of the waterproofing systems and shall be provided jointly and severally by the Contractor and the Supplier/Applicator.

9.3 Hard Rock Excavation

This section is applicable to construction of shaft and cut and cover station in rock, but not for excavation of bored and NATM tunnels in rock,

1. Excavation Method

The Contractor shall provide to the Engineer full details of the proposed rock excavation methods for obtaining his 'Notice of No Objection' at least 28 days before the commencement of excavation.. Similarly, the Contractor shall submit his plans for methods for monitoring, particularly vibration adjacent to EBS

2. Blasting and other methods (where blasting is not permitted) such as mechanical, pneumatic or hydraulic plants or expansive chemical agents etc. are expected to be used in rock excavation/Rock Stabilisation
 - a) The rock stabilization measures should be based on rock joint mapping result carried out by the Contractor and agreed by the Engineer. The rock joint mapping results shall be kept on the Site and submitted to the Engineer within 48 hours after the excavation. The name of the personnel who will carry out mapping shall be submitted to the Engineer for Notice of No Objection.
 - b) The Contractor shall carry out rock stabilization measures with minimum delay after the excavation of each round. In order to facilitate this, the Contractor shall request that the Engineer always accompanies him when inspecting the existing structures and excavated rock surfaces revealed after excavation operations.
 - c) All rock stabilization proposals shall be submitted to the Engineer for Notice of No Objection.

9.4 Blasting

9.4.1 General

9.4.1.1 Definitions

- (1) "**Controlled blasting**" means that a designed drill and charging pattern has been noticed and will incorporate one of the following techniques.
- (2) "**Pre-splitting**" means drilling a line of closely spaced parallel holes of appropriate diameter along the excavation surface, charging the holes with an appropriate amount of explosive and detonating these holes simultaneously, prior to the main production blast, to shear the rock along the line of drill holes.
- (3) "**Smooth blasting**" means the drilling of a line of closely spaced parallel holes along the excavation surface, with a suitable burden/spacing ratio, loading all the holes lightly with an appropriate amount of explosive and detonating all these charges simultaneously, after the detonation of the main production blast.

9.4.1.2 General Requirements

- (1) All blasting operations shall be conducted under the direction of a certified blaster. Evidence of blaster certification shall be carried by blasters or shall be on file at the Engineer office during blasting operations. The blaster and at least one other person shall be present at the firing of a blast at all times.
- (2) A blast design shall be submitted to the Engineer for 'Notice of No Objection' prior to any blasting operations. The blast design will include sketches of drill patterns, delay times and blasting mats and shall indicate the type and amount of explosives to be used, critical dimensions, and the location and general description of structures to be protected, as well as an outline of design factors to be used, which protect the public and meet the applicable air blast and ground vibration standards. The Work shall be programmed so as to minimise blasting adjacent to previously constructed sections of the Works.
- (3) Every precaution including the use of blast mats, timber boarding or other means

shall be exercised to protect the Works and persons, animals and property in the vicinity of the Site. The Contractor shall accept responsibility for all injury or damage occasioned by any blasting operations and shall make good such damage without any additional payment.

- (4) The Contractor shall, in particular, note the requirement that he must limit to the maximum extent practicable the spillage of material from surface excavations, whether by blasting or other means. To this end the Contractor shall take all necessary precautions including, if necessary, covering the rock prior to blasting with sufficient loose material to prevent the blasted material being thrown into the adjacent areas. If the Engineers is of the opinion that insufficient precautions are being taken to minimise the spillage of material, he may instruct the Contractor to adopt further measures to reduce the spillage. No additional payment will be made to the Contractor for any such measures required and extension of time will not be granted.

9.4.2 Use of Explosives

- (1) Use of explosives for blasting shall be permitted only after obtaining 'Notice of No Objection' from the Engineer and only after all appropriate applications and permits have been approved. Notice of No Objection for blasting does not remove Contractor's liabilities or responsibilities to ensure that his method of blasting is safe and complies with all statutory and imposed limitations.
- (2) A Relevant Authority will issue all blasting permits and related permissions pertaining to storage, transportation, control and use etc. The permits will include local/national requirements and other requirements of the International Fire Code and other international standards for explosive and blasting procedures, explosives training, blaster's handbook and safety practice manual etc.. All explosives and related material shall be in conformity with the requirements of the Relevant Authority having jurisdiction and the specifications contained herewith. Blasting will not be permitted close to any building structure without appropriate monitoring systems and no objection from the Engineer.
- (3) Blasting shall be done only by those experienced in the handling of explosives, and in accordance with the recommendations of the Associated General Blaster's Manual of Accident Prevention (AGCMAP) in Construction and appropriate IS regulations.
- (4) In locations where flying rock may be present, additional overburden shall be ready for use and/or in place before denotation. All trenching operations utilizing explosives shall be suitably backfilled to prevent any fly rock endangerment to persons or property. The use of these procedures does not relieve the blaster of responsibility for damage to life and property.
- (5) Both cartridge and bulk explosives may be used where appropriate.
- (6) Only sufficient explosives and detonators may be brought on to the Site for immediate blasting requirements. Explosives and detonators remaining unused after each blasting operation shall be disposed of, or removed from the Site.
- (7) The Contractor shall appoint a Responsible Person or Persons to order and receive explosives on the Site. The name(s) shall be notified to the Employer/Engineer.

- (8) No persons other than those authorised by the Engineer shall approach within 50m of the area being prepared for blasting, i.e. during charging and firing of the blast holes. The Contractor shall inform the Engineer of the names of his authorised personnel and his method for excluding others.
- (9) The Contractor shall provide an agreed system of warning and preparing the general public and all Site personnel of an impending blast by both audible and visual means and shall ensure that the blasting area is cleared of all personnel immediately prior to blasting. This system shall comply with all statutory requirements.
- (10) The limits for air-overpressure and vibration monitoring together with actions associated with the alert, alarm and action levels shall be addressed in the Blast Assessment Report / Method Statement for the Notice of No Objection from the Engineer.
- (11) The Contractor shall use a lightning detector on site to assess the potential risk of lightning risk during delivery, loading and charging blast holes with explosives. The lightning detector shall be capable of detecting thunderstorms.
- (12) The Contractor shall check for stray electric current at the blasting site prior to commencing charging.
- (13) All blast air, exhaust gases and dust shall be filtered in an agreed manner before being ventilated into the air exhaust system. A detailed method statement will be required for seeking a Notice of No Objection from the Engineer.

Blast partition doors separating the Contractor's Working Areas from the public and other operational areas shall be of adequate fire protection, water tightness, weight, thickness and density to effectively reduce the noise, water and dust transmitted from the Works and confine the effects of the blast to acceptable levels. The effective damping mass of the partitioning materials shall not be less than 30 kg/m^2 Blasting

9.4.3 Delivery of Explosives

- (1) The handling of explosives including storage, transportation and charging will be carried out in accordance with BS 5607, 'Code of Practice for Safe use of Explosives in the Construction Industry' and IS 10386 Part 4 'Handling Storage & Transportation of Explosives'.
- (2) The Contractor shall submit his proposal for explosives collection and delivery for Notice of No Objection from the Engineer. The risk assessment for the proposed arrangement shall be addressed in the Blasting Assessment Report.
- (3) The Vehicle shall not carry more than 200kg of explosives at any one time or the figures agreed by the Engineer. Upon each delivery of explosives, the Vehicle shall be escorted by the Contractor's appointed Responsible Person(s) and armed guards and as agreed by the Relevant Authority & the Employer/Engineer.
- (4) The explosive container shall be secured to the body of the Vehicle.
- (5) At least two serviceable fire extinguishers shall be installed on the Vehicle.
- (6) The Vehicle which has been fitted out to the above requirement is required to be presented for inspection and agreed with the Employer/Engineer.

9.4.4 Blasting Trials

- (1) The Contractor shall submit to the Engineer for Notice of No Objection full details of the blasting trials at least 14 days before the trials are carried out. Blasting trials shall be carried out for each proposed blasting procedure to demonstrate that
 - (a) the procedure is safe;
 - (b) the dust and noise created are within acceptable limits;
 - (c) the resulting maximum peak particle velocity and maximum allowable vibration amplitude at locations stated in the Contract, or instructed by the Employer/ Engineer, can be satisfactorily predicted, recorded and demonstrated to be within the prescribed limits, and shall not adversely affect the safety and stability of adjoining structures, installations and land, facilities and equipment; and
 - (d) the specified tolerances for the final blasted surfaces and formations can be achieved.
- (2) Blasting trials shall be carried out in accordance with the blasting procedure submitted to the Engineer. The location and size of blasting trials shall have a Notice of No Objection from the Engineer. These trials should not normally be part of the permanent works.
- (3) Blasting trials shall be completed at least 7 days before the related main blasting starts.
- (4) Blasting trials for pre-splitting and other methods of controlled blasting shall be carried out to form a face similar to the permanent works design. The blasting trials shall be carried out on rock which has similar properties to production blast areas and which is at least Employer/ Engineer.
- (5) The blasting trials shall be sufficient to demonstrate the effectiveness of the Contractor's proposed methods of blasting in all of the different areas of the blasting works.
- (6) The blasting trials shall be conducted by qualified personnel with a Notice of No Objection from the Employer/ Engineer.
- (7) If in the opinion of the Employer/ Engineer any aspect of the proposed blasting procedure as demonstrated by the blasting trials is unsatisfactory, particulars or proposed changes to the procedure shall be submitted to the Employer/ Engineer for Notice of No Objection; further blasting trials shall be carried out until the procedure is demonstrated to the satisfaction of the Employer/ Engineer.
- (8) The results of all trial blasts shall be interpreted using regression analysis method. Regression lines together with all blasting data showing the relationship of peak particle velocity against scaled distance shall be plotted on logarithmic scale to define the site vibration constants for the 50%, 84% and 95% confidence levels. All subsequent main production blasting results shall be produced on the same plot, and the plot modified and updated, as appropriate to allow for the additional information. Separate trials are required for different blasting types and areas.
- (9) Blasting shall not proceed until the Engineer has issued a Notice of No Objection to the proposed blasting procedure.
- (10) If changes to the agreed blasting procedure are proposed further blasting trials shall

be carried out to demonstrate proposed changes are acceptable.

9.4.5 Blasting Schedule

- (1) The Contractor shall submit a weekly schedule to the Engineer advising the proposed dates, times and locations of blasting, in advance of each week.
- (2) The Contractor shall confirm his intention to proceed with each scheduled blast to the Engineer not less than 18 hours, nor more than 24 hours in advance of the predetermined time. The confirmation shall show the location of and the intended time of each blast and the name of the licensed blaster and shift foreman responsible.
- (3) The Contractor shall distribute written notification to all organisations on Site 24 hours prior to undertaking surface blasting. Any delay or postponement of any blasts shall be notified to all organizations immediately

9.4.6 Vibration Due to Blasting

- (1) Arrangements for installing instruments and taking measurements both inside and outside the Site shall be made by the Contractor.
- (2) Measurement of vibrations generated by blasting shall be taken at locations proposed by the Contractor in his Blasting Assessment Report, Building Damage Assessment Report and Monitoring Proposal or as instructed by the Engineer at all times when blasting are carried out. Records of the vibrations shall be kept by the Contractor on the Site and a copy provided to the Engineer within 24 hours of measurement.
- (3) Vibrations due to blasting shall be measured in terms of Peak Particle Velocity (PPV) and Vibrational Amplitude. The peak values shall be taken as the maximum resultant calculated by vector summation of the three orthogonal components of velocity and amplitude respectively measured as instantaneously as the resolution of the recording instrument permits.
- (4) Measurements shall be made with seismographs of a type with Notice of No Objection from the Engineer. The accuracy of seismographs shall be checked before blasting are carried out and shall be calibrated at least once a year.
- (5) No blasting works shall be permitted without vibration measurements being recorded with approved vibration monitoring equipment mounted on a geophone pad which is rigidly bonded to form an integral part of the structure.
- (6) If a production blast results in vibration amplitudes or peak particle velocity in excess of the specified limits, the Engineer shall be notified immediately. The Contractor shall immediately check the fixing of monitoring equipment to confirm the reading accuracy and inspect the integrity of affected structures to ensure no immediate danger to the public and to implement remedial measures if necessary. No further blasting shall take place until measures to reduce the PPV and/or amplitude are adopted with a Notice of No Objection from the Engineer.

9.4.7 Blasting Near Structures

- (1) Blasting will not be permitted within 3m of the outside face of any existing underground structure. The Contractor shall propose alternative appropriate means of mechanical, pneumatic or hydraulic splitting for excavations at connections to existing structures for the Relevant Authorities' and Engineer's Notice of No

Objection.

- (2) The Contractor shall be responsible for avoiding personal injuries and damage to adjacent structures from fly rock by erecting barricades and/or the use of blast mats or other means acceptable to the Engineer. Should any damage be caused by his operations this shall be made good without any additional payment.
- (3) The unrestricted use of explosives will generally not be permitted in any part of the Works. The amount of explosives that may be detonated shall not result in a ground vibration sufficient to damage the nearest point of any part of the Permanent Works to the blasting Site.
- (4) In each and every case where the Contractor wishes to blast within 15 m of a structure, he shall prepare a proposal for this blasting and submit it to the Engineer for a 'Notice of No Objection. No blasting work of this nature may be carried out without the Notice of No Objection from the Engineer.
- (5) The Contractor shall prepare a photographic record of each structure within 100 m of any Works, whether on the surface or underground, prior to any blasting taking place.

9.4.8 Limits of Peak Particle Velocity and Vibration Amplitude

- (1) The vibrations at structures and installations due to blasting measured in terms of peak particle velocity and vibrational amplitude shall not exceed the values stated in Table 1.

Table 1 : Restriction on PPV and Vibration Amplitude

Description	Max Allowable PPV (mm/sec)	Max Allowable Vibration Amplitude (mm)
structures in "good" condition Roads/Pavements/open areas	25	0.2
Structures in "fair" condition	12	0.15
Structures in "poor" condition and Heritage Structures/bridges and water supply structures	5	0.1
<u>Fresh concrete:</u>		
• Less than 2 days old	5	0.1
• 2 to 8 days old	25	0.2
• more than 8 days old	50	0.2

- (2) The Contractor shall submit calculations which demonstrate that the charge weights per delay period proposed at 84% Confidence Level do not exceed the vibration limitations stated in Table 1. to the Engineer for Notice of No Objection. No blasting operations shall be carried out without Notice of No Objection from the Engineer.

9.4.9 Blasting Risk Assessment

- (1) The Blasting Risk Assessment and Blasting Risk Assessment Report shall be

undertaken by a qualified Engineer with the Notice of No Objection from the Engineer.

- (2) The Blasting Risk Assessment and Blasting Risk Assessment Report shall be carried out in accordance with the procedures submitted to and agreed by the Engineer. The location and size of the blasting trials associated with the Blasting Risk Assessment shall have a Notice of No Objection from the Engineer.
- (3) The Blasting Risk Assessment shall evaluate the impact caused by blasting using gradual increase in vibration levels generated by trial blasts, which shall not be exceeding the specified values in the Contract. Planned vibration target levels generated by the trial blasts shall be obtained by adjusting explosive charge weights at the same time taking in to consideration changes in distance, drilling pattern, confinement of the blast and rock condition. The design of explosive charge weights shall be made from linear regression based on previous blasting works. The predicted PPV(not exceeding the specified values in the Contract) for each trial blast shall be made in accordance to a confidence level of 84%.
 - (4) After each trial blast a structural inspection of structures and tunnels shall be carried out to assess the effect of blasting induced vibration. The scope and extent of the structural inspection shall be agreed with the Engineer. When no structural defects are reported the subsequent trial blasting may be increased to the next higher vibration target level, which shall not be exceeding the values specified in the Contract. Following completion of the Blasting Risk Assessment field works a Blasting Risk Assessment Report shall be required to be submitted to the Engineer for Notice of No Objection.

The Report shall include the followings as a minimum contents

- (a) drilling and explosive loading details for each trial blast;
- (b) delay plan for each trial blast;
- (c) charge weight per blast hole and charge weight per delay for each trial blast;
- (d) details of vibration monitoring instruments and geophone locations and orientation for each trial blast;
- (e) details of instrumentation and settlement monitoring for each trial blast;
- (f) graphical record of Elapse Time against Particle Velocity and Acceleration for each of the three orthogonal geophone directions for each trial blast for each filtering frequency used. All records are to identify the following: date, time, monitor, location, filtering frequency, channel number, channel maximum, project and trial blast identification;
- (g) full wave form of the vibration measured on structures and installations showing; PPV, predominate frequency, displacement and acceleration;
- (h) maximum resultant peak values calculated by vector summation of the three orthogonal components of velocity and amplitude for the monitoring point closest to each trial blast at each filtering frequency used. Results to include distance from blast and range of the dominant vibration frequency;
- (i) results of structural condition survey conducted following each trial blast, and results of vibration monitoring and all other structures and buildings;
- (j) results of all trial blasts plotted as a linear regression defining constants for

that site condition and the 50%, 84% and 95% confidence levels. Results to include dominant vibration frequency recorded.

9.4.10 Blasting: Tunnels and Shafts

9.4.10.1 General

- (1) One probe hole shall be drilled ahead of every rock face for probing the ground conditions ahead prior to the blast hole drilling. Probing ahead shall be by impact or rotary drilling techniques, and is intended to detect any ground water or potential unstable soils, which may be treated by grouting techniques (ground treatment techniques)
- (2) All blasting work for bulk excavation of tunnels and shafts shall be carried out using perimeter drilling and blasting techniques to control the geometry of and to minimise any damage to the theoretical excavation profile and minimise geological over break.
- (3) All charges shall be accurately made up and inserted into the holes at the correct spacing, and all holes shall be correctly stemmed and connected in the correct sequence with detonators being correctly delayed.
- (4) Where tunnel excavation by explosives is within 6m of the ground surface or an adjacent opening the Contractor shall modify his blasting pattern to reduce the overbreak and to produce the minimum amount of disturbance to the surrounding rock mass. Such Controlled Blasting shall incorporate, but may not be limited to, pre-splitting or smooth blasting techniques, decoupled charges and shall make use of explosives specifically manufactured for these purposes.

9.4.10.2 Controlled Blasting Tolerance

- (1) The Contractor shall carry out Controlled Blasting so as to achieve a final blast surface that exhibits a regular fracture plane between barrels without underbreak or overbreak greater than those which have been considered in deriving the theoretical excavation line and the required finished tunnel profile.
- (2) If at any time the methods of drilling and blasting do not produce a uniform profile within the tolerances to achieve the required finished tunnel profile, no further blasting works shall be permitted until the Contractor establishes a technique that results in an excavation profile to the acceptable tolerances.

9.4.11 Blasting: Stations

- (1) Screens and other protective covers as specified in the Method Statement shall be erected to prevent the projection of flying fragments of material resulting from blasting.
- (2) Presplitting and other methods of controlled blasting shall be carried out in such a manner that the rock mass is cleanly split on the required plane such that the remaining rock mass is not shattered or loosened.
- (3) Faces formed by presplitting or other methods of controlled blasting shall not exceed 1.5m in height in any one blasting operation or as agreed by the Engineer.
- (4) If at any time, any method of drilling and blasting does not produce a uniform final surface profile without overbreak, all within the required tolerances, the Contractor shall undertake further trials until a technique is established that results in an excavation profile to the acceptable tolerances.

9.4.12 Submission

- (1) The following are a minimum contents of blasting procedures that shall be submitted to the Engineer for Notice of No Objection:
 - (a) Any conditions or restrictions imposed by the Relevant Authorities, including copies of applications, licences, permits and correspondence;
 - (b) Names, qualifications and experience of the persons responsible for the design and supervision of blasting operations;
 - (c) The roles and responsibilities of key personnel for blasting supervision shall be clearly defined on the Blasting Assessment Report.
 - (d) Location with survey control, diameter, inclination and depth of holes to be charged with explosive;
 - (e) Type and total mass of explosive to be used and its mass and distribution in each hole;
 - (f) Initiation sequence, delay periods and mass of explosive per delay;
 - (g) Burden and bench height;
 - (h) Ratio of diameter of explosive to diameter of hole;
 - (i) Ratio of explosive charge weights to both volume and weight of rock to be removed by the proposed blast;
 - (j) Arrangements for vibration monitoring system (e.g. relevant vibration and air overpressure monitory points) and methods of instrumentation and monitoring the effects of blasting;
 - (k) Details of vibration monitoring system, including manufacturers literature and calibration certificates;
 - (l) Methods of controlled blasting; and
 - (m) Protective measures that have been agreed by the Engineer to ensure there is no damage to surrounding property or equipment or EBS and to fully comply with the provisions of the Contract in this respect.
- (2) Items (a) & (b) shall be submitted at least 30 days before blasting in a particular works area starts. Items (c) to (m) shall be submitted to the Engineer at least 48 hours before the relevant blasting starts.
- (3) The blasting procedures shall be reviewed as blasting continues and shall be updated to suit particular local conditions. When the procedures are required to be revised, the Items (c) to (m) shall be submitted to the Engineer for Notice of No Objection at least 48 hours before blasting starts.

Maha Metro



Tender Documents

**UGC-02: DESIGN AND CONSTRUCTION OF UNDERGROUND STATIONS AT
BUDHWAR PETH, MANDAI AND SWARGATE AND ASSOCIATED TUNNELS**

PART II – EMPLOYER’S REQUIREMENT

**Section VIII - Outline Construction Specification
S.02 Station Planning, Building and Finishing Works**

June 2018

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2.1 General Requirements

2.1.1 Preambles to Outline Construction Specification

General

- (1) For convenience, this document contains references to a variety of International standards which are included as indicative information only wherever practical Indian Standards [IS], Codes of Practice, etc. shall be utilized and take precedence.
- (2) The document and the individual clauses contained within it have been included for general and outline purposes only; and, in consequence:-
 - The contents are to be accepted as indicative only; and are to be reviewed, amended and developed, as deemed appropriate, to suit the formulated designs and site specific requirements.
 - The contents, as included, are to be considered as limited in extent and overall scope; and shall be developed and expanded to specify the entirety and detail of the works.
 - Items included in this, Outline Document may or may not be finally incorporated into the Contractor's working specification.

2.1.2 Technical

- (3) The final Specification document shall be structured to clearly address both the Material and the Workmanship [including Protection] aspects of the works. The Contractor shall prepare and submit the detailed performance specification to the Engineer for Notice of No Objection. The Contractor shall not commence the work without a Notice of No Objection from the Engineer.
- (4) Emphasis shall be placed on the Contractor and all Sub-contractors to abide by the requirement to take all appropriate site dimensions, as deemed necessary to undertake and complete the works
- (5) Equal emphasis is to be placed on the Contractor and all Sub-contractors, as considered appropriate, to abide by the requirement to prepare and submit drawings to the Engineer for Notice of No Objection, prior to commencement of any specialist works
- (6) It shall be made abundantly clear that the Contractor and all appropriate Sub-contractors / Suppliers shall be duty bound to furnish the Engineer with a sufficient quantity of samples, mock-ups and process and the continuance of the works at no additional cost to the Employer
- (7) Wherever deemed appropriate, materials and workmanship shall be in strict accordance with manufacturer's recommendations
- (8) In all given circumstances, sufficient due care and attention shall be paid to prevent electrolytic corrosion between dissimilar materials and metals, in particular.
- (9) Similarly all necessary precautions shall be taken to ensure adequate corrosion protection for all exposed and hidden elements.

2.1.3 General Requirements Materials

The Contractor shall note the requirement to use materials available in India as far as possible. These materials must meet the requirements of the relevant Indian Standard (IS), or, where appropriate an equivalent International Standard.

2.1.4 Compliance with Specification

- (10) The Contractor shall comply fully with the requirements of the following specifications in regard to quality of materials, submission of samples to the Engineer for Notice of No Objection prior to commencement of installation work and methods and procedure of installation.
- (11) All proprietary materials or processes submitted by the Contractor and noticed by the Engineer shall be used or carried out strictly in accordance with the manufacturer's instructions and recommendations and also to comply with this Specification.
- (12) Where one or more proprietary materials or processes are named in this specification for Architectural and Building Works as acceptable materials or workmanship, the Contractor shall still be responsible to ensure that these materials or workmanship comply with the requirements described in this Specification. In particular all materials shall comply with appropriate requirements for fire resistance.
- (13) Where materials are proposed by the Contractor for any part of the Works that require certain tests and where no previous test certificates have been issued by any competent authorities or approved testing laboratory, the Contractor shall at his own cost, submit the material for the appropriate test at an approved laboratory and furnish the test certificates to the Engineer.

2.2 Masonry

2.2.1 Materials

- (1) Cement and water for mortar shall be as specified under Section VIII, Clause 1.5 "Concrete".
- (2) Sand shall be clean and sharp, free from salts, loam and organic matter, complying with the requirements of BS 1199/1200, as appropriate and be well graded from 5mm down.
- (3) Plasticisers shall comply with BS 4887. Integral waterproofing agents for mortar may be either powder additive or equal approved mixed in accordance with the manufacturer's instructions.
- (4) Bricks shall be facings from an noticed kiln, machine pressed, well burnt, hard, uniform shape, colour and size with all sharp clean arises and free from all defects. Samples shall be submitted to the Engineer for Notice of No Objection before placing an order.
- (5) Concrete blocks shall be obtained from a manufacturer agreed with the Engineer. Concrete blocks shall be solid with a minimum average compressive strength of 7.0N/mm².
- (6) Materials for precast concrete lintels shall be as specified under Section VIII, Clause 1.5 "Concrete."
- (7) Horizontal wall reinforcement shall be galvanized steel mesh reinforcement, 22 gauge. Steel bar reinforcement shall be as specified under Section VIII, Clause 1.5 "Concrete."
- (8) Movement joint filler shall be as proposed by the Contractor's Designer and with a Notice of No Objection from the Engineer; sealer shall be coloured silicone sealant and shall have a Notice of No Objection from the Engineer.

2.2.2 Mortar

- (1) Mortar shall comprise one part cement and six parts sand, thoroughly mixed with just sufficient water to provide workability.
- (2) Plasticisers may only be used if proposed by the Contractor's designer and noticed by the Engineer and shall be added strictly in accordance with the manufacturer's instructions.
- (3) Mixing of mortar shall be done by mechanical batch mixer or by hand on a clean, watertight platform of adequate size. All constituent materials shall be accurately gauged.
- (4) Mortar shall be used within one hour of mixing. Mortar that has started to set shall not be used. De-tempering of hardened or partly hardened mortar will not be permitted.

2.2.3 Block Work Generally

- (1) Block work shall, unless otherwise described, be built in stretcher bond of hollow cellular or solid block work.
- (2) Blocks shall be well wetted before laying and kept wet until laid.
- (3) Hollow blocks shall be grouted solid with mortar where required by the design.
- (4) Blocks shall be laid in true and regular courses on a full bed of mortar of 10mm average thickness, exclusive of any key in the jointing surfaces of the blocks. Sufficient mortar shall be used in bedding and jointing to ensure that all keys are solidly filled.
- (5) All horizontal joints shall be properly level. The vertical joints shall be properly lined and quoins, jambs and other angles plumbed as the work proceeds. All walls shall be plumbed vertical.
- (6) Standard size blocks shall be used wherever possible. Broken blocks shall not be used except where required for bonding purposes. Walls and partitions shall be bonded to one another at angles and junctions.
- (7) Joints on faces of block walls which are to be rendered or plastered shall be raked out for a depth of 10mm as the work proceeds.
- (8) Walls shall be carried up regularly without leaving any part more than one metre lower than another. Work which is left at different levels shall be raked back.
- (9) Before commencing any block work the Contractor shall confer with other trades to ensure that all pipes, ducts, conduits, sleeves, bolts, frame lugs, etc. or any other materials necessary to be installed in the block work at the time it is built have been fixed or provided for.
- (10) Firepots around ducts, cable trays, water pipes, drains and the like shall be of a notified intumescent material.

2.2.4 Block Work Reinforcement

- (1) Block work shall be reinforced to BS 5628.
- (2) Mesh wall reinforcement is to be built in at every second course. Mesh shall be 100mm wide for 150mm block work and 150mm wide for 200mm block work.
- (3) Where shown on the design drawings, the block units are to be vertically reinforced through the core of the block units with high yield steel bars, securely tied to the starter bars left projecting from concrete structure. The core of block unit is to be grouted solid around bar with mortar or with a lean

mix concrete with 10mm maximum aggregate.

2.2.5 Movement Joints

Movement joints shall be sealed by a noticed sealer applied in strict accordance with the manufacturer's instructions. The surface of the concrete or block work to which the sealer is to adhere shall be straight and cleaned of all filler material, dirt, oil, grease and other matter. The sealer shall be applied by methods recommended by the manufacturer so that the sealer is brought flush to the surface of structure and a smooth surface is achieved. Excess material and spillage shall be properly cleaned off and removed.

2.2.6 Precast Concrete Units

Precast concrete units shall be cast, reinforced, handled and erected all as specified under Sub-section 1.5 "Concrete".

2.3 Pavement

2.3.1 Materials

- (1) Cement and water for screeds, beddings, paving's, jointing, pointing, etc. shall be as specified under Outline Construction Specification, sub-section 1.5 "Concrete."
- (2) Sand shall be clean and sharp, free from salts, loam and organic matter, complying with the requirements of BS 1199/1200 as appropriate.
- (3) Metallic oxide pigments for colouring shall be of the tints required and of a noticed brand, complying with the requirements of BS 1014.
- (4) Non-metallic floor hardener shall be of natural aggregates blended with cement and resin mortars with abrasion resistance complying with ASTM C779-74, hardness of 9 mohs minimum, an adhesion of minimum 4.5kg/sq.cm., chemical resistance of at least 4 to 6 times greater than untreated surface and shall produce non-slip and non-dusting surface. Non-metallic hardener shall be obtained from a noticed manufacturer and/or supplier. Surfaces of hardener shall be coated with two coats of dust proofing epoxy resin sealer.
- (5) Integral waterproofing agents and plasticisers shall be as previously specified under Clause 2.2.
- (6) Hardcore shall be composed of hard dry stone, brick, concrete, block, laterite or other sound, hard material agreed by the Engineer, broken to a gauge of 50-75mm and well rammed and consolidated in layers not exceeding 150mm thick. The surface of hardcore shall be dense and well watered prior to laying screeds.
- (7) Aggregate laid in planters shall be clean, smooth and free from dirt and grease.
- (8) Topsoil to planters shall be vermiculite granules and shall contain no deleterious or foreign matter.
- (9) Granulated peat shall be compressed and laid in the planter box on a prepared layer of rounded aggregate.
- (10) Waterproofing membrane to platforms and wet rooms shall be polythene sheet or equal.
- (11) Waterproof membrane to inside of planter boxes shall be an adhesive membrane and shall be installed in accordance with the manufacturer's instructions.

- (12) Blanket filters to planter boxes shall be 15mm thick of fibreglass.
- (13) Precast concrete cover slabs, bedding, jointing and pointing shall be as specified under Outline Construction Specification, sub-section 1.5 "Concrete". Panels shall be 75mm thick with interlocking edges.
- (14) Textured (flamed) granite slabs for floors and stairs shall be of the best quality. The colour of the granite slabs shall be as proposed by the Contractor and agreed by the Engineer.
- (15) Polished granite slabs for floors shall be of best quality. The colour of the polished granite shall be as proposed by the Contractor and agreed by the Engineer.
- (16) Polished marble slabs for floors shall be as proposed by the Contractor and agreed by the Engineer.
- (17) Textured (honed) granite slabs for floors shall be as agreed by the Engineer.
- (18) Granite shall be supplied to site pre-cut, dressed and drilled for fixing cramps, rebated and worked as finished slabs. No grinding or polishing will be allowed on site except for final cleaning.
- (19) The Contractor shall allow for all necessary protection of granite work. No residual staining or other surface blemishes will be allowed whether from backing mortar fill or water penetration from such backings or from other sources.
- (20) The Contractor shall allow for further selection of granite types and colours to conform to floor or wall patterns using mixes of granite types.
- (21) Shop drawings showing the proposed layout of granite surfaces illustrating panel sizes, jointing and patterns are to be provided by the Contractor together with all fixing details and materials for the Notice of No Objection from the Engineer.
- (22) Ceramic floor tiles shall be heavy duty anti-slip homogeneous unglazed ceramic tiles complying to BS 6431 with a hardness of minimum 6 mohs per DIN 18155, and abrasion resistance of $6 \text{ cm}^3/50\text{cm}^2$ maximum per DIN 52108 of an noticed manufacturer. Skirting shall be in matching coved tiles. Special nosing tiles with anti-slip grooves or ribbed edge shall be provided to treads and landings.
- (23) Artificial granite paving stones shall be heavy duty, anti-slip, artificial compressed granite stones of an noticed manufacturer and of texture and colour to be agreed by the Engineer.
- (24) Expansion joint filler in pavings shall be selected polystyrene board filler. The joint shall be sealed with coloured silicone sealant with a neoprene backer rod. Selected Silicone colour shall be as agreed by the Engineer.

2.3.2 Samples

- (1) The Contractor shall provide a minimum of six samples of each type of tile and granite for the Engineer's review and Notice of No Objection.
- (2) The Contractor is to provide samples of each different type of floor finish, each to be laid in representative areas of not less than 2000 x 2000mm, for the Engineer's review and Notice of No Objection before commencing in general areas. The noticed sample areas, which shall include skirtings where required, shall be used for the purposes of comparison and any work not equal to its

noticed sample will be rejected.

2.3.3 Preparation of Surfaces

- (1) Paving or finishes shall not be applied on any work which may be unfinished, imperfect, and wrong or in any other improper condition. Improper work shall not be covered up or finished against until it has been rectified.
- (2) The surface of concrete to receive screeds shall be thoroughly roughened by picking or other means and cleaned of all dust and debris. Immediately before laying screeds or other wet finishes, the surface shall be well dampened and slurry of neat cement and water brushed on. The new paving shall be applied while the slurry is still wet.
- (3) The surface of screeds to receive vinyl floor covering or other floor coverings shall be washed and cleaned thoroughly and allowed to dry completely before the actual laying of such coverings is allowed to commence.
- (4) Where screeds are required to be reinforced they shall include for one layer of chicken wire mesh. This mesh shall be cleaned and kept free from dirt, dust, grease or rust before it is laid. It shall be laid into the screed with adequate cover and no protrusions to the surface.

2.3.4 Levels

- (1) Unless otherwise specified or indicated levels shown on the Drawings are to be finished floor levels.
- (2) Floors shall be finished truly plane either level or to falls as indicated.
- (3) All finished surfaces shall be finished to a true and even surface over whole areas to within 3mm when tested with a 3000mm long straight edge and the rate of departure shall not be greater than 1.5mm for each 500mm in distance from any point of contact along the straight edge.
- (4) Floors shall be laid to the falls where necessary but in any case floors other than level floors, shall fall not less than 25mm in 10 metres and shall be free from all irregularities and depressions so that water drains off the floor leaving none standing.
- (5) The total thickness of the floor finish including any screed or bed shall be such as to bring the finished floor to the levels required.

2.3.5 Mortar

- (1) Adjoining finishes including those to falls shall finish at the same level at doors and elsewhere as applicable.
- (2) Mortar for screeds, beddings, pavings, jointing and pointing, etc. shall comprise one part cement to three parts sand, thoroughly mixed with just sufficient water to provide workability.
- (3) Mixing of mortar and use of plasticisers shall be as previously specified under Outline Construction Specification, sub-section 2.2
- (4) Pigments for colouring shall be dry mixed with the cement to produce a uniform colour for the tint required in the finished work. They shall comply with BS 1014.

2.3.6 Workmanship Generally

- (1) No paving works shall be carried out in unsuitable weather conditions unless

adequate protection is arranged beforehand.

- (2) All workmanship shall be of best quality.
- (3) The paving contractors are required to do all making good of work specified in this trade after all other trades including those other contractors.
- (4) All arises, internal angles, external angles, etc., shall be clean and slightly rounded with neatly formed miters.
- (5) All pavings shall be properly made good around all pipes, brackets, gratings, electrical floor boxes and the like.
- (6) Where shown on the Drawings or as directed by the Engineer, expansion joints shall be provided in floor finishes.

2.3.7 Granite Paving

- (1) The Contractor shall provide shop drawings showing laying patterns and details of cut slabs in accordance with BS 5385.
- (2) Bedding mortar shall be as specified in these Specifications.
- (3) When laying granite finishes, the sub-base shall be prepared in accordance with these Specifications, moistened and then the setting bed shall be spread evenly over the whole area to ensure a good bond. The bed shall be screeded to required levels and to a smooth surface to receive slabs. After the bed has set sufficiently to be worked over, dry cement shall be sprinkled over surface and the laying of slabs may begin.
- (4) Straight edges shall be set to lines established and then re-set at suitable intervals to keep joints parallel. The slabs shall be laid to the straight edge.
- (5) Where shown on the shop drawings slabs are required to be set out, cut and laid to sizes and patterns indicated.
- (6) Slabs shall then be tamped solidly onto the bed ensuring a solid bedding free from depression.
- (7) As soon as the bed under the slab paving has hardened sufficiently, the joints shall be colour grouted by careful filling the joints solid with grout mix. Every care must be taken not to stain the granite; all excess grout shall be removed and slabs thoroughly cleaned. The slabs must be protected and not walked on for at least five (5) days after laying.

2.3.8 Clay Floor Paving

- (1) The clay floor paving work shall be carried out in accordance with BS 5385 for "Tile Flooring and Slab Flooring" where not inconsistent with this Specification.
- (2) After the concrete surface has been satisfactorily roughened and cleaned it shall be thoroughly moistened but not soaked. The mortar for the setting bed shall then be spread on the concrete to ensure a good bond over the whole area and screeded to provide a level and smooth bed for tiles. After the bed has set sufficiently to be worked over, dry cement shall be sprinkled over surface and the laying of tiles may begin.
- (3) Clay floor tiles shall be laid as scheduled with skirting tiles where required finishing flush with the wall surface above to all walls, columns, piers, upstands and solid bases or with projecting planes if required and only as shown on the Drawings. Tiling shall be carried over top of solid bases where exposed and with bull-nosed and coved or 45 degree angled tile raiser. Tiles shall be wetted,

not soaked, and laid to a true and even surface with even falls as required. No chipped, warped or defective tiles shall be laid.

- (4) Floors shall be laid from some suitable central point outwards so that all significant adjustments required will be made at the walls. The setting bed for tile floors shall be composed of one part cement and three parts sand to which not more than 5% of hydrated lime by volume of cement may be added. Grouting mortar shall be in coloured cement as approved.
- (5) Straight edges shall be set to lines established and then reset at suitable intervals to keep joints parallel over the entire area. The tiles shall be laid to the straight edge.
- (6) Tiles shall be tamped solidly onto the bed ensuring solid bedding free from depressions. As soon as the bed under tile floor has hardened sufficiently any paper sheets shall be moistened and removed and joints colour grouted by screeding and brushing the grout mix over the tiles until joints are thoroughly filled. All excess grout shall be removed and tiles thoroughly cleaned. The tiles shall be protected and not walked on for at least five (5) days after laying.

2.3.9 PVC Floor Covering

PVC floor covering shall not be used. Flooring materials shall be halogen free.

2.3.10 Division Strips, and Matwell Frames

- (1) Stainless steel dividing strips 5 x 25mm shall be provided at junctions between different floor finishes bedded into the screeds, set flush with the finished floor level and polished on the exposed edge.
- (2) Matwell frames shall be constructed from 20 x 20 x 3mm brass angle, properly brazed at corners with brass lugs brazed on for fixing to screed. Frames shall have exposed edges polished.

2.3.11 Curing

The Contractor shall protect all paving surfaces from drying out, for a minimum period of seven days.

2.3.12 Protection

- (1) The Contractor shall take all precautions to protect floor finishes and bases and shall replace at his own expense any floor finish or base which is damaged or defaced and shall hand over all floors on completion in a clean condition. Replacement of damaged or defaced work may be extended at the Engineer discretion to include the whole of the room or area affected. It shall be the Contractor's responsibility to ensure proper adhesion between all paving and the structure and he shall replace at his own cost any loose or defective work, notwithstanding any claim by the Contractor that he has followed the Specifications regarding the preparation of the surfaces and the formation of a key and notwithstanding the Conditions of Contract.
- (2) The Contractor shall protect concrete surfaces which are to receive finishes against damage, etc. immediately after finishing. If, when the later finish is to be laid, the concrete shows irregularities likely to affect the finish, the affected areas shall be mechanical ground back within limits to 2.5mm below the intended finished slab level and brought up to a finished level by the application of an approved levelling compound applied in accordance with the manufacturer's recommendations and instructions.

- (3) The Contractor is to protect floor finishes after laying, if possible by locking up the area. He shall limit traffic over the floor to essential traffic only, tape down building paper over the floor and remove it immediately prior to Completion. The Contractor shall use more robust means of protection as circumstances demand.
- (4) The protection coverings shall be taken up and re-laid as required for cleaning, sealing and polishing. Protection shall include a periodical cleaning where required to prevent dirt, grit, etc. becoming engrained into any finish.
- (5) No protective finish is to be laid or applied which will in any way inhibit fixing of later floor finishes.

2.4 Concrete Roofing

2.4.1 General

The complete roofing system shall be carried out by a licensed applicator recommended by the supplier in strict accordance with the manufacturer's instructions, and shall obtain a Notice of No Objection from the Engineer.

2.4.2 Materials

- (1) Cement, water, sand, waterproofing agents and plasticisers shall be as previously specified under Outline Construction Specification, sub-section 2.2.
- (2) Liquid-applied modified polyurethane elastomer roofing as required shall be as given notice to by the Engineer.
- (3) The roofing shall be laid by Specialist applicator authorized by the manufacturer. The roofing shall be laid in accordance with the manufacturer's instructions.
- (4) Aluminium flashing is to be 2.0mm or 3.0mm thick as described, shop fabricated and anodized to the approved colour minimum 20 microns, laid with 100mm minimum laps, sealed at joints and clipped and fixed to wall with approved fasteners at 750mm centres.
- (5) Aluminium gutter lining to the roof shall be 3.0mm thick, shop fabricated and anodised to approved colour minimum 20 microns, laid with 100mm minimum laps, sealed at joints and laid on cement and sand screeded underbed in the reinforced concrete gutter.
- (6) Rainwater pipes and fittings for casting into concrete and other concealed locations shall be in cast iron complying with BS 460 type-A jointed with hemp gasket and cold caulking compound and fixed with holder bats or hangers. Cast iron roof outlets shall comply with BS 416 and have circular domical gratings. Pipes cast into concrete shall be secured to the reinforcement with binding wire.

2.4.3 Sample

A representative section of the complete roof covering (minimum area 2000 x 2000mm) shall be installed as prototype for Notice of No Objection from the Engineer before the main work is put in hand. This shall involve showing all details including laps, skirtings, dressing to outlets, etc. as will be required for the whole of the roofing.

2.4.4 Preparation of Surfaces

- (1) Preparation of surfaces shall be as previously specified in Clause 2.3
- (2) The surfaces of concrete or screeds to receive roofing membrane shall be

thoroughly cleaned.

2.4.5 Roof Screeds

- (1) Mixing, placing, finishing and curing shall be as previously specified under Outline Construction Specification, sub-section 2.3.
- (2) Screeds shall be laid to the required falls and cross falls in alternate bays not exceeding 10 square metres.

2.4.6 Installation of Liquid-Applied Modified Polyurethane Elastomer Roofing

- (1) Surface to receive the roofing shall be dry and free from dusts, oil, paint, rust or other foreign matter and shall be level, free from cracks, cold joints or other structural defects. Surfaces shall be primed with concrete primer and the roofing system applied in accordance with the manufacturer's instructions.
- (2) The liquid-applied polyurethane roofing top coat surface shall be of a noticed standard colour to be selected by the Engineer.
- (3) A layer of minimum 25mm thick cement and sand (1:3) underbed shall be laid to receive the roofing system at horizontal roofs. The underbed shall be laid to falls on flat roof to receive the roofing system. The roofing system shall be laid directly on the concrete surfaces of the shell roof.
- (4) The roofing shall be dressed up vertical edges minimum 150mm high and tucked into pre-formed groove 15 x 12mm chased in the wall, beams or up-stand and sealed with approved polyurethane sealant. At the junction between horizontal and vertical surfaces a 13 x 13mm polyurethane caulking bead shall be provided before dressing over with the roofing.
- (5) The junction with vent pipes or other penetrations through roof and around roof outlets shall be sealed with an approved sealant.

2.4.7 Installation of Insulation

Insulation units shall be installed loose-laid with tight interlocking butt joints spot bonded with an approved adhesive.

2.4.8 Ponding Test

- (1) After the completion of the roofing membrane installation and before the laying of the insulation and paving the roofing shall be ponded to test for roof leakage and seepage. All rainwater outlets must be plugged and the entire roof area flooded with 75mm of clean water for three days, after which the roof shall be inspected for any sign of water penetration. Should the ponding test reveal defective areas, the Contractor shall bear the entire cost of remedying the defects by a method agreed with the Engineer and re-testing to the satisfaction of the Engineer. As required, the Engineer may direct ponding to be carried out to parts or sections of the roof. The Contractor shall provide all temporary kerbs in cement mortar or by other means to provide enclosures to contain ponding water.
- (2) On satisfactory completion of ponding test, any kerb or temporary barrier and plugs to outlets shall be carefully broken up and debris removed. The Contractor shall take care in doing so to prevent damage to the roof structure or surface. Ponding water shall be drained by approved means and steps must be taken at all times to prevent breeding of mosquitoes and choking of rainwater down pipes.

2.4.9 Completion

On completion of the roof work, the Contractor shall remove all debris, unused materials, rubbish etc. from the roof to the satisfaction of the Engineer. The Contractor shall make good any defects in the roofing work due to defective workmanship or premature breakdown of materials.

2.4.10 Guarantee

The whole of the membrane roofing shall be guaranteed for a minimum period of fifteen (15) years from the date of Completion of the Whole Works and all defects including consequential damage occurring during this period are to be made good by the Contractor.

2.4.11 Profiled Metal Roof Decking

(1) General

This Section specifies the furnishing and installation of profiled metal roof decking for station roofs and entrances, etc.

(2) References

- a) References should be made to codes and regulations of authorities having jurisdiction over this work.
- b) British Standard Reference
 - i) Sheet roof and wall covering: CP143
 - ii) External fire exposure roof Ref.: BS476:Part 3

(3) Submittals

- a) Shop Drawings:
 - i) The Contractor shall prepare shop drawings for the fabrication and erection of all assemblies of the custom Metal Roof Decks which are not otherwise completely shown by the manufacturer's data sheets. These shall include plans and elevations at not less than 1:10 scale, and include details of sections and connections at not less than 1:5 scale and will show anchorage, accessory items and finishes.
 - ii) Acceptance of the shop drawings will not relieve the Contractor of any responsibility including accuracy of dimensions and details.
- b) Manufacturer's Literature:

The Contractor shall submit to the Engineer, for information only, copies of manufacturer's specifications and installation instructions for proprietary products including metal finishing materials.
- c) Samples
 - i) The Contractor shall submit three (3) samples of each type of Metal Roof Deck to show the range of colour, texture and finish.
 - ii) Each Metal Roof Deck sample to be in 1000 x 1000mm square and of the profile required for the work.
 - iii) The Contractor shall submit three (3) samples of each type of anchoring and fastening device.
- d) Certificate:

The Contractor shall submit manufacturer's certificate as required by the Engineer.

(4) Materials

a) General:

- i) So far as practicable, the products of one manufacturer shall be used.
- ii) Metal Surfaces: For the fabrication of work which will be exposed to view, only materials which are smooth and free of surface blemishes shall be used. Materials which have stains and discolourations, including welds which do not match the materials in colour shall not be used.
- iii) Surface Flatness and Edges: For exposed work materials shall be provided which have been cold-rolled, cold-finished, cold-drawn, extruded, stretcher levelled, machine cut and otherwise produced to the highest commercial standard for flatness with edges and corners sharp and true to angle or curvature as required.

b) Decking:

- i) Galvanized: To conform with BS-729, BS-4921, gauge as shown.
- ii) Ungalvanized: gauge to be as shown, coated with the manufacturer's standard rust - inhibiting primer.
- iii) Where torn-coated stainless steel is to be installed over decking, decking to be fabricated with clear space between ribs 13mm wide maximum.
- iv) Anodized aluminum shall be minimum 22 gauge.

c) Accessories:

- i) Accessories shall be of the types shown as necessary to complete installation, and include 14-gauge recessed sump pans for roof drains, cover plates where panels abut or change direction and closure plates.
- ii) Accessories shall be of the same gauge and finish as the decking, unless otherwise shown or specified.

d) Fasteners:

Only concealed fasteners shall be provided.

(5) Fabrication

a) General:

- i) All parts of the work shall be of the materials, design and dimensions required.
- ii) Metal parts shall be accurately formed, and all joints except those designed to accommodate movements shall be accurately fitted and rigidly assembled. Framed joints shall be sealed to prevent leakage.

- b) Deck units shall be countersunk at ends to form a smooth, finish on the top surface at overlapping ends, except for 12-gauge and 14-gauge material.
- c) Deck units shall have interlocking side laps, shall be in standard width and of longest practicable lengths.

(6) Installation

- a) Metal decking and accessories shall be erected in accordance with the shop drawings with Notice of No Objection from the Engineer and the manufacturer's recommendations.
- b) Decking units shall be placed on the supporting steel, aligned and adjusted to final position before permanently fastening.

- c) Decking shall be continued over three or more spans.
 - d) Welding shall be carried out in accordance with the welding specification.
 - e) Electric-arc welding shall be used to weld deck panels to end supports as shown on the Construction Reference Drawings or on approved shop drawings. Where panel ends meet, a minimum four-inch overlap shall be provided and welded to fuse ends of units together.
 - f) Side joints of adjacent panels shall be crimped and welded at intervals not exceeding 1 metre
 - g) Burrs and sharp edges shall be removed.
 - h) Where welding occurs through deck, welding washers and plug welds shall be used to ensure proper attachment.
 - i) Cut levels and other special cutting and fitting shall be carried out at the job site.
 - j) Necessary support framing and reinforcement and openings for items penetrating deck panels shall be provided.
 - k) Cutting of openings for work of other trades shall be coordinated with trades involved.
 - l) Mechanical equipment or other loads shall not be hung from steel deck.
- (7) Cleaning
- a) Rubbish and debris caused by this work shall be collected and removed from site.
 - b) Decks and areas surrounding work shall be left in a clean condition.

2.4.12 Profiled Metal Roof Coverings

- (1) The profile metal sheet roof coverings shall be copper roofing or fluorocarbon coated aluminium roofing minimum 22 gauge of batten seam. Metal decking and substrate to be prepared as recommended by the roofing manufacturer. 50mm batten seam with seams and laps located as indicated on drawings shall be used.
- (2) Roof coverings to steel purlins and rails shall be laid and fixed complete with flashings and concealed fastenings, in accordance with the Manufacturer's recommendations to make the whole sound and weathertight.
- (3) Sheetings shall be in single length panels up to the maximum lengths available. Where end laps are inevitable, the sheets shall be lapped a minimum of 300mm sealed with non hardening mastic and secured with self tapping screws for bolts.
- (4) Sheet flanges at the high end of the roof shall be turned up and flanges at the low end shall be turned down using the proper bending tools. Exposed ends of ribs shall be fitted with end stops.
- (5) No person shall be allowed to go on the roofing without using crawling boards or cat ladders.
- (6) Upon completion of the roofing works all rubbish and left over's such as rivet shanks, sheet off cuts, nails shall be removed. The entire roof shall be swept with a soft broom paying particular attention to areas where drilling or sawing has taken place. All gutters shall also be cleared out.

2.4.13 Roofmesh

The roofmesh for supporting roof insulation shall be a galvanised mesh with a Notice of No Objection from the Engineer laid over and wired to steel purlins.

2.4.14 Aluminium Foil Insulation

The foil insulation shall be an aluminium foil building paper with a Notice of No Objection from the Engineer.

2.4.15 Metal Roofing Finish

The metal roofing sheet shall be copper roofing sheet or aluminium roofing sheet coated with fluorocarbon coatings on all the exterior exposed surfaces to a selected standard colour. The interior surface shall be in natural aluminium anodized finish.

2.5 Carpenter and Joiner

2.5.1 Reference to Other Trades

Refer to Outline Construction Specification, sub-section 2.6 - Steel and Metal Worker for specifications of metal doors and door frames.

2.5.2 Timber

- (1) Timber for carpentry and joinery work shall be tanalised hardwood unless otherwise stated.
- (2) All timber exposed to view shall be wrought.
- (3) All timber shall be the best of its kind, thoroughly dry and well seasoned and free of defects.
- (4) All timbers to be used shall be seasoned so that the moisture content is between 12% and 15%.
- (5) All timber shall be treated with wood preservative, carried out by a specialist firm, by the full cell vacuum/pressure impregnation process in accordance with BS 144. Timber shall be dry before incorporation into the works.
- (6) Timber skirtings shall be secret fixed by screws at maximum 600mm centres and concealed with matching timber pellets set flush. Skirtings shall be secured to timber grounds fixed to walls with plugs and screws.

2.5.3 Plywood

- (1) Plywood shall be of the grade appropriate for its use. Unless otherwise required plywood shall be grade 2 with type 1 adhesive and shall be either WBP (weather and boil-proof) or MR (moisture and weather resistant) where used for weather resistant locations.
- (2) Plywood shall be treated with an appropriate flame retardant treatment and be designated Class 0 fire resistant with Clause 1 surface spread of flame when tested to BS 476.

2.5.4 Laminated Plastic Sheeting

- (1) Decorative laminated plastic sheeting shall be an approved melamine surface sheeting 2mm thick.
- (2) Samples of the type the Contractor proposes to use indicating the texture and pattern shall be submitted to the Engineer for Notice of No Objection prior to use.

2.5.5 Adhesives

- (1) Adhesives for joinery and timber work shall be cold setting synthetic resin adhesive moisture resistant gap filling type complying with BS 1204. The use of animal glues will not be permitted.
- (2) Adhesives for plywood shall be either:-
Type 1 Phenol formaldehyde resin adhesive classified as weather and boilproof

(WBP) in BS 1203.

Type 2 Urea formaldehyde resin adhesive classified as moisture and weather resistant (MR).

- (3) Adhesive for bonding plastic sheeting to timber is to be noticed synthetic resin adhesive used strictly in accordance with the manufacturer's instructions. Plastic sheeting must not be applied to timber at a temperature less than 60°F or with a moisture content of more than 15%.

2.5.6 Workmanship

- (1) The whole of the carpentry and joinery work shall be executed in the best and most workmanlike manner.
- (2) All necessary templates, lining blocks, stops and the like are to be provided and fixed and all trimmings, tongue & groove, mitre joint etc. incidental to the work are to be undertaken even though not specifically mentioned.

2.5.7 Raised Access Floors

- (1) Raised access floors shall be an approved flooring system. Floors shall be of monolithic homogeneous totally primed fibre reinforced calcium silicate material with balanced density all over the panel. Panel size shall be 600 x 600 x 41mm thick. Also the panel shall meet Class-A Non Combustible. All support stringers shall be of solid steel construction.
- (2) Floors shall be installed in accordance with the manufacturer's instructions.

2.5.8 Sound Absorbing Material

- (1) Sound insulation shall be 50mm thick moisture resistant colour coated mineral wool fixed sheet, laid loose and secured with fixing clips to the upper surface of the suspended ceiling to the areas indicated on the design Drawings.
- (2) Insulation shall be neatly finished around all penetrations.

2.5.9 Acoustic Non-Combustible Board Suspended Ceilings

- (1) Acoustic non-combustible board suspended ceilings shall be acoustic mineral fibre board suspended ceilings.
- (2) Mineral fibre ceiling boards shall be 15mm thick with regular or recessed edges in panels of 600 x 600mm and moisture resistant. The 600 x 600 x 15mm mineral fibre board ceiling shall be laid on exposed suspension system consisting of aluminium tee grid system or of other approved metal suspension system.
- (3) Openings shall be provided for recessed light fixtures, air-conditioning diffusers, grilles, registers, columns, access panels, etc. including provision of additional framings, wall angle trims, hangers and the like.
- (4) The Contractor shall submit full details on the type of ceiling systems proposed complete with fixing and suspension system details for Notice of No Objection from the Engineer.

2.5.10 CEM Board Ceilings

- (1) Non-combustible board suspended ceilings shall be Cem board suspended ceilings or equivalent.
- (2) The Cem board ceiling panels shall be 16mm thick with recessed edges in panels sizes of maximum 1200 x 600mm as directed by the Design. The 1200 x 600 x 16mm Cem board ceiling shall be fixed butt jointed concealed suspension system consisting of aluminium tee grid system or of other approved metal suspension system. The

Cem board ceiling panels shall be fixed to the aluminium or metal tee grid by means of screws or with edges grooved or recessed for housing the edges of the tee grids.

- (3) If screws are used for fixing the ceiling panels to the suspension grids, the screw heads shall be countersunk and stopped up with approved filler and prepared the board surface for receiving paint.
- (4) Provide and apply one coat of alkali resisting primer and two coats of emulsion paint to the Cem board ceilings on completion.
- (5) Openings shall be provided for recessed light fixtures, air-conditioning diffusers, grilles, registers, columns, access panels, etc. including provision of additional framings, wall angle trims, hangers and the like.
- (6) The Contractor shall submit full details of the type of ceiling systems proposed complete with fixing and suspension details for Notice of No Objection from the Engineer.

2.5.11 Fibrous Gypsum Plaster Board Ceilings

- (1) Fibrous gypsum plaster board ceilings shall be installed on concealed suspension system in areas where indicated on the design drawings.
- (2) Fibrous gypsum plaster board ceilings shall be in 13mm thick in convenient panel sizes fixed to aluminium or other approved metal suspension system in accordance with the manufacturer's instructions.
- (3) The panels shall be fixed butt jointed and taped over, grouted on at back of board and filled in with gypsum plaster to obtain a jointless and even surface. All screw heads shall be sunk into the ceiling boards and filled in with gypsum plaster. The gypsum plaster board shall be prepared to receive a skim coat of gypsum plaster minimum 3mm thick to be finished to smooth and even surface. The gypsum plasterboard ceiling shall be finished with patent sealer and two coats of emulsion paint of approved colour.
- (4) The concealed suspension system for the fibrous gypsum plaster board ceiling shall generally consist of a channel grid system with main spines spaced at 600mm centres and firing channels at minimum 600mm centres and with suspension rods spaced at 600mm centres both ways.
- (5) Openings shall be provided for recessed light fixtures, air-conditioning diffusers, grilles, registers, columns, access panels, etc. including provision of additional framings, hangers and the like.
- (6) The Contractor shall submit full details on the type of ceiling systems proposed complete with fixing and suspension system details for Notice of No Objection from the Engineer.

2.5.12 Metal Suspension System

- (1) All ceiling systems as before specified shall be in aluminium or other approved metal suspension system for both exposed and concealed suspended ceilings.
- (2) The suspension system shall consist of the appropriate T-bars to form the panel sizes and with minimum 38mm deep main carrying channels or spine spaced at maximum 600mm centres. The whole suspension system shall be hung from the concrete soffit by means of minimum 5mm diameter galvanised rod hangers fixed to cast in support anchors.
- (3) The 5mm diameter galvanised rod hangers shall be in two parts. The top portion hooked on to an angle bracket, one end holed to receive the rod hanger and other

end in the concrete soffit. The lower portion of the hanger is fixed to the main carrying channel or spine of the grid system at 600mm centres both ways by means of spring clips or hooking around the channel and fixed to the upper portion with a flat spring clip to permit adjustments in the levelling of the ceiling boards.

- (4) The above description on the suspension system shall be the minimum standard required. The Contractor shall submit the details of the suspension system and hangers together with catalogues, detail drawings and samples, if any, for each type of ceiling offered for Notice of No Objection from the Engineer.

2.5.13 Modifications Generally

- (1) The Contractor may make changes in detailing the work in order to conform to standard procedures or as required to facilitate field erection.
- (2) The Contractor, with the Notice of No Objection from the Engineer, may make changes in the shapes and sizes of the members before final agreement of ceiling types.

2.5.14 Workmanship Generally

- (1) The installation of the suspended ceilings under this Contract must be carried out by specialist workmen who shall verify all dimensions shown on the design Drawings with actual site measurements before fabrication of the ceiling panels. Any cutting to enlarge size of openings, etc.. to suit site requirements shall be executed by the Contractor without additional costs.
- (2) Ceiling framing and ceiling tiles as offered shall be erected in accordance with the manufacturer's recommendations, laid and fixed to level lines in all directions and levelled in individual rows across all areas scheduled to receive them. Where ceilings are shown to be sloping, the angle of the slope must be properly set out.
- (3) The height of the primary bars of the suspension system for the ceilings shall be adjusted to ensure a level flat plane.
- (4) Ceiling tiles and panels shall be rigidly fixed to the type of suspension system and shall present an even, flat and rigid soffit to the areas concerned. All joints in both directions shall form perfect straight lines.
- (5) Openings shall be provided for recessed light fittings, ducted light fittings, air diffusers, access panels, etc. with all necessary framings and trimming pieces to ensure a perfect fit for these fittings. Ceiling tiles and panels shall be cut and fitted to all perimeters as necessary and as shown on the design Drawings.

2.5.15 Protection

All work is to be handed over on completion in a clean undamaged condition free of scratches and surface blemishes.

2.5.16 Ironmongery

- (1) All Ironmongery shall be fixed with matching screws. Ironmongery, except butts, shall be removed before decoration and subsequently re-fixed, oiled and adjusted.
- (2) All keys shall be labelled and handed to the Engineer. Master and sub-master keys shall be handed over in the original factory sealed packing.
- (3) All locks shall be of the Mortise type; and are to be a model which incorporates a Removable Key Cylinder containing the facilities of a Master Key Suiting System.
- (4) The Contractor shall make full allowance for the provision of Temporary Locking facilities, - as and where deemed necessary, during the Construction phase of the works.

- (5) The Contractor shall coordinate With the Employer / Engineer, to integrate certain doors of station building with BMS System. Contractor shall interface with system contractor to design and install locking system of to be compatible with BMS System.

2.6 Steel and Metal Worker

2.6.1 Shop Drawings

- (1) The Contractor shall be required to prepare detailed shop drawings necessary for carrying out the work.
- (2) These drawings shall be prepared before any manufacturing or fabrication work is proceeded with.
- (3) Drawing submitted shall show complete and detailed particulars, which shall include but not be limited to the following items: -
 - a) Proper drawings showing full construction, support and fixing details.
 - b) Proposed methods of supporting and fixing exterior screens, and louvers.
 - c) Complete specifications of materials and coating used, steel or aluminium alloys from which the sections are manufactured including chemical and mechanical properties and detailed results of tests.
 - d) Details of guarantees covering materials, manufactured items and fixings from manufacturers (if obtainable) shall be provided to the Engineer.
- (4) Shop drawings are specifically required for but not limited to roller shutters, door sets, louvers walling system, balustrades, handrails, aluminium suspended ceiling, track canopy, track access stairs, kiosk, footway bridge cladding and roof structure.

2.6.2 Materials

- (1) All ferrous metals shall be free from rust, scale, and any other defects and the various shapes and sections shall be clearly rolled or otherwise formed to uniform sections. All non-ferrous metal shall have uniform finished surfaces, machined and buffed, free from defects and all sections shall conform accurately to the sizes and shapes required.
- (2) Steel shall comply with the requirements of BS 4360 and the Contractor shall produce the manufacturer's test certificates when so required by the Engineer.
- (3) Wrought iron shall be malleable quality, straight and of constant section.
- (4) Aluminium shall be to BS 1470 (sheet) or BS 1161 (sections). Where stated, aluminium shall be polyester powder coated or colour anodised to BS 3987 to colours selected by the Engineer.
- (5) Bolts generally shall have hexagonal heads and nuts unless otherwise stated and all bolts shall be fitted with washers.
- (6) Anchors shall be noticed expansion tapered nut type anchors for fixing all bolts in brickwork or concrete. Mortises for anchors shall be drilled to the required diameters in accordance with the manufacturer's instructions so that no damage is done to the receiving surface. Power fixing shall be as noticed.
- (7) Metal lathing shall be to BS 1369 or 405 as appropriate.

2.6.3 Galvanizing

- (1) All galvanizing shall be done by the hot dip process in accordance with BS 729 Table 1 galvanized after fabrication.

- (2) Metal surfaces shall be thoroughly cleaned of all mill scale, rust, dirt, grease, oil, moisture, and other deleterious material by pickling or sand blasting prior to galvanizing.
- (3) Steel to be galvanized shall be dipped in a 93.5% pure zinc bath and given a coating of 0.60kg/m^2 minimum of zinc.

2.6.4 Stainless Steel

- (1) All stainless steel work shall conform to the requirements of BS 1449 Part 2. Stainless steel shall be low carbon chromium nickel austenitic steel, type 302 or 304.
- (2) The surface of stainless steel shall be in No. 4 brushed with an abrasive 150 or 200 mesh in one direction to achieve a hairline finish.
- (3) All stainless steel shall be factory fabricated to the best standard of workmanship and under factory supervision and control.

2.6.5 Chromium Plating

Chromium plating finishes shall be electroplated chromium coating to BS 1224 and shall be guaranteed to be permanent and unaffected by normal tropical atmospheric conditions. The Contractor must submit samples of the chromium plated sections for the Engineer's notice before commencement of fabrication.

2.6.6 Shop Priming

- (1) All ferrous metals except galvanized, chromed, stove enamelled surfaces or stainless steel shall be cleaned and shop primed with one shop coat of metal primer compatible with later finish coats of paint. All ferrous metals exposed to the weather or attached to the exterior of the building shall receive one additional coat of metal primer on the concealed surfaces before their installation.
- (2) Ferrous metals shall be thoroughly cleaned of all oil, grease, rust, mill scale and other deleterious materials by solvent cleaning and wire brushing or other approved means.
- (3) Shop priming shall be applied immediately after cleaning the metal. Priming shall be applied in dry weather or under cover and metal surfaces including edges, joints, holes, corners, etc. shall receive primer and all surfaces which will be concealed after assembly shall be shop primed prior to assembly. All primers shall be used in accordance with the manufacturer's printed instructions and the use of any thinners, adulterants, or admixtures shall be only as stated in the instructions. Priming shall be applied uniformly and completely over the metal surfaces. No work shall be delivered to the Site until the shop-primed coat has thoroughly dried.
- (4) Any damaged or abraded surfaces of the metal items shall have their priming touched up in the shop and if necessary after assembly on the Site. Touching up primer shall be the same as the primer applied in the shop.

2.6.7 Protective Coatings

Wherever dissimilar metals will be in contact or wherever galvanized or aluminium metals will be in contact or embedded in the concrete, cement, mortar, plaster or masonry, the contact surfaces shall be separated by coating each contact surface prior to assembly or installation with one coat of bituminous aluminium paint which shall be in addition to the specified shop prime or galvanizing. Those surfaces not required to receive protective coatings shall be masked off.

2.6.8 Polyester Powder Coating

- (1) Polyester powder coating shall be of polyester powder and be applied by a specialist

firm to a minimum thickness of 70 microns.

- (2) The various colours to be coated are to be selected by the Engineer from the full BS colour range.
- (3) Before applying the powder coating, all weld slag, weld spatter, anti-spatter compounds, paints, grease, flux, rust, burrs and sharp arises are to be removed. All defects which would show after application of the coating are to be made good and finished smooth.
- (4) All surfaces shall be prepared in accordance with the powder manufacturer's recommendations including de-burring, degreasing, and oven drying.
- (5) Powder coating shall be applied after fabrication of the components is complete and all fixing holes have been drilled unless otherwise specified.
- (6) Unless otherwise specified two coats of bitumen solution or mastic impregnated tape shall be applied before fixing to surfaces of aluminium in contact with cement or plaster and between dissimilar metals and alloys where contact could lead to electrolytic corrosion.

2.6.9 Fluorocarbon Coating

- (1) General
 - a) This section specifies the requirements of fluorocarbon coating for extruded aluminium sheets and galvanized metal sheets and extrusions.
 - b) Fluorocarbon coatings shall be carried out by a selected or approved applicator and shall observe strict factory application requirements as recommended by the coating manufacturer.
- (2) Quality Assurance

The Fluorocarbon coatings shall meet the performance requirements of the AAMA 605.2 - Specification for high performance Organic Coatings on Architectural Extrusions and Panels.
- (3) Coat System
 - a) The Fluorocarbon coating for extruded aluminium and aluminium sheet shall be factory applied, oven baked finish. The Fluorocarbon coatings cannot be field applied.
 - b) The Fluorocarbon coating system shall be applied to properly cleaned and pre-treated aluminium. The pre-treatment shall meet ASTM D1730-67, Type B, Method 5 or Method 7. Processing shall conform with ASTM B- 449-67 (1972) section J. Conversion coating weight shall be between 30- 110 mg per sq. ft.
 - c) Coating

The Fluorocarbon coating (3 coat system) shall consist of an inhibitive Primer with dry film thickness averaging 5 to 7 microns, top-coat (colour coat) with a minimum dry film thickness of 25 microns and a clear top coating with a minimum dry film thickness of 10 to 20 microns. The total minimum dry film thickness of the 3 coat system shall be 40 microns. The Fluorocarbon coating system shall meet or exceed the performance requirements of the AAMA 605.2 "Specification for High Performance Organic Coatings on Architectural Extrusions and Panels" which has the following performance requirements.

 - i) Colour Retention

Maximum of 5E units (NBS) colour change as calculated in accordance with

ASTM D2244-68, PPG. 3.3.1.4, after 5 years of 45° South Florida exposure. Colour change shall be measured on exposed painted surface. New colours may be qualified without 5 years of actual exposure provided that they are produced with the same pigments in the same coating system as a colour on which 5 years exposure data is available and which is within + or - 10 percentage points in lightness (L).

ii) Chalk Resistance

Chalking shall be no more than that represented by a No. 8 rating for colours and a No. 6 rating for whites based on ASTM D659-44 (1970) after 5 years of 45° South Florida exposure. Chalking shall be measured on exposed unwashed painted surface.

iii) Humidity

In accordance with ASTM D2247-68 (1973) withstand 3,000 hours at 100° F at 100% relative humidity with no formation of blisters to extent greater than "Few" blisters also No. 8 as shown in figure No. 4, ASTM D714-56 (1970).

iv) Salt Spray

In accordance with ASTM B117-73 withstand 3,000 hours at 5% salt fog at 95° F with 1/16 inch maximum under-cutting of film from scored line or cut edges when taped and pulled off at right angles.

v) Pencil Hardness

F minimum Eagle turquoise pencil.

vi) Gloss

25-35 on 60° glossmeter in accordance with ASTM D523-67 (1972) for most colours. The Engineer may accept a slightly lower gloss for certain colours.

vii) Adhesion

No removal of finish after 1/16 inch cross hatching to bare metal, after subjecting the cross hatched finish to quick removal with 3M transparent #710 tape.

viii) Abrasion Resistance

In accordance with ASTM D968-51 (1972), the falling sand Abrasion Co-efficient Value shall be 20 minimum.

ix) Impact Resistance

Withstands 0.10 inch direct deformation of sample with Gardner Variable Impact Tester, 160 inch-pound range, no removal of film taping with 3M transparent #710 tape.

x) Sealant Compatibility

Sealants shall exhibit no deleterious effects to the coatings.

Note:- The fabricator of the finished product shall consult with his sealant supplier in selection of sealant which will exhibit adequate adhesion to the painted aluminium surface. Panel exhibits of the specific manufacturer for tests as described TT-S-227E and TT-S-00230C are suggested.

xi) Mortar Resistance

Withstands wet mortar, 24 hours pat test at 100% R.H. without gaining adhesion or any visual effect on the painted surface of solid colours. Metallic may show slight stain. Mortar is 75 grams of dry sand plus 100 grams of water to make a soft paste.

xii) Muriatic Acid Resistance

Withstands exposure to 10% muriatic acid solution - 15 minutes spot test with no blistering, or visual change in appearance.

xiii) Detergent Resistance

Withstands immersion in 30 synthetic detergent solution for 72 hours at 100°F with no loss of adhesion and no visible change.

2.6.10 Workmanship Generally

- (1) All metalwork shall be fabricated and installed by experienced fabricators or manufacturers. The materials, methods of fabrication, fitting, assembling, brazing, supporting, fastening, operating devices and erection shall be in accordance with the working drawings, this Specification, approved shop drawings and best practices of the trade. All materials shall be new and clean having structural properties sufficient safely to sustain or withstand stresses and strains to which materials and assembled work will be subjected. All work shall be accurately and neatly fabricated assembled and erected.
- (2) In so far as practicable fitting and assembly of work shall be done in the shop. Work that cannot be permanently shop assembled shall be completely assembled, marked and dismantled in the shop, before shipment, to ensure proper assembly on the Site. All work shall be shop assembled in the largest practicable sizes to minimize Site work. It is the responsibility of the Contractor to ensure that the shop fabricated items will properly fit into the Works. In the event that shop fabricated items do not fit into the Works the items shall be returned to the shop for correction.
- (3) Metal shall be cut by sawing, sheering or blanking. Flame cutting will be permitted only if cut edges are ground back to clean smooth edges. All cutting shall be accurate, clean sharp and free of burrs without deforming adjacent surfaces or metals. All holes required in the metalwork shall be drilled or cleanly punched holes. Burning to form holes is prohibited.
- (4) Where exposed to the weather. Joints shall be located where least conspicuous. Unless otherwise shown shop connections shall be welded or bolted and Site connections shall be bolted or screwed. Expansion and contraction joints to allow for thermal movement of metals shall be provided.
- (5) For the metals being welded, welds shall be continuous except where spot welding is specifically required. Welds exposed to view shall be ground flush and dressed smooth to match the finish of the adjoining surfaces. Where welds are required to be flush the metal edges shall be undercut. All welds on or behind surfaces which will be exposed to view shall be executed so as to prevent distortion of the finished surface. Weld spatter and welding oxides shall be removed from all welded surfaces.
- (6) Brazing shall be to BS 1723.
- (7) Threaded connections shall be made tight with threads entirely concealed and the use of lock nuts. Bolts and screw heads exposed to view shall be flattened countersunk with projecting ends of exposed bolts and screws cut off flush with

the nuts or adjacent metal surfaces.

- (8) Abutting bars shall be soldered and headed, doweled and pinned or small bars shall pass through larger bars and then be pinned.
- (9) Castings shall be in one piece where practicable and of uniform thickness sufficient to ensure the required strength for the design and use. Castings shall be clean, smooth, true to dimensions and pattern, free from defects and the best quality with all surfaces and edges clean, smooth and perfect.
- (10) Operating devices, mechanisms and hardware used in connection with metalwork shall be fabricated, assembled, installed and adjusted after installation so that they will operate smoothly, freely, noiselessly and without excessive friction.
- (11) All supplementary and miscellaneous parts for each item of work shall be provided as necessary so that it may serve its function properly even though these may not be specifically shown in the Contract Documents.
- (12) All metalwork shall be fabricated to co-ordinate with other trades and services and work shall be accurately cut, fitted, drilled and tapped to accommodate such trades and services. Templates and drawings shall be provided for proper co-ordination of this section of the Works.
- (13) In addition to the foregoing and other requirements of the Contract Documents metalwork shall conform to the following:
 - a) All surfaces exposed to view shall be clean and free from dirt, stains, grease, scratches, distortion, waves, dents, buckles, tool marks, burrs and other defects which mar the appearance of finished work.
 - b) All surfaces exposed to view shall be straight and true to lines or curves. Arises and angles shall be as sharp as practicable. Mitres shall be formed in true alignment with profiles accurately intersecting and all joints carefully matched to produce continuity of line and design. Exposed edges shall be eased to a radius of approximately 1mm unless otherwise shown. Metal corners shall be bent to the smallest radius possible without causing grain separation or otherwise impairing the work.
- (14) All exposed connections shall be formed with hairline joints flush and smooth using fasteners wherever possible. Exposed fastenings where permitted shall be of the same material, colour and finish as the metal to which they are applied unless otherwise indicated and shall be of the smallest practicable size, flat headed countersunk screws or bolts.

2.6.11 Installation Generally

- (1) All work shall be installed square, plumb, straight, true to line or radius, accurately fitted and located, with flush type hairline joints (except as indicated otherwise or to allow for thermal movement), with provisions for other trades, with provision for thermal movement, with provision to exclude water where exposed to the weather and with attachment devices as required for a secure and rigid installation, all in accordance with the noticed shop drawings.
- (2) Unless otherwise specified work to be built in concrete or masonry shall be anchored with galvanized steel strap anchors shop welded on. Work to be attached to concrete or masonry shall be anchored by bolts embedded into inserts or expansion shields. Work attached to structural steel shall be anchored by welds or bolts and work attached to metals other than structural steel shall be anchored

by bolts or screws. Power actuated fasteners are not permitted unless approved by the contractor's Designer and with a Notice of No Objection from the Engineer.

- (3) The Contractor shall protect all metalwork and subsequently remove all protective applications and clean prior to Completion of the Works. Where shown on drawings or directed by the Engineer, joints and edges, etc. are to be pointed with an noticed coloured silicone sealant. Sealants shall be applied in accordance with the manufacturer's instructions with backer rods provided where necessary. All surfaces to receive sealant shall be thoroughly cleaned; excess material and spillage shall be properly cleaned off and removed.

2.6.12 Site Measurements

The Contractor is solely responsible for ensuring total co-ordination of all work and shall take Site measurements prior to the preparation of any shop drawings or before commencing fabrication.

2.6.13 Roller Shutters and Roller Grilles

- (1) Rollers shutters shall have all exposed metal in pressed steel with stoved enamel finish to approved colours and roller grilles shall have all exposed metal in natural anodized aluminium.
- (2) Shutters and grilles shall be completed with spring counter balance, bracket plates, guides and stainless steel hoods.
- (3) Operation shall be by motor operator which shall include high starting torque motor, reduction gearing, solenoid brake, limit switches for upper and lower limits of door travel, magnetic relay contractor, overload protection, prewiring to terminal block, two button operating station. Motor is to be removable for repair without affecting emergency operation. Manufacturer is to furnish wiring diagram.
- (4) Safety edges are to be furnished for motor operated shutters. Upon contact with an obstruction the shutter is to stop and return to open position.
- (5) Cylinder locks shall be supplied in bottom bars masterkeyable to building system.
- (6) A pull handle mounted in recessed box to open the motor operated shutter manually for emergency exit shall be provided.
- (7) The Contractor shall carry out the field wiring and make electrical connection into the adjacent power outlet.

2.6.14 Fire-rated Metal Doors, Hollow Metal Doors and Door Frames

- (1) All fire-rated doors, comprising door, frames, Ironmongery, and installation shall be supplied and installed by specialist manufacturers.
- (2) Fire-rated doors shall be to the required size and thicknesses batch inspected, and certified. The fire doors shall comply (testing of fire doors) to the relevant NFPA Standards (including UL Certification) and/or to the relevant BS 476 Part 8 standard for the periods of fire-resistance required.
- (3) Hollow metal doors shall be obtained from Specialist Manufacturers and shall comply with the following requirements: -
 - a) Interior hollow metal doors shall be fabricated of 1.2mm thick (approx. 18 gauge) cold rolled stretcher-level sheet steel, free from rust, scale, pits and surface defects.
 - b) Exterior hollow metal doors shall be fabricated of 1.5mm thick (approx. 16 gauge) zinc-coated bonderized sheet steel.
 - c) Construction:

- i) Doors shall have continuous internal reinforcing channels or Z-shaped members of 1.5mm thick (approx. 16 gauge) steel, for the full height of the door, spaced not more than 150mm and spot welded to face sheets every 75mm.
 - ii) Doors with continuous truss inner core, full height and width, spot welded to face sheets every 75mm both vertically and horizontally are also acceptable.
 - iii) Stile channels 0.6mm thick (approx. 24 gauge) and 1.87mm thick bottom of doors welded to face sheets.
 - iv) All hollow portions of doors shall be filled completely with mineral rock wool or equal.
 - v) Exposed joints shall be fully welded, filled and ground smooth.
 - vi) Interlocking joints or seams are not acceptable on faces or edges.
 - vii) Single swing doors shall be provided with not more than 3mm clearance at jambs and heads and not more than 6mm clearance at meeting edges of pair of doors (3mm on fire rated doors).
 - viii) Door shall have a 3mm in 50mm level on the strike side.
- d) Construction and core materials of labelled doors shall meet NFPA 130 or equivalent, requirements.
- e) Exterior doors shall have flush top and bottom caps sealing against water, of same gauge and materials as face sheets.
- f) Reinforcement for finish hardware shall be provided as follows:
 - i) Reinforcement for butts shall be 4.76mm thick by 230mm long and 6mm narrower than the thickness of the door.
 - ii) Reinforcing plates for closers, holders, stops and checks shall be 4.76mm thick by template requirements as to length and width.
 - iii) Reinforcement for locks and escutcheons shall be box type of 1.87mm thick (approx. 14 gauge) steel, with spring leaf contracts for lock cases.
 - iv) Reinforcement for exit devices and mortise or surface applied hardware shall be minimum 2.6mm thick and by template requirements as to length and width.
- g) Glazed openings shall be provided with removable 1.2mm thick (approx. 18 gauge) glazing beads of same material as doors. Construction and installation shall be as specified under Pressed Metal Frames.
- h) Door panels shall be free from buckles, twists or other imperfections. Panels having a buckle exceeding 1.5mm, as determined by a straight edge applied to the face of the panel, shall not be used.
- (4) Pressed metal frames shall be of profiles to suit the details shown on design Drawings and shall be of new prime quality hot-rolled carbon steel. Exterior frames shall be fabricated from zinc-coated sheet chemically treated after fabrication for paint adhesion.
- (5) Pressed metal frames shall be of the following minimum thickness and sizes:
 - a) Exterior pressed metal frames: 1.87mm (approx. 14 gauge).
 - b) Interior pressed metal frames for single leaf openings: 1.5mm (approx. 16 gauge).

- c) Interior pressed metal frames for double leaf openings: 1.87mm (approx. 14 gauge).
 - d) Frames for labelled openings shall be in accordance with certifying laboratory or agency requirements.
 - e) All pressed metal frames for fixed glass settings adjacent to and in conjunction with doorframes shall be of the same thickness as frames.
 - f) Frames for independent interior glazed units shall be 1.5mm (approx. 16 gauge).
 - g) Frames indicated on the Construction Reference Drawings to be lead lined shall receive lead linings arranged to provide effective lead insulation between the partition and the door, and equal to that specified for the partition.
 - h) Wall anchors shall be same thickness and materials as frame.
 - i) Removable glazing beads: 1.2mm (approx. 18 gauge) for interior and 1.5mm (approx. 16 gauge) galvanized steel for exterior.
 - j) Frame splines: same thickness and material as frames.
 - k) Hinge reinforcement: 4.76mm by 40mm x 250mm.
 - l) Strike reinforcement: 4.76mm by 40mm x 100mm.
 - m) Closer and holder reinforcement: 3.4mm (approx. 10 gauge) by the required length and width.
- (6) Frames shall have all construction joints welded full depth and width, or weld equivalent splice plates on exposed faces of frames. Exposed surfaces of welded joints shall be dressed to produce invisible connections. Reinforcements and stiffeners shall be welded to inside surface of frames.
 - (7) The finished work shall be strong and rigid, neat in appearance and free from warp and buckle. All members shall be clean cut, straight and true. Mitres shall be well formed and in true alignment. Fastenings shall be concealed wherever possible.
 - (8) 0.76mm thick steel plaster guards or motor boxes shall be provided of the same material as the frame, welded to the frames at the back of all finished hardware cutouts and reinforcements.
 - (9) All single doorframes shall be punched and provided with three (3) rubber silencers. All double doorframes shall be punched to receive four (4) silencers similarly provided. Silencers are to be shipped loose for installation after final painting.
 - (10) Pressed metal frames for labelled doors shall be constructed and anchored in strict accordance with certifying laboratory or agency requirements and bear an applicable label.
 - (11) Anchors:
 - a) Adjustable anchors for frames in masonry walls shall be "T" - shaped steel. The frame leg shall be the full width of jamb depth less 3mm by jamb face width less 3mm. The stem of the anchor shall be 75mm wide, corrugated, or perforated for mortar bond and extend at least 250mm into the masonry. Each jamb for openings up to and including 1500mm high shall be provided with two (2) anchors, and an additional anchor shall be provided on each jamb for each additional 750mm of height or fraction thereof.
 - b) Frames in concrete walls shall be anchored by means of expansion shields and

flat-head machine screws. Screw heads shall be counter-sunk in soffit of the jamb. Machine screws shall be 9mm diameter by 44mm minimum long malleable iron or steel expansion shell. The jamb shall be reinforced at each expansion screw location with 4.76mm thick by 38mm wide steel fitting into inside of stop and welded to backbends. Anchors shall be located not more than 150mm from top and bottom of each jamb with intermediate anchors spaced at a maximum of 650mm centres.

- (12) Hollow metal doors and pressed metal frames shall be prepared at the manufacturer's plant for all hardware in accordance with templates furnished and shall be drilled and tapped to receive hardware as indicated on the hardware templates.
- (13) All Ironmongery to fire-rated doors are to be supplied and installed by a Specialist Contractor together with the doors and frames complete.
- (14) All ironmongery is to be noticed stainless steel supplied and fixed by the Contractor.
- (15) All doors, including fire-rated doors and frames, hollow metal doors are to have spray enamel painted finish and frames to hollow metal doors are to be finished with electro - powder baked enamel coated finish.

2.6.15 Perforated Metal Ceilings

- (1) Perforated metal ceilings to public and non-public areas shall be approved 600 x 600mm x 0.8mm thick perforated aluminium panelled suspended ceilings complete with concealed suspension system, trims and the like supplied and installed in accordance with the manufacturer's instructions.
- (2) Perforated metal ceilings shall be insulated with mineral wool insulation where described and indicated.
- (3) The ceiling panels shall be finished with fluorocarbon coating as before described to the colours selected by the Engineer.

2.6.16 Granite Trim to Metal Ceiling

- (1) Granite trims to metal ceilings shall be fixed to the concealed galvanized steel suspension system with stainless steel or other approved non-ferrous metal fixing cramps or anchors. The granite slabs shall be fixed butt jointed. Granite slabs used shall be polished granite slabs of best-selected quality.
- (2) Openings for recessed light fixtures, air-conditioning diffusers, grilles, registers, columns, framings, hangers and the like shall be provided.
- (3) The Contractor shall submit full details on the type of ceiling systems proposed complete with fixing and suspension details for the Notice of No Objection from the Engineer.

2.6.17 Aluminium Strip Ceilings

- (1) Aluminium linear ceilings to public and non-public areas shall be noticed 200mm wide aluminium linear ceilings complete with concealed suspension system installed in accordance with the manufacturer's instructions.
- (2) The aluminium strip ceilings shall be insulated with mineral wool or other equivalent insulation material.
- (3) The strip ceilings shall be finished with fluorocarbon coating as before described to the custom colours selected by the Engineer.

2.6.18 Metal Wall Cladding

- (1) Metal wall cladding shall be designed, supplied and installed by specialist manufacturer and/or contractor.
- (2) The metal wall cladding shall be designed to comply with the following requirements:
 - a) The base metal for the cladding face shall be of commercial quality open coil annealed decarbonised enamelling steel complying to BS 1449 with carbon content of maximum 0.008 percent and minimum 1.6mm thick.
 - b) The surface finish of the cladding metal shall be in vitreous enamel finish in two coat work separately fired to an overall thickness of over 200 and not more than 400 microns and of custom colours to be selected by the Engineer.
 - c) The structural frameworks shall be in hot-rolled galvanized steel sections with galvanizing coating of 500 g/m² of zinc on all surfaces. The galvanized steel frameworks shall be a minimum 2mm thick.
 - d) The metal cladding shall be filled in with sound-deadening, non- combustible, asbestos free, rot and vermin proof insulation.
 - e) At grooves and junctions between panels or between panels and other wall finishes, non-structural synthetic rubber gasket and sealant shall be provided, of colour to be selected by the Engineer.
 - f) The metal cladding panels shall be designed to be mounted on structural, non-structural walls or as independent wall partition where indicated on the Drawings with all necessary fixing brackets. The panels should also be designed for convenient fixing and dismantling to suit ease of maintenance. All fasteners are to be concealed.

2.6.19 Aluminium Windows, Panels, Louvres and Grilles

- (1) Aluminium windows, panels, louvres and grilles shall be supplied and installed by one specialist manufacturer.
- (2) Aluminium frames and sections shall be constructed from aluminium extrusions to the sizes and sections required and shall be a minimum of 3.0mm thick and as detailed to BS 1161 and free from all defects impairing appearance, strength or durability.
- (3) Hardness of the sections shall be TS conforming to BS 1474.
- (4) The extrusions used shall be free from distortion and of suitable wall thickness for rigidity. The gauge of the aluminium shall be submitted for Notice of No Objection from the Engineer.
- (5) As far as possible, extruded sections shall be such as will permit interlocking of parts, weather-tight fit with a flush face, without use of built-up strips and exposed screws.
- (6) All corners and intersections are to be accurately machined, milled and fitted to hair line joints prior to assembly.
- (7) Allowance is to be made in the design, fabrication and erection for all aluminium work and all supporting steelwork. A system of drainage holes to control drainage and seepage is to be provided. Details of design of supporting steelwork are to be included in the shop drawings.
- (8) Frames shall be fabricated in sizes to enable them to be handled in position

and fixed to the structure without risk or damage. Frames are to be fixed in position to true line, using approved fixings.

- (9) Where frames are to be cold formed from aluminium sheets, the profiles shall conform to details and shall present clean, straight, sharply defined lines, and shall be free from die marks or defects. Screw reinforcing pads shall be provided in all framing sections for all clip, angle and screw points. Frame edges shall be cleanly sheared and free from burring. All corners shall be neatly mitred, secured, jointed and reinforced by means of structural corner assemblies.
- (10) All frames and supporting steelwork shall be designed and installed in positions to withstand deflection and wind pressure of 150 kg/m² and shall be rigid to support and retain the glass under all conditions.
- (11) All aluminium windows and grilles are to be fluorocarbon coated as referred to in Outline Construction Specification, sub-section 2.6.9.
- (12) Joints between aluminium frames and adjacent structure shall be pointed with noticed coloured silicone sealant and backer rods.
- (13) To prevent damage by agents such as contaminated moisture, condensation, cement and plaster splashes, the significant surfaces shall be protected by non-yellowing transparent lacquers which weather away naturally in service or strippable tapes/wax casts which can be easily removed.
- (14) Strippable tapes shall possess a bond strength between the tape and the adhesive which is greater than that between the adhesive and the metal surface so that it can be readily stripped even after 12 months or more external exposure, leaving no residue. If for any reason, tapes are removed during the building operations they must be promptly replaced.
- (15) The Contractor shall be responsible for the water proofness of the windows and shall provide a ten (10) years guarantee for such water proofness and all other defects arising from the designs effective from the Completion of the Whole Works.
- (16) Tubular Balustrades, Handrails and Arm Rests
 - a) Balustrades, handrails and arm rests etc. shall be of stainless steel referred to and as described in Outline Construction Specification, Clause 2.6.4 to sizes and sections as detailed on the construction Drawings.

2.6.20 Entrances and Storefronts

- (1) Where shown on the construction Drawings, entrances shall be constructed of glazed stainless steel to comply with the following standards and the finish product shall be to No. 4 satin stainless steel finish.
- (2) Stainless Steel: Stainless Steel elements shall conform to the following:
 - a) Sheet : ASTM A167, ASTM A480, and AISI Type 302 or 304, 2mm minimum thickness.
 - b) Castings : ASTM A296, iron-chromium, nickel.
 - c) Extruded Shapes : Manufacturer's standard complying with drawings.
 - d) Structural Steel : Conform to ASTM A36.
 - e) Glazing : Glass for glazing complying to BS 952.
 - f) Glazing Gaskets : Neoprene formulated complying to the requirements of ASTM C509.

- g) Weather strips : Closed cell neoprene sweep strip, conforming to ASTM C509.
- h) Fasteners and : Welding electrodes and filler metal shall be an alloy and Anchorage Materials type required for strength, work-ability, compatibility and colour to match the fabricated product.
- i) Hardware : Provide hinges, door springs, locksets, door closers, door handles, rails in BHMA 630 or US32D satin stainless steel finish to match the finish metal of the Entrance.

2.7 Plasterer and Tiler

2.7.1 Materials

- (1) Cement, water, sand, colouring agents, waterproofing agents and plasticisers shall be as specified in Outline Construction Specification, sub-section 2.3.
- (2) Gypsum plaster shall be class B or class C plaster in accordance with BS 1191.
- (3) Metal plastering accessories such as corner beads, stop beads, architrave beads and the like shall be galvanized steel or equal approved.
- (4) Ceramic tiles to walls shall be ceramic tiles complying to BS 6431. Colours, pattern and designs shall be subject to the Engineer's selection.
- (5) Glazed ceramic tiles to walls shall be ceramic tiles complying to BS 6431. Colour, pattern and designs shall be subject to the Engineer's selection.
- (6) The Contractor shall allow for special moulded profile tiles and for further selection of colour shades and decorated tiles to conform with wall patterns.
- (7) Granite shall be supplied to the Site precast dressed and drilled for fixing cramps, rebated and worked as finished slabs. No grinding or polishing will be allowed on site except for final cleaning.
- (8) Protection of granite work, selection of granite types and colours and submission of shop drawings for granite laying shall be as described under Outline Construction Specification, sub-section 2.3.

2.7.2 Samples

The Contractor is to provide samples of each different type of plastering and tiling each to be in representative areas of not less than 2000 x 2000 mm for the Engineer's Notice of No Objection before commencing general areas. The noticed sample areas shall be used for the purposes of comparison and any work not equal to its noticed sample will be rejected.

2.7.3 Preparation of Surfaces

- (1) Plastering or tiling shall not be applied on any work which may be unfinished, imperfect, wrong or in any other improper condition to receive such finishings.
- (2) Improper work shall not be covered up or finished against until it has been rectified and a Notice of No Objection to proceed has been given by the Engineer.
- (3) All joints of brickwork are to be thoroughly raked out and loose particles of mortar, etc. brushed off to form a key for plaster.
- (4) If concrete surfaces are not sufficiently rough to provide a key, the surfaces are to be hacked or an approved bonding agent or a dash coat comprising 1:2 cement and coarse sand dashed wet are to be applied on to the surface to provide a key.
- (5) All surfaces to be plastered must be brushed clean and well wetted before each coat is applied.

2.7.4 Workmanship Generally

- (1) All plastering works and tiling works shall be carried out in accordance with BS 5385 where not inconsistent with this Specification.
- (2) Materials shall be mixed in sufficient quantities for immediate use and shall not be used after one hour has elapsed from the addition of water. Gauges are not to be mixed with each other or old batches retempered.
- (3) No plastering or tiling works shall be carried out in unsuitable weather conditions unless adequate protection is arranged beforehand.
- (4) All workmanship shall be of the best quality.
- (5) The plastering and tiling contractors are required to do all making good of work specified in this trade after all other trades.
- (6) All finishes shall be properly made good around all pipes, brackets, electrical boxes, switches, and the like.
- (7) Where shown on the construction Drawings expansion joints in plastering or tiling are to be provided.

2.7.5 Internal Plain Face Plaster

- (1) Internal plain face plaster shall be applied in three coats to a total finished thickness of 20mm.
- (2) Undercoat and floating coat shall comprise one part cement, one part lime and six parts sand by volume.
- (3) The undercoat shall be 12mm thick rough plastering laid on evenly, straightened to rule and scratched to form a key to receive floating coat.
- (4) The floating coat shall be 5mm thick lightly scratched to form a key to receive finishing coat.
- (5) The finishing coat shall be 3mm thick comprising gypsum plaster gauged with not more than one-quarter volume of lime, trowelled to a smooth, hard surface with a steel trowel.
- (6) A minimum of seven days must elapse between the applications.
- (7) Usage of Plasticisers may be notified to the Engineer and then shall be added in accordance with the manufacturer's instructions.
- (8) Metal plastering accessories shall be used where shown on the Drawings and are to be fixed in accordance with the manufacturer's printed instructions.

2.7.6 Backing Screeds

Backing screeds for tiling shall be in single coat work and to the same general specification as for undercoat to plaster work, laid on evenly, straightened to rule and scratched to form a key for the applied finish.

2.7.7 Curing

Each coat of all plastering work or backing screeds is to be maintained in a moist condition for a minimum of three days after it has developed enough strength not to be damaged by water.

2.7.8 Tiling Generally

- (1) All work shall be carried out by experienced first class tilers to the standard sample.
- (2) Tiles shall be neatly cut where necessary keeping well clear of taps, etc. All cut edges of tiles must be carefully ground and jointed.

- (3) Internal angles are to be formed by abutting one tile over the edge of the jointing tile.
- (4) External angles generally are to be formed by abutting the tile neatly against the edge of the adjoining tile. Where called for on the construction Drawings rounded edge tiles shall be used at free edges or angles.
- (5) All tiles shall be grouted with cement coloured to match the tiles upon completion.
- (6) Where circular work is executed to a small radius the Contractor is to allow for additional grouting to joints of tiles.
- (7) Upon completion all tiled surfaces are to be thoroughly washed with clean water.

2.7.9 Glazed Wall Tiling

The tiles after being well soaked overnight in water are to be bedded in cement and sand (1:3) mortar, the mortar buttered on the back of the tiles after which the tiles are to be pressed and tapped home, taking care to keep the joints as thin as possible.

2.7.10 Protection

- (1) The Contractor shall take all precautions to protect wall finishes and shall replace at his own expense any wall finish which is damaged or defaced and shall hand over all areas on completion in a clean condition.
- (2) Replacement of damaged or defaced work may be extended at the Engineer's discretion to include the whole of the room or area affected.
- (3) It shall be the Contractor's responsibility to ensure proper adhesion between all plastering and tiling and the structure and he shall replace at his own cost any loose or defective work, notwithstanding any claim by the Contractor that he has followed the instruction of the Engineer and the Specification regarding the preparation of the surfaces and the formation of a key and notwithstanding the Conditions of Contract.

2.8 Plumber

(Refer Outline Construction Specifications – Architectural Works)

2.9 Glazier

2.9.1 Glass

- (1) The Contractor shall submit samples not less than 150mm square of the various types of glass, as notice to Engineer before cutting panes.
- (2) Glass for glazing shall conform to the requirements of BS 952 for the respective types.
- (3) Glass shall be free from specks, air bubbles, wanes, air holes, scratches and other defects. Glazing shall comply with the requirements of BS 6262.
- (4) Toughened glass shall be float type conforming to BS 952, clear or body tinted as required, flat and parallel surfaces, provide a clear and undistorted vision and shall have a minimum thickness of 12mm.
- (5) Toughened glass shall have a flexural strength a minimum of four to five times greater than normal glass before treatment.
- (6) Glass shall be cut to accurate sizes as determined by accurate field measurements before the tempering treatment. No cutting or treating of edges in the field shall be allowed. All cut and process edges shall be done in accordance with the glass manufacturer's recommendations.

2.9.2 Glazing Compounds and Accessories

- (1) Glazing compounds, including putties, shall be of a type recommended by the window and glass manufacturers and suitable for tropical use.
- (2) Distance pieces and location blocks shall be of PVC with a thickness equal to the specified space between glass and bead and of a depth to give not less than 6mm cover of sealant.
- (3) Setting blocks shall be of lead, sealed hardwood or nylon.
- (4) Sleeves and washers for fixing mirrors shall be polyethylene.

2.9.3 Glazing Generally

- (1) Glazing shall be carried out in accordance with BS 6262.
- (2) The Contractor shall ensure that rebates are dry and clean and have been primed or sealed as required.
- (3) Setting and location blocks shall be used in panes of ordinary glazing over 0.2m^2 and with all sizes of laminated glass, toughened glass and factory made double glazing units.
- (4) Distance pieces shall be provided to all panes where a non-setting compound is used and they shall not be located coincident with setting and location blocks. In laminated and toughened glazing or with factory made double-glazing units the positions and sizes shall be as recommended by the glass or unit manufacturer.

2.9.4 Compound Glazing

Glazing in compound or putty shall be executed with proper bed and back putties, sprigs, clips and splayed and mitred front putties. The back putties shall be trimmed off flush with the tops of the rebates and the splayed front putties shall be finished 3mm back from sight lines to allow for sealing between glass and putty with paint.

2.9.5 Bead Glazing

- (1) The Contractor shall take out beads which have been loosely pinned in by the surround manufacturer, ease and adjust beads and refix timber ones with countersunk brass cups and screws or rustproofed panel pins at an adequate number of points to prevent flexing or movement.
- (2) Where internal glass is glazed with beads and compound, there shall be a 3mm bed of compound both sides of and around the glass.
- (3) Where internal glass is glazed with beads and glazing tape, glazing tape shall pass round both sides of the glass, be mitred at corners, and trimmed off flush with the beads and rebates.

2.9.6 Gasket Glazing

- (1) The Contractor shall ensure that surfaces to which the gasket will be fixed are free from dirt, grease, burrs, weld spatter, other projections and are smooth and undisturbed.
- (2) Gaskets shall be prefabricated with moulded corners and site made joints positioned in the centre of the top edge of each opening and bonded with adhesive. Mitre locking strips shall be provided at all corners.

2.9.7 Mirror Fixing

- (1) The Contractor shall fix mirrors with proprietary concealed fixing systems or with chromium plated dome headed screws.

- (2) Mirrors shall not be distorted when tightening fixings. The Contractor shall use spacer washers or buffers to compensate for irregularities in wall surfaces, and shall use sleeves and washers to prevent contact between mirror and fixings.

2.9.8 Cleaning and Protection

- (1) Painted or stuck on indicators on solar control or coloured glass shall not be used. Whitewash may be used on ordinary glass but must be restricted to small central areas of panes.
- (2) The Contractor shall remove all smears and excess compound and leave clean inside and out and free from scratches.
- (3) All glass and fixing materials broken or damaged before acceptance of that part of the Works as substantially completed shall be replaced.

2.10 Painter

2.10.1 Materials

- (1) All primers are to be appropriate for the surface and for the subsequent coats. All primers shall be brush applied. All materials for multiple coat work (priming, undercoats, and finishing coats) shall be obtained from the same manufacturer and shall be those recommended by the manufacturer as suitable for using together and for the surface concerned.
- (2) Coatings to be applied externally shall be of a quality suitable for external use.
- (3) Black bituminous paint shall comply with BS 3416 Type IB for general use or Type II for drinking water tanks.
- (4) Knotting shall comply with BS 1336.
- (5) Primers shall be of a type recommended by the manufacturer for the type of surface to which they are applied.
- (6) Varnishes shall be clear and transparent.
- (7) All materials shall be delivered to the Site in their original unbroken containers or packages bearing the manufacturers names, labels and brands and formulae and shall be mixed and applied in accordance with their directions and instructions. Mixing of all paints shall be done on site when required. Colours shall be non-fading and as selected by the Engineer.
- (8) Stopping materials for: -
 - a) concrete, plastering or brickwork shall be of similar material to the background and finished with a similar texture;
 - b) asbestos cement and asbestos based insulating board shall be either a plaster based filler for internal work or a cementitious based filler for external work;
 - c) internal woodwork, hardboard, fibreboard and plywood shall be a cellulose based filler or putty tinted to match the colour of the undercoat;
 - d) external woodwork shall be white lead paste with or without the addition of red lead complying with BS 217 Type 2 and shall be tinted to match the colour of the undercoat;
 - e) clear finished woodwork shall be a stopping tinted to match the surrounding wood work.

2.10.2 Samples

The Contractor is to provide samples of each type of paint in sealed containers to the Engineer for Notice of No Objection prior to bulk delivery of the paints and start of the

work. During the execution of the Works, the Contractor shall provide the Engineer with such further samples as he may request.

2.10.3 Preparation of Surfaces

- (1) All metal fittings, fastenings, and Ironmongery shall be removed prior to commencement of preparatory work and replaced after final finishing coat has been applied.
- (2) All surfaces shall be inspected prior to commencement of works to make certain all defective workmanship has been remedied and materials replaced.
- (3) All surfaces shall be allowed to dry thoroughly before decorating. The Contractor shall brush down all surfaces immediately before decorating to remove dust, dirt and loose materials.
- (4) Cement render surfaces shall be scraped and wire brushed and any defective joints made good with cement mortar. Holes and uneven surfaces shall be filled and finished flush with surrounding surfaces. All surfaces shall be clean and dry. Plaster and concrete surfaces are to be cleaned of all dirt and grease and any cracks or holes are to be pointed up flush or cut out and replastered.
- (5) Metal surfaces shall be scraped and brushed to remove all rust and scale and all surfaces shall be clean and free from dust, dirt and grease. Priming coats that have deteriorated shall be touched up to the Engineer's satisfaction.
- (6) Minor imperfections shall be filled with the same filler used for jointing the plasterboard. The Contractor shall repair any damage to the surface in accordance with the plasterboard manufacturer's recommendations.
- (7) Wood surfaces shall be well sanded to a smooth finish. Knotting shall be applied to all knots, gum veins and resin streaks. Large or loose knots shall be cut out and neatly plugged. Open grain, nail holes, cracks, open joints and mitres shall be stopped and filled level. The Contractor shall rub down timber surfaces, and fill plywood surfaces to be painted with plasterer cellulose based filler after painting and rub down.

2.10.4 Workmanship Generally

- (1) No work shall be done when plastering is in progress or is drying. Paint shall not be applied over wet or damp surfaces nor shall succeeding coats be applied until the previous coat is thoroughly dry.
- (2) An ample supply of clean dustsheets to protect the work is to be available during decorating works.
- (3) Suitable moveable receptacles shall be provided for liquid waste which shall on no account be thrown down any drain, sink, lavatory etc.
- (4) No exterior or exposed decorating work shall be carried out under adverse weather conditions such as extremes of temperature, rain and mist or when the surfaces are damp.
- (5) Paints shall be thoroughly stirred to attain an even consistency before use unless otherwise recommended by the manufacturer.
- (6) Priming coats shall be applied by brush and worked into surfaces, joints, angles and end grain. Subsequent coats may be applied by brush, roller or spray.
- (7) Backs of timber frames and linings and bottoms of doors shall be primed before fixing.

- (8) The Contractor shall prime rebates and beads before glazing, and prime and paint or seal putty after glazing and extend coating on to glass up to sight line.
- (9) Each coat of paint shall be thoroughly dry, faced up, rubbed down with abrasive paper and cleaned off before application of subsequent coats.
- (10) Each undercoat shall be of a different tint.
- (11) Paint is to be evenly spread and thoroughly brushed.

2.10.5 Protection

The Contractor shall take all precautions to protect Decorations and shall replace at his own expense any Decorations which are damaged or defaced and shall hand over all areas on completion in a clean condition. Replacement of damaged or defaced work may be extended at the Engineer's discretion to include the whole of the room or area affected.

2.10.6 Textured Acrylic Sprayed Paint

- (1) Textured acrylic sprayed painting shall be as approved and of colours and texture to be selected by the Engineer.
- (2) The textured sprayed painting shall be applied to a cement and sand plastered base and used in accordance with the manufacturer's instructions.

2.10.7 Solvent Type Acrylic Coating

- (1) Solvent type acrylic coating shall be as noticed and of colours and texture to be selected by the Engineer.
- (2) The acrylic coating shall be applied in accordance with the manufacturer's instructions.

Maha Metro



Tender Documents

**UGC-02: DESIGN AND CONSTRUCTION OF UNDERGROUND STATIONS AT BUDHWAR
PETH, MANDAI AND SWARGATE AND ASSOCIATED TUNNELS**

PART II – EMPLOYER’S REQUIREMENT

Section VIII - Outline Construction Specifications

S.03 Tunneling

June 2018

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3 Tunneling

3.1 Introduction

This section specifies materials, methods and workmanship required for the construction of bored and NATM tunnels, shafts and other underground structures.

3.2 General

- (1) All works shall be carried out in compliance with the Health and Safety requirements as detailed in the Appendix 20 to the Employer's Requirements and in the Contractors Safety Plan.
- (2) All aspects of excavation in tunnels shall comply with the requirements of:
 - a) BS 6164 : Safety in Tunnelling in the Construction Industry
 - b) CIRIA Report 80 : A review of instruments for gas and dust monitoring underground.
- (3) All work shall be carried out in compliance with the Acts, Rules and Regulations of Government of India & Government of Maharashtra State Standards and Regulations.

3.3 Survey

- (1) Before commencement of any work, the Contractor shall prepare and submit appropriate survey method statements relating to his proposed methods of working.
- (2) Contractor shall establish the system for underground surveying, setting out and correcting deviations from theoretical alignment, using a laser based system. Reference point and targets shall be used in conjunction with lasers to ensure the accuracy of the system and it should be easy to monitor by the Engineer. Laser based guidance systems shall have an alternative system as back-up.
- (3) In the case of tunnel boring machines, where construction shall be computer controlled, the Contractor shall use appropriate software for ring selection logic, steerage logic, etc.
- (4) If at any time during the excavation for the tunnel, it is evident that the alignment for the tunnel is outside the specified/permissible tolerances then, before proceeding further with the excavation, the Contractor shall submit his proposal for the necessary corrections to the alignment, and the Contractor shall forthwith make the corrections as accepted by the Engineer.

3.4 Field control and Monitoring Equipment

3.4.1 Setting out of line, level and profile

Prior to starting underground work, the Contractor shall submit to the Engineer proposals on the setting out the Works and for correcting any deviations.

3.4.2 Chainage markers and Bench marks

Chainage markers shall be provided in tunnels at 10m intervals. The markers shall be painted in white durable paint. The contractor shall provide the Engineer the location and description of all survey stations, and all survey data.

3.4.3 Monitoring Equipment

- (1) The Contractor shall provide basic equipment for measurement of deformations along excavation perimeters and ground surface conditions. The types of basic underground equipment to be provided comprise: levelling instruments, wire extensometer for convergence measurement, 3 D optical targets for 3D

displacement monitoring and multi point borehole extensometers. The equipment shall be installed as agreed by the Engineer.

- (2) During the execution of excavation works, the Contractor need to procure supplementary types of equipment as may be required for standard tunneling methods.
- (3) Measurements by all types of equipment shall be performed by the Contractor as directed by the Engineer. Results from each measurement shall be submitted to the Engineer expeditiously.

3.5 Tunnel Boring Machine (TBM)

3.5.1 General

- (1) The Contractor shall be fully responsible for the selection, design and supply of shield machines and ancillary equipment.
- (2) The Contractor shall take into consideration all geological and other relevant parameters applicable for the contract reach. He shall satisfy himself as to the suitability of the TBM Shield machines which he will provide.
- (3) The Contractor shall make all arrangements and provide all the labour, plant, equipment and materials necessary at the TBM launch sites for receiving the TBM. The Contractor shall co-ordinate the required delivery arrangements with the manufacturer suiting the site constraints.
- (4) The Contractor shall be responsible, under the supervision of the TBM manufacturer, for the erection and commissioning of the TBM and all back-up equipment required to allow the TBM to commence excavation in a fully operational condition in all respects and in accordance with the manufacturer's recommendations.
- (5) The Contractor shall be responsible for the design and installation of the temporary TBM launch structures and for ensuring they are satisfactory in all respects for receiving and assembling the machine components. The shaft walls (or other structures) and surrounding ground shall have sufficient capacity to sustain without excessive deformation the thrust from the TBM shove-rams during the launch of the TBM.
- (6) The Contractor shall be responsible for the design and installation of the temporary/permanent (part of station structure) TBM retrieval structures, except where the Contractor has been permitted to break-in his TBM in adjacent Contractor's works/structures as per the Contract provisions, and for ensuring they are satisfactory in all respects for TBM breaking-in, receiving the TBM and dismantling and removing the machine components. The shaft walls (or other structures) and surrounding ground shall have sufficient capacity to sustain without excessive deformation the thrust and torque from the TBM during the breaking-in operations.
- (7) The Contractor shall be responsible for the provision of any and all ancillary structures at the shaft bottoms (for example fixed or moveable cradles to act as a "base" for commencing machine erection) and for coordinating design and configuration of such ancillary structures with the TBM manufacturer.
- (8) The Contractor shall provide and regularly maintain a mechanical lift of adequate capacity at his main working shafts that complies with all applicable safety standards for the vertical movement of people.

3.5.2 General Requirements for TBMs

- (1) All TBMs shall be robust with adequate safety margins for the anticipated duty, designed and manufactured to comply with all relevant safety standards.
- (2) The external diameter of the Shield Machines shall be designed to produce minimum over-break and the least necessary clearance for the proper construction of the tunnels. Design shall take into account the horizontal and vertical alignment. Provision shall be made to limit and correct the roll of the machine.
- (3) Whenever possible hydraulic piping shall be of rigid metal tubing, the use of flexible hose shall be kept to a minimum. Liquids for use with hydraulic equipment shall be non-toxic and of low flammability. Hydraulic equipment shall be designed to operate up to twice the working pressure but shall not exceed 500 bars.
- (4) All machines and shields shall be self propelled. Where propulsion is by means of hydraulic rams thrusting off previously constructed segmental lining, shove- ram shoes and shoe-facings shall be designed to distribute the thrust without causing damage to the as-built lining. Shove-ram shoe pads shall be adequately secured.
- (5) Shove-rams shall be capable of operating individually or collectively in any combination. The shove-rams shall permit the insertion of a key closing segment, in any location.
- (6) Segment erection systems shall be capable of lifting and placing segments safely. Lifting and gripping systems shall be designed to handle the loads with an adequate factor of safety and without damaging the segment and segment sealing systems. Segment erection systems shall be capable of compressing all joint gaskets.
- (7) The erector shall be in clear view of the operator. A safety device shall be fitted to avoid accidental release of segments during lifting, handling and placing.
- (8) There shall be adequate access to all areas of the TBM where work, including maintenance, may be carried out. A clear means of egress in an emergency shall be provided and maintained at all times. Minimum dimensions shall conform to the appropriate international standard.
- (9) Arrangements for extraction, transport and disposal of spoil shall be appropriate for the material to be handled.
- (10) Alignment control
 - a) The Contractor shall ensure the TBM is provided with a suitable guidance and control system capable of providing the necessary survey information such that the TBM operator is able to accurately control the TBM and tunnel alignment to within the required tolerances.
 - b) The guidance system shall have the capability to predict ahead of the face and to determine the inclination, line, level, roll and square of the TBM.
 - c) Detailed guidance information shall be checked against the tunnel alignment control at regular intervals, as agreed with the Engineer
- (11) All information and data shall be clearly displayed in the TBM operator's control panel and shall also be linked to a data-logging system.

3.5.3 Particular Requirements for TBMs

- (1) The cutter-head shall be capable of clockwise and anticlockwise rotation and shall only be able to excavate the ground whilst the hydraulic rams are being actuated.

The design shall ensure that the cutter-head can be retracted back from the unexcavated ground to minimize the risk of the cutter-head jamming and to facilitate maintenance.

- (2) The cutting tools shall incorporate wear detection systems. The cutter-head discs and/or picks shall be able to be replaced from the rear of the cutter-head and shall be interchangeable.
- (3) Where boulders could occur on the tunnel face the TBM design shall permit a boulder of at least 300 millimetres across its smallest cross-sectional dimension to be pushed through the cutter-head. The TBM shall have the capability to handle, break up as required and remove such boulders through the screw conveyor, slurry discharge aperture or other spoil discharge system without special procedures.
- (4) The TBM shall be designed to allow forward drilling through the cutter-head for the purpose of probing ground conditions and to carry out ground treatment to the face.
- (5) Grouting facilities
 - a) The TBM shall be designed to enable the void behind the segments to be grouted continuously and completely from the shield as it is propelled forward. The grout ports shall be incorporated within the shield tail-skin rather than mounted externally on it.
 - b) There shall be grout ports in each quadrant of the shield tail-skin circumference. The TBM shall have the facility and the capacity to inject grout simultaneously through the grout ports. The grouting pressure will be at least 1 bar above the confinement pressure and the volume 110% above the theoretical one.
 - c) Two grout components A/B will be used. A component will be cement grout prepared in the batching plant and stored in holding tank, and B component will be sodium silicate.
 - d) The proper mix will be liquid A/B will be determined after trials which will ensure they meet the proper design strength and gel time.
 - e) Secondary grouting will be done with liquid A, at least, at the crown of the segment lining once the tail skin has passed. The frequency and pressure of the secondary grouting will be determined by the engineer at site
 - f) The TBM design shall enable the grout pipes to any individual port to be cleaned or replaced from within the shield in the event of a blockage without impairing the performance or preventing the use of any other grout port. At least one grout port in each quadrant of the shield shall be operational and available for grouting at all times during shield advancement.
 - g) Grout pressure and flow rates shall be maintained at all times whilst the shield is advancing. The shield shall incorporate automatic systems for monitoring and controlling the volume and pressure of the grout being delivered to the tail void.
- (6) The TBM shall be designed for and equipped with a supplemental ground stabilization system. This system shall comprise regularly spaced grout ports built into the shield for grouting the ground ahead of the tunnel face. The location and number of ports shall be adequate for implementation of face stabilization measures needed for access to the face in all ground conditions. All ports shall be readily accessible and fitted with valves.

- (7) The cutter-head shall be articulated such that the cutter-head can be retracted from the excavated face and can be turned in any plane so that it is at an angle to the main body. The TBM shield must be capable of negotiating 200 meter radius horizontal curves.
- (8) The TBMs to be employed for this Contract shall be capable of being operated in a closed face mode, such that they can be operated in a closed face mode wherever the encountered ground conditions and water in-flow conditions so demand. All closed face TBM shall be designed to maintain pressure on the excavated ground at all times. The TBM shall be able to at least balance the total overburden pressure (including hydrostatic pressure) and shall be capable of varying the face pressure as the overburden pressure changes. Earth pressure sensors shall be located at the crown, at TBM axis level and at the invert of the chamber.
 - a) In case Earth Pressure Balance Machine (EPB TBMs) are used, they shall be equipped with the facility to generate foam conditioners and deliver them to the face during excavation.
 - b) Material extracted by TBMs should be recorded per 300mm of advance and per ring built.
 - c) In case of EPB the volume of material extracted shall be measured by calibrates belt weighers or material scanners or any other device accepted by the engineer in conjunction with skip counting.
 - d) In the case of Slurry Pressure Balanced Machine (SPB TBMs) a real time automatic system for measurement of the volume of material extracted shall be undertaken by comparison of flow rate and slurry density pumped into the cutterhead against flow rate and spoil/slurry mis desnity pumped out.
 - e) If over-excavation is suspected to have take place, the Contractor shall implement immediately measures to safeguard any building, structure or road pavement over the tunnel and carry out such measures as are agreed with the Engineer.
 - f) When excavation has commenced for a ring of tunnel lining, the work shall continue without a break until the ring has been erected and secured against water inflow and ground movement.
 - g) The distance between any two tunnel faces in operation at the same time is in no circumstances to be less than three times the TBM cutter head diameter. When tunnel drives are parallel or approximately parallel, the distance shall be measure parallel to the direction of drive.
 - h) Where a close-face Pressure Balanced TBM is used the Contractor shall ensure that adequate face pressure is maintained for face support. The face pressure shall be pre-determined to acceptance of the Engineer. The face pressure shall be monitored continuously to ensure that it does not drop below the pre-determined value.
- (9) TBMs shall incorporate a two compartment air-lock for man access to the cutter-head and face.
- (10) The Contractor shall not carry out cutter head interventions under free air where there is a risk of face instability or risk of water ingress and excessive ground loss.
- (11) Where a screw-conveyor is used, the discharge gate on the screw-conveyor shall be fitted with an accumulator which automatically closes the gate in the event of a power failure.

- (12) All TBMs shall incorporate a system which enables the face to be closed expeditiously to avoid any ground loss in the event that unstable ground is encountered or water in-flow is encountered during the drive. This shall take the form of hydraulically operated gates on the cutter-head or a similar system to the notice of the Engineer.
- (13) The TBM shall be fitted with a data-logger which shall be linked by the Contractor to a color monitor display (to be provided by the Contractor) in the Engineer's office. Each TBM shall have its own dedicated color monitor. The data-logger shall display and record information in real time and shall have the facility to store all accumulated data from the tunnel drive and to read and display past data. As a minimum the data-logger shall record and report the following information:
 - a) Start and finish time of the excavation stroke.
 - b) Stroke number, chainage and guidance system's prediction of the next ten strokes after each build.
 - c) Numbers of thrust cylinders, location and pressures used during the stroke.
 - d) Extensometer readings of thrust cylinders at the start and end of the stroke.
 - e) Articulation cylinder position at the start and the end of the excavation stroke - articulation angle.
 - f) Amount of TBM roll at start and end of the excavation stroke.
 - g) Cutting direction, speed, pressure/torque of cutter-head.
 - h) Shield position and attitude for each ring.
 - i) Earth pressure readings throughout the excavation stroke at the plenum chamber and screw-conveyor.
 - j) Volume and pressure of grout injected per stroke. Pressure shall be measured at the point of injection.
 - k) Volume, type and location of ground conditioners added per ring and the cumulative amount per shift with the concentration value.
 - l) Quantity of tail grease consumed per shift.
 - m) Speed and torque of screw conveyor
 - n) Rate of advance of TBM
 - o) Use of copy cutter, amount and location
 - p) Gas detector sensors readings
- (14) All data-loggers and ancillary equipment shall be fully operational at all times and shall be maintained by the Contractor.

3.5.4 Inspection and testing

- (1) Where a new, modified or purpose-built TBM is proposed by the Contractor the Employer/Engineer shall be permitted to visit the TBM manufacturer's premises for the purposes of inspection.
- (2) The Contractor shall be responsible for the quality of all materials used or present within the TBM and must ensure that all such materials used or present are adequate for the task they are to perform.
- (3) The Employer/Engineer shall be permitted at any stage during manufacture of the TBM to inspect, examine and test on the manufacturer's premises the materials, workmanship and performance of all plant and components to be supplied under the Contract. Such inspections, examination or testing shall not release the Contractor from any of his obligations under the Contract.
- (4) New and reconditioned machines shall be assembled at the manufacturer's works on completion of fabrication or modification and tested to demonstrate that all

components operate correctly and in compliance to the Contract provisions. Test running will also be required at the Site following assembly, prior to commencement of tunnel driving.

3.5.5 Personnel and Training

- (1) The Contractor shall ensure that all key personnel who are responsible for driving, maintenance and controlling the TBM have received the necessary training in the duties that they are required to perform and have appropriate experience.
- (2) The Contractor shall provide and maintain a complete list of the names of persons, and their duties, responsible for TBM operation, who have completed the appropriate training to an acceptable standard. The details and experience of all key personnel for driving and controlling the TBM shall be submitted to the Engineer for obtaining a Notice of No Objection.

3.6 Contractor's Submission for TBM Working

3.6.1 General

- (1) The machine characteristics and specifications shall be submitted to the Engineer for obtaining his Notice of No Objection prior to procurement of TBM.
- (2) The Contractor shall submit his programme for the provision, inspection, testing, transport, erection and commissioning of each and every TBM supplied for the Works, for obtaining Notice of No Objection from the Engineer.

3.6.2 TBM Method Statement

Not less than 60 days before the Contractor intends commencing TBM excavation, he shall submit to the Engineer for obtaining his Notice of No Objection, a detailed method statement, which shall include but not be limited to:

- Methods of transportation and erection of the TBM;
- Method of commencing the tunnel drives, including details of the temporary thrust arrangements;
- Methods of determining ground conditions ahead of the face and methods of treating such conditions;
- Methods for dealing with water wells/borewells that may be intersected or influenced by the excavations;
- Methods of junctioning with the launch, retrieval and any other shafts, including dismantling of the TBM;
- Operational details, including excavation, segment handling, ring selection/orientation control, ring building procedures, annulus and proof-drilling, grouting and control, alignment control, tunnel logistics, maintenance, slurry plant operation (STBM), effluent disposal, muck disposal, ground and spoil conditioning control (EPBM) , interventions, changing cutters & picks and the like ;
- Safety procedures, including compressed air working, cutter head entry, cutting tool changes, ventilation details, emergency evacuation procedures and the like ;
- Details of the proposed monitoring and reporting systems;
- Details of key personnel responsible for supervising, operating, maintaining and controlling the TBM.

3.6.3 TBM Daily Record

The Contractor shall produce operational data for each Earth Pressure Balance Machine (EPBM) or Slurry Pressure balance Machine (SPBM) throughout the whole tunneling process in both hard and soft (electronic) copy for each working shift. These shift reports shall be submitted to the **Engineer** within 24 hours for Notice of No Objection and shall provide the following minimum information.

- Start and finish time of the excavation stroke including all stoppages, recording the reasons for the stoppages.
- Ring number, chainage and key position.
- Start and finish time of the ring build including all stoppages, recording the reasons for the stoppages.
- All delays and the reasons for those delays during the shift.
- Earth pressure readings at start, middle and end of excavation stroke for cutter chamber and screw-conveyor.
- Quantity of material excavated for each ring e.g. number of skips removed.
- Total advance for the shift and the accumulative advance.
- Number and location of any cutter bits/discs changed.
- Volume of grout injected per ring and the pressure, the accumulative volume of grout for the shift.
- Volume, type and location of ground/spoil conditioning added per ring and the accumulative amount per shift with the concentration value.
- General comments on description of the excavated material. Quantity
- of tail grease consumed per ring.
- Any segment damage on completed rings.
- The timing and nature of any machine maintenance carried out.

3.6.4 TBM Daily Monitoring and reporting

Not less than 60 days before the commencement of TBM excavation, the Contractor shall submit details of his proposed monitoring and reporting scheme for the notice of **Engineer**. The content of this submission shall include, but not be limited to, the following:

- Chainage of face at the start and end of each shift;
- Line and level of the tunnel rings erected during each shift, including details of any corrections made to the plane of the rings;
- Survey control data;
- Serial numbers of the segments erected, referenced against ring numbers and tunnel chainage;
- Details of the geological conditions encountered during each shift, including details of any geological anomalies encountered;
- Operational data of the cutter-head drive, including torque and RPM;
- Thrust of propulsion rams;
- Operational data of slurry system(if applicable);
- Hours of operation of the TBM;
- Details of any operational delays, including the TBM, backup and slurry systems(if applicable), recorded in 5 minute intervals;
- Details of any probing undertaken;

- Detailed cycle times for each ring, identifying the boring and erection times;
- Details of any planned or unplanned maintenance carried out;
- List of cutting tools replaced, their position and serial numbers;
- List of spare parts used;
- Quantities and pressures used in the annulus grouting, with a reconciliation of the amount used;
- Number and classification of supervisors and workmen engaged during each shift;
- Any other information that the Engineer may reasonably request.

3.7 Segmental lining

3.7.1 Tunnel Linings

- (1) The segments shall be designed to ensure that the full design life is achieved. In the case of pre-cast concrete linings special care shall be taken to ensure that corrosion of reinforcement or other cast in metal components does not affect the durability of the segments. Notwithstanding the requirements of the Specification, the design shall assume that the tunnel waterproofing measures will not be completely effective and therefore allowance shall be made for the effect of groundwater on any face of a segment.
- (2) To achieve full design life of concrete lining, impermeable concrete shall be produced and shall be tested in accordance with DIN 1048. The ability of concrete to resist chloride ion penetration shall be tested in accordance with ASTM C-1202. Suitable property enhancers shall be used in appropriate % by the weight of cement to ensure the protection of precast linings against corrosion of reinforcement.

3.7.1.1 General

- (1) The Contractor shall be entirely responsible for the design, manufacture and installation of the precast concrete tunnel lining segments for the bored tunnel. Manufacture shall be carried out in pre-casting facilities used solely for the production of precast units. The design and manufacture of the facilities and the control of production procedures shall be undertaken by experienced specialist personnel familiar with the manufacture of high strength, durable, dimensionally accurate precast concrete units.
- (2) The segmental lining shall be a bolted lining built under the protection of the TBM's tail-skin.
- (3) The lining joints shall be watertight; caulking grooves and gasket recesses shall be provided. Elastomeric gaskets with appropriate configuration shall be provided to achieve the required water tightness and design life as stipulated in the Contract.
- (4) Prior to the commencement of manufacture of precast segments, the Contractor shall submit a statement to the Engineer of his proposed method of carrying out all operations connected with the manufacture, testing and quality control and assembly of precast segments, including:
 - details of the casting yard(s) and location of manufacture, testing and storage of segments;
 - a programme which shall include, but not be limited to, trial mixes, design and manufacture of prototype moulds, casting of prototype units, establishment of the casting yard, design and manufacture of moulds; general arrangements of the

production lines and typical mould details; types, sources and quality of cement, aggregate, reinforcement and water;

- types and sources of any concrete admixtures proposed; proposed methods of compacting, curing and protecting the units; proposed quality assurance arrangements;
- proposed method of handling the units, transport arrangements and logistics;
- details of proposed suppliers and subcontractors;
- Samples of all cast-in items, e.g., sleeves, lifting sockets and the like.
- No work shall start until the Engineer has issued a no objection statement in writing.

3.7.1.2 Moulds

- (1) Moulds for the precast concrete segments shall be strongly constructed with smooth casting faces so that a true, sound surface of concrete is obtained. Joints shall be completely tight and close to prevent the escape of laitance from the concrete. All chamfer and radius strips, bolt hole formers and pockets, liners, cores, and all cast-in items shall be provided where required. Loose mould components which affect the integrity of the mould shall be clearly identified as being part of the main mould. The parts of one mould within a ring set shall not be interchanged with another. A marking system shall be adopted to ensure compliance with this requirement.
- (2) The design of the moulds to be used for all the pre-casting work shall receive a 'Notice of No Objection' from the Engineer before any such moulds are manufactured.
- (3) The fabricator shall make a trial casting using the first set of moulds. The internal dimensions of the moulds shall be measured to 0.1mm before each trial pour. One trial unit shall be cast from each mould. The units shall be provided with a full reinforcement cage including radial joint reinforcement. As soon as possible after stripping from the moulds the segments shall be checked against the dimensions shown on the drawings.
- (4) During these trials, the segments are to be cured and stored in conditions equivalent to those to be used during works production. The segment dimension deviations shall be measured at 7, 28, and 90 days. Concurrent records of concrete temperatures, ambient humidity and any other relevant details shall be kept at these dates. No segment production shall be instituted until the tolerances shown on the drawings are achieved in the trials.

3.7.1.3 Segment Storage on Site

- (1) The Contractor shall establish a system of Site segment stock ordering, supply, and control which shall eliminate the possibility of tunnel construction stoppage due to lack of material.
- (2) The Contractor shall satisfy himself that segment design takes account of the method of delivery of the segments to the face, erection expedients, shove ram disposition, and other features of the TBM having an impact on the segments. To this end, the Contractor shall work closely with the TBM manufacturer to ensure lining and machine compatibility. The Contractor shall be responsible for ensuring a full ring of the lining is delivered to the TBM manufacturer, at no

additional cost to the Employer, and at an appropriate time during the TBM manufacturing programme, to ensure compatibility with the TBM segment handling and erection systems.

- (3) The Contractor shall, for the duration of the tunnel drive(s), maintain a stock of fully cured (age >28 days) segments. These shall be sufficient for a minimum of 4 weeks driving at each location from which the Contractor may decide to supply material at the programmed rates of advance. During the closing stages of the tunnel drives these stocks shall be drawdown.

3.7.1.4 Trial Assembly

There shall be a trial assembly, before commencement of the bulk manufacture, of three rings bolted together on a horizontal plane platform to demonstrate compliance with this Specification of rings of each material and diameter. The rings shall be built one above the other with the cross joints offset by half a segment as appropriate. The fully bolted bottom ring shall be bolted to the platform or otherwise secured in position and shall be retained as a master ring until the completion of tunnel construction. From time to time, as may be required, segments shall be built to form two rings on the master ring to ensure that tolerances and interchangeability of the segments are maintained. Adequate notice of the trial assembly shall be given to the **Engineer** to enable him to arrange inspection and checking of the assembly.

3.7.1.5 Marking of Segments

- (1) All tunnel segments delivered to site shall bear the indelible marks described as below. Any segment which is delivered to site and upon which the markings cannot be read for whatever reason, shall not be used in the Works.
- (2) The markings must in no way compromise any requirement of this Specification, i.e. cover to reinforcement or waterproofing.
- (3) The following minimum information shall be included on the marking:
 - Internal diameter
 - Type of segment:
 - `O` ordinary
 - `T` top (the T shall be put near the key end of the segment)
 - `K` key segment
 - `X` special or taper

3.7.1.6 Transporting and Storing Segments

- (1) Segments shall be transported face up with timber spacers. When stored on site segments shall be stacked on edge, on a prepared level base with timber packing as necessary.
- (2) The method of lifting and handling, the type of equipment and method of transport shall not damage the segments.
- (3) Segments shall not be transported to site until they have achieved the 28 days compressive cube strength.
- (4) If the grout hole is to be used for segment handling, the Contractor shall ensure that this has been catered for in the design.

3.7.1.7 Joints

The faces of joints shall be cleaned before bolting segments. Bolts shall be tightened at the time of erection of each ring. For a shield drive the circle bolts shall be re- tightened prior to release of the shoving jackforce.

3.7.1.8 Rolled Rings

Rings may be rolled to facilitate the construction of openings, and may also be rolled to facilitate maintenance of the plane of the rings. Tapered rings shall be rolled as appropriate to achieve the specified alignments and gradients of the tunnels.

3.7.1.9 Bolts

The length of each bolt shall allow for two washers and two grommets and for all adjustments required in the alignment of the tunnels. When fitted in position the bolt threads shall be exposed for at least 3 mm clear of the nut.

3.7.1.10 Plane

- (1) Errors in the plane of a ring should be kept to a minimum. When they occur, the plane of the ring shall be adjusted by packing of maximum practicable continuous lengths of resilient, durable material which shall have received Notice of No Objection from Engineer. Packing in a single joint shall not exceed 6 mm for concrete lining.
- (2) The packing shall be supplied in various thickness, as required, but not less than 2 mm, and when in place, shall be clear of the sealing strip.
- (3) In tunnel drives which utilize all tapered rings, packing shall not exceed 3 mm per circle joint.

3.7.1.11 Sealing Strips and gaskets

- (1) Two Sealing strips comprising a gasket of the hydrophilic type and a gasket of the elastomeric type shall be provided at all faces between segments to provide a seal against ingress of ground water.
- (2) Immediately prior to the erection of a gasketed segment the gaskets shall be checked for cleanliness and position

3.7.1.12 Caulking Grooves

- (1) Caulking grooves shall be formed in segments in accordance with the design and this Specification to ensure that caulking to circle joints and radial joints may be made effectively continuous, the depth of caulked material in the joints being not less than 25 mm.
- (2) Prior to caulking all joints shall be inspected and thoroughly cleaned out as necessary. Any packing, grout or other foreign material projecting into the caulking space shall be cut out by an appropriate method.
- (3) Immediately prior to caulking, the joints shall be blown out with a compressed air jet as necessary to remove any loose debris or water.

3.7.1.13 Grout valves

For linings built behind tunneling machines, having a pressurized face system, grout holes if provided in the linings segments shall incorporate one-way valves to prevent ground and water loss during the grouting operation

3.7.1.14 As-built Tolerances

- (1) The finished bored tunnel for single track after accounting all as-built tolerances (all shape, roll, survey, setting out, positional, deformational, related to ring building, related to TBM functioning, and casting tolerances/errors etc.) shall be of a minimum 5600 mm (that means with tolerances the overall diameter of tunnel shall be 5800mm) internal diameter with respect to the designed/theoretical longitudinal axis of the tunnel (theoretical/designed centre of the tunnel). This means that at no point of internal circumference of the as-built tunnel, the distance between the designed/theoretical longitudinal axis of the tunnel and internal circumference of the as-built tunnel shall be less than 2800 mm. Subject to this the as-built segmental lined tunnel in general shall conform to the tolerances noted below:
 - a) The maximum and minimum measured diameters in any one ring shall be within 40mm of the theoretical design diameter of the ring.
 - b) Lipping:
The lip between adjacent segments in a ring shall not exceed 5mm and shall not be so great as to prevent the connections between segments from being correctly installed, nor prevent the effective functioning of gaskets, nor reduce the face-to-face radial joint bearing area to an extent where structural efficacy will be compromised
 - c) Stepping:
The step between adjacent rings shall not exceed 10mm and shall not be so great as to prevent the connection between adjacent rings from being correctly installed, nor prevent the effective functioning of gaskets.
 - d) The plane of the leading face of each ring, including a taper ring, shall not depart at any point from the plane surface by more than 6 mm.
 - e) The roll of adjacent circle joint bolt holes shall not be greater than 5 mm or the tolerance in the bolt holes, whichever is smaller; the maximum total allowable bolt hole roll of any ring shall be controlled to be within limits as determined to achieve the overall construction tolerances and it shall not deviate from the relevant TBM roll excessively.

3.7.1.15 Non-Compliance with Tolerances

Where any part of the lining does not comply with the specified tolerances the Contractor shall submit to the Engineer for Notice of No Objection, proposals for remedial or other measures to correct the defect or negate its effects as appropriate.

3.7.1.16 Damaged Concrete

- (1) Any segments which are damaged or defective shall be indelibly marked and removed from the Site and replaced by the Contractor. Such damaged or defective segments shall be destroyed. No damaged or defective segments shall be used in the Works.
- (2) Rings which have been built and shoved and are subsequently damaged may have to be removed and rebuilt.

3.7.1.17 Grade of Concrete

The minimum grade of concrete shall be at least M45.

The Contractor shall designate its grade of concrete as follows: Concrete M45 / 20

The letter M refers to the mix

The number 45 represents the characteristic compressive strength of 15cm cubes at 28 days in MPa (Mega Pascal: 1 MPa: 10 kg/cm² approximately). M45 concrete thus has a characteristic strength of 450 kg/cm². Other mix design will also be denoted in same way.

The number 20 represents the nominal size of the aggregate in mm.

3.7.1.18 Tolerances

The dimensions of precast concrete segments shall be within the following tolerances:

- | | |
|--|--|
| (a) Circumferential Length | ± 1mm |
| (b) Thickness | ± 3mm |
| (c) Width | ± 1mm |
| (d) Internal diameter of completed ring | ± 0.2% internal diameter or 6mm whichever is the greater |
| (e) Bolt holes size | +1mm, -0.2mm |
| (f) Bolt holes position | 1mm |
| (g) Width of gasket sealing groove | ± 1mm |
| (h) Depth of gasket sealing groove | +1mm, -0.5 mm |
| (i) Mismatch of gasket sealing groove at corners | <2mm |

Steel templates fit for purpose shall be provided for the control of the production of segments to the required tolerances.

3.7.2 Concrete for Segmental lining

3.7.2.1 General

- (1) The Contractor shall establish a fully-fledged most modern concrete laboratory with trained engineers, Quality Control (QC) Manager and technicians at site/in the casting yard. Concrete laboratory shall contain facilities for testing physical properties of cement, workability of concrete, cube strength, permeability of concrete, sieve analysis, RCPT, aggregate tests, tests required for mix design, chloride and sulphate tests of water and admixture, concrete temperature, oven, accelerated tests for cement/concrete strength, flexural strength of concrete etc. One room shall be air-conditioned to control temp and humidity for cement tests.
- (2) All off-site material sampling and testing shall be done at laboratories accredited by NABL (National Accreditation Board of Testing and Calibration Laboratories) or internationally accredited laboratory to ISO 17025.
- (3) The durability requirements as brought out in DAAR, in terms of environment condition, concrete cover, type and quality of constituent materials, cement content and water cement ratio etc and workmanship to obtain full compaction and efficient curing, shape and size of members and technical specifications of the Contract shall be taken into account in the structural design.

- (4) The Contractor shall submit to the Engineer full details and samples of all materials which he proposes to use for the manufacture of the precast concrete segments at least 60 days before the commencement of manufacturing and obtain Notice of No Objection from the Engineer. Any subsequent change in these materials, proposed by the Contractor shall also be permitted only after a Notice of No Objection has been obtained by the Contractor from the Engineer.
- (5) All the provisions in Section VIII, Sub-division 1 pertaining to the concrete and concrete works, to the extent found relevant, shall also be applicable to the concrete segmental lining in addition to these specifications.

3.7.2.2 Materials

- (1) The cement, fine and coarse aggregate, reinforcement, water and admixtures shall comply with the Section VIII, sub-section 1.5.1.
- (2) The alkali-silica reaction requirements for concrete shall comply with Section VIII, subsection 1.5.1.

3.7.2.3 Batching Plant, Mixers and Vibrators

- (1) Unless otherwise specified, for all structural concreting work the Contractor shall provide automatic weigh-batching plant of suitable capacity. The plant used shall conform to IS: 4925.
- (2) The Contractor shall provide Concrete mixers (IS: 1791 – Batch type concrete mixers, IS: 2438 – Roller Pan Mixer) and Vibrators (IS: 2505 – Concrete Vibrators Immersion Type, IS: 2506 – Screed board concrete vibrators, IS: 4656 – Form Vibrators for Concrete) supplied by recognized manufacturers

3.7.2.4 Mix Design and Workmanship

- (1) It is the complete responsibility of the Contractor to design the concrete mixes by approved standard methods and to produce the required concrete conforming to the specifications and the strength, durability (fulfilling the requirements of DARR), workability requirements as required by the Specifications.
- (2) Mix Design once approved must not be altered without prior Notice of No Objection obtained from the Engineer. However, should the Contractor anticipate any change in quality of future supply of materials than that used for preliminary mix design, he should inform the Engineer in advance and bring fresh samples sufficiently in advance, to carry out fresh trial mixes. Design mix will indicate by means of graphs and curves etc., the extent of variation in the grading of aggregates which can be allowed. The S.D. and coefficient of variation shall be established for each grade of concrete. SQC graphs shall be submitted monthly.
- (3) In addition to tests stated in Section VIII, the Permeability Test (in accordance with DIN 1048) and the RCPT (in accordance with ASTM-C-1202) shall be carried out as stipulated in Section VII. The contractor shall set up the required facilities or make the necessary arrangements for conducting these tests as per the scheme for which Notice of No Objection has been obtained by the Contractor from the Engineer.

3.7.2.5 Curing

- (1) Segments shall not be de-moulded until the concrete has achieved sufficient strength to prevent damage to the segments during the de-moulding process.
- (2) Secondary curing of segments is to be initiated immediately following initial stripping of the moulds. The segments are to be maintained for 7 days at a minimum of 100 % humidity, under cover prior to stacking and placing in the

stockpile.

- (3) Curing of concrete shall be complete and continuous using potable water free from chlorides and sulphates, water that is free of harmful amounts of deleterious materials that may attack, stain or discolour the concrete as per IS 456.
- (4) Immediately after compaction and completion of any surface finishes the concrete shall be protected from the evaporation of moisture by means of polythene sheet, wet Hessian or other material kept soaked by spraying. As soon as the concrete has attained a degree of hardening sufficient to withstand surface damage moist curing shall be implemented and maintained for a period of at least 21 days after casting.
- (5) Method of curing and their duration shall be such that the concrete will have the required durability and strength and members will not suffer distortion, be free from efflorescence and will not cause undue cracking in the works beyond the specified design crack width.
- (6) Steam curing with approved methodology can be adopted if required.

3.7.3 Cracks

If cracks, which in the opinion of the Engineer may be detrimental to the stability, strength and durability of the works, develop in concrete construction, the Contractor at his own expense shall test the structure in accordance with the requirements of the tests and as agreed by the Engineer.

3.7.4 Defective Concrete Segments

Precast concrete segments damaged by improper curing, during stripping from the mould, during storage, handling or any other cause or any which are honeycombed or have interstices or are not homogeneous or which are not true to dimensions, or the surface finish defects fall outside those required by these Specifications, may be classed as defective concrete segments, and, if so the Contractor shall immediately remove the defective concrete segments and shall replace them with acceptable concrete segments of specified Specifications without any additional cost to the Employer.

The decision of Engineer in this regard shall be binding on the Contractor.

3.7.5 Tolerances and Inspections

- (1) The tunnel lining segments shall be cast to the dimensions shown on the Contractor's drawings and within the tolerances specified. Segments shall be cast with such accuracy and uniformity of dimensions that all similar segments shall be interchangeable with corresponding segments of other rings.
- (2) A comprehensive quality control and inspection procedure shall be instituted by the Contractor. The Contractor shall be responsible for the production of segments of the required quality and accuracy and, in addition, shall institute an appropriate inspection regime for quality control.
- (3) Templates, gauges and testing apparatus as required for quality control shall be provided and kept suitably protected from damage and distortion and free from dirt and corrosion, ready for use in checking the segments as required. The segments shall be checked for dimensional accuracy using a noticed measuring system.
- (4) The first segment cast in any mould shall be gauged. Thereafter 5 per cent of the segments shall be gauged. Further, the number of segments gauged shall,

whenever any variation in quality has occurred, be that required to establish the accuracy and consistency of production as quickly as possible.

- (5) A record shall be kept of the units cast in each mould and any mould that becomes distorted or which casts faulty units shall be withdrawn from service. A fully detailed record of the result for each measured segment shall be made available within 24 hours of the verification.

3.7.6 Elastomeric Gaskets

- (1) The gasket shall be capable of providing a watertight seal under all combinations of specified tolerances associated with manufacturing and ring erection. Gaskets shall be dense, elastomeric synthetic rubber and shall be supplied from approved manufacturers and shall be tested in the presence of the Engineer.
- (2) The test rig shall simulate a range of conditions of displacement and joint gap, including the worst combination to be encountered in the completed structure. In each test the water pressure shall be increased in increments of 0.5 bar and held at each value for 5 minutes. The final pressure shall be at least 1 bar in excess of the maximum hydrostatic pressure to which the structure may be subjected. This pressure shall be maintained for 24 hours during which no leakage shall occur at the gasketed faces. Tests shall be carried out at normal ambient temperature.
- (3) Gaskets shall be manufactured to fit the groove preformed in the segment. Prototype gaskets shall be fit-tested to assess stretch characteristics.
- (4) The material from which the gaskets are to be manufactured shall withstand any aggressive response from the ground or groundwater. In particular the gasket material shall withstand chemical attack and biological degradation such that the gasket functions properly for the design life of the facility.
- (5) Elastomeric gaskets shall comply with the requirements of BS 7874, BS EN 681 and BS EN 682. The material shall consist of a compound based on EPDM able to withstand the long term stresses and strains without detriment to the specified performance.
- (6) The gasket cross section shall be dimensioned to suit the groove as detailed in the Drawings for the mating faces of the segmental tunnel linings. Manufacturing tolerances shall be ± 1 mm for width and ± 0.5 mm for thickness.
- (7) Gaskets shall be manufactured from extruded solid sections with appropriate spaces within the section to enable the gasket to be fully compressible within the groove formed in the concrete segments. The gasket shall still be capable of further compression when its top surface is level with the groove.
- (8) The extruded section shall be joined to form a rectangular gasket that is a stretch fit into the grooves of the segments. The corner joint shall be shot moulded and the corner pieces shall be of different section from the extruded lengths in order that the water-tightness characteristics described in the specification may be achieved and to avoid excessive load on the corners of the concrete segments.
- (9) Gaskets shall be fitted into the groove cast in the segmental tunnel linings prior to erection. The adhesive used shall be as recommended by the gasket manufacturer with a 'notice of no objection' from the Engineer.

The Contractor shall submit to the Engineer full details and samples of the gaskets which he proposes to use at least 60 days before the commencement of manufacturing.

3.7.7 Bolts and Grommets

- (1) Bolts
Radial and circumferential joint bolts shall be made from steel grade 8.8 to BS 5950 and sherardized to BS 4921.
- (2) Grommets
Grommets shall be plastic and to a specification that has a 'Notice of No Objection' from the Engineer.
- (3) Packings
Stress distribution packings for radial and circumferential joints shall be detailed and specified and shall be cut from an approved bituminous felt fibre based sheet or marine hardboard to a minimum thickness of 2 mm.
Timber packings that may be required for the correction of the plane of the ring shall be marine hardboard or plywood, sawn to shape with boltholes. They shall be treated to retard rot and fire, and shall be available in all necessary thicknesses as may be required to suit the tapered ring.

3.8 Grouting

3.8.1 General

- (1) The Contractor shall submit the method statement (both for primary and secondary grouting), including proposed materials, equipments, methodology and grout strength to the Engineer for Notice of No Objection.
- (2) A grouting system shall be provided on the TBM which shall be designed to inject grout continuously into the void behind the tail shield as it advances. This system shall be kept piped up to the tail shield ports but have the facility for emptying the pipes and washing them when not in use.
- (3) The system shall be capable of automatic operation linked to the advance of the TBM. The system should have the facility for selectable volume and pressure control and should be sized to suit the anticipated tail shield void and the annulus between the excavated surface and the extrados of the segmental lining.
- (4) Control and monitoring of grout injection volumes and pressures shall be possible on the operator's control panel and at the grouting station within the back up of the TBM and the results shall be recorded in the datalogger.
- (5) Primary grouting is the annulus grouting which is applied immediately after lining has been built.
- (6) Secondary grouting is done subsequent to the primary grouting and the purpose of which is to ensure that all cavities in the primary grouting are filled.
- (7) The grout mix design shall require a Notice of No Objection from the Engineer

3.8.2 Secondary Grouting

Secondary grouting of the segmental lining shall be done within 14 days of undertaking primary grouting at that location and preferably at a time when the tunnel face is at a distance between 30m to 100m from the proposed secondary grouting location.

3.8.3 Contractor's Submission

- (1) Method Statement
Prior to commencement, the Contractor shall submit a method statement for Primary and Secondary grouting and obtain the 'Notice of No Objection' from the Engineer. The method shall include details of the mixing plant and grout pump(s),

mix design and constituents, proposed grout strength, pumping rates and pressures, injection points, the methodology of grouting, the methods of monitoring, recording and controlling the sequence and timing of grouting, the method of preventing grout leakage, and details of the relevant experience of the personnel and supervisors to be deployed for this work.

(2) Grouting Record

The Contractor shall record at each stage (both for Primary and secondary grouting) of the grouting process the quantity and type of grout and the pressure applied at each injection point. Grouting records shall be kept in the Contractor's offices and be available for inspection by the Engineer

3.8.4 Grouting Pressure

- (1) The Contractor shall ensure that the grout pressures are sufficient to properly place the grout and to fully fill the annulus/voids but do not cause ground heave, over stress or distort the lining, distort or damage the gaskets or damage other structures.
- (2) Generally the grouting pressures should not exceed 1 bar above the hydrostatic pressure prevalent at the location of grouting.

3.8.5 Mix

The grout shall be a mixture of Ordinary Portland Cement and water with a water/cement ratio in the range of 0.35 to 0.5 by weight as appropriate to the circumstances. PFA, GGBS or additives such as plasticizers or non-shrink agents excepting those containing calcium chloride may also be proposed. The proposed grout and grouting system shall be compatible with the TBM's tail seal system

3.8.6 Injection

- (1) The grout shall be injected, continuously as the tunneling machine moves forward through pipelines embedded within the shield tail-skin, by positive displacement pumping. The Contractor shall ensure that grouting pressures used are consistent with his proposals and shall adopt appropriate methods and procedures for controlling and monitoring the process.
- (2) The Contractor shall ensure that the tail-skin seals and sealing material shall prevent grout loss. Rings shall be restrained by the shove rams to prevent distortion or floatation, whilst allowing the free flow of grout in the voidSegmental Lining Design

3.8.7 Grout Plugs

Upon completion of grouting, all grout plugs shall be greased and shall be fully tightened into the segment. Hydrophilic 'O' rings shall be provided at all grout plugs

3.8.8 Grout Valves

For lining built behind tunneling machines, grout holes in the linings segments shall incorporate one-way valves to prevent ground, water and grout loss during grouting operation Waterproofing (Cross-passages and NATM tunnels)

3.8.9 Monitoring Pressures

The Contractor shall monitor secondary grouting pressures and quantities to ensure that grouting does not damage the Works or third party utilities or structures Cavity grouting.

3.8.10 Caulking

- (1) Caulking, wherever specified/required, shall be carried out after completion of primary and secondary grouting. Caulking grooves shall be formed in segments in accordance with the design and the specifications to ensure that caulking to circle joints and radical joints may be made effectively and continuous, the depth of caulked material in the joints being not less than 25 mm.
- (2) Prior to caulking all joints shall be inspected and thoroughly cleaned out as necessary. Any packing shall be cut out by an appropriate method.
- (3) Immediately prior to caulking, the joints shall be blown out with a compressed air jet to remove any loose debris.
- (4) Caulking materials shall be forced into the joints so that the full depth is filled. No visible leaks shall remain on completion of caulking.

3.9 NATM Tunnel Construction (Including Cross- Passage Construction)

3.9.1 Excavation

3.9.1.1 General

- (1) The Contractor shall carry out NATM works in accordance with the Contract Provisions and conforming to the dimensions shown on the drawings that have received a Notice of No Objection from the Engineer.
- (2) Prior to commencing any NATM works, the Contractor shall prepare and submit appropriate designs, drawings and method statements relating to NATM works. The safety and security of all works under the Contract, shall, at all times during the construction, be the responsibility of the Contractor. The Contractor shall implement such measures, including supporting, dewatering and ground treatment/improvement etc., as may be necessary to fulfil his obligations under the Contract.
- (3) The Contractor shall construct the Works under the Contract in such a way that the ground surface settlement and distortion effects are kept as small as possible and in any case not exceeding the limits that would infringe any of the Contract provisions in this respect. Suitable measures shall be taken to ensure that all the Contract provisions are complied with. Such measures shall include, but not be limited to:
 - a) special tunneling methods to reduce ground loss;
 - b) protection measures such as:
 - Underpinning
 - ground improvement
 - ground treatment
 - compensation grouting
 - structural jacking and
 - supporting structural strengthening
 - curtain walling
 - other suitable supporting methods
- (4) Excavation with Care:

All necessary precautions shall be taken in order to prevent softening or deterioration of excavation surfaces such as installation of initial support as quickly as possible etc.

 - a) Where necessary to ensure the safety and security of the Works, excavation

for underground Works shall be continuous by day and night. The Contractor's procedures may allow intermissions at weekends and general holidays, provided the Works are safe at all times and are inspected by the Contractor at appropriate intervals.

- b) In case of NATM tunnelling the Contractor shall make adequate arrangements to support the face in an emergency. The support system shall be maintained in good order at all times and it shall be stored as close to the face as practicable. A detailed drawing of the support system shall be available close to the tunnel face for reference.
- c) Temporary support may be required to the face during manual excavation. The type of support to be provided must suit the ground conditions.
- d) Where the excavation is to be discontinued for any period of time, the excavated tunnel shall be adequately supported and the face shall also be supported in such a manner that ground movement is prevented.

3.9.1.2 Excavation Method and Equipment

- (1) Rock excavation shall be performed by using modern blasting methods, road header, excavator or breaker, expansive chemical agents etc. depending upon the ground conditions and site constraints.
- (2) Controlled blasting methods(where permitted by the Engineer) such as “smooth blasting” shall be used to limit the over-break , prevent the shattering of the rock surfaces, limit the vibration/noise and prevent adverse effects on the Works & EBS.
- (3) Road header shall have transverse type of cutter head and shall be capable of working in the type of rocks likely to be encountered in the tunnel excavation

3.9.2 Disposal of Excavated Material

The surplus excavated material (that cannot be used in the works), shall be treated as Contractor's property. The Contractor shall be free to take away and make use of this surplus spoil in the manner he wishes to. The muck/spoil that is acceptable and can be used at a later stage in the Works, shall be temporarily stockpiled in a dumpsite as proposed by the Contractor and agreed by the Engineer and the concerned regulating authorities. The muck/spoil, which is not acceptable or cannot be accommodated for use in the Works or cannot be made use of by the Contractor for his own purpose, shall be disposed of in spoil dumps or elsewhere as approved by the Engineer/concerned parties and regulating authorities. Please also refer related provisions in Section VI, Employer's Requirements.

3.9.3 Excavation for Contractor's Convenience

Excavations for the Contractor's own use and convenience shall conform in every respect with this Specification. For this purpose, the Contractor shall submit detailed proposals to the Engineer for obtaining his Notice of No Objection. The proposals shall include the Contractor's method of backfilling and reinstatement.

3.9.4 Definition of Excavation Profile

- (1) The finished tunnel profiles as shown on the Employer's indicative Tender Drawings are only for information and the concept adopted is shown in the Figure 3.9.4-1.
- (2) Depending on the quality of the rock/ground, the proposed theoretical excavation line shall take into account the applicable deformation tolerances so that the as-

built tunnel doesn't infringe the required finished tunnel profile.

- (3) The proposed theoretical excavation line shall also take into account the proposed construction tolerances (as-built tolerances) so that the as-built tunnel doesn't infringe the required finished tunnel profile.
- (4) Deformation tolerances (including the tunnel convergence and ground relaxation) are to be proposed by the Contractor, on the basis of detailed analysis so as to contain the ground surface settlements and distortions to protect the EBS against damage and to comply all the Contract provisions in this respect, for obtaining a Notice of No objection from the Engineer.
- (5) The actual deformations (including tunnel convergence and ground relaxation) during tunnel construction shall be contained within the proposed deformation tolerances and the adjustments made to the tunnel support and excavation sequence etc. during the tunnel excavation shall ensure that the actual deformations do not exceed the tolerances that have been agreed by the Engineer.
- (6) The Contractor shall contain the actual construction tolerances during construction within his proposed construction tolerances.

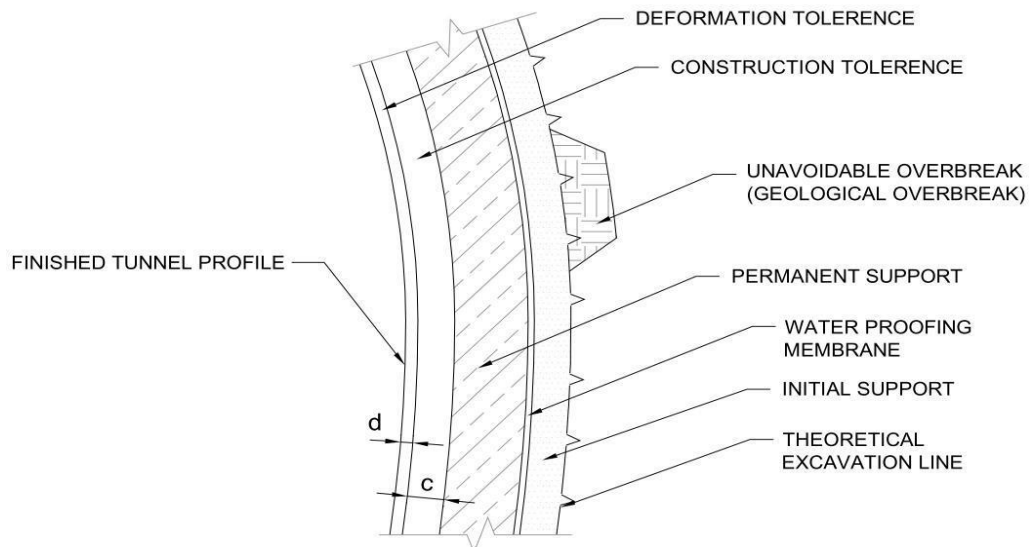


Figure 3.9.4 -1- Definition of Deformation and Construction Tolerances

3.9.5 Method of Profile Control

3.9.5.1 General

- (1) It is the Contractor's responsibility to ensure that the finished tunnel profile, which complies with the Project schedule of dimensions and also all other requirements of the project including that of Designated/ Interfacing Contractors in respect of Track/ OHE/ other Systems etc. and as shown on the Drawings (to be prepared by the Contractor) that have Notice of No Objection from Engineer, is achieved. The Contractor shall propose his methodology with regard to the systematic checking of the geometry template during profiling operations and obtain a Notice of No Objection from the Engineer.
- (2) The Contractor shall use advance surveying techniques and data processing to establish the required "finished tunnel profile", and define a method of marking out

areas of deviation from the required “ finished tunnel profile” with a Notice of No Objection from the Engineer.

3.9.5.2 Execution

- (1) Immediately after completion of initial support (Primary Support) installation of each excavation round, the Contractor shall perform an initial profile check and submit the records to the Engineer.
- (2) The checking of the finished tunnel profile shall not commence before the geotechnical measurements show that the deformations at any position of the tunnel have, in the opinion of the Engineer, largely stopped.
- (3) The as constructed finished tunnel profile after the completion of all support works and after all deformations of the tunnel shall as a minimum conform to the theoretical(required) finished tunnel profile as indicated on the Drawings, that have Notice of No Objection from Engineer.
- (4) In case a profile being an under-profile, the Contractor shall submit a proposal for remedial measures to the Engineer for his Notice of No Objection and subject to the following stipulations:
 - a) No reshaping or re-profiling of the tunnel support shall be permitted
 - b) Geotechnical measurements before, during and after the respective tunnel reshaping measures shall be carried out in accordance with the remedial works proposal. The measurement points such as convergence bolts and/or extensometers shall be retained or substituted well in advance in order to establish "transfer – zero – readings".
 - c) Records shall be kept for each stage of the remedial measures executed.
- (5) Geotechnical measurement stations shall not be removed and abandoned without the Notice of No Objection from the Engineer.

3.9.6 Construction Tolerance

3.9.6.1 Tolerances for lining

The actual thickness of the final support shall not be allowed to be less than the designed thickness of the final support unless agreed by the Engineer. To achieve this requirement, no support elements such as primary shotcrete (initial support), rock bolts and steel ribs etc. shall penetrate into the theoretical outer boundary of the final support (inner lining), as shown on the construction drawings.

3.9.6.2 Over-break

- (1) Over break is the space created when the ground breaks beyond the theoretical excavation line. Unavoidable over-break is caused by unfavourable geological conditions. In the event of excessive over-break, support shall be installed immediately as required to stabilize the ground. The Engineer shall be informed immediately and the remedial works shall be proposed by the Contractor for obtaining a Notice of No Objection from the Engineer.
- (2) The remedial works shall be executed before further advance of the face unless agreed by the Engineer.
- (3) Where over break occurs more than 150 mm beyond the theoretical excavation line, the Engineer will inspect the area and decide if shotcrete or concrete shall be provided as backfill. In areas where there is to be a concrete lining or concrete structure adjoining the rock, the over break backfill shall be of the same quality as that required for the lining or structure. The remedial works for the over-break

(whether avoidable or unavoidable) shall be carried out by the Contractor at no extra cost to the Employer.

3.9.7 Contractor's Submission

- (1) The Contractor shall submit, but not be limited to, the following information to the Engineer for obtaining Notice of No Objection, at least 60 days before the commencement of any NATM tunneling work.
 - Equipments proposed to be used in the excavation.
 - Detailed description of proposed excavation method and sequence(In this connection it is brought to the notice of the Contractor that there may be certain stretches on the alignment in the Contract reach where blasting shall not be permitted and for such locations the Contractor shall propose alternative excavation methods).
 - Ground treatment and dewatering, where required for controlling the water-inflow, stability of excavation, protection of EBS or any other purpose.
 - Contingency plans in the event of unusual/unexpected tunnel behavior under construction.
 - Safety measures for EBS protection.
 - Working cycle for excavation and proposed supports in each rock class.
- (2) The name and qualification of the independent geotechnical engineer(who shall be required to be deployed for the Works by the Contractor for advising the support requirements) proposed by the Contractor for Notice of No Objection from Engineer.
- (3) Relevant training certificates and work experience of the shotcrete nozzle men and other personnel proposed to be deployed by the Contractor.

3.10 NATM Tunnel Support

3.10.1 General

- (1) The type and amount of tunnel support to be installed immediately after excavation is directly related to the rock classification as established by the Contractor. The standard initial support associated with the established rock classification system shall be proposed by the Contractor for obtaining a Notice of No Objection from the Engineer. However, as a consequence of variations from the anticipated rock conditions the standard support systems as shown on the Construction drawings(prepared by the Contractor and noticed by the Engineer) for each rock class may require modifications and adjustments during construction for which a Notice of No Objection for the revised scheme shall be obtained from the Engineer.
- (2) The Contractor shall ensure that support elements are installed or applied in such a manner, time and sequence as to prevent disintegration and loosening of the rock mass surrounding the excavated tunnel.

3.10.2 Initial Tunnel Support

- (1) The initial tunnel support will generally consist of the following:
 - Steel ribs or lattice arches and wire/reinforcement mesh sprayed with shotcrete to an appropriate thickness

- Shotcrete with wire/reinforcement mesh or fibre and rock-bolts/rock-dowels
 - A combination of the above.
- (2) Wherever ground conditions require pre-support, the contractor shall provide the same by way of inserting an 'umbrella' type forepoling either by installing a pipe roof that will be closed poled or spiling with grouted pipes or bars depending on the ground stability.
 - (3) The face support during stoppages or lining (support) installation will either consist of a spoil buttress which will be supported by shotcrete and mesh or shotcrete and mesh with grouted rock dowels inserted into the face.
 - (4) Where the water in-flow into the excavation is expected, ground treatment such as grouting etc. shall be done by the Contractor before commencing the excavation. However, the localized dewatering in the tunnel face can be carried out by either drainage pipes inserted into the face or a mild vacuum system duly ensuring that it doesn't lead to unacceptable ground surface settlements/distortions adversely affecting the EBS.
 - (5) The initial Support will be monitored continually for settlements/deformations throughout the stabilization process. Other monitoring shall include force in rock bolts and stresses/strains in shotcrete lining.
 - (6) The initial support system including the design of the supporting pattern with respect to each Rock Class shall be determined and proposed by the Contractor for obtaining a Notice of No Objection from the Engineer before commencing the works.

3.10.3 Final Tunnel Support

The final tunnel support shall comprise of Concrete lining (or reinforced concrete lining).

(1) Concrete lining

The Contractor shall design concrete linings to meet the requirements of the Contract Specifications pertaining to concrete.

(2) Preparation of surfaces

The surface against which concrete is to be placed shall be cleaned of loose material and dirt. A waterproofing membrane shall be placed between the initial support and the final concrete lining. No concreting of final support shall take place before inspection of the initial support surface and the waterproofing membrane by the Engineer.

(3) Placing of concrete

Concrete shall be placed so that the space between the lining form and the surface against which concrete is to be placed, is filled as completely as possible, to avoid any voids formation especially in the crown area. After the placed concrete attains a 28 days strength, the interface between the concrete lining and the initial support shall be contact grouted without damaging the waterproofing membrane.

3.10.4 Sprayed Concrete (Shotcrete)

3.10.4.1 General

- (1) Sprayed concrete may be applied by either a wet or dry mix process.
- (2) The sprayed concrete after completion is not to be touched up, trowelled, smoothed off or worked in any way, but left undisturbed unless otherwise agreed by the Engineer.

- (3) If required a layer of sprayed concrete (called flash shotcrete or sealing layer) shall be applied immediately following the excavation to stabilize the unstable/loose patches.
- (4) Sprayed concrete shall be applied to the excavated rock surface with or without mesh reinforcement, as the case may be, and to the designed thickness as indicated in the construction drawings prepared by the Contractor and agreed by the Engineer.
- (5) Sprayed concrete shall be applied in one or more layers of appropriate thickness to achieve the total designed thickness.
- (6) All the provisions in the Contract pertaining to the concrete shall be applicable to the sprayed concrete (shotcrete) as well, to the extent found relevant.
- (7) The type of cement to be used for shotcrete shall be according to IS 456. A specific fineness of the cement after Blaine between 4,000 and 5,000cm²/g can be used to achieve sufficient early strength of the shotcrete. Additives (conforming to the relevant BIS standards), such as fly ash, ground granulated blast furnace slag and silica fume for the improvement of performance, and workability etc. may be added to the shotcrete mix, with the approval of Engineer. The performance of the shotcrete mix with additives shall be determined by field suitability tests.

3.10.4.2 Aggregates

- (1) The coarse aggregates shall not contain a large quantity of long stone pieces. The maximum size of the aggregates shall not exceed 12 mm for wet process or 16 mm for dry process. The proportion of aggregate larger than 8mm in size should not exceed 15% for the wet process in order to minimise rebound. The grain size distribution shall be as shown in Table 3.10.4-1. It is the responsibility of the Contractor to choose the most suitable grading for the process and materials available.
- (2) The amount of fine particles under 0.1mm shall not exceed 8%. During rainy and cold weather periods, the aggregates for the dry process shall be stored undercover for at least 48 hours before being used and kept sufficiently dry.

Table 3.10.4-1 Recommended Grain Size Distribution of Aggregates with Wet-mix Shotcrete

Standard Sieve	Sieve Size (mm)	Passing in %
ASTM	12.5	96 – 100
IS	10	92 – 98
IS	4.75	70 – 80
IS	2.36	50 – 60
IS	1.18	24 – 34
IS	0.60	20 – 28
IS	0.30	10 – 17
IS	0.15	5 – 12

3.10.4.3 Steel Fibres

- (1) The types and dimensions of steel fibres shall be suitable for shotcrete application and the requirements of shotcrete reinforcement. The steel fibres shall be supplied by a supplier as agreed by the Engineer before their use in the Works.
- (2) Steel fibres shall be collated or uncollated deformed steel fibres conforming to the requirements of ASTM A820-90.
- (3) Fibres shall be stored in dry sealed containers until ready for use and shall be free from corrosion, oil, grease, chlorides and deleterious materials which may reduce the efficiency of the mixing or spraying process, or which may reduce the bond between the fibres and the sprayed concrete.
- (4) Fibres shall have an aspect ratio (ratio between fibre length and fibre diameter) in the range of 30 to 150 for lengths of 12.7 to 63.5 mm. Tolerances shall be in accordance with ASTM A820-90.

3.10.4.4 Accelerators

- (1) Accelerators may be used to achieve a fast set and to get sufficient early strength development. The proposal along with references from suppliers shall be obtained and submitted to the Engineer for Notice of No Objection.
- (2) Accelerating admixtures shall be compatible with the cement used. The compatibility shall be tested in the laboratory by the Manufacturer and verified by the Contractor in field suitability tests to achieve the required properties for early and final strength as proposed by the Contractor.
- (3) Only alkali-free accelerators shall be used. The alkali content shall be less than 1% mass (Na₂O-equivalent, EN 480-12).
- (4) The dosage rate determined by the field suitability tests shall not exceed 2% of the cement content of the mix design by weight. The dosage of accelerator shall be kept to the minimum required for spraying in-situ.
- (5) Automatic devices shall be used to add the accelerator.

3.10.4.5 Plasticizers and retarders

- (1) Plasticizers and super plasticizers, complying with BS 5075: Part 1, may be used to achieve pumpable shotcrete with minimum water content. Plasticizers shall be checked regularly, or as required by the Engineer, for setting time, water reduction and development of strength as compared with the design mix.
- (2) Compatibility of plasticizers with cements, latent hydraulic binders and accelerators shall be verified by field suitability tests.
- (3) The effects and optimum dosages of plasticizers and super plasticizers shall be determined by the field suitability tests to achieve the shotcrete properties as required.

3.10.4.6 Compressed air

Compressed air used in the process shall be clean, dry, contamination-free and free of oil.

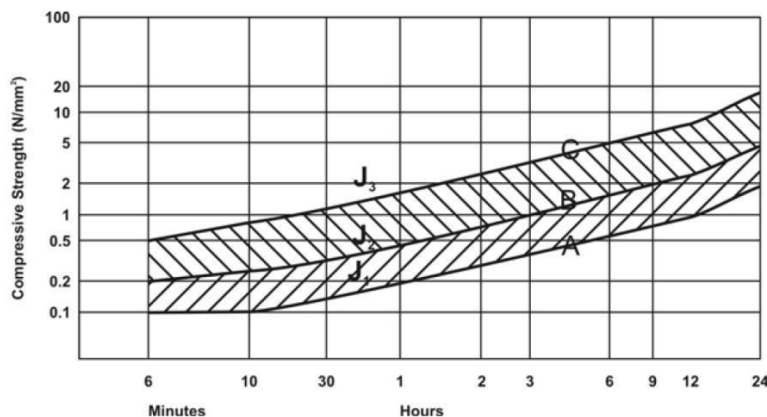
3.10.4.7 Design of Sprayed concrete

- (1) The mix design shall be carried out by the Contractor and details submitted to the Engineer for Notice of No Objection.
- (2) The mix for shotcrete shall be designed by field suitability tests to meet the

requirements. The following factors shall be taken into consideration:

- Material and gradation curves of aggregates
 - Cement content
 - Water-cement ratio
 - Plasticizer or super plasticizer type and dosage, if any
 - Hydration control admixture type and dosage, if any
 - Internal curing admixtures, if any
 - Accelerating admixtures
 - Early and final strength
 - Strength loss as compared to the design mix strength of the shotcrete Rebound
 - Temperature of the mix
 - Establishment of target slump and slump retention of the mix for optimum performance and placement
 - Other additives, if any
- (3) Cement Content
- a) For the dry shotcrete process the quantity of cement shall not be less than 350 kg/m^3 of dry mix.
 - b) For the wet shotcrete process the minimum cement content shall be 400 kg/m^3 .
 - c) Variation from the above cement content shall require agreement of the Engineer. The cement content shall be designed to meet the strength requirements of shotcrete applied in the field.
- (4) Requirements for shotcrete
- a) Early Strength
- The early strength of shotcrete shall conform to the early strength class J2 according to Figure 3.10.4-1. For explanations regarding the use of Early Strength Classes J1, J2 and J3 Austrian Guideline for Shotcrete may be referred to.

Figure 3.10.4-1: Early Strength Requirement for Shotcrete



The measurement of early strength shall be done by using the penetration needle, Hilti Shotbolt(stud-bolt) system (or equivalent) according to the Austrian Guideline for Shotcrete, August 2006.

- b) Further Strength Development

The 72 hours strength of the shotcrete shall be at least 12.5 N/mm^2 .

The strength of the shotcrete after 7 days shall be at least 70% of the specified 28 days strength of the mix.

c) Final Strength

The 28 days strength of shotcrete shall conform to the 28 days design mix strength. A maximum factor of 0.85 (the ratio of in-situ strength to the design mix strength) shall be taken into consideration while designing the mix to account for the effects of in-situ installation conditions as compared to the conditions obtainable in the Field Suitability tests.

3.10.4.8 Equipment

- (1) All the equipment used for batching and mixing of materials and the application of sprayed concrete shall be of noticed design and in proper working order. The sprayed concrete gun and ancillary equipment shall be of adequate capacity for the volumes to be applied. The equipment shall be capable of handling and applying 16 mm maximum size of aggregate. A stand-by gun and ancillary equipment shall be available at all times. Air for the equipment is to be provided at the equipment at not less than the required operating pressure.
- (2) Dosing of additives by hand will not be permitted. Equipment for dosing the additives shall be adjustable for various quantities and provide a uniform rate of discharge evenly mixed with the other ingredients of the mix. The equipment shall be capable of delivering admixture to ensure the noticed dosage ratio to an accuracy of $\pm 5\%$.
- (3) The working area shall be well illuminated to a minimum lighting intensity of 50 lux. Cap lamps attached to safety helmets will not be accepted as the sufficient measures. Dust pollution shall be minimised by means of pre-damping of materials, additional ventilation, water sprays, and maintaining equipment in good order. Protective clothing and dust masks shall be provided for and used by all sprayed concrete operators.
- (4) If at any time the Engineer considers that the environmental conditions of the area where sprayed concrete is being applied are likely to cause a health hazard or affect the quality of the finished work because of excessive dust or lack of adequate ventilation or lighting, he may instruct the Contractor to suspend operations on sprayed concrete work until steps are taken to improve the conditions in the affected area. No additional payment shall be made to the Contractor either for the additional measures called for or for any delays resulting from such suspension of works.

3.10.4.9 Batching

- (1) Dry Shotcrete Process
 - a) Cement and aggregates shall be batched in the proportions as designed. Batching shall be done by weight. At the time of batching all aggregates shall have been dried or drained sufficiently to result in a stable moisture content, which shall not exceed 7%.
 - b) Mixing of cement and aggregates shall be performed by a mechanical mixer. Shotcrete shall not be used unless placing can be completed within a period of 90 minutes from the time of mixing unless a hydration control admixture is used that is suitable to inhibit setting and retain consistency for the required time period till the placing of shotcrete. The hydration control admixture must have a notice of No Objection from the Engineer.
 - c) The mixing time shall be in accordance with BS5328.

- d) A system of delivery notes shall be maintained to record the date, the time of mixing, mix design number, quantity, delivery point, time of delivery and completion of placing. The delivery notes shall be available to the Engineer for inspection.
 - e) For the dry process, powder or liquid type accelerating admixtures shall be added to the dry-mix. The powder type accelerator shall be proportioned and added just before the dry mix enters the shotcrete machine through a mechanical device (dispenser). Periodic calibration checks shall be performed in accordance with the procedures prescribed by the manufacturer. Liquid type accelerator shall be delivered by a special dosage pump and added to the dry-mix at or near the nozzle. Dosage pump and the hoses to the nozzle shall be kept in good order.
 - f) Dry-Mix delivered to the shotcrete machine shall have a minimum temperature of 5°C and a maximum temperature of 32°C.
 - g) During hot weather periods the water content of the aggregates for the dry process shall be kept above 4%, in order to avoid cement loss at the rotor of the shotcrete machine.
 - h) During transportation the dry mix shall be effectively protected against the influence of weather.
 - (2) Wet Shotcrete Process
 - a) Only liquid types of accelerator can be used in the wet process; these shall be added at or near the nozzle. The delivery from the accelerator pump must be controlled to be proportional to the output of the concrete pump. Accelerator pump calibration shall be periodically checked in accordance with the procedures prescribed by the manufacturer. The nozzle must be such as to ensure a homogeneous mixture of the accelerator with the wet-mix.
 - b) Shotcrete shall not be used unless placing can be completed within a period of 120 minutes from the time of mixing unless a hydration control admixture is used that is suitable to inhibit setting and retain consistency for the required time period till the placing of shotcrete. At high temperatures, hydration control admixtures shall be used to ensure fresh concrete and sufficient initial setting time.
 - c) Concrete delivered to the shotcrete machine shall have a minimum temperature of 15°C and a maximum temperature of 32°C.
 - d) A system of delivery notes shall be maintained to record the date, the time of mixing, mix design number, quantity, delivery point, time of delivery and completion of placing. The delivery notes shall be available to the Engineer for inspection.
 - (3) Materials shall be batched by weight and cement shall not be added more than 1 hour before the anticipated time of placing the sprayed concrete. Aged material shall be discarded.
 - (4) Batching and mixing equipment shall be cleaned at least once per shift to prevent accumulations of aged material.
 - (5) The addition of steel fibers shall be at a stage in the mixing suitable for the

sprayed concreting equipment. The procedure for the addition of steel fibers shall be determined during the Site trials. Fibers shall be added and mixed in a manner to avoid clumping and bending of the fibers. Any fiber clumps in the mix shall be diverted and removed by means of a screen placed over the concrete hopper. Fibers shall be uniformly distributed throughout the mortar matrix without isolated concentrations. Fibers shall not be added to the mix at a rate faster than that at which they can be blended with the other ingredients without forming clumps or balls.

3.10.4.10 Placing

- (1) Sprayed concrete shall not be applied to any surface without the prior inspection and a Notice of No Objection from the Engineer.
- (2) Preparation of surfaces
 - a) Before sprayed concrete is applied, checking and correction of the excavated cross-section profile shall be carried out. The surfaces to which sprayed concrete is to be applied are to be barred down of all large loose material and the area cleaned down of all loose and foreign material with a mixture of water and air applied at high pressure.
 - b) The water inflow shall be controlled over the area on which shotcrete is to be applied such that the surface is not too wet. Where the inflow of groundwater renders the surface too wet for the normal application of sprayed concrete, the surface shall be treated by suitable measures to be proposed by the Contractor and as agreed by the Engineer.
 - c) All surfaces to receive sprayed concrete shall be moist and free of all traces of dirt, oil, rebound or other deleterious material.
- (3) If the design thickness is to be applied in more than one layer, then the previous layer must have developed sufficient strength to support the additional layer(s).
- (4) Rebound shall be removed immediately after finishing of each shotcrete application. In particular at horizontal shotcrete connections and at all construction joints the rebound shall be removed, if necessary, by pneumatic hammers, prior to further application of shotcrete.
- (5) Under no circumstances rebound material shall be worked back into the construction. The work shall be continuously kept free of rebound material.
- (6) Measures to establish the thickness of shotcrete shall be set up by the Contractor and as agreed by the Engineer. These may include visual guides installed prior to shotcreting, holes drilled after completion of shotcreting or a full control by laser scanning.
- (7) Curing of the shotcrete shall be performed after application by water spraying or other appropriate measures subject to the agreement of Engineer.

3.10.4.11 Operators for Sprayed Shotcrete

- (1) Only trained and tested operators shall be used for sprayed concreting operations. The Contractor shall satisfy the Engineer that the personnel are capable of doing work of a high standard prior to any sprayed concrete work being undertaken in the Works. For this purpose each nozzleman and back-up team shall carry out a series of trial applications in the presence of the Engineer

to demonstrate their ability in applying sprayed concrete on vertical and overhead surfaces. Test panels shall be made by each operator. No operator will be approved unless the 28 days compressive strengths of all tests exceed the design strength requirements.

- (2) The Engineer may at any time withdraw his Notice of No Objection given to the Contractor's personnel if the quality of sprayed concrete applied falls below the acceptable standard

3.10.4.12 Initial Testing

- (1) For the first 50 m² of sprayed concrete applied in each shift, test panels shall be prepared and tested. Initial testing of shotcrete shall consist of one test panel for every 10 m² of sprayed concrete applied. The test panels shall be prepared by the nozzleman doing the work during normal sprayed concrete operations.
- (2) The test panels shall be made by spraying into moulds 750mm x 750mm x 150mm deep with sides splayed outwards at 45° to prevent entrapment of rebound. Panels shall be made for each mix and position sprayed (that is overhead, vertical, or downward) by fixing the moulds to the surface being sprayed. Panels shall be clearly marked to identify the time and date of spraying, and the area where they were sprayed.

3.10.4.13 Acceptance and routine testing of Sprayed concrete (Shotcrete)

Prior to commencement of spraying concrete in the Works and also during the actual shotcreting works at site, testing shall be carried out by the Contractor as detailed below.

- (1) Test panels shall be sprayed for each design mix and for each position of spraying required in the Works such as downward, vertical and overhead positions.
- (2) Cores shall be cut from these panels and 3 cores tested for each strength requirement (8 hours, 24 hours and 28 days).
- (3) The average of the 3 results tested at 8 hours, 24 hours, and 28 days age shall be not less than the 8 hours, 24 hours, and 28 days required strengths respectively. In addition, the value of each core tested shall be within 20 % of the average value.
- (4) Sufficient tests shall be done to prove the acceptability of the sprayed concrete to meet the requirements with regard to:
 - Compressive strength at 8 hours, 24 hours and 28 days (as per the relevant standards)
 - Boiled absorption (as per ASTM C 642)
 - Volume of permeable voids (as per ASTM C 642)
 - Setting time; initial and final (as per the relevant standards)
- (5) For this purpose the Contractor shall prepare and submit a test plan specifying the tests, test procedures, test frequencies and results to be obtained for acceptance and routine testing of shotcrete for obtaining a Notice of No Objection from the Engineer.

3.10.5 Rockbolts

3.10.5.1 General

- (1) For the purpose of this Specification rockbolts and dowels are defined as follows :

“**Rockbolt**” is a high yield deformed bar, or glass fibre reinforced resin rod, of specified diameter and length (in rock) which is end anchored with resin grout, fully column bonded with resin or cement grout, equipped with a faceplate, hemispherical washer and nut and tensioned to a specified load;

“**Dowel**” is a high yield deformed bar, or glass fibre reinforced resin rod, of specified diameter and length (in rock), which is fully grouted with either resin or cement grout. Dowels will not be fitted with accessories nor will they be tensioned.

3.10.5.2 Materials

- (1) Rockbolts and dowels shall be manufactured from hot rolled deformed bars with a minimum steel grade of Fe 415, with the exception of areas to be excavated subsequently where glass fibre reinforced resin rods shall be used.
- (2) Face plates, hemispherical washers and nuts for rockbolts shall be manufactured to suit the loading requirements.
- (3) Resin grout shall be a commercially produced epoxy product in capsule form with both fast and slow setting times as applicable especially formulated for use with rockbolts or dowels, and transported, stored and utilised in accordance with the manufacturer's recommendations.
- (4) Cement grout shall be a commercially prepared product in capsule form especially produced for use with rockbolts or dowels. The product shall not contain any material which could corrode the rockbolts or dowels.
- (5) Alternatively, where a pumped cement grout is used for the installation of rockbolts or dowels, the materials shall comply with the requirements of the relevant Standards.

3.10.5.3 Manufacture of Rockbolts

- (1) Rockbolts shall be manufactured from high yield deformed bar of appropriate diameter. The bar length shall be the required length of bar to be bonded to the rock with a due extra allowance for the cutting length including the threaded portion protruding from the rock as required for installation. One end shall be threaded with a coarse cut thread which shall not reduce the overall specified bar diameter by more than 3 mm. The other end shall be chamfered to facilitate installation.
- (2) Face plates shall be of adequate size and thickness with a centralised slot to suit the dimensions of the rockbolts.

3.10.5.4 Manufacture of dowels

- (1) Dowels shall be manufactured from high yield deformed bar, with the exception of areas to be excavated subsequently where glass fibre reinforced resin rods shall be used.
- (2) Dowels shall be either straight bars or shall have the protruding end bent to facilitate the specified connection between the rock and surrounding concrete or sprayed concrete when so required.
- (3) Dowels for installation with resin or cement cartridges shall be threaded at one end sufficiently for attachment of the installation equipment. The other end shall be chamfered to facilitate installation.

3.10.5.5 Testing of rockbolts

- (1) Prior to installation of rockbolts in the Works, the Contractor shall carry out a

series of tests as agreed with the Engineer to prove the efficacy of the system and the Contractor's capability to correctly install and tension the rockbolts.

- (2) The tests shall demonstrate:
 - Number of resin cartridges required to provide the end anchorage with an applied load equal to the bar's characteristic strength and taking into account the over-length variation of holes.
 - Number of resin or cement cartridges to fill the annulus around the rockbolt or dowel over the length of the hole between the anchorage and collar of the hole.
 - Strength of the resin grout to fully anchor the bars up to the characteristic strength of the rockbolts.
 - Capacity of the equipment to install the longest fully grouted rockbolts or dowels.
 - Equipment for tensioning the bolts to the specified loads.
 - Capability of each crew to correctly install and tension the rockbolts.
- (3) The Contractor shall undertake the tests with the equipment to be used in the Works.
- (4) The Contractor shall provide a suitably calibrated direct tensioning jack and/or load cell of capacities in excess of the characteristic strength of the rockbolts. Loads and bolt elongations shall be recorded during the tests.

3.10.5.6 Installation of rockbolts

- (1) The method of installation and tensioning of bolts must have a Notice of No Objection from the Engineer prior to commencement. Manufacturer's instructions for the use of proprietary components shall be followed wherever appropriate.
- (2) Unless otherwise proven acceptable by site trials, the rockbolts shall be installed in holes of diameter 10 mm to 15 mm greater than the maximum diameter of the rockbolt. The holes shall not be more than 100 mm longer than the grouted length of the rockbolt unless otherwise proven acceptable by site trials. A sufficient number of cartridges shall be used to ensure the annulus around the rockbolt is completely filled over the full length of the hole.
- (3) The effectiveness of the rockbolt installation during tunnel driving shall be checked by testing a minimum of 1 per 100 installed bolts to a load corresponding to 80% of yield load. Should the assemblies fail at tensions less than 80% of the yield load of the bolt, the Contractor shall investigate the cause and take such remedial measures as may be necessary. Tests shall continue thereafter at a rate of 1 per 50 bolts until the Engineer is satisfied that the cause of failure has been identified and adequately addressed.
- (4) Regular calibration of tensioning devices shall be carried out by the Contractor.

3.10.5.7 Installation of dowels

- (1) The method of installation of dowels shall have a Notice of No Objection from the Engineer prior to commencement. Manufacturer's instructions for the use of proprietary components shall be followed wherever appropriate.

- (2) Holes of diameter 10mm to 15mm greater than the maximum diameter of the dowel shall be drilled and cleaned. The gauged amount of pumped cement grout or cartridges of resin/ cement grout shall then be inserted and the bar driven firmly into the hole. If pumped cement grout is used, the grout shall be inserted using a tremmie pipe pushed down to the bottom of the hole and withdrawn slowly as the grout is placed. After installation the bar shall be vibrated for a short period to ensure the complete distribution of the grout around the full length of the bar. Additional grout shall be added to make up any shortfall. Where required, grouting of the hole shall be carried out in stages to allow the flow of grout into cavities, each stage being topped up by the following stage.

3.10.5.8 Records

For each rockbolt or dowel installed the following information shall be recorded

- reference number;
- type of installation;
- name of person taking record;
- date of drilling and installation;
- length and orientation of the drilled hole;
- length of installed rockbolt or dowel;
- tension applied to the rockbolt
- details of any tests carried out

3.10.6 Lattice Girders

3.10.6.1 General

- (1) This sub-section applies to the supply and installation of the lattice girders required and used as support in underground excavations.
- (2) The Contractor shall be solely responsible for the design and manufacture of lattice girders.

3.10.6.2 General Requirements

- (1) Lattice Girders shall be effective as initial support immediately after excavation and shall subsequently act as reinforcement and load distributing members for the initial shotcrete lining.
- (2) The lattice girders shall be manufactured to meet the geometrical requirements for the excavation geometries including the construction tolerances for each rock class.
- (3) During transport, storage and handling of lattice girders, adequate measures shall be taken by the Contractor to prevent their bending, scraping, overstressing or any other damage. The damaged pieces shall not be used in the works.

3.10.6.3 Submission

Shop Drawings for the fabrication of the lattice girders shall be submitted for Notice of No Objection from the Engineer prior to the commencement of the work. The submission shall comprise the following:

- Complete fabrication details of the lattice girders.
- Installation procedures and layout.
- Details of joints, connections, spacers, geometry etc.
- Certificates of compliance for the materials.

3.10.6.4 Design of Lattice Girders

- (1) Lattice girders are three dimensional, lightweight steel frames manufactured of round or corrugated steel bars in compliance with the required excavation geometry of the tunnel.
- (2) Lattice girders shall consist of three primary bars, connected by stiffening elements as per the design. They shall be designed so as to:
 - a) Facilitate shotcrete penetration into and behind the girder, thereby minimizing the creation of projection shadows.
 - b) Provide good quality bonding between the steel and shotcrete, to form a composite structure in the sense of a continuous reinforced shotcrete lining.
- (3) A minimum 5% of the total moment of inertia shall be provided by the stiffening elements. This percentage is calculated as an average value along repeatable lengths of the lattice girder.
- (4) To ensure stability against buckling, the maximum spacing between stiffening elements shall be less than three times the cross sectional height of the girder.
- (5) In case of fabrication on site, the Contractor shall submit a detailed method statement for obtaining a Notice of No Objection from the Engineer.
- (6) The Contractor shall submit related detailed drawings of the lattice girders, showing also the number of sections in the frame and details of the connection between the sections. The details with appropriate calculation shall be submitted to the Engineer for obtaining a Notice of No Objection.

3.10.6.5 Materials

- (1) Each of the primary bars of a lattice girder segment shall be composed of only one piece of high strength steel having yield strength of 500 MPa or more.
- (2) The connection elements at the end of lattice girder segments shall be constructed of angled structural steel having yield strength of 250 MPa or more, or of welded flat steel ensuring similar strength characteristics

3.10.6.6 Manufacturing of Lattice Girders

- (1) Geometry
The lattice girders shall be fabricated to meet the minimum clearances duly taking into account the permissible inaccuracy of placement during construction and the permissible material tolerances.
- (2) Welding of Lattice Girders
 - a) Testing of materials and workmanship shall be carried out in accordance with AWS D1.4. A third party testing agency shall be employed by the Contractor to carry out the tests.
 - b) The manual metal-arc welding process shall be employed. The Contractor shall be responsible for ensuring that the capacity of the welding plant and ancillary equipment is adequate for the welding procedure to be used and for maintaining all welding plant and ancillary equipment in good working order.
 - c) Covered electrodes complying with German Standard DIN 1913 shall be used.

Electrodes shall be selected with regard to the particular application (welding position, joint design etc). Electrodes shall be stored in their original containers in a dry, preferably heated place, adequately protected from the effects of the weather and in accordance with the Manufacturer's Specifications.

- d) Surfaces to be welded shall be dry. Fusion faces and the surrounding surfaces shall be free from heavy scale, moisture oil, paint or any other substance which might affect the quality of the weld. Slag shall be removed from each run of weld metal before a further run is superimposed. The most favourable welding position for each case shall be chosen.
- e) For the cutting of the steel profiles the manual flame cutting process may be employed. Sawing will also be permitted.
- f) Further preparation of joint and fusion faces shall be done by grinding.
- g) Parts to be welded shall be assembled such that the joints are easily accessible and visible to the operator.
- h) Slag shall be removed from all welds in order to allow visual inspection.
- i) Welding operations shall be supervised by a suitably trained supervisor who shall have particular production experience.

3.10.6.7 Installation of Lattice Girders

- (1) Lattice girder shall be installed to conform to the excavated shape. The geometry of Lattice Girders shall take into account the permissible inaccuracy of construction and tolerances of materials.
- (2) Lattice girders shall be erected to the lines and levels as required. The exact excavation levels will be determined by the Contractor suiting his equipment and construction method subject to a Notice of No Objection by the Engineer.
- (3) Lattice girders shall be secured by use of spacers as well as temporary wood blocking or other appropriate means to maintain position during shotcreting.
- (4) Butt plates for steel girder segments and expansion unit in invert shall be provided as required. Tight connection of all elements shall be ensured such that the static efficiency of the cross section is maintained.
- (5) Lattice girders shall be embedded in shotcrete, in order to get contact between rock and lattice girder by a solid shotcrete packing which shall have a minimum cover to steel of 20 mm.
- (6) The lattice girders shall be erected perpendicular to the tunnel axis.

3.10.7 Forepoling

3.10.7.1 General

Forepoling is a pre-excavation support element that may be required for tunnel excavation works. Forepoling shall be applied in rock and soil conditions, which tend to produce overbreak, collapses or material inflows immediately following excavation. Forepoling may be applied locally or systematically as per the requirement for the safety of the works and to prevent overbreaking. All forepolings must be fully grouted.

3.10.7.2 Material

- (1) In case Boreholes are stable
Steel pipes with a minimum outer diameter of 40 mm shall be used. Wall

thicknesses of steel pipes shall not be less than 4 mm. Dowels (spiles) consisting of deformed high yield steel bars of grade Fe 500 with a minimum diameter of 32 mm may also be used instead of steel pipes, where found suitable.

- (2) In case Boreholes are not stable

Self-drilling bolts shall be used as forepoling elements where stability of the predrilled boreholes cannot be achieved, due to the encountered ground conditions. Self-drilling bolts shall be installed only if permitted by the Engineer and shall have a yield load of at least 200 KN. The grout used for self-drilling bolts shall be in accordance with the requirements specified by the bolt manufacturer. Grouting shall be carried out simultaneously with drilling to achieve a better grouting effect along the bolt.

3.10.7.3 Installation

- (1) Forepoling shall be applied as shown on the drawings that have a Notice of No Objection from the Engineer.
- (2) Forepoling elements at 300 to 500 mm centres shall be inserted into the predrilled holes (steel pipes or dowels) at the face or drilled into the face (self-drilling bolts) towards the unexcavated ground.
- (3) The length of forepoling elements shall be according to the design and drawings and shall be at least 1.50 meter longer than the excavation round length.
- (4) Forepoling shall be used together with lattice girders or any other steel support system.
- (5) Grouting of forepoling pipes and dowels shall be done with cement mortar, either before or after their insertion, as per the approved scheme.
- (6) Forepoling shall be required to be properly supported by the lattice girder/steel sets and the shotcrete above the lattice girder/steel sets. Therefore, shotcreting of the gap between lattice girder/steel sets and rock in the portions of forepoling shall be completed only after the installation of forepoling.

3.10.7.4 Pipe Roof

A pipe roof is a special type of long forepoling (typically 9 – 15 m). The forepoling elements shall consist of steel pipes with a minimum outer diameter of 76 mm and a minimum yield load of 1200 KN. The length and spacing of the pipes shall be as per the design and drawings and as agreed by the Engineer. The pipes shall be grouted with cement mortar.

3.10.8 Grouting for In-situ Linings and Junctions

- (1) All voids remaining unfilled outside the in-situ concrete permanent (final) linings in tunnels, including junctions, headwalls and the like, shall be grouted as required. For this purpose the grout shall be injected through pipes set in the concrete, through drilled holes, or through grout holes. Drilled holes shall not be used where there is a possibility of damage being caused to the Permanent Works such as puncturing of waterproofing membranes.
- (2) Where grout is to be placed in voids occurring within the design thickness of linings the grout shall have a characteristic strength equal to or greater than the required characteristic strength of the linings.
- (3) Injection points used for cavity grouting shall be provided at least one per 2.0 linear metres of tunnel and more frequently in any areas of excessive over break.

The injection points for cavity grouting in arched roofs shall be located within 500 mm of the crown. The injection points for grouting of shafts shall be determined to ensure complete filling of the cavities.

- (4) Grout pipes set in concrete shall be fitted with means of preventing blockage and, before injecting grout, they shall be drilled or pricked through to provide a clear passage for grout. Grout pipes and grout holes for grouting shall be atleast 40 mm diameter.
- (5) The grouting of the upper portion of concrete works in junctions and the like shall be carried out through a series of grout pipes and vent pipes built into the concrete for the purpose and extending to the highest part of the excavation. The number and locations of pipes shall be determined to ensure that cavities are completely filled.
- (6) The grouting of the upper portion of concrete works shall be continued until the grout emerging from the vent holes or adjacent grout holes is of the same consistency as the grout being injected. No vented grout shall be re-injected.
- (7) Grout and vent pipes shall not be permitted to remain within 50 mm of a finished concrete internal surface (intrados) and, when no longer required, all holes in concrete linings shall be cleaned and filled with a polymer modified non-shrink mortar.
- (8) Grouting equipment shall be fitted with a pressure gauge and automatic pressure release valves capable of being preset to a specific pressure. Grout pressure is to be measured at the point of injection with a suitable gauge.

3.10.9 Water Tightness of Tunnel

3.10.9.1 General

The water tightness of the tunnels as completed shall comply with the stipulations in the Section VII, Outline Design Specifications.

3.10.9.2 Waterproofing membrane

Waterproofing membranes shall consist of an impermeable heat welded sheet of one of the following materials: high density polyethylene (HDPE), soft polyethylene chloride (PVC), ethylene copolymerical bitumen (ECB). The membrane as supplied shall be of such dimensions and shape as will result in the minimum of on-site seam welds. The loosely laid PVC sheet shall have a minimum thickness of 2 mm +/- 10%.

3.11 Geological Mapping & Rock Classification

3.11.1 General

- (1) The purpose of engineering geological mapping is to record rock and rock mass conditions as encountered during excavation. The mapping and documentation shall enable the verification of the suitability of the designed support and excavation measures, the prediction of rock mass conditions ahead as well as the interpretation of results of the geotechnical monitoring related with ground deformations.
- (2) The mapping and documentation of encountered geological conditions during excavation shall be based on a uniform legend and shall use uniform terms for the description of features which need to be recorded.
- (3) In general the mapping shall be performed to a scale of 1:100 or as suitable.
- (4) Based on the follow-up mapping a vertical as well as a horizontal cross section

shall be drawn, where the actual mapping results shall be incorporated continuously on a daily basis.

- (5) The vertical section shall be located along the axis of the tunnel. The horizontal section may be fixed according to the chosen sequence for excavating the tunnel cross section (full face, top heading - bench etc.). In case the tunnel is excavated by top heading – bench excavation sequence, the horizontal cross section shall be drawn at the level of the invert of the top heading. The scale could be between 1:200 to 1:500; horizontal and vertical scale shall be the same.

3.11.2 Geological Documents

3.11.2.1 General

- (1) The geological documentation shall include one page, showing the mapping of the exposed rock face in a scale of 1:100, the full periphery mapping of the crown and side walls in a scale of 1:100 as well as a data sheet with all recorded features.
- (2) Mapping shall be performed at fresh excavated faces, right after installation of measures, which will enable safe entry to the excavated section.

3.11.2.2 Terminology

- (1) Rock Types / Rock Mass Types

- The rock types shall be filled in with standardized names and terms.
- The rock mass can occur in different qualities according to the influence of weathering, tectonic stress and/or strain (shearing, faulting, folding etc.). Therefore the rock mass type shall be described such that the different qualities can be distinguished.

- (2) Discontinuities:

The terms given in this section are examples only and can be adjusted or supplemented according to the encountered features.

- a) Possible types of discontinuities and abbreviations:

- B bedding plane
- S schistosity
- J joint
- SL slickenside
- F fault
- A axis (of fold etc.)
- S striation

- b) Orientation of discontinuities:

- Discontinuities shall be measured in dip direction / dip angle.

- c) Shape of discontinuities and abbreviations:

- P planar
- U undulating
- S stepped

d) Roughness of discontinuities and abbreviations:

- P polished
- S smooth
- R rough

e) Persistence of discontinuities and abbreviations:

The persistence of discontinuities shall be related to the size of the unsupported area (e.g. tunnel face).

- H: high, discontinuities can be traced in a length exceeding the unsupported area
- M: medium, discontinuities can be traced within the unsupported area exceeding the half of its span
- L: low, discontinuities can be traced within the unsupported area less than half of its span

f) Spacing of discontinuities:

The spacing of discontinuities shall be classified according to the following ranges:

- 60 cm,
- 20 - 60 cm,
- 6 - 20 cm, 2 - 6 cm, and
- < 2 cm

g) Filling/Thickness of discontinuities and abbreviations:

The type and thickness of fillings of open discontinuities shall be described. Possible types with abbreviations are stated below.

- Cl: clay (weathering product)
- Qu: quartz
- FG: fault gouge
- FB: fault breccia
- O: open without filling The thickness shall be measured in cm

(3) Jointing of Rock Mass

- a) The jointing of rock mass shall be described by determination of the maximum average spacing of discontinuities using the prepared chart shown on the data sheet, and the degree of dilation of the rock mass.
- b) The dilation of rock mass is related to the degree of opening of the discontinuities exposed in the mapped area.

(4) Water

Water seepage shall be described by the determination of location, amount (dry, damp, wet, dripping, running [l/sec]) and condition [colour, smell] of the water as well as by the impact of the water on the rock mass [soaking, break down].

(5) Weathering

The description of the degree of weathering shall be based on the terminology shown in the Table 3.11.2-1.

Table 3.11.2-1 Weathering Terminology

Descriptive term with abbreviation	Field identification test
Fresh (F)	Rock shows no signs of weathering (discoloration, decomposition).
Slightly Weathered (SW)	Rock is locally discoloured (stains of discontinuities, discoloured adjacent to discontinuities).
Moderately Weathered (MW)	Rock is dis-coloured, discontinuities have discoloured surfaces with weathering starting to penetrate inwards
Highly Weathered (HW)	Rock is discoloured almost throughout. Weathering penetrates deeply inwards, but corestones are still present
Completely Weathered (CW)	Rock is decomposed to soil but original fabric and structure are still visible, occasionally small corestones are possible
Residual Soil(RS)	All rock material is converted to soil. The mass structure and material fabric are destroyed, change in volume but no significant transportation.

(6) Rock Strength

The description of the rock strength shall be based on the terminology shown in the Table 3.11.2-2.

Table 3.11.2-2 Rock Strength

Descriptive term with abbreviation	Field identification test
Extremely Strong (ES)	Rock material only chipped under repeated hammer blows
Very Strong (VS)	Requires many blows of a geological hammer to break intact rock specimens
Strong (S)	Hand held specimens broken by single blow of geological
Medium Strong (MS)	Firm blow with geological pick indents rock to 5 mm, knife just scrapes surface
Weak (W)	Knife cuts material but too hard to shape triaxial
Very Weak (VW)	Material crumbles under firm blows of geological pick, can be shaped with knife
Extremely Weak (EW)	Indented by thumbnail

(7) Behaviour of Rock Mass

a) The behaviour of the rock mass during excavation and at recently excavated

faces until support installation shall be described.

b) Terms which shall be used are stated below.

- Stable
- Afterbreaking
- Friable
- squeezing
- loose

(8) Overbreak

In case overbreak due to geological reasons has been encountered -- location, shape, and reasons of the overbreak shall be recorded where possible.

3.11.3 Mapping

3.11.3.1 General

- (1) The documentation of the tunnels shall be based on the mapping of the face and the full periphery mapping method. The full periphery mapping method shall be applied for the permanent walls only.
- (2) The frequency shall be adjusted to the variability of the encountered ground conditions. In case ground conditions are varying even within one round length, then each round shall be mapped. Each drive which is under construction shall be checked at least once a day.
- (3) Geological mapping and ground support prediction shall be carried out by the independent geotechnical engineer.

3.11.3.2 Face Mapping Sheet

The form sheet for mapping shall show the area to be mapped in a scale of 1:100 and shall have a grid of 1 × 1 m for easier drafting, marked with "+".

The sketch of the exposed face shall contain:

- interfaces of different rock types (e.g. lithology), respectively rock mass types
- visual features of rock mass (e.g. weathering)
- major structural discontinuities points of water inflow
- position and shape of overbreak

The different degrees of weathering of the rock mass can be depicted as its independent feature separated from the lithology.

Remarks can be stated directly on the mapping sheet or can be referred to the data sheet.

3.11.3.3 Data Sheet

The data sheet shall contain the minimum topics as explained below.

Items	Description
TUNNEL	Name of construction area (e.g. name of tunnel segment)
LOCATION	Name of the drive and working face
CHAINAGE	Chainage of the face

Items	Description
EXCAVATION	Excavation method (excavator, hydraulic hammer, bulldozer, road header, blasting, expansive chemical agents etc.).
MAPPED BY	Name of geologist to carry out tunnel mapping
DATE/TIME	Date and time of recording
ROCK TYPES/ROCK MASS TYPES	<p>Rock types shall be described with standardised names and terms according to the legend. The description shall include</p> <p style="padding-left: 40px;">Type of rock colour remarks on mineralogy short remarks on rock strength (for terminology see Subsection 3.11.2.2).</p> <p>Rock mass types shall be described with standardised names and terms.</p>
DISCONTINUITIES	Discontinuities shall be recorded by the determination of type, orientation, shape, roughness, persistence, spacing, filling, thickness of filling and additional remarks if necessary (for terminology see Subsection 3.11.2.2).
JOINTING OF ROCK MASS	Jointing of rock mass shall be described by determination of the maximum average spacing of discontinuities and general shape of joint blocks using the prepared chart as well as by the degree of loosening of the rock mass (for terminology see Subsection 3.11.2.2).
WATER/WEATHERING	<p>Water seepage shall be described by the determination of location, amount and condition of the water as well as by the impact of the water on the rock mass (for terminology see Subsection 3.11.2.2).</p> <p>Weathering shall be described as its own feature, not combined with the description of the rock types (for terminology see Subsection 3.11.2.2).</p>
BEHAVIOUR OF ROCK MASS	<p>The behaviour of the rock mass during excavation and at fresh excavated faces until support installation shall be described (for terminology see Subsection 3.11.4.6).</p> <p>In case overbreak due to geological reasons has been encountered, which exceeds the tolerance--- location, shape and reasons of the overbreak shall be recorded where possible.</p>

Items	Description
GENERAL REMARKS	<p>Additional remarks concerning the encountered conditions shall be noted.</p> <p>Photos shall be taken of areas of special interest as well as to complete the geological documentation. Motive and number of photos shall be recorded. A scale shall be shown on the photos.</p> <p>Samples shall be taken of representative rock types or in case specific geological and hydro geological conditions are encountered (e.g. fault zones, coloured or smelling water). Location, kind and purpose of samples which have been taken shall be recorded.</p>

3.11.4 Rock Classification

3.11.4.1 General

This section covers the description of rock mass types and rock classes relevant to the underground excavation with respect to the geotechnical properties of rock encountered and its behavior under the influence of tunnel construction. The terminology “rock” in this context shall also include soil conditions.

3.11.4.2 References

- Guideline for the Geotechnical Design of Underground Structures with Conventional Excavation – The Austrian Society for Geomechanics(2010).
- NATM – The Austrian Practice of Conventional Tunnelling by Austrian Society for Geomechanics.

3.11.4.3 Application and Procedure

- (1) Rock classes shall be determined on the grounds of the appearance of the rock at the excavation face of the tunnel before the commencement of the respective excavation sequence.
- (2) The results of geotechnical measurements under similar rock conditions shall be taken into account for prediction of deformations and for the determination of rock classes.
- (3) Depending on the size of the overall excavation and the ground conditions, subdivisions for the excavation may become necessary and may influence the classification and its evaluation.
- (4) In case of a drivage subdivided into top heading – bench – invert excavation, the rock conditions of the top heading drivage shall govern the classification.
- (5) The behaviour of the rock in a newly exposed round is time dependent, i.e. rock mass quality will decrease with the free span if no support is installed within a reasonable time. Accordingly, the maximum length of a round which can be excavated and supported in time shall be a criterion for the rock classification.
- (6) The rock classification at the face for each round shall have to be as agreed by the Engineer.
- (7) The classification shall be done in writing on form-sheets as agreed by the Engineer. The classification record is a collection of all classification sheets, which shall be kept accessible for consultation and modification whenever drivage

works are under progress.

3.11.4.4 System Description

- (1) The rock classification system for the Pune Metro, NATM tunnels shall in general follow the standard classification used in Austria, with project- specific adaptations.
- (2) After determining the Rock Mass Types, the establishment of Rock Mass Behavior Types shall be performed. Construction measures such as ground improvement methods, dewatering methods, excavation method, excavation & support sequence, pre-supports, support concept and possible round length and the like, shall be derived from the rock mass behavior keeping in consideration the actual boundary conditions. Rock classes shall then be determined based on the behavior types and the excavation and support methods.
- (3) Difficult ground conditions may frequently require augmentation to the tunnel support during tunnel driveage. The support shown on the construction drawings for a particular rock class shall be regarded as the standard for that rock class. Any change to the standard support system and to the excavation sequence shall need a Notice of No Objection from the Engineer.

3.11.4.5 Rock Mass Types

Rock mass types shall be described by the Contractor in his Geo-technical Interpretative Report (GIR) and for this purpose he shall undertake the required Ground Investigations work as found necessary. The Contractor's GIR shall require a Notice of No Objection from the Engineer. The Geotechnical Investigation Report as available with the Employer will be shared as part of the tender documents.

3.11.4.6 Rock Mass Behaviour Types (RBT)

A general indication of tunneling conditions is described by means of Rock Mass Behaviour Types. An indicative RBT is given in the table below. However, the Contractor shall modify/supplement it with the further required sub-divisions, as may be necessary for adapting it to the Project/Contract specific conditions.:

S. No.	Behaviour Type (BT)	Description of potential failure mechanisms during excavation unsupported rock mass
1	Stable	Stable rock mass with the potential of small local gravity induced falling or sliding of blocks
2	Stable with potential of discontinuity controlled block fall	Deep reaching discontinuity controlled, gravity induced falling and sliding of blocks, occasional local shear failure
3	Shallow shear failure	Shallow stress induced shear failures in combination with discontinuity and gravity controlled failure of the rock mass.
4	Deep seated Shear failure	Deep seated stress induced shear failures and large deformation

S. No.	Behaviour Type (BT)	Description of potential failure mechanisms during excavation unsupported rock mass
5	Buckling failure	Buckling of rocks with a narrowly spaced discontinuity set, frequently associated with shear failure
6	Shear failure under low confining pressure	Potential for excessive overbreak and progressive shear failure with the development chimney type failure, caused mainly by a deficiency of side pressure
7	Ravelling ground	Flow of cohesionless dry or moist, intensely fractured rocks or soil
8	Flowing ground	Flow of intensely fractured rocks or soil with high water content

3.11.4.7 Rock Classes

Based on the anticipated Rock Mass Behaviour, the excavation sequences and required support measures, the rock classes shall be developed by the Contractor for obtaining a Notice of No Objection from the Engineer.

3.12 Invert Concrete

The Contractor shall provide the first pour (stage) concrete including the shear connectors required for laying the track work and also prepare the upper surface of the first stage concrete to meet the requirements of Track bed design specifications duly interfacing with the Trackwork Contractor.

3.13 Backfilling of Shafts and Adits

- (1) Temporary shafts and adits shall be completely backfilled on completion of the Works. Backfill material shall be Grade M10 concrete covering 2m over the tunnel crown which may be placed either wet or dry. Adits shall be backfilled in sections working from the permanent Works.
- (2) Temporary bulkheads shall be formed at agreed intervals and the upper part of the adit completely filled by grouting through pipes which have been installed into the adit roof. The bulkhead shall be moved back in stages until the whole of the adit is backfilled. Shafts shall be backfilled in layers not thicker than 250 mm, each layer being thoroughly compacted with an appropriate power rammer. The backfill material shall be homogenous, no large pieces of concrete or "plums" shall be used. As far as practicable all extraneous materials such as steelwork and temporary timbers shall be removed as the backfilling progresses. Shaft linings shall be dismantled to two metres below finished ground level and the site reinstated with suitable granular material compacted as specified in Earthworks. Details of temporary works left in place shall be included in the as-built information and drawings.

3.14 Daily Records

- (1) The Daily Report shall be submitted by 09:00 hrs the following day and in a format agreed by the Engineer. Such a format, which may require modification from time to time during the progress of the work, may include the required information in tabular and/or graphical form, as appropriate for the information being presented.
- (2) In addition, wherever possible the recording of the required information should be automatic and be available to download at any time to a computer located in the Engineer office. Any evaluation software shall be in English and be made available to the Engineer at no extra charge to the Employer. The database shall be recorded to CD ROM and submitted to the Engineer on a weekly basis.

3.15 Safety and Underground facilities

3.15.1 Safety General

- (1) Safety in the underground works shall be to the highest internationally recognised Standards. At an early stage of the work, the Contractor shall undertake the organisation, equipping and training of rescue teams. These teams shall be trained in underground rescue work and the administration of first aid.
- (2) No workmen shall be employed underground until they have shown themselves conversant with basic safety precautions. The Contractor shall strictly enforce all safety regulations and shall provide adequate protective clothing and safety gear for his workmen.
- (3) The Contractor shall observe all precautions to avoid accidents or injury to Workmen or the Works and to minimize the extent and severity of any accident or injury which may occur. Such precautions shall have due regard to the skill and training of the Labour force employed underground and shall comply with local/national mining or other applicable regulations.
- (4) The Contractor shall be solely responsible for day and night warning systems (visual and sound) for machine operations and “clear off the track” warning shall be installed at the site and preventative measures taken against accident.

3.15.2 Underground Facilities

- (1) General
The Contractor shall submit descriptions of the installations he proposes to use for supply of water, ventilated air, compressed air, lighting, power supply, etc., and for the disposal of drainage and waste water, contaminated air, etc., for the Engineer’s Notice of No Objection in advance of starting underground works.
- (2) Telephone Communications
Telephone communications shall normally be provided between the working faces, portals and other areas where work is going on. Telephone locations shall be prominently displayed.
Telephone network should be provided for Engineer office including telephone connection to the work’s place and tunnel shafts.
- (3) Electric Cables
 - a) All lighting and power cables installed underground shall be adequately

insulated with joints made in a noticed manner. All installation and maintenance work shall be done by qualified personnel to a high standard. Cables shall be securely fixed above floor level with the exception of cables needed for occasional work.

- b) Separate circuit breaker systems shall be provided for the supply of power for equipment and for lighting, respectively, and they shall be kept well separated from signalling and telephone cables.
- c) Circuits used for firing explosives shall be kept separate from all other circuits by placing them on the opposite wall.
- d) All electric installations shall be adequately earthed in accordance with normal practice and local requirements and be noticed by the Engineer. Installations shall furthermore be protected by earth-fault breakers, all in accordance with modern practice and safety standards and obtain a Notice of No Objection from the Engineer.

(4) Ventilation

- a) The Contractor shall install, operate and maintain a forced ventilation system in the underground works to enable the Works to be constructed in healthy, well ventilated conditions. Dust shall be abstracted at or adjacent to the source.
- b) To minimise the dust hazard arising from drilling operations in rock excavations, all holes shall be wet drilled. Water sprays or atomisers shall be used to prevent dust rising including keeping the floors of haulage ways damp.
- c) The Contractor shall submit to the Engineer for his Notice of No Objection a full and detailed method statement detailing his proposed ventilation system, and where necessary cooling system, in the tunnels. The statement shall be accompanied by supporting calculations. The method statement shall be submitted at least 28 days before the start of any underground excavation.
- d) The ventilation system used during construction shall ensure that at all times a minimum oxygen content of 20 % by volume is available in any underground works. Furthermore, the minimum fresh air requirements given herein refer to the required ventilation conditions and additional provision shall be made to account for any losses, e.g. due to leaks in the ducts, for which the Contractor shall make provision in the ventilation calculations.
- e) The Contractor shall supply and utilize a hot-wire anemometer for the purpose of measuring air flows in the ventilation ducting.
- f) Instruments to register all the various noxious gases and dust shall at all times be available at the heading in good working order and condition. These shall be supplied and maintained by the Contractor, throughout the duration of the underground work.
- g) The Contractor shall be responsible for operating the ventilation system in the underground works until all his construction work is completed.

(5) Lighting

- a) All underground areas where work is going on shall be illuminated with electric lights of adequate strength and number to allow work, inspection, mapping and surveying to be carried out in a proper and safe manner.
- b) Generally, the illumination on a horizontal plane at floor level shall be not less than 10 lux. At working faces (Tunnel face, excavation areas and crane lifting

points), the illumination shall be not less than 100 lux. However at other general working areas, the illumination shall not be less than 50 lux. Hand inspection lamps and electric battery torches shall be available at working faces at all times, together with emergency backup light for evacuation.

(6) Dewatering

- a) The Contractor shall keep all underground areas free from water by providing drains, ditches, pipes, pumps, sumps, etc. to drain water away. The Contractor shall submit to the Engineer details of his proposals for dealing with water from any source prior to commencing underground work.
- b) In the event that gravity flow cannot be satisfactorily arranged, the Contractor shall remove the water by pumping and he shall provide, install, operate and maintain all necessary pumps, piping and other equipment required. The Contractor shall also provide sufficient numbers of standby pumps and generator to serve during periods of breakdown or maintenance.
- c) Where water bearing seams, fissures or broken ground is yielding undesirably large quantities of water, the Contractor shall grout such seams, fissures or broken ground to stem the same.
- d) The Contractor shall provide devices for measuring the quantities of water removed from underground excavations, by pumping or by gravity as the case may be. The Contractor shall provide certified calibration charts for all measuring devices and shall submit to the Engineer a complete record of the quantities of water disposed either by pumping or by gravity and the times during which pumping has occurred.
- e) The Contractor shall provide water treatment facilities for wastewater disposal that satisfies the applicable environmental standards.

(7) Stand-by Generator

The Contractor shall provide Stand-by generator for emergency case, details of proposals for this system shall be submitted to the Engineer for obtaining his Notice of No Objection.

(8) Noise control

- a) The Contractor shall take all necessary measures to minimize the impact of noise. Such measures shall include:
 - placing of covers over and around the source of noise.
 - fitting adequately sized mufflers to ventilation and other noise generating equipment.
 - erecting screens to separate the source of noise from the rest of the working area. use of electrically powered plant where possible.
- b) The Contractor shall provide a means of measuring the noise level and shall regularly calibrate such equipment. Measurements shall be taken regularly by the Contractor and a full report of readings made shall be submitted to the Engineer within 24 hours. If in the opinion of the Engineer noise levels are unacceptable or there are complaints from the local residents, the Contractor will take additional measures to restrict noise.
- c) The Contractor shall provide suitable ear protectors to his entire workforce and other persons on Site. Zones of risk shall be clearly identified with

warning signs.

(9) Hot work

- a) Welding and burning operations (hot work) within the tunnel and upon the TBM or trailing backup system shall be kept to a minimum. Wherever possible, components shall be prepared on the surface and consideration given to alternative methods such as bolting and sawing/discutting.
- b) In addition to the above, hot work includes specialist operations such as conveyor belt vulcanisation procedures. Hot work may be undertaken provided the following measures are adhered to:
 - The relevant permits are in place.
 - Only qualified personnel are permitted to perform hot work.
 - All gas cylinders underground shall be stored and transported within steel protective cages.
 - Gas bottles shall be fitted with flashback arresters.
 - A designated fire watch is in place and aware of his duties.
 - One dry powder hand held fire extinguisher shall be available at the work location.
- c) A fire watch shall be maintained during burning operations. The fire watch shall have a fire extinguisher or fire hose readily available. The fire watch shall continue for a minimum of 30 minutes following the cessation of burning operations. When the maintenance teams do not change shift at the work area then all burning operations shall cease 30 minutes before the work area is vacated.
- d) Whenever it is necessary to carry out hot work in a confined space, a specially assigned person shall stand-by throughout the operation at the nearest point of entry. The stand-by person shall be equipped to give prompt assistance in the event of an emergency.
- e) Only one acetylene bottle and one oxygen bottle shall be permitted within the TBM and trailing backup system at any time. Upon job completion, gas bottles shall be removed as soon as possible.
- f) All welding sets, cables, connectors and terminations mounted upon the TBM or trailing backup system shall be maintained in a safe and serviceable condition. Earth returns shall be coupled directly to the item to be welded and to an independent earth in such a manner that the earthing path remains inside the protected work area. Pipes or vessels containing hydrocarbons must not be used for earthing purposes. Earth leads mounted upon the trailing backup system shall not be connected to hydraulic oil pipelines, motors, conduits, panels or switch panels. All supplies for welding equipment must be made with noticed cables and plug boxes, and must be controlled from a circuit which includes protection sensitive to earth current security.
- g) Where stationary transformers are being used, a suitable switch shall be provided close to the equipment which allows for the isolation from the main supply.

(10) Safety notices

The Contractor shall obtain, erect and maintain adequate safety notices for underground work to satisfy statutory regulations and to the satisfaction of the Engineer.

(11) Control of entry

- a) The Contractor shall establish and maintain effective systems to control access to the underground works by all persons. A system utilising the issue and retrieval of tokens or similar method shall be employed. The systems of control used by the Contractor shall obtain a Notice of No Objection from the Engineer. The Engineer reserves the right to withdraw his Notice of No Objection if he is not satisfied that the systems are being applied and enforced adequately.
- b) Where persons not normally engaged on the Works are authorised to enter the underground works they shall at all times be accompanied by a representative of the Contractor or Engineer.
- c) The Contractor shall also establish and maintain effective systems to control access to the TBM cutterhead, including electrical lockout procedures and obtain a Notice of No Objection from the Engineer for the procedure.

(12) Compressed air working in cutterhead chamber

The Contractor shall submit for obtaining the Engineer's Notice of No Objection a method statement describing the type, capacity and arrangement of plant and medical facilities he proposes to install with full details of his decompression chamber, standby plant, power sources, air cleaning, air cooling plant, bulkhead and locking arrangements. The method statement should also describe the proposed system of signalling, communications and controls to be used in the compressed air operations.

(13) Stores, offices, workshops

The erection of stores, offices and workshops in the underground works, excepting those contained within the TBM backup, will not be permitted without the prior Notice of No Objection from the Engineer.

(14) Quality of air

- a) When called for by the Engineer, the Contractor shall collect gas samples and send them for laboratory analysis. The concentrations shall not exceed the following limits:

Carbon dioxide:	5,000 ppm
Carbon monoxide:	30 ppm
Nitric oxide:	25 ppm
Nitrogen dioxide:	3 ppm
Hydrogen sulphide:	10 ppm
Flammable gas (Butane):	600 ppm

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

Carbon dioxide:	15,000 ppm
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Carbon monoxide:	200 ppm
Nitric oxide:	35 ppm
Nitrogen dioxide:	5 ppm
Hydrogen sulphide:	15 ppm
Flammable gas (Butane):	750 ppm

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

(15) Dust

The Contractor shall check at the face and elsewhere for concentrations of dust at least weekly and more regularly if necessary and when called upon to do so by the Engineer. In the case of air breathed by persons in the underground works the air shall not contain more than the following concentrations of total respirable airborne particles of dust (size from 5.0 to 1.2 micron):

- Limit of Crystalline silica content (as a % of dust): < 1%
- Limit of total respirable dust : 5 mg/m³

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

(16) Ventilation

- a) The ventilation system in each section of the Works shall ensure that the following minimum air quantity requirements are provided at all times:
- 1.3 m³/min for each person or worker in the underground works;
 - 4.8 m³/min for each operating kW power of diesel plant, or equipment working in the underground works, based on 70 % of the installed power being in operation at any one time;
 - Sufficient to maintain an average air velocity of 0.5 m/s on every cross-section in working areas.
 - Notwithstanding the above, the minimum quantity of fresh air delivered at the advancing face shall be 7 m³/s.
- b) The ventilation, and where necessary cooling, arrangements shall be designed to ensure a working environment such that:
- at any time the mean wet bulb temperature at all workplaces in any one tunnel drive shall not exceed 27 °C.
 - similarly the weighted mean wet bulb temperature at all workplaces within 100 m of the advancing face of any one tunnel drive shall not exceed 27 °C.
- c) To ensure compliance with the foregoing, the Contractor shall provide all necessary equipment to measure the wet bulb temperatures at regular intervals during each working shift or such other interval agreed with the Engineer, and ensure that suitable air coolers are available for use with the ventilation system at all times.
- d) The procedures shall be subject to a Notice of No Objection from the Engineer.
- e) Maintenance of ventilation and cooling systems

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

- f) Failure by the Contractor to comply with the requirements or to maintain the prescribed ventilation and cooling standards will entitle the Engineer to order a temporary halt of all work within the affected area until the specified requirements are met.
- g) Use of internal combustion engine
No internal combustion engine other than a diesel engine shall be used in the underground works. Any diesel engine used in the underground works shall be provided with a means, which shall be maintained in efficient order, of cooling exhaust gases and reducing the concentration of toxic gases in the exhaust gases to acceptable levels and prevent emission of flames, sparks or pollutants.
- h) Notwithstanding the Contractor's compliance with the above requirements for ventilation, the operation of all diesel engines in the underground works shall be discontinued and ventilation improved or other acceptable measures taken if any of the acceptable specified limits are exceeded.
- i) No diesel equipment shall be allowed underground if the exhaust gases contain more than 2,000 ppm carbon monoxide or 1,000 ppm of oxides of nitrogen.
- j) The engines of diesel powered equipment underground shall not be kept running idle except while being tested or during brief halts while in use. No equipment shall be refueled underground unless proper precautions are taken.
- k) Modification of ventilation system
 - After excavation of any tunnel which will be lined, the ventilation system used for the excavation phase may have to be modified to allow for subsequent phases. Any such modifications, which shall be subject to a Notice of No Objection from the Engineer, shall be allowed for by the Contractor in his design of the ventilation systems for the underground works.
 - These allowances shall also include for increased localised ventilation during concreting and grouting operations and during the time that Subcontractors or others are carrying out welding or painting operations in the underground works.
 - After concreting of linings the ventilation system shall be so operated as to maintain satisfactory conditions for curing of the concrete.
- l) Records
The Contractor shall record all readings and submit two copies to the Engineer on a weekly basis unless otherwise instructed.

3.15.3 Hazardous gas

- (1) General
 - a) The Contractor shall continuously monitor the underground works for the

presence of hazardous gas. Should hazardous gas be detected the level shall be controlled by dilution via the ventilation systems.

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

(2) Methane detection

- a) The atmosphere upon the TBM and trailing backup system, and NATM tunnel shall be constantly monitored for both the ingress of methane and oxygen levels.
- b) Regular testing for methane shall be carried out at each probe hole. Particular attention shall be paid for testing of methane when intrusive rocks are intersected by the probe hole.

The Contractor shall provide a procedure and appropriate equipment to allow the safe re-entry and recommissioning of the TBM and trailing Backup system following a gas initiated power shutdown.

- c) Prior to the start of any shift, the person responsible for that shift shall test the underground works for the presence of methane and declare the area safe for excavation or otherwise.

- d) Inspection of tunnels is to be carried out on a weekly basis.

(3) Ventilation equipment

- a) Ventilation equipment shall be provided in accordance with Section 3.15.2
- b) In the case of the tunnel boring machine, special attention shall be paid to ensuring that air is directed into areas of the machine and back-up equipment where methane may be trapped, and if necessary auxiliary ventilation equipment shall be provided.

(4) Contractor's equipment

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

- Sufficient calibrated hand held methanometers of an noticed type or other noticed gas detection devices shall be provided at all times.
- All equipment shall be suitably earthed.
- All diesel driven plant shall be fitted with effective scrubbers to the exhaust systems.
- In the case of excavation by drill and blast/other mechanised means, no mechanical equipment shall be brought to the face until the examination for methane has been completed.

(5) Personnel

The following minimum requirements are to be adhered to:

- At all times persons shall be present in the working tunnel only if that has passed a gas testing course acceptable to the Engineer.
- Entry of unauthorised persons to the underground works shall be prevented at all times, whether work is in progress or not.
- Appropriate precautions shall be taken to prevent persons bringing into

the underground works matches, lighters and similar items and to prohibit smoking in the underground works.

(6) Acceptable concentrations of methane

Should methane be detected in any part of the underground works then all work in that part shall immediately be halted and the Engineer shall be informed without delay. The Contractor shall then decide in conjunction with the Engineer the appropriate action to be taken. Generally if the percentage of methane recorded is less than 10% of the Lower Explosive Limit (0.44% by volume; LEL being 4.4%) then work may be restarted immediately on notification to the Engineer of the occurrence. In this case monitoring for methane shall be pursued continuously during all operations to detect any increase in the level of methane.

(7) Records

The Contractor shall record all readings taken and submit two copies to the Engineer on a weekly basis.

3.16 As-built Survey of Alignment

3.16.1 Objective

As soon as practicable after the completion of the tunnelling over specific lengths of the tunnel as the work progresses, the Contractor shall carry out an as-built survey of the tunnel alignment. The objectives of the survey are as follows:

- (a) to discover the position of every 5th ring of lining in case of bored tunnel and final support at every 5m in case of NATM tunnel, with respect to the theoretical alignment; this includes both vertical and horizontal geometry;
- (b) to plot the positions of the rings/tunnel profile at points around the circumference (intrados) with respect to their theoretical positions;
- (c) to produce an accurate record of the position of the tunnel with respect to the city infrastructure;
- (d) to verify the finished alignment and profile of the as-constructed tunnel with respect to the theoretical alignment and design profile to ascertain compliance with the Contract provisions in this respect.

3.16.2 Procedure

- (1) The Contractor shall carry out the alignment survey. He shall determine the position, with respect to the theoretical tunnel alignment, of the leading edge of every 5th ring of tunnel lining (in case of bored tunnel) and finished tunnel profile (in case of NATM tunnel) at not less than 8 points (in case of NATM platform tunnels the number of points shall be suitably increased) on the circumference/profile. These shall be as follows:
 - tunnel crown;
 - tunnel invert;
 - axis left;
 - axis right;

- 45° above axis left;
 - 45° above axis right;
 - 45° below axis left;
 - 45° below axis right.
- (2) The Contractor shall take all necessary actions to ensure that the zones where measurements are required are clear of all construction-related obstructions.

Maha Metro



Tender Documents

**UGC-02: DESIGN AND CONSTRUCTION OF UNDERGROUND STATIONS AT
BUDHWAR PETH, MANDAI AND SWARGATE AND ASSOCIATED TUNNELS**

PART II – EMPLOYER’S REQUIREMENT

Section VIII - Outline Construction Specifications

S.04 E&M Works

June 2018

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4.1 GENERAL REQUIREMENT

4.1.1 General Description

The Technical Specifications (Outline Design Specification and Outline Construction specification) and the Employer's Drawings issued in the Tender Documents are intended to be mutually explanatory and all works required in one, even if not in the other, shall be fully executed.

These documents are intended to be the basic design guidelines for the Contractor to develop the Detailed Design and Build the E & M Works – Stations Utilities and associated tunnels, which is compliant with the relevant standards and complete in all aspects to the satisfaction of Employer / Engineer.

This also includes any material, appliances, equipment not specifically mentioned herein or noted on the drawings as being furnished or installed but which are necessary and customary to make complete installation properly connected and in working conditions.

The Technical Specifications describes the Scope of Works and the technical requirements of all systems, equipment and components to be Designed, Supplied, Installed, Tested and Commissioned under the Contract.

4.1.2 Submittal of Data for Notice of No Objection

The Contractor shall submit to the Employer / Engineer complete information regarding details of materials and equipment involved, prior to any purchase or manufacturing operation. Any purchase or manufacturing operations carried out prior to obtaining such Notice of No Objection shall be at the Contractor's sole responsibility.

Information of equipment shall be separately submitted by listing all the details and with attached catalogue indicating at least the model, series, size and performance etc.. Such data shall be in sufficient detail to enable the Employer / Engineer to identify the particular product and to form an opinion to its conformity to the Contract Specifications/Stipulations.

The Contractor shall stamp the name of his company and sign all documents to be submitted for Notice of No objection.

4.1.3 Submittal of Materials for Notice of No Objection

Only new materials and equipment shall be incorporated in the Works. All materials and equipment furnished by the Contractor shall be subject to inspections and Notice for No Objection of the Employer / Engineer. The materials and equipment used for Works shall be as per the Notice of No Objection by the Employer / Engineer. Any materials which, in the opinion of the Employer / Engineer, have lower quality than the one meant in the Notice of No Objection by the Employer / Engineer, shall promptly be removed from the Works site/Works.

Whenever requested by the Employer / Engineer, the Contractor shall organize/arrange the testing of materials at his own cost by an independent institute/laboratory selected by the Employer / Engineer without any additional cost to the Employer, whatsoever.

4.1.4 Shop Drawings

The Contractor shall prepare shop-drawings comprising complete details of items to be fabricated and Works to be installed.

The drawings shall be checked by the Contractor for accuracy with regard to dimensions taken in the building(s) and shall closely follow manufacturer's recommendations. All drawings shall be signed by the Contractor, and shall indicate the date of submission and the date(s) of revision(s).

In case shop-drawings require modifications for any reason, the Contractor shall clearly identify the portion that has been modified, and shall indicate the running number of revision every time that a revision-drawing is submitted.

The installation details shall be checked and coordinated with the building works, the structure and other related trades to prevent conflicts that may cause delay of the project and ensure complete compatibility.

Size and scale of the shop-drawings shall be at least 1:100 scale except for enlarged scale details done for clarity, which shall be in conformity with the international standards or as directed by the Employer / Engineer.

Where required by the Employer / Engineer, the Contractor shall prepare additional drawings, diagrams, etc., which in the opinion of the Employer / Engineer, are considered necessary for the proper execution of the Works.

The Contractor shall not proceed with the Works for any part or section, prior to obtaining the Notice of No Objection from the Engineer on the shop-drawings. Therefore, any expenses/costs incurred by the Contractor on account of modifications that may have to be made as a result to get the Notice of No Objection of the Engineer on the shop-drawings shall be borne by the Contractor.

The Notice of No Objection on the shop-drawings by the Employer / Engineer shall not be construed as a complete check rather will only be considered as a general check on method of installation and its details being satisfactory.

The Notice of No Objection of the Employer / Engineer shall not absolve the Contractor, in any manner, from his duties, responsibilities, obligations and the liabilities under the Contract.

Shop-drawings submitted without sufficient details shall be rejected requiring re-submission.

The format of the notice, to be given to the Employer / Engineer for the inspection, and also of the documents and drawings shall comply with the Contract Stipulations.

4.1.5 Operation and Maintenance Instructions Manual

The manual shall be prepared in hard cover binding in sets to be submitted to the Employer / Engineer for Notice of No Objection for the entire Works.

Section 1 Comprising submittal data of all equipment and materials that have been approved and are to be used in Works,

Section 2 Comprising catalogues, categorized in groups, complete with installation operations and the maintenance manuals from the manufacturers as suited for the Works under the Contract,

Section 3 comprising formats/check-lists for inspections and testing and also the filled out test reports in the field,

Section 4 Comprising spare parts list and recommended spare parts,

Section 5 Comprising maintenance and services schedule, and service and maintenance procedures for individual equipment listing daily, weekly, monthly, quarterly and yearly schedules etc.,

Section 6 Comprising system operations manual;

A draft copy of the manual shall be submitted to the Employer / Engineer for Notice of No Objection, first.

Works to Completion

The Contractor shall commission, clean down, and leave in full working order the Works as specified.

As the installation proceeds the Contractor shall prepare 'as built drawings'. It shall be sufficient to modify the approved construction drawings showing any amendments to the service which have taken place and submit the marked-up prints to the Employer / Engineer for Notice of No Objections.

The Contractor shall deliver to the Employer / Engineer on completion of the works, manufacturers' literature, specifications, technical information and 'as built drawings' for all the equipment installed.

4.2 STANDARDS, CODES AND REGULATIONS

The entire system and its basic components shall comply in all respects to the relevant International Standards and regulations of the National Building Code of India (NBC), and Bureau of Indian Standards.

In addition to the International Standards and NBC listed in the Technical Specifications, the Design shall also be governed by all applicable local codes, regulations, standards and requirements issued by all the Local Authorities, agencies and services providers. Given below is the list of standards to be followed at least, note that this list is not exhaustive.

Also latest version must be indicated / adopted.

AMCA	Air Moving and Conditioning Association (USA)
ANSI	American National Standard Institute
ANSI B16.21	Standard for nonmetallic flat gaskets for bolted flanged joints in piping
ARI	Air-conditioning and Refrigeration Institute (USA)
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers (USA)
ASME	American Society of Mechanical Engineers (USA)
ASTM	American Society of Testing Materials
ASTM A 53	Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless

ASTM D2000	Standard Classification System for Rubber Products in Automotive Applications
BIS	Bureau of Indian Standards
BS	British Standard
BS 1387	Specification for screwed and socketed steel tubes and tubulars and for plain end steel tubes
BS 159	Specification for high-voltage busbars and busbar connections
BS 3464	Specification for cast iron gate valves for general purposes
BS 381C	Specification for colours for identification, coding and special purposes
BS 5041: Part 1	Fire hydrant systems equipment. Specification for landing valves for wet risers
BS 5041: Part 5	Fire hydrant systems equipment. Specification for boxes for foam inlets and dry riser inlets
BS 5266	Standards for Emergency Lighting Systems
BS 5306- 3	Standards on Installation, Commissioning & Maintenance of Portable Fire Extinguishers
BS 5306-1	Code of practice for fire extinguishing installations and equipment on premises. Hose reels and foam inlets
BS 5424-3	Specification for controlgear for voltages up to and including 1000 V a.c. and 1200 V d.c. Additional requirements for contactors subject to certification
BS 5499	Specification For Safety Signs, Including Fire Safety Signs
BS 5499-10	Code of practice for the use of safety signs, including fire safety signs
BS 5839-1:2008 + A2:2008	Standard for Fire Detection & Alarm System
BS 5839-Part 8	Code of practice for the design, installation, commissioning and maintenance of voice alarm systems
BS 5839-Part 9	Code of practice for the design, installation, commissioning and maintenance of emergency voice communication systems
BS 5856-1	Specification for motor starters for voltages above 1 kV a.c. and 1.2 kV d.c. Direct-on-line (full voltage) a.c. starters
BS 7371: Part 8 Class S1	Specification on Coating on Metal fasteners - Part-8 Coating Thickness Class S1-30 Microns
BS 7671	Requirement for Electrical Installations
BS 8214	Code of practice for fire door assemblies
BS 9990	Code of practice for non-automatic fire-fighting systems in buildings
BS 9999	Code of practice for fire safety in the design, management and use of buildings

BS EN 10255	Specification for screwed and socketed steel tubes and tubulars and for plain end steel tubes
BS EN 1092-2	Flanges and their joints. Circular flanges for pipes, valves, fittings and accessories, PN designated. Cast iron flanges
BS EN 12288	Industrial valves. Copper alloy gate valves
BS EN 12334	Industrial valves. Cast iron check valves
BS EN 12845: 2004 + APPENDIX-2, 2009	Fixed firefighting systems. Automatic sprinkler systems. Design, installation and maintenance
BS EN 15004-1	Fixed firefighting systems. Gas extinguishing systems. Design, installation and maintenance
BS EN 3	Standards for Portable Fire Extinguishers
BS EN 54 Part 1- 24	Standard for Fire Detection and Alarm System and Components
BS EN 54: Part 20	Fire detection and fire alarm systems Part 20: Aspirating smoke detectors
BS EN 545	Specification For Ductile iron pipes, fittings, accessories and their joints for water pipelines. Requirements and test methods
BS EN 5839	Code of practice for the design, installation, commissioning and maintenance of voice alarm systems
BS EN 600085 Class B, Class F and Class H	Electrical insulation. Thermal evaluation and designation
BS EN 60470	High-voltage alternating current contactors and contactor-based motor starters
BS EN 60947-4-1	Low-voltage switchgear and control gear. Contactors and motor-starters. Electromechanical contactors and motor-starters
BS EN 671	Fixed fire fighting systems. Hose systems. Hose reels with semi-rigid hose
BS EN 671-3	Fixed firefighting systems. Hose systems. Maintenance of hose reels with semi-rigid hose and hose systems with lay-flat hose
BSI	British Standards Institute
BSP	British Standard Pipe threads
CCITT	International Telegraph and Telephone Consultative Committee (Comité Consultatif Internationale de Télégraphique et Téléphonique)
CENELEC	European Committee for Electro technical Standardization(Comité Européen de Normalization Electro technique)
CIE	International Lighting Commission
CISPR	The International Special Committee on Radio Interference (Comite International Special des Perturbations Radioelectriques)

EN	European Norms
EN 50121-1	Railway Applications – Electromagnetic Compatibility Part1: General
EN 50121-2	Railway Applications – Electromagnetic Compatibility Part 2 : Emission of the Whole Railway System to the outside world
EN 50121-4	Emission and Immunity the signaling and of Telecommunication Apparatus
EN 50121-5	Railway applications. Electromagnetic compatibility. Emission and immunity of fixed power supply installations and apparatus
EN 50121-5: Part 5	Emission and Immunity of Fixed Power Supply Installations and Apparatus
EN 50122-1: Part 1	Railway applications: fixed installations; protective provisions relating to electrical safety and earthing
EN 50122-2: Part 2	Railway applications: fixed installations; protective provisions against the effects of stray currents caused by D.C. traction systems
EN 50123	Railway applications. Fixed installations. D.C. switchgear. General
EN 61000-4-16	Electromagnetic compatibility (EMC). Testing and measurement techniques. Test for immunity to conducted, common mode disturbances in the frequency range 0 Hz to 150 kHz
EN 61000-4-3	Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test
EN 61000-4-6	Electromagnetic compatibility (EMC). Testing and measurement techniques. Immunity to conducted disturbances, induced by radio-frequency fields
ENV 50204	Radiated Electromagnetic Field from Digital Radio Telephones Immunity Test
FM	Factory Mutual
IEC	International Electro-Technical Commission
IEC 158	Specification for control gear for voltages up to and including 1000 V a.c. and 1200 V d.c. Additional requirements for contactors subject to certification
IEC 60632-1	Specification for motor starters for voltages above 1 kV a.c. and 1.2 kV d.c. Direct-on-line (full voltage) a.c. starters
IEC 61000-2	Electromagnetic compatibility (EMC) - Part 2: Environment
IEC 61000-3	Electromagnetic compatibility (EMC) - Part 3-2: Limits
IEC 61000-5-2	Electromagnetic compatibility (EMC) - Part 5: Installation and mitigation guidelines - Section 2: Earthing and cabling

IEC 947-7-1	Low Voltage Switchgear and Controlgear
IEE	The Institute of Electrical Engineers
IER	Indian Electricity Rules, 1956
IES	International Illumination Engineering Society
IS	Indian Standards
ISO	International Organization for Standardization
ISHRAE	Indian Society of Heating , Refrigerating and Air Conditioning Engineers
ITU-T	International Telecommunication Union Telecommunication Standardization Sector
LPC	Loss Prevention Council
NBC	National Building Code of India, 2016
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NFPA 130: 2017	National Fire Protection Association (USA)
SFSRTS	Standard for Fire Safety in Rapid Transit Systems
SMACNA	Sheet Metal and Air-conditioning Contractors National Association Inc.(USA)
SS CP5	Code of Practice for Electrical Installations
SS CP52	Code of Practice for Automatic Sprinkler System
UK - G5/4	Electricity Association Recommendation For harmonics
UL	Underwriters Laboratories
UL 864	Standard for Control Units and Accessories for Fire Alarm Systems
VDE	Verband der Elektrotechnik (German Association for Electrical, Electronic and Information Technologies)
VDE 0611	Low-voltage switchgear and controlgear and Ancillary equipment
	Sub Surface Regulations – 2009, (UK)
	Local authorities, agencies and services providers
	Local code, standard, rules and regulations

NFPA: 130, 2017 shall be followed with the exception of Fire Detection & Alarm and Suppression Systems (Water & Gas Based) and all associated Interfaces within the Main Fire Alarm System. These Systems shall comply with BS or BS-EN or Other Equivalent International Standards.

The design of E&M Services for this Metro Rail Project shall be governed by all latest applicable local codes, regulations, standards and requirements issued by all the applicable local authorities and statutory bodies.

4.3 ABBREVIATIONS

ACRONYM	DESCRIPTION
ELECTRICAL	
HV	High voltage
MV	Medium voltage
LV	Low voltage
ac or AC	Alternating current
dc or DC	Direct current
kVA	Kilo volt-amp
kW	Kilowatt
V	Volt
A	Amp
FRLS	Flame Retardant Low Smoke
SCADA	Supervisory Control and Data Acquisition
MCB	Miniature Circuit Breaker
MCCB	Moulded Case Circuit Breaker
ACB	Air Circuit Breaker
ELCB	Earth Leakage Circuit Breaker
MCC	Motor Control Centre
ASTS	Automatic Source Transfer System
TC/TB	Terminal Connector/Terminal Block
ACOS/ATS	Automatic Change Over Switch/ Automatic Transfer Switch.
COS	Change Over Switch
MDB	Main Distribution Board
SDB	Sub Distribution Board
CP	Control Panel
SWA	Steel Wire Armoured
MS	Mild Steel
SB	Switch Board
PP	Power Panel
XLPE	Cross Link Poly Ethylene
PVC	Poly Vinyl Chloride
HT	High Tension
LT	Low Tension
CT	Current Transformer
PT	Potential Transformer
HRC	High Rupturing Capacity
APFC	Automatic Power Factor Control
PF or pf	Power Factor
UPS	Uninterruptible Power Supply
DG or GEN	Diesel Generator
I/C or i/c	Incoming
O/G or o/g	Outgoing
Ph	Phase

ACRONYM	DESCRIPTION
N	Neutral
PLUMBING & FIRE FIGHTING	
ASD	Aspirating Smoke Detector
BRE	Building research Establishment
BSI	British Standards Institute
BSP	British Standard Pipe threads
CCITT	International Telegraph and Telephone Consultative Committee (Comité Consultatif Internationale de Télégraphique et Téléphonique)
CCL	Communication Certification Laboratory
CENELEC	European Committee for Electrotechnical Standardization(Comité Européen de Normalisation Electrotechnique)
CGP	Clean Gas Panel
CISPR	The International Special Committee on Radio Interference (Comite International Special des Perturbations Radioelectriques)
CRT	Cathode Ray Tube
CSD	Combined Services Drawing
E&M	Electrical & Mechanical
EMC	Electro Magnetic Compatibility
EN	European Norms
EPROM	Erasable Programmable Read Only Memory
FAHU	Fresh Air handling Units
FM	Factory Manuals
FR	Fire Resistance
FRP	Fibre Reinforced Plastic
FSSD	Fire Safety and Shelter Department
HDHC	Hard Drawn High Conductivity
HDLC	High-level Data Link Control
HMI	Human Machine Interface
HRC	High Rupture Capacity
HVAC	Heating, Ventilation and Air Conditioning
IDC	Insulation Displacement Connection
IE	Indian Electricity Rules
IEE	Institution of Electrical Engineers
IFAT	Integrated Factory Acceptance test
IP	Ingress Protection
ISM	Industrial, Scientific and medical band
ITU-T	International Telecommunication Union - Telecommunication Standardization Sector
LCD	Liquid Crystal Display
LCX	Leaky Coaxial Cable
LED	Light Emitting Diode
LPC	Loss Prevention Council
LSC	Local Sequential Control
MAP	Main Alarm Panel
MMI	Man Machine Interface
PCB	Pollution Control Board

ACRONYM	DESCRIPTION
ROM	Read Only Memory
RP	Repeater Panel
RTV	Response Threshold Value
SAP	Sub Alarm panel
SEM	Structural, Electrical and mechanical
SFSRTS	Standard for Fire Safety in Rapid Transit Systems
SPDT	Single Pole Double Throw
SWC	System Wide Contractors
TCF	Technical Construction File
UL	Underwriters Laboratories
V DC	Volt Direct Current
VDE	Verband der Elektrotechnik (German Association for
VESDA	Very Early Smoke Detection and Alarm
WLAN	Wireless Local Area Network

4.4 ELECTRICAL SERVICES

4.4.1 General Requirement

Scope of Work

The Electrical Works include the furnishing of materials, labour, equipment, tools, transportation and services required to Design, construct, install, test and commission the complete electrical system as shown on the Drawings and/or specified in the Contract Documents. This also includes any material, appliances, equipment not specifically mentioned herein (in the Contract documents) or noted on the drawings as being furnished or installed but which are necessary and customary to make complete installation properly connected and in working condition. The work shall include all incidental jobs / minor civil works connected with installation such as, cutting, drilling, grouting, fixing, sealing etc. It shall be the responsibility of the Contractor to provide a completely safe and workable system in accordance with the requirements of the Specifications/Contract documents, and to the satisfaction of the Engineer. The Contractor shall coordinate with the other Contractors of the Project to ensure that the system and its components as furnished form a complete electrical system with the established construction schedule. The boundary line and Control philosophy for E & M works inside the tunnel shall be as indicated in the Employer's drawings and as agreed by the Engineer.

4.4.1.1 Environment

The material and equipment shall be installed to suit the tropical climate of PUNE as indicated below. However, for more accurate data the Contractor shall follow the National Building Code and ASHRAE recommendations and also the values obtained from the concerned authorities.

The indicative Weather conditions for material and general equipment selection (to be confirmed at the time of design and as approved by the Engineer):

- | | |
|------------------------------------|--------------------------------|
| (1) Altitude | : Approximately mean sea level |
| (2) Maximum temperature | : 35.3°C |
| (3) Minimum temperature (all year) | : 14°C -17°C |
| (4) Maximum relative humidity | : 80% |
| (5) Minimum relative humidity | : 65% |

4.4.1.2 Examination of Drawings and Specifications

The Contractor shall examine all relevant architectural and structural drawings (together with all other utilities systems involved in the Project) as approved/agreed/noticed by the Engineer, prior to installation of machines, materials and equipment. Figure dimensions as indicated on the approved/noticed Drawings are to be followed and in no case dimensions shall be scaled from the approved/noticed Drawings. The Contractor shall ensure that the dimensions are checked on the site and/or building and reconciled with those on the approved/noticed Drawings and the Contractor shall be responsible for the accuracy of such dimensions regardless of the comparable dimensions on the approved/noticed Drawings.

4.4.1.3 Material

Nameplates and Identification

All parts of the installation, which are of interest for its operation and maintenance, shall be provided with nameplates, tags or arrows, especially in enclosed areas, such as ceiling, shafts, and other places accessible for maintenance service. The identification plates shall be used for identification of device number of all major equipment in the station. Materials, sizes and colour shall be as shown on the shop drawings proposed by the Contractor and agreed by the Engineer. The danger notices shall be used for danger warning at the required locations as mentioned on the approved/noticed drawings and in specifications.

4.4.1.4 Submittal of Data for Notice of No Objection

The Contractor shall submit the complete information regarding details of materials and equipment involved to the Engineer, prior to any purchase or manufacturing operation. Any purchase or manufacturing operations carried out prior to such Notice of No Objection shall be at the Contractor's sole risk/responsibility. The information of equipment shall be separately submitted by listing all the details with catalogue indicating at least the model, series, size and performance etc. Such data shall be in sufficient detail to enable the Engineer to identify the particular product and to form an opinion regarding its conformity to the Specifications and the Contract Stipulations.

4.4.1.5 Submission of Materials for Notice of No objection

Only new materials and equipment shall be used for the Works. All materials and equipment used for Works shall be of good quality. Any material which, in the opinion of the Engineer, has lower quality than the one meant in the Notice of No Objection by the Engineer, shall promptly be removed from the Works site/Works.

Whenever requested by the Engineer, the Contractor shall organize/arrange the testing of materials at his own cost by an independent institute/laboratory selected by the Employer

/ Engineer without any additional cost to the Employer.

If it is unavoidable (as agreed by the Engineer) to use materials and equipment that deviate from the noticed specifications or approved samples, then the Contractor shall immediately inform the Engineer in writing and submit the proposal for substitute items of equal/equivalent quality for obtaining the Notice of No objection from the Engineer.

The Contractor shall protect all electrical equipment, materials and their assembled parts during storage and during construction against the ingress of moisture, contamination or corrosion that might damage the finish or lower the electrical integrity of these items.

After the materials and equipment have been completely installed, the Contractor shall have to protect these materials and equipment from damages at the Contractor's expense/Cost.

In reference to inspections, all Works rejected by the Engineer shall be repaired, corrected or replaced as agreed by the Engineer at the Contractor's expense/cost to attain good workmanship, and conformance to the Contract Specifications/Stipulations/Documents.

4.4.1.6 Transportation of Materials and Equipment

The Contractor shall submit in advance a transportation schedule of materials to the Engineer and prepare passage ways and storage facilities.

The Contractor shall be responsible for all expenses incurred during shipping and transporting of material and equipment to the Works site. The materials and equipment shall be handled in a manner to prevent warping, twisting, bending, breaking, chipping, rusting and any injury, theft or damage of any kind whatsoever.

The shipping documents of the materials and equipment shall be submitted to the Engineer as soon as the materials and/or equipment have arrived at the Site.

4.4.1.7 Materials and Equipment Storage

The Contractor shall prepare storage areas of sufficient size for all necessary materials and equipment brought to the Works site. The storage areas shall be provided with access for inspection and removal of the stored materials and equipment.

Materials and equipment delivered to the Site without suitable storage arrangements shall not be accepted.

4.4.1.8 Corrosion Protection

All ferrous components and fittings exposed to the atmosphere shall be hot-dip galvanized (1000 g/sqm) unless specified otherwise.

4.4.1.9 Acoustic Criteria

Noise emanating from the equipment / service installations shall not exceed 55dB for the static machines and 65dB for rotating machinery at a distance of one meter to match or exceed the relevant international standards for each of the equipment.

4.4.1.10 Service life

All equipment, cables and wiring shall be designed, manufactured and installed so as to secure a service life as shown below:

Sub – main switchboards	30 Years
-------------------------	----------

Cables	30 Years
Luminaries	20 Years
Tray, trunking and supports	30 Years
All other equipment	minimum 20 Years

4.4.1.11 Tools and Appliance

The Contractor shall provide, unless otherwise stipulated, at his own cost all the tools and other facilities necessary for the execution and completion of the Works.

If in the opinion of the Engineer, the tools, equipment and materials arranged by the Contractor, either prior to the commencement or during the progress of works, are insufficient or inappropriate to secure the required quality and rate of progress of the Works, the Engineer may order the Contractor to increase their efficiency, improve their characteristics, augment their number or replace them with new tools, equipment and materials as the case may be and as required.

4.4.1.12 Shop Drawings

The Contractor shall prepare shop-drawings comprising complete details of items to be fabricated and Works to be installed.

The drawings shall be checked by the Contractor for accuracy with regard to dimensions taken in the building(s) and shall closely follow manufacturer's recommendations. All drawings shall be signed by the Contractor, and shall indicate the date of submission and the date(s) of revision(s).

In case shop-drawings require modifications for any reason, the Contractor shall clearly identify the portion that has been modified, and shall indicate the running number of revision every time that a revision-drawing is submitted.

The installation details shall be checked and coordinated with the building works, the structure and other related trades to prevent conflicts that may cause delay of the project and ensure complete compatibility.

Size and scale of the shop-drawings shall be at least 1:100 scale except for enlarged scale details done for clarity, which shall be in conformity with the international standards or as directed by the Employer / Engineer.

Where required by the Employer / Engineer, the Contractor shall prepare additional drawings, diagrams, etc., which in the opinion of the Employer / Engineer, are considered necessary for the proper execution of the Works.

4.4.1.13 Execution Responsibility

The Contractor shall connect electrical wires, telephone wires and water pipe for his own use at suitable connection points, for temporary site work use, and shall bear the expenses/costs of usage, which shall be removed upon completion of sections of the Works.

The Contractor shall establish, maintain, and supervise all precautions and programs for safety and provide protection to prevent damage, injury or loss to:

- (1) All workmen on the worksite and other persons who may be affected thereby.
- (2) All works and all materials or equipment to be incorporated in the Works , whether in storage on or off the site.

As the work proceeds, the Contractor shall progressively remove rubbish and surplus materials away from the construction site to a place/dumping site as agreed/noticed by the Engineer and shall maintain his working area in a clean and tidy condition as far as is practicable.

Upon completion of the Works the Contractor shall, without delay, remove all his temporary works and buildings, all tools, equipment and surplus materials, and shall clean the whole area affected by his work and make it ready for immediate use .

All materials, equipment and finished works shall be kept in good condition. The security and upkeep of the completed Works shall be the Contractor's responsibility until taken over by the Employer.

4.4.1.14 Colour Coding

Color coding for power cables, bus-bars shall be as follows:

- | | | |
|---|---|-----------------------------|
| (1) Phase R | : | Red |
| (2) Phase Y | : | Yellow |
| (3) Phase B | : | Blue |
| (4) Neutral | : | Black |
| (5) Ground | : | Green or Yellow Strip Green |
| (6) Emergency Lighting | : | Orange |
| (7) Large wires and cables shall be color coded with tapes as specific color. | | |

Color coding for Junction boxes shall be as follows:

- | | | |
|-----------------------|---|--------|
| (1) Normal power | : | Orange |
| (2) Essential power | : | Yellow |
| (3) Telephone system | : | Green |
| (4) Fire alarm system | : | Red |
| (5) Control system | : | Blue |

4.4.1.15 Field Testing

Testing of all electrical equipment shall be required upon completion of installation to ensure/demonstrate that the equipment operate satisfactorily and conform to the Contract requirements/stipulations.

Field testing shall be required for all cables and electrical equipment furnished, installed and/or connected by the Contractor to ensure proper installation, setting, connection, and functioning in accordance with the plans, specifications and manufacturer's recommendations and compliance with the Contract Stipulations.

Testing shall be conducted in the presence of the Engineer and, when necessary, under the supervision of equipment manufacturer's field engineer.

All tests recommended by the equipment manufacturer whether specified in these

Specifications/Contract documents or not, shall be included, unless specifically waived by the Engineer.

Testing shall include any additional tests asked by the Engineer to determine the conditions/performance of that equipment, material and system to meet requirements of this Specifications/ Contract stipulations.

The Contractor shall maintain in quadruplicate a written record of all tests showing date, personnel conducting test, equipment or material tested, tests performed and results. Two copies of test records shall be given to the Engineer.

The Contractor shall notify the Engineer two weeks prior to commencement of any testing.

The Contractor shall be responsible for any damage to equipment or material due to improper test procedures or handling test apparatus, and shall replace or restore any damaged equipment or material to the original condition meeting the Contract Specifications/requirements.

Safety devices such as rubber gloves and blankets, protective screens and barriers, danger signs, etc. shall be provided by the Contractor and shall be used to protect and warn adequately all personnel in the vicinity of the test location.

The Contractor shall furnish all testing equipment and proper temporary power source for testing purpose when normal supply is not available at the time of testing.

Conduit and wiring system shall be checked to ensure that the system has been installed in safe and reliable way.

The lighting system shall be checked at night to ensure that illumination levels as specified have been met.

Operation of all interlocks, control and alarm circuits shall be tested (if any).

The Conductor's insulation value shall not be lower than the acceptable level as required by the concerned Authority.

The grounding system test shall be done as per local standards and regulations.

Tests on all the miscellaneous equipment, such as circuit breaker, low voltage switchboard, motor (if any) etc., shall be conducted as per the recommendations/stipulations of the equipment manufacturer and as agreed by the Engineer unless specifically waived by the Engineer.

All the additional tests as deemed necessary by the Engineer on account of field conditions and to determine that equipment, materials and systems meet the requirements of these Specifications/Contract stipulations, shall also be conducted by the Contractor.

4.4.1.16 Operation and Maintenance Manual

The manual shall be prepared in hard cover binding in sets to be submitted to the Engineer on acceptance of the completed work.

- (1) Section 1 : Comprising submittal data of all equipment and materials that have been approved and are to be used in Works.

- (2) Section 2 : Comprising catalogues, categorized in groups, complete with installation, operations and the maintenance manuals from the manufacturers as suited for the Works under the Contract.
- (3) Section 3 : Comprising formats/check-lists for inspections and testing and also the filled out test reports in the field.
- (4) Section 4 : Comprising spare parts list and recommended spare parts quantities etc.
- (5) Section 5 : Comprising maintenance and services schedule, and service and maintenance procedures for individual equipment listing daily, weekly, monthly, quarterly and yearly schedules etc.
- (6) Section 6 : Comprising system operations manual

A draft copy of the manual shall be submitted to the Engineer for Notice of No objection.

4.4.1.17 Works to Completion

The Contractor shall commission, clean down, and leave in full working order the Works as specified.

As the installation proceeds, the Contractor shall prepare As Built Drawings of the Electrical system installation. It shall be sufficient to modify the approved construction drawings showing any amendments to the service which have taken place and submit the marked-up prints to the Engineer for Notice of No objection.

The Contractor shall deliver to the Engineer on completion of the works, manufacturer's literature, specifications, technical information and As Built Drawings for all the equipment installed.

4.4.1.18 Manufacturers and Suppliers

Materials and equipment shall only be supplied from the manufacturers and suppliers for whom the Engineer has issued a Notice of No Objection.

4.4.2 Low Voltage Switchgear

4.4.2.1 General

The scope of Low Voltage electrical distribution commences from the outgoing cables from the feeders of the Main LV Switchboards.

4.4.2.2 Standard and Reference

The Main low voltage switchboard, distribution boards, capacitor bank and its accessories shall comply with the following codes and standards.

(1)	IEC 61439-1	:	Low-Voltage switchgear and control gear assemblies – Part 1: Type-tested and partially type-tested assemblies
(2)	IEC 60269	:	Low voltage fuse
(3)	IEC 60529	:	Degree of protection provided by enclosures (IP Code)
(4)	IEC 60947-1	:	Low-voltage switchgear and control gear – Part 1: General Rules
(5)	IEC 60947-2	:	Low-voltage switchgear and control gear – Part 2: Circuit-breakers
(6)	IEC 60947-7	:	Low-voltage switchgear and control gear – Part 7: Ancillary equipment

(7)	IEC 61439-2	:	Low-Voltage switchgear and control gear assemblies – Part 2: Particular requirements for Bus-bar trunking system (Bus-ways)
(8)	IEC 61921	:	Power capacitors – Low voltage power factor correction banks
(9)	IEC 60831-1	:	Shunt power capacitors of the self-healing type for AC systems having a rated voltage up to and including 1000V-Part 1: General – Performance, testing and rating – Safety requirements – Guide for installation and operation
(10)	IS 13947	:	Low Voltage switchgear & control gear
(11)	IS 8828	:	Low Voltage switchgear & control gear - Part V Control circuit devices and switching elements MCBs
(12)	IS 11353	:	Marking of Switchgear bus-bar
(13)	IS 3231	:	Electrical relays for power system protection
(14)	IS 10118	:	Code of Practice for selection, installation and Maintenance of switchgear & control gear
(15)	IS 8623	:	Low Voltage switchgear & control gear assemblies
(16)	IS 2147	:	Degree of protection enclosures for low voltage switchgears
(17)	IS 3231	:	Electrical relays for power protection
(18)	IS 2551	:	Danger notice plate
(19)	IS 4201	:	Application guide for current transformers
(20)	IS 4140	:	Application guide for voltage transformers
(21)	IS 3842	:	Application guide for relays
(22)	IS 5051	:	Electromagnetic relays

4.4.2.3 LV system Description

The Main LV Switchboard shall be designed and fabricated for use on a 415 3 phase, 4 wires /240V 1 Phase 2 wires A.C, 50 Hz, solidly grounded neutral system. Control and distribution of power to auxiliary equipment and the lighting systems in the Stations and tunnels shall be by means of the Main LV Switchboards installed in the LV switch gear room/ASS room of Stations.

There shall be two Auxiliary Transformers provided for each underground station, which shall be capable of supplying power to all auxiliary loads and each separately installed in the Transformer room and two Main LV Switchboard located in LV switch gear room/ ASS room. The connection between the Auxiliary Transformers and the Main LV Switchboard will be a power cable/busway distribution system.

The two Main LV Switchboards shall be connected together via a Tie Circuit breaker with an interlocking system. The two Main Incoming Circuit Breakers shall be interlocked, electrically and mechanically, so that the both breakers cannot be closed at the same time and the two transformers cannot be operated in parallel to supply power to the loads.

The switchboard shall be provided complete with Circuit Breakers, fused switches, isolators, relays, meters, control switches and other electrical component necessary for the correct operation and protection of the installation as described in this specification.

The switchboard shall be provided complete with housing, bus-bar chambers, bus-bars, cabling chambers, cable boxes, glands, gland plates, cable trays, conduit entries, wiring trays, cable lugs, secondary wiring terminals, nameplates, labels and all accessories, whether described in detail or not, necessary for the correct operation and protection of the installation as described herein.

The main LV Switchboards shall have the changeover sequence for the essential section board and shall be as follows;

- a) If the supply failure exceeds 10 seconds, the generator set shall be started automatically.
- b) When the voltage reaches 85% of the nominal value the changeover contactor shall be energized.
- c) Resumption of the normal supply shall cause the change-over contactor to disconnect the system from the generator and re-connect the system to the normal supply. This shall cause a signal to be given to the engine controls to initiate an automatic generator set shut-down sequence.

The quantity of main and feeder breakers shall be as shown on the schematic diagram and relevant drawings and as agreed by the Engineer.

An under voltage sensing relay shall be installed on the secondary side of each transformer to sense loss of voltage and it shall have an adjustable time delay feature so that if the supply voltage drops to zero, it must remain at that value for a period of 3 seconds before tripping the main incoming Circuit Breakers and non-essential Circuit Breakers.

Spare breakers with aggregate three phase current rating not less than 25% of the main bus bar current rating shall be provided. Spare panel space on top of the 20% spare breaker capacity shall be provided for future expansion.

All cable terminations and component circuit references shall be properly labeled & tagged.

The low voltage switchgear shall have the electrical characteristics as follow:

- | | | |
|--------------------------|---|--|
| (1) System Wiring | : | 3-phase, 4-wires solidly grounded Neutral system |
| (2) Rated Voltage | : | 415V/240V |
| (3) Rated Frequency | : | 50 Hz. |
| (4) Insulation Class | : | 660-750V (Minimum) |
| (5) Degree of protection | : | IP 42 (For Indoor), IP54 (For Outdoor) |

The main switchboard shall be constructed so as to allow for future additions and extensions.

The total harmonic voltage distortion at each Main Low Voltage Switchboard shall not exceed less than 1 % linear load and not less than 5% for non-linear load.

All circuit breakers installed in switchboard shall comply with IEC 60947-1, IEC 60947-2 standard. All circuit breakers shall be selected to perform in coordination pattern along the protective lines. Terminals of all circuit breakers rating < 225 AF shall be cable lugs and the others shall be bus-bar terminals.

The Station Load shall be classified into three categories:

1. Normal load: shall receive power from two (2) transformers and shall comprise of the

following in addition to those listed as essential and critical loads :

- Normal lighting;
 - Escalators;
 - Power socket outlets;
 - Station Air conditioning System;
 - Station Ventilation System;
 - All other loads as required
2. Essential loads: shall receive power supply from standby diesel generator sets for all stations . It shall be comprising of the following in addition to the critical loads: :
- Fire Fighting system;
 - Tunnel Ventilation system;
 - Essential Station Air conditioning System;
 - Essential Station Ventilation system;
 - Lifts;
 - Escalators (if considered for evacuation during emergency)
 - Cold water pumps and waste water pumps and ejector pumps in stations and tunnels;
 - Uninterruptible Power Supply (UPS);
 - Emergency small power outlet;
 - Platform Screen Door System
3. Very essential (Critical) loads: shall receive power supply from UPS with 30 minutes operation time, which in turn shall be fully backed up by DG power. It shall be comprising of the following:
- Telecommunication system;
 - Signalling system;
 - AFC System
 - Fire alarm and detection system;
 - Master clock system;
 - Public address system;
 - Closed circuit television (CCTV);
 - PC work stations in SCR;
 - M & E SCADA, Power Supply SCADA and TVS SCADA
 - Emergency lighting;
 - Tunnel and Cross passage lighting ;
 - Tunnel and cross passage emergency evacuation signage lighting
 - Exit and emergency signage ;
 - Platform Screen Door Control system
 - Blue light stations provided by Power Supply and Traction Contractor

4.4.2.4 Components

(1) Panel Construction

- a) The LV switchboard shall be of sturdy and robust, metal enclosed, moisture, termite and vermin proof with ventilation louvers, free-standing, front or rear

accessible. The cubicle tops, floor plates, side panels, front and rear doors shall be detachable gasket sheets metal plates. The bare edges shall be lipped. Each panel shall be divided vertically by isolating sheet metal and horizontally by insulation between compartments for each item of switchboard and/or instrument.

- b) The overall height of the switchboards shall not exceed 2,200mm above floor finished level. It shall be fully extensible, self-supporting and constructed from non- hygroscopic and non-inflammable materials.
- c) The cubicle shall be fabricated from a minimum 2.0mm thick mild steel using folded and welded sections and angle iron bracing where necessary. All welds shall be flush.
- d) Arc chutes and ventilating outlets shall be so situated that any emission of flame or hot metal particles shall not cause electrical breakdown and shall be directed away in such a manner as to avoid endangering the operator.
- e) Metal barriers shall divide the switchboard unit into compartments to provide separated totally 3 basic compartments from front to rear in Form 4b Type 5 in accordance with BS EN 60947-1 & BS 61439-2 as follows:
 - (i) Circuit breaker compartment for installation of switching equipment.
 - (ii) Bus-bars Compartment, which is the chamber for bus-bar installation both horizontal and vertical.
 - (iii) Cable compartment which will be provided for power cable incoming and outgoing from the switchboard.

Each compartment as mentioned above shall have sheet metal safety partition with minimum thickness not less than 2.0mm.

- f) The top, sides and rear cover plates shall be removable and attached to the frame with rustproof screws. The front doors shall be attached to the frame with the hidden hinged and approved keys providing easy opening to the doors.
- g) All front plate used for mounting meters, selector switches or other front mounted devices shall be hinged with all wiring installed and laced with flexibility at the hinged side. The back closure plate shall also be hinged type and other closure plates shall be screw removable and small enough for easy handling by one man.
- h) Door or lift-off panels as applicable, shall be fitted to the front of cubicles and unless otherwise noted, lift-off panels shall be fitted to the rear of cubicles. Doors and lift-off panels shall be stiffened in an approved manner to prevent distortion and shall be fitted all around with compression gaskets to exclude dust.
- i) All interior shall be completely factory assembled with circuit breakers and wire connections. All wire connectors, except screw terminals, shall be of the anti-turn solder-less type and all shall be suitable for copper wire of the sizes indicated/required.
- j) Interiors shall be so designed that circuit breakers can be replaced without disturbing adjacent units and without removing the main bus connectors and shall be so designed that circuits may be changed without machining, drilling or tapping.
- k) All steel parts of the panel shall be completely dry and chemically clean,

prevent corrosion, before being painted with the non-rusting primer and not less than two stoves enamel-coating finished on top both inside and outside. Finish shall be light grey with RAL standard color, unless otherwise directed by the Engineer.

- l) Mimic diagram shall be black plastic strip adhered on the front of the panel showing single line diagram of the system. Mimic bus shall be 3 mm. thick and 10 mm. widths.
- m) Nameplates shall be furnished and mounted by the Contractor. Each assembly, each piece of equipment mounted on an assembly, and each power and control circuit shall be provided and mounted with a nameplate. All nameplates materials shall be designed and proposed to the Engineer for Notice of No objection.
- n) The nameplates shall be furnished to identify the list of panels, circuit breakers, etc. in accordance with the nameplate designations shown on the approved Shop Drawings.
- o) Where specified, instruments, push buttons, indicating lights and other similar items shall be fastened direct to the fixed or hinged fascia panel and stiffened as necessary to hold the items firmly in position under all conditions of operation.
- p) Ventilating louvers shall be provided on the sides and backs of panels such that adequate ventilation shall be provided for the internal heat dissipation and under no circumstances shall the internal temperature rise above 40°C. All louvers shall be screened, vermin proofing.
- q) A flexible ground strap shall connect all removable doors to the frame.
- r) All of the feeder cubicles shall be designed for feeder cables entering from the top. Removable cover plates for all cable entrances shall be provided.
- s) Suitable supports for cables and wiring shall be provided within the cubicles to prevent undue stresses on terminal connections.
- t) The switchboards shall be provided with adequate lifting means, and be capable of being rolled or moved into position and bolted directly to the floor without the use of floor sills.

(2) Bus-bars and Supports

- a) Bus-bar supports shall be formed of high-dielectric strength and low moisture absorption molded compound with the high impact strength and low creepage surface. All current carrying parts shall be of copper.
- b) The Main Bus-bar shall be arranged throughout the switchboard in the sequence of R-Y-B from left to right, top to bottom and front to back as viewed from the front and to permit future additions. Bus-bars shall be bare copper and permanently labeled by phase for identification of each phase, neutral and protective conductor as following:
 - (i) Phase R of three-phase ac. Circuit with Red colored
 - (ii) Phase Y of three-phase ac. Circuit with Yellow colored
 - (iii) Phase B of three-phase ac. Circuit with Blue colored
 - (iv) Neutral of three-phase ac. Circuit with Black colored
 - (v) Earthing conductors with Green or Green-and-Yellow strip colored.
- c) The main Bus shall have a continuous current rating not less than the main breaker,

and the individual unit buses shall have a current rating not less than of the feeders. Buses shall be braced and supported for the maximum allowable fault current of the incoming breakers.

- d) The Bus bar shall be air insulated, solid rectangular bars of electro-tin plated, hard drawn, high conductivity, 99%, copper bars and shall be mechanically braced to withstand the maximum symmetrical short-circuit current rating of the main breaker in each assembly.
- e) The bus bar shall have sufficient cross sectional area to continuously conduct rated full load current, for operation in 50°C ambient temperature and for limit temperature rise within the requirements of IEC 61439-1. The current carrying capacity of bus bar shall be of the bare bus bar rating, conformed to IEC 61439-1.
- f) Neutral bus shall be furnished through the entire length of the switchboard and it shall be connected to the transformer neutral. Neutral bus size shall not be less than full size of phase bus and shall have the same bracing. All switchboard equipment requiring neutral shall be connected to this bus. Bolted type terminal lugs shall be furnished for connecting the neutral bus to the incoming and outgoing cables.
- g) A ground bus, 50% size of phase bus, shall be furnished to the entire length of the switchboard. All switchboard equipment requiring grounding shall be connected to this bus.
- h) All bolted bus joints shall be tin plated, and all joints shall be securely tightened to Manufacturer's standards for each size of hardware. Bolted, Nut and Washer for buses connection shall be high tension class and the contact point between buses and terminal pad shall be electrical compound painted.
- i) Bus-bar holder shall be of fiber-glass reinforced polyester (FRP) type or Epoxy- resin or as per manufacturer's recommendations. The calculation sheet and technical data showing the minimum spacing between the bus-bar holders for withstanding the maximum force caused by short circuit current from the bus-bar holder's manufacturer shall be submitted for Notice of No objection. The horizontal main bus-bar supports, connections, and joints shall be bolted to be free of required periodic maintenance.
- j) Anti-Condensation Space Heaters
1 No. 100 W, 240 volts, single phase, 50 Hz AC Anti Condensation space heaters controlled by thermostat and protected by 6 amps SP MCB's shall be provided in each vertical section of main LT panel and 1 No. 60 watt Anti Condensation space heater shall be provided in each cable alley of main distribution boards and sub distribution boards. Supply and control equipment for the above shall be provided by the Contractor through vendors.

(3) Air Circuit Breakers (ACB)

- a) The ACBs shall meet the following requirements:

The incomer ACBs and bus-section ACB shall be four-pole type.

All ACBs shall be of the air break horizontal withdrawable pattern complete with interlocks to prevent withdrawal when the breaker is closed. Electrical connection between the breaker and "Switchboard" shall be of plug and socket type with automatic screening shutters which will shield the fixed terminals in the "Switchboard" in a manner such that no access can be made to the fixed terminals when the breaker is withdrawn. In order to prevent unauthorized operation, the withdrawable air circuit breakers shall be

provided with padlock facilities to secure them in their CONNECTED, TEST and ISOLATED positions.

ACB shall have microprocessor based protection releases for type of faults, as required, and shall have an LED/LCD display to show true RMS current in all the three phases and the highest current among three phases. The release should have an internal fault indication by LED's for fault differentiation. The release shall be equipped with self diagnostic feature with indication.

- i) Number of poles : As indicated in the drawings.
- ii) Continuous rated current : As indicated in the drawings.
- iii) Rated short-circuit making capacity: shall be atleast 2.1 times of ultimate short ckt breaking capacity at 0.25 power factor,
- iv) Rated ultimate short-circuit breaking capacity (Icu): min 70/65 kA and based on actual fault level,
- v) Rated short-time withstand current (Icw): 70/65kA for 1 second (minimum).
- vi) Rated service short-circuit breaking capacity (Ics): 100% of Icu, and
- vii) Rated insulation voltage : 1000V ac.
- viii) Rated frequency : 50 Hz.
- ix) Rated working temperature : 40 deg. C.
- x) Short-circuit performance categories: P-2.
- xi) Spring charging can be operated by either manual or motorized.
- xii) 2-steps operating mechanism:
 - (1) Step 1 Charge closing spring. (can be operated by either manual or motorized)
 - (2) Step 2 After the spring is fully charged, press button at the front of circuit breaker to close the circuit breaker contacts.

The release should be capable through Modbus over Serial (RS 485 port) communication.

- b) All ACBs shall be certified by an approved national testing authority to show compliance with the short circuit duty as specified above.
- c) Isolating and main contacts shall be silver plated, self-aligning cluster type backed by phosphor bronze springs. The arcing tip shall be specially treated to minimise erosion and eliminate contact welding under all conditions. Heat resistant arc quenching devices shall be provided.
- d) Maximum number of circuit breaker auxiliary switches, spare auxiliary switches to be equally divided between normally open and normally closed. At least 4 spare pairs of N.O. and N.C. volt free contacts shall be provided. All auxiliary wiring shall be connected to a plug by a flexible cable with socket type adapter at the outer casing of the circuit breaker.
- e) Draw-out pattern, ACBs shall also meet the following requirements:
 - i) Electrical connection between the ACB and the bus-bar system of the LV switchboard shall be of the plug and socket type with automatic screening shutters to shield the fixed terminals in the switchboard when the ACB is withdrawn. The shutters shall be properly labelled to indicate whether they are for incoming or outgoing terminals and provided with padlock facilities.

- ii) The ACB shall not be capable of insertion or withdrawal when in the closed position. Attempted withdrawal shall not trip a closed ACB.
- iii) Live parts of the ACB shall not be accessible from the front of the LV switchboard unless the ACB is drawn out.
- iv) Means shall be provided to padlock the ACB in its CONNECTED, TEST and ISOLATED positions.
- f) The draw out mechanism shall hold the breaker rigidly in the CONNECTED, TEST, and DISCONNECTED position (for draw out type). Interlocks shall be provided which will prevent connecting the breaker to, or removing it from the bus stabs unless the breaker is OPEN (tripped). All spare contacts on breaker position switches and auxiliary relays shall be wired to accessible terminal blocks.
- g) Each Air circuit breaker shall have an independent manual “CLOSE” push button and a “TRIP” push button with stored energy or spring assisted mechanism, and shall be provided with “CLOSED”, “OPEN” indicator, whether the mechanism is fully “charged” and “discharged” indicator shall be provided.
- h) Geared motor for automatic charging of closing spring shall be provided. The motor charges the closing springs again immediately after the circuit breaker has closed.
- i) The closing springs can, however, be charged manually (using the relative operating mechanism lever) in the event of a power supply failure or during maintenance work.
- j) Control contacts shall make when the breaker is in the “CONNECTED” position and break when in the “DISCONNECTED” position. The auxiliary contacts shall make when the breaker is in the “CONNECTED” position and break when in the “TEST” and “DISCONNECTED” position.
- k) Notwithstanding the above, each ACB shall be equipped with, but not be limited to, the following:
 - i) A mechanically operated indicating device to indicate breaker positions.
 - ii) Key operated interlocks between breakers where required.
 - iii) Auxiliary Switches.
 - iv) Time Delay Under-voltage Trip
 - v) Shunt Trip
 - vi) Motor Operated spring charger
 - vii) Alarm Switch
 - viii) Microprocessor based adjustable Trip Unit as followings;
 - a) Long time protection (LT) can be adjusted from 0.4–1 time of ampere rated current (In) and can be adjusted time delay from 15–480 seconds at 5.5 time of ampere rated.
 - b) Short time protection (ST) can be adjusted from 1.5–12 time of ampere rated current (In).
 - c) Short time delay / Long time delay
 - d) Instantaneous trip (INST)
 - e) Thermal Memory up to 180 minutes.
 - f) Ground fault protection, current picks up adjustment and time delay type.
 - g) LCD display for current value, trip history, type of fault, pre-trip alarm and

main contact maintenance shall be built-in the circuit breaker.

h) Healthy unit LED for self inspection.

ix) Breaker OPEN/CLOSED/TRIPPED-ON-FAULT indicating lamps.

x) Phase indicating lamps (for incoming breakers and bus-sections only).

xi) Control circuits, with anti-pumping relays, to ensure positive operation of the ACB.

xii) Lamp test push button.

xiii) REMOTE/LOCAL-MANUAL breaker control selector switch.

(4) Molded Case Circuit Breaker (MCCB)

- a) All Molded case circuit breakers shall be 3-pole, rated 415V a.c, 50Hz and shall be manual operated, except MCCB for Essential loads which shall be complete with motor operated, trip free from the handle and provided with adjustable thermal overload and instantaneous magnetic short-circuit protective elements. The MCCB ampere frame rating < 400 AF shall be thermal magnetic trip type and others shall be electronic trip type.
- b) Load handling contacts shall be of anti-welding silver/tungsten tips electrolytic deposited onto high conductivity copper backing.
- c) The MCCBs shall be 'Trip Free'. The tripping mechanism shall be thermal-magnetic, except MCCB for Fire Pump which shall be magnetic trip only, and must be fully compensated for ambient temperature of 25 degree C to 50 degree C and calibrated at 40 degree C to carry full load.
- d) MCCBs shall be complete with overload, short circuit and earth leakage protection (if specified/required) and shall have an inverse current/time characteristic with time delay inversely proportional to the current up to seven times full load rating. On higher over current and earth leakage, the breaker shall trip instantaneously. Wherever specified/required, additional under voltage relay protection shall be provided. Clear indication of type of fault when tripped shall be indicated for all MCCB'S
- e) Where required, MCCB shall be provided with a shunt trip unit that shall shunt trip the MCCB during an earth fault condition. The shunt trip unit shall be controlled by an earth fault current sensing device and static electronic circuitry with an adjustable earth leakage tripping range and an adjustable tripping time of 0 - 5s. The shunt trip coil shall operate on the dc supply as specified hereinafter. An indicating lamp with lamp test and reset buttons shall also be provided to indicate MCCB tripped on earth fault.
- f) Quick-make, quick-break and trip-free for over-current and short circuit current, and have a common trip on all multi-pole breakers with internal tie mechanism.
- g) Drives shall be toggle operating mechanism, operated by trip-free system and shall have clearly indication whether the circuit breaker is "ON", "OFF" or "TRIP". All breakers shall be provided with terminal connectors for connecting to the outgoing feeders.
- h) De-rating factors shall be considered where applicable to compensate for ambient temperature, enclosure, loading duty cycle, frequency and altitude.
- i) All MCCB shall be installed with the additional devices such as shunt trip, under-voltage relay, auxiliary switch, alarm switch, rotary handle, pad locking device, etc to increase performance of the protection control.

- j) Trip unit for the MCCB rating from 100 AF to 250 AF shall be thermal-magnetic trip with adjustable thermal current from 0.8–1.0 time of AF rated.
- k) Trip unit for the MCCB rating > 400 AF shall have rating plug to adjust ampere rating. The ampere rating can be adjusted from 0.4–1.0 time of rating plug for overload current and 3-8 times of rating plug for short circuit current.
- l) All circuit breakers rating > 1000 AT, Air Circuit Breaker (ACB) shall be completed with ground fault sensor. The sensor shall have the following characteristic:
 - (1) Ground-fault clearing time of main circuit breaker shall be more than the clearing time of feeder circuit breaker.
 - (2) Ground fault pick up current > 200A. (adjustable)
 - (3) Time delay can be set at 0.1, 0.2, 0.3 and 0.5 Sec.
- (4) Motorized MCCB Units
 - a) Motorised MCCB units shall comprise an MCCB as specified and with electrically operated solenoid and control as specified hereafter.
 - b) Where approved by the Engineer, a motorised MCCB shall be provided for control purposes or tripping the MCCB during an earth fault or under-voltage condition. Operation of the MCCB shall be by an individual momentarily energised solenoid mounted on the breaker. The closing solenoid shall operate on the mains supply while the tripping solenoid shall operate on the dc supply as specified hereinafter.
 - c) Where approved by the Engineer, an earth fault current sensing device and static electronic circuitry with an adjustable earth leakage tripping range and an adjustable tripping time of 0-5 seconds shall be provided.
 - d) Where approved by the Engineer, an under- voltage trip relay capable of holding the circuit closed for a period of 0-5 seconds adjustable at the commencement of complete mains failure shall be provided. The under- voltage relay shall be of the self-resetting type. A time delay circuit shall be incorporated to close the MCCB automatically within a period of 0-30 seconds adjustable at the commencement of mains restoration.
 - e) Notwithstanding the above, each motorised MCCB unit shall be equipped with, but not be limited to, the following:
 - (i) MCCB OPEN/CLOSED/TRIPPED ON FAULT indicating lamps.
 - (ii) MCCB OPEN/CLOSE push buttons.
 - (iii) Control circuits, with anti-pumping relays, to ensure positive operation of the MCCB.
 - (iv) Auxiliary contacts for local status indications, controls and 20% spares.
 - (v) Lamp test push button.
 - (vi) Auxiliary contacts for remote status indications, controls and 20% spares for future use.
 - (vii) REMOTE/LOCAL-MANUAL MCCB control selector switch.
- (5) Relay and Measuring Devices

Relays shall be Micro processor based, of well proven design having auxiliary contacts and RS 232 / 485 connectivity, as required.

 - (a) Multifunctional Digital Power Meter (DPM)
 - (i) The DPM shall be panel mounted type, complete with LCD or LED display unit.

- (ii) The display unit shall have the minimum 3 rows with 16 characters per row for value monitoring.
- (iii) The DPM shall be able to measure true RMS values as following (minimum):
 - (1) Current : per phase
 - (2) Voltage : VL-L and VL-N
 - (3) Power : kW,kVAR, kVA per phase and total at 3 phases
 - (4) Power Factor : per phase and average at 3 phases
 - (5) Frequency : incoming electrical source (Hz.)
 - (6) Energy : kWh, kVARh, kVAh
 - (7) Harmonic : THDi and harmonic order from 3rd Up to 11th
- (iv) The DPM shall be completed with built-in RS-485, Mod bus communication port or RS-422 communication ports (2 ports) to interface with M & E SCADA System.
- (v) The DPM shall be operated at rated voltage not exceeding 600 VL-L and current rating < 5 A (from secondary of current transformer).
- (vi) The accuracy of power meter shall be:

- (1) Current/Voltage : 0.25 %
- (2) Power/Energy : 0.5 %
- (3) Power Factor : 1.0%

(b) Analog Ammeter, Voltmeter

- (i) Each indicating instruments shall be semi-flush mounted, back connected, dustproof, fully tropicalized, switchboard type with a dull black case for mounting on a steel panel. Each shall be suitable for operation with the instrument transformers.
- (ii) Except as otherwise specified, all indicating instruments shall be approximately 96mm x 96mm square with a 90° scale arc. All ammeters and voltmeters shall be of the moving iron type. The maximum error of each indicating instrument shall not be more than 1% of full scale range.
- (iii) The scale ranges of ammeters, voltmeters, wattmeters and var meters shall be chosen so that, under normal operating conditions, each instrument will read between 60-75% of the effective scale range. Scale plates shall have a permanent white finish with black graduations and numerals.
- (iv) The ammeters for which the upper limit of the effective range does not exceed 20 amps may be direct (series) connected. For higher range, current transformer operated ammeter shall be used, and shall be designed for a secondary current of 5 amps.
- (v) Accuracy Class of the meters shall be 1.0 or better.
- (vi) Voltmeters shall be the direct connection type with the accuracy class 1.0 and scale range 0-500V.

(c) Instrument Transformers

- (i) The current transformers shall be suitable for use with meters and tropical proof types with a 5 A secondary and a primary rating equal to the breaker continuous current rating. All current transformers shall have thermal and mechanical limits coordinated with the short-time rating of the circuit breakers

with which they are used.

- (ii) All current transformer secondary leads shall be brought out to shorting type terminal blocks located in the instrument compartments and shall be arranged to provide any combination of connections or polarity.
- (iii) The current transformer shall not be used in dual-purpose role serving both instrument and protective device.
- (iv) Accuracy Class of the current transformers shall be in accordance with the following function:

(1) Tariff metering	:	0.5
(2) Non-tariff metering	:	1.0
(3) Switchboard indicating instrument	:	1.0
(4) Protection	:	10P
- (v) The voltage transformer (if applied) shall be of the air-insulated type, with the windings encapsulated in epoxy resin or other suitable synthetic material. All voltage transformer secondary leads shall be brought out and connected, through secondary fuses, to terminal blocks for external connections or connection to other devices integral to the switchboard. These fuses and terminal blocks shall be mounted in the instrument compartments.
- (vi) On 3-phase, 4-wire systems, ammeter switches shall have four operating positions, marked 'R', 'Y', 'B', 'N', and 'OFF' position, and shall enable the single ammeter to read, in sequence, the currents in each of the three phases and the neutral wire. Ammeter switches shall have 'make-before-break' contacts and shall be connected so that the associated current transformers are short-circuit when they are not connected to the ammeter.
- (vii) On 3-phase, 4-wire systems, voltmeter switches shall have six operating positions, marked 'R-Y', 'Y-B', 'B-R', 'R-N', 'Y-N', 'B-N', and 'OFF' position, and shall enable the single voltmeter to read, in sequence, each of the three line voltages and each of the three phase-to-neutral voltages. Voltmeter switches shall have 'break-before-make' contacts.
- (viii) Undervoltage relay shall be provided to turn off the main circuit breaker when the voltage falls below premeditated level. Undervoltage relay shall be 3-phase, 4-wire, 415/240V, 50Hz unit. The undervoltage setting shall be adjustable to 10% with time delay setting 0-10s. The undervoltage relay shall include phase sequence and phase failure to trip the breaker when one phase falls symmetrically.
- (d) Asymmetrical Relay
 - (i) Asymmetrical relay shall be provided to turn off the main-circuit breaker in the event the difference in the voltage among the three (3) phases is incorrect.
 - (ii) Asymmetrical relay shall be 3 phase, 4 wire, 380/220V, 50Hz unit. The asymmetrical setting for the difference in the voltage among the three (3) phases shall be adjustable.
- (e) Under-voltage Relay
 - (i) Under-voltage relay shall be provided to turn off the main-circuit breaker when the voltage falls below premeditated level.
 - (ii) Under-voltage relay shall be 3 phase, 4 wire, 380/220V, 50Hz unit. The Under-voltage setting shall be adjustable to 10%.

- (f) Control and Auxiliary Relays
 - (i) Control and auxiliary relays shall be provided where necessary to ensure sound and effective operation of the ACBs, MCCBs and contactors.
 - (ii) Relays shall be plug-in type, rack mounted, provided with cable connection sockets and anchored by quick fastening vibration-proof devices.
 - (iii) All contacts shall be of the double breaking type. Relay coils shall be suitable for ac or dc operation as required.
- (g) Volt-free Contacts (Dry Contacts)
 - (i) Volt-free contacts shall be provided where required. They shall comprise a pair of contacts operated directly by the equipment but electrically separated such that no electrical potential derived from the equipment appears at the contacts. Volt-free contacts shall also be used to complete external control, alarm or indication circuits.
- (h) HRC Fuses and Fuse Links
 - (i) All equipment shall be fitted with suitably rated fuses. Heaters, indications, alarms, control circuits and measuring instruments shall each be fused separately and all fuses shall be housed in all insulated carriers with shrouded bases. All fuse links shall be properly labelled to identify the rating.
 - (ii) The HRC, if applied, shall be three (3) poles, surface mounting, and knife-contact type. The HRC fuses shall have the rated voltage of 500V and the rated current as indicated/required .
 - (iii) The HRC fuses shall be provided with side barriers and phase-separation barriers. Fuse base and the HRC fuse shall be manufactured in according to the IEC or VDE standards.
 - (iv) A fuse puller shall be provided for the distribution panel which uses the combined HRC fuse and fuse base.
- (i) Control wiring and terminal blocks
 - (i) All control wiring shall be with flexible, stranded copper conductors, switchboard wire and shall not be less than 1.5mm^2 except for current transformer circuits which shall not be less than 2.5mm^2 . All hinged wiring shall be extra flexible. The wiring shall be neatly and carefully installed in suitable wiring ducts with removable covers and shall be terminated at suitable terminal blocks. Splices shall not be permitted in control wiring or instrument leads.
 - (ii) The switchboard shall be provided with terminal blocks for termination of all wiring devices and each terminal block shall be clearly identified to show wiring which will be installed by the Contractor. Extra terminals, in a quantity of not less than 25% of the active terminals, shall be provided on each terminal block for circuit modifications and for future use. The terminal blocks shall be located so that the accessibility to them will not be lessened by interference from structural members or panel instruments. Ample space shall be provided at terminal blocks for termination of external circuits.
 - (iii) Terminal blocks shall be of the rail-mounted type and shall be of screw-less type terminals 600V a.c. moulded block type with molded insulating barrier between terminals. Terminal connections shall be such that the conductors shall be connected with the necessary maintained contact pressure. Terminals shall be so constructed that the conductors can be clamped between suitable surface

without any significant damage either to conductors or terminals.

- (iv) Terminal blocks for final connections for indication, instrumentation and metering circuitry shall have test probe facilities for connections of test leads and an integral disconnecting device to facilitate testing. Terminal blocks utilized in the secondary circuits of current transformers and electrical measuring transducers shall be of short-circuiting elements type.
- (v) Wiring shall be identified at each end with a legible printed black marking sleeve. Sleeves shall be white tubing, sized to fit the insulation. Sleeves shall be able to rotate on the wire so as not to inadvertently hide the wire number.
- (vi) Nameplates shall be furnished and mounted by the Contractor. Each assembly, each piece of equipment mounted on an assembly, and each power and control circuit shall be provided with a nameplate. All nameplates shall be made of laminate plastic. Characters shall be black on a white background.
- (vii) All indicating and pilot lamp assemblies shall be of the low power, cool operating, 24V, switchboard type, with color caps and integrally mounted resistors. The color caps shall be Red, Green, and Yellow as required. The lamp bulbs shall be replaceable from the front of the panels.

(6) Surge protection devices

- (a) The surge protection equipment shall conform to IEC61643-1/EN61643-11, IEC61312-1, VDE0675 standard.

- (b) Lightning Current Arrester shall be as Shunt Surge Protection to capture and discharge lightning current, and shall have the following characteristic;

- (i) Arrester Class I/B
- (ii) Nominal Voltage (Un) 240 VAC, 50 Hz
- (ii) Arrester Voltage (Uc) > 120% of Un/50 Hz
- (ii) Lightning test current 50 kA per phase (10/350 μ s)
- (iii) Quenching Short Circuit at Un 50 kA per phase (10/350 μ s)
- (iv) Protection level 0.9 kV
- (v) Response time 1 μ s
- (vi) Temperature Range -40°C to 85°C
- (vii) Protection type IP 20

- (c) Surge Voltage Arrester shall be made from Metal Oxide Arrester to capture the rest of voltage surge from low voltage feeder. The arrester shall be completed with status indicator ("Normal", "Fault", "Defect", etc.) and self-disconnection, and shall have the following characteristic.

- (i) Arrester Class II/C
- (ii) Nominal Voltage (Un) 240 V. AC
- (ii) Arrester Rated Voltage (Uc) 275 V. AC
- (iii) Discharge Current to PE with Un 0.3 mA.
- (iv) Nominal discharge Surge Current 20 kA per phase Isn (8/20 μ s)
- (v) Max Discharge Surge Current 40 kA per phase Imax (8/20 μ s)
- (vi) Response time 25 ns
- (vii) Protection level with Isn 1.35 kV
- (viii) Temperature Range -40°C to +85°C

(ix) Protection type IP 20

- (d) The installation of the equipment shall be fully 4 poles connection (LA – Ground, LB – Ground, LC – Ground and Neutral – Ground).
- (e) Unit shall be installed in parallel with the protected equipment. No series connected protective elements shall be used.

4.4.2.4.2 Distribution boards

(1) General

- (a) The distribution boards shall serve the distribution of electrical power to machinery/motors, socket outlets, lighting system, etc. The loads shall be connected either directly to these boards or via sub-distribution boards.
- (b) The distribution boards shall be of metal-enclosed indoor, factory-built type. A minimum protection of enclosure IP42 shall be provided. Distribution boards of 100A and above shall be provided with voltmeter and ammeter complete with selector switches. All distribution boards shall be provided with incoming and outgoing LED indication lights.
- (c) Each distribution boards shall be provided with 25% load spare breakers. The overall rating, incoming cable and upstream provision shall be such that a 20% load increase for future expansion can be accommodated without alternation to the distribution system.

(2) Panel Construction

- (a) The distribution board enclosure shall be made of electro-galvanized steel sheet (minimum thickness 2 mm) and finished with epoxy-powder coating (minimum 60 micron) colored to the Engineer's acceptance. The enclosure shall be completed with hinged doors and to be provided with standardized key lock and 3 sets of keys shall be provided for each distribution board. All DB doors shall be provided with separate latches in addition to the door locks.
- (b) The distribution boards shall be supplied fully equipped, wired, and proofed against vermin, dust and moisture, designed for free-standing or for wall-mounting, and cable access from beneath or above. Proper warning signs indicating danger and voltage level shall be provided.
- (c) Unless otherwise accepted, access to the boards shall be from the front, the doors shall be furnished with lift-off hinges to permit an opening enabling an unrestricted access to the board interior. All doors and covers shall be fitted with moulded gaskets of non-ageing material.
- (d) The distribution boards shall be provided with 3-phase tinned copper conductor bus-bars rated for continuous current and short circuit current. The bus-bars shall be designed to withstand dynamic forces due to peak short circuit current. All bus-bars including droppers and termination to the circuit breakers shall be colour coded as per the local standard.
- (e) Each distribution board shall also be furnished with neutral and earthing bus-bars having the same rating as the phase-buses.
- (f) As-built single line diagram, control circuit and layout plan shall be inserted in a permanent pocket on the inner side of the panel door of each distribution board.

(3) Circuit Breakers (CB)

- (a) Molded case circuit breakers shall comply with IEC 60947-1, IEC 60947-2 standard with appropriate rated short-circuit breaking capacity at 415V. The

short circuit performance categories shall be dependent on the application of the breaker. All MCCB shall be of triple-pole or double-pole as required, thermal magnetic type, with magnetic adjustable for MCCB's rated at 400A and above, independent manual operated to provide quick-make, quick-break, trip free mechanism so that the unit cannot be held closed against overload and short-circuit.

(4) Current transformer

- (a) Current transformers shall be single-phase, cast resin insulated. They shall withstand a continuous overload of 120%. The type, burden and accuracy class shall be suitable for its purpose.

(5) Instruments

- (a) The indicating instruments shall be flush-mounted, measuring 96mm high x 96mm wide.
- (b) The instruments shall be of Class 1 accuracy or better.
- (c) The voltmeter shall be provided with a selector switch, for reading the values of the three phases i.e. phase to phase, and phase to neutral voltage. The measuring range shall be indicated on the diagrams or drawings.
- (d) The scale shall not be less than 90° angular degrees and the designation shall be in Amps or Volts on white plate.

(6) Internal cabling

- (a) All internal cabling in each item of equipment shall be installed in cabling channels or conduits. Exposed cabling shall be kept to a minimum but where necessary, the wires shall be formed into compact groups suitably bound together and properly supported.
- (b) All conductors shall be terminated with suitable pressure type terminal lugs of proper sizes for terminal studs at the terminal blocks or shall be terminated in a manner compatible to the terminals of the instruments.
- (c) All conductors shall run continuously between terminal studs without splices or taps and all conductors shall be labeled at each termination with wire number as designated on the circuit diagrams.
- (d) All internal cabling shall be insulated stranded copper wire, rated at not less than 450V/750V. And minimum cross-sectional area shall be;
 - (i) 1.5mm^2 for control circuits.
 - (ii) 2.5mm^2 for voltage and current circuits.

4.4.2.5 Installation

All low voltage switchgears and capacitor banks shall be installed at the switch room. The main low voltage switchboard shall be installed on a concrete base at least 150 mm. height. All equipment shall be installed as recommended and certified by the manufacturers.

4.4.2.6 Testing and Commissioning

4.4.2.5.1 Field Testing

- (1) Field inspection and testing for Switchboards shall occur after installation is complete, feeders are terminated, and the room is secure. Testing shall be

conducted not more than 4 weeks before equipment is energized.

(2) Testing scope; (Routine Tests)

- (a) Visual and physical inspection of equipment.
- (b) Check control wiring and metering.
- (c) Meter calibration
- (d) Ground fault protection.
- (e) Insulation testing for equipment.
- (f) Adjust circuit breaker setting based on recommendations in the short circuit and co-ordination study.
- (g) Primary current injection testing of circuit breakers.
- (h) System grounding.
- (i) Function and operation testing for equipment inclusive interlocking scheme.

(3) Certified test report;

- (a) Verify that the installation is in accordance with Standards and regulations.
- (b) Verify that the equipment has been fully tested and is operational.

4.4.2.5.2 Factory Testing

- (1) The Low Voltage Switchboard shall conform to IEC 61439-1 with type test certificates issued by an independent and approved test authority. Type test shall include
 - (a) Temperature-rise limit
 - (b) Dielectric properties
 - (c) Short-circuit withstand strength
 - (d) Effectiveness of the protective circuit
 - (e) Clearance and creepage distances
 - (f) Mechanical operation
 - (g) Degree of protection
 - (h) High Voltage test
- (2) The Low Voltage Switchboard shall be licensee type tested and shall have certificates for testing all range of Ampere rating, Degree of Protection (IP), Short-circuit current, Temperature-rise limits as indicated above.
- (3) The routine testing for Switchboard at factory shall follow IEC 61439-1 and cover the following :
 - (a) Wiring and Operation testing
 - (b) Protective measures
 - (c) Insulation resistance.

4.4.2.5.3 Quality Control:

All low voltage switchgears and capacitor banks installed must be of industrial grade quality and the quality control shall be undertaken in accordance with the procedures set out in the Contractor's Quality assurance and Quality management plan.

4.4.3 Not used

4.4.4 Load Centre (distribution boards) and Circuit Breaker

4.4.4.1 General

The Contractor shall Design, supply and install load centres, safety switches and circuit breaker as specified herein.

4.4.4.2 Standard and Reference

The load centre, safety switch and circuit breaker shall comply with the following codes and standards.

(1)	IEC 60947-1	:	Low-voltage switchgear and control gear – Part 1: General Rules
(2)	IEC 60947-2	:	Low-voltage switchgear and control gear – Part 2: Circuit-breakers
(3)	IEC 60898-1	:	Circuit breakers for over current protection for household and similar installations – Part 1: Circuit breakers for a.c. operation
(4)	IEC 60947-3	:	Low-voltage switchgear and control gear – Part 3: Switches, dis-connectors, switch-dis-connectors and fuse-combination units
(5)	IS 10118	:	Code of Practice for selection, installation and Maintenance of switchgear & control gear
(6)	IS 8623	:	Low voltage switchgear & control gear assemblies
(7)	IS 13947	:	Specification for Low voltage switchgear & control gear
(8)	IS 2516	:	MCCBs

4.4.4.3 Material Description

All equipment shall have the electrical characteristics as follows:

- (1) System Wiring : 3-phases, 4-wires with ground or 1-phase, 2 wires with ground.
- (2) Rated Voltage : 415V/240V
- (3) Rated Frequency : 50 Hz.
- (4) Rated Continuous Current : As required
- (5) Rated Short Circuit Current : as specified/required (at 415 or 240 V.)

4.4.4.4 Component

4.4.4.4.1 Load Centre

- (1) The load centres shall be of dead-front safety surface mounted type, fitted with hinged front door and shall enclose all miniature and main circuit breaker suitably shrouded for safe working conditions. Degree of protection shall be minimum IP 42 for Indoor use and IP-54 for semi outdoor area.
- (2) Miniature circuit breakers which are equipped with the load centres shall be of frame, trip rating and interrupting capacity (including blank spaces for future addition). The circuit breakers shall be quick-make, quick-break, thermal-magnetic, trip-indicating conforming to IEC 60898-1 or IS 8828 and have a common trip on all multi-pole breakers with internal tie mechanism.
- (3) Main circuit breakers for the load centre (if applied) shall comply with IEC 60947-1, IEC 60947-2 or IS 13947 standard and shall have electrical characteristics as

specified/required.

- (4) Bus bar connections to the branch circuit breaker shall be in the “phase-sequence” type.
- (5) On the inside of the door of each cabinet, a typewritten directory shall be provided which shall indicate the location of the equipment or outlets supplied by each circuit. The directory shall be mounted in a metal frame with a non-breakable transparent cover. The load centres designation shall be typed on the directory card and the panel designation stenciled in 40 mm. high letters on the inside of the door.
- (6) Residual Current Device (RCD) shall be provided to protect all socket outlet circuits with rated at 30mA sensitivity. The RCD shall not trip out on loss of supply voltage and shall have the appropriate short-circuit strength for the location in the system at which they are installed and shall be capable of making, carrying and breaking the full short- circuit current.

4.4.4.4.2 Enclosed Circuit breakers

- (1) Enclosed circuit breakers shall be molded-case circuit breakers assembled in enclosed steel box which have electrical characteristics as specified/required.
- (2) Enclosed circuit breakers shall be IP31 general purpose enclosure with knockouts unless otherwise required. The enclosed circuit breakers which are located in an outdoor area or in a wet area shall be IP55 enclosure.
- (3) The circuit breakers shall comply with IEC 60947-1, IEC 60947-2 or IS 13947 standard.

4.4.4.4.3 Safety Switches

- (1) The safety switches shall be either Fused Safety Switches or Non-Fused Safety Switches as required.
- (2) The switches shall be heavy duty type equipped with switch blades, a quick-make and quick-break operating handle and mechanism which shall be an integral part of the box. Service door of each safety switch shall be interlocked so that it cannot be opened while the switch is in "ON" position.
- (3) Current rating of the switches shall be as specified/required.
- (4) All fuses for "fused safety switch" shall be of the high rupturing capacity (HRC) type of voltage rating up to 600 volts. Current rating shall be as specified/required.
- (5) The switches shall be IP31 general purpose enclosure with knockouts unless otherwise noted or required. Switches located outdoor or in wet areas shall have IP55 enclosures.

4.4.4.5 Installation

All equipment shall be mounted 1.80 m above the finished floor level and in accordance with the manufacturer’s recommendations.

The Contractor shall supply, adapt and install a steel work at the top and/or the bottom of the equipment to permit where necessary the incoming or outgoing of the cables, conduits, and wires.

4.4.4.6 Testing and Commissioning

Field Testing

- (1) Field inspection and testing for the load centre, safety switch and enclosed circuit breaker shall occur after installation is complete, feeders are terminated, and the room is secure. Testing shall be conducted not more than 4 weeks

before equipment is energized.

(2) Testing scope;

- (a) Visual and physical inspection of equipment.
- (b) Checking of control wiring.
- (c) Ground fault protection.
- (d) Insulation testing for equipment.
- (e) Adjust circuit breaker setting based on recommendations in the short circuit and co-ordination study.
- (f) Primary current injection testing of circuit breakers.
- (g) System grounding.
- (h) Function and operation testing for equipment.

(3) Certified test report;

- (a) Verify that the installation is in accordance with the relevant Standards and regulations.

4.4.4.7 Quality Control

All Distribution Boards and Circuit breakers installed shall be of industrial grade quality and the quality control shall be undertaken in accordance with the procedures set out in the Contractor's Quality assurance and Quality management plan.

4.4.5 Uninterruptible Power Supply (UPS)

4.4.5.1 General

Each Underground station shall have two nos Uninterruptible power supplies (UPS) with individual battery banks of 30 minutes battery autonomy with battery manager to have interoperability of the battery banks for UPS are designed to provide back-up power for systems essential for Metro rail operations.

4.4.5.2 Standard and Reference

The UPS shall comply with the following codes and standards.

- (1) IEC 60146 : Semiconductor Converters – General requirement and line commutated converters – Part 1-1: Specification of basic requirements.
- (2) IEC 60950 : Information technology equipment – Safety – Part 1: General Requirements.
- (3) IEC 62040-3 : Uninterruptible power systems (UPS) – Part 3: Performance requirements
- (4) Safety : Europe : EN 500091-1
: USA/Canada: UL1778 - Standards for Uninterruptible Power Supply Equipment.
- (5) Emission and Immunity : Europe: EN 500091-2
: USA/Canada: FCC Class A
- (6) CE-Marked
- (7) ISO 9001 Certification : The supplier shall be ISO 9001 certified.

4.4.5.3 Submittal

The Contractor shall submit material lists and technical data including schematic diagrams to the Engineer for obtaining Notice of No Objection before procurement .

The Contractor shall submit the following technical data for obtaining Notice of No Objection from the Engineer before installation:

- (1) Installation detail drawings of the UPS and Stationary Batteries (Dimension plan, section view, required clearances and location of all associated equipment).
- (2) Installation detail drawings of Cables & Raceways and its accessories connected with the UPS and Stationary Batteries.
- (3) Installation and operation manuals

The Contractor shall submit calculation sheets for batteries capacity based on ambient operating temperature.

The Contractor shall submit the battery de-rating curve and the data related to decrease in life expectancy due to room temperature variation.

The Contractor shall submit the necessary list of spare parts and special tools recommended by the manufacturer.

4.4.5.4 Material Description

The equipment and/or components shall be fully tropicalised and designed to operate 24 hours a day, 365 days a year.

The UPS system shall be True Online Double Conversion System consisting of rectifier/charger, inverter, static bypass transfer switch, manual bypass switch, battery bank, sealed Valve Regulated lead acid batteries and other equipment necessary for completion of the system.

The UPS shall be a dual unit parallel-100% redundant type, and suitable for continuous operation.

Each unit shall be modular in construction to facilitate unit replacement and all electronic control cards shall permit plug in type replacement

All materials and parts comprising the UPS system shall be new, of current manufacture and shall not have been in prior service except as required during factory testing.

The Contractor shall ensure that the harmonics generated by each UPS unit shall not affect the performance of other UPS units and the entire electrical distribution system.

Environmental Conditions

The UPS shall be capable of withstanding any combination of the possible environmental conditions without mechanical or electrical damage or degradation of operating characteristics. The UPS system shall operate satisfactorily under the applicable project Environmental conditions as agreed by the Engineer .

Operation Mode

(1) Normal Mode

- (a) During normal mode operation, the AC supply line from the station auxiliary supply shall supply power to the rectifier/charger which converts AC power to the regulated DC power. Simultaneously, the regulated DC power shall be

used to float-charge the batteries while it supplies the inverter.

- (b) The inverter shall invert DC power into AC power for supplying critical(very essential) loads within specified parameters.

(2)Emergency Mode

- (a) Upon failure or loss of the main AC supply line, the critical (very essential) loads shall be still continuously supplied, without any switching, interruption or excessive disturbance, by the batteries through the inverter.
- (b) Upon restoration of the main AC supply line, the rectifier/charger shall recharge the batteries in preparation for future auxiliary supply line failure and still supply full rated power through the inverter to the loads without interruption.
- (c) The UPS shall shut down itself if the batteries are discharged to their minimum discharge voltage. These batteries shall be able to supply rated output power for the time specified after recharging.

(3)Bypass Mode

(a) Automatic Bypass

- (i) The static bypass switch shall automatically transfer the load synchronously and without interruption, to the reserve supply in the event of any UPS malfunction (system overload, heavy in-rush current, etc. or inverter shutdown) which could cause the load to deviate beyond the specified tolerance. Upon restoration of the UPS function, the output of the UPS shall be synchronized with the reserve supply and then the load shall be allowed to transfer from the static bypass switch to the inverter without interruption.

(b) Manual Bypass

- (i) If the UPS must be taken out of service for maintenance or repair, a manually operated mechanical bypass system shall be provided to avoid the danger of working on live part; this system shall be designed to isolate the inverter and static switch while maintaining the critical(very essential) loads via the reserve supply.
- (ii) Transfer by the manual bypass or re-transfer back to the UPS system shall take place synchronized with the reserve supply (or main supply in case of re-transfer) and with no disturbance to the loads.

(4)Parallel Operation

The UPS modules shall be capable of running in parallel operation for increased capacity or for redundant operation. The parallel board shall ensure proper control of parallel units and proper load sharing. One parallel board shall be provided for each unit connected in parallel.

Physical
Requirements

- (1) The UPS equipment shall be housed in a free-standing, floor mounted with

protection degree at least IP21 cubicle, designed for heavy-duty applications and constructed of steel, or equivalent. All components and materials shall be new version of the current state-of-the-art.

- (2) All equipment in the system shall form a match and line-up configuration.
- (3) Equipment shall be designed for front access.
- (4) Enclosures shall be coated with several coats of anti-sulphuric or anti-alkaline enamel inside and outside within the manufacturer standard colour. All equipment doors shall be hinged and provided with lockable handles (all keyed alike), or pad- lockable handles.
- (5) All status, alarm and instrumentation displays and all normal operator controls shall be visible and accessible to a person standing on the floor.
- (6) All power circuit sub-assemblies except major magnetic elements shall have the capability of insertion or removal by one person without the use of mechanical means except to remove screws/bolts. Sub-assemblies performing similar functions shall be interchangeable. All power connections shall be bolted and readily accessible.
- (7) Control sub-assemblies shall be in racks or trays. Printed circuit boards shall be grouped according to function in a single location/rack in the module.

Protective Devices Requirement

The following protective devices and system shall be equipped within the UPS system:

- (1) Switches with Fuse for main AC input protection
- (2) Circuit Breakers for DC input protection
- (3) Switches with Fuse for AC output protection
- (4) Alarm warning system for the Rectifier, Charger, Inverter and Bypass Switch
- (5) Phase sequence, Reverse Power Relay, Earth fault, Low battery voltage, Self diagnostic annunciation system.

Performance Requirement

- (1) Overload : >110% for 10 minutes
: > 125% for 5 minutes
: > 150% for 1 minute
- (2) Overall efficiency : > 90% at 50% load to 100% load
- (3) Back-up time : 1/2 hours for 100% load, 0.8 pf lagging
- (4) Noise level : < 50 dBA peak when measured at 1.0 m from front panel

4.4.5.5 Components

4.4.5.5.1 Current Limiting

The rectifier/charger provides for input current limiting, whereby the UPS modules shall draw only sufficient power to drive the critical (very essential) load with an additional pre- set maximum power level to recharge the battery. Thus the input kVA drawn by the system is the sum of two components due to the critical (very essential) load and due to battery charging. The input current

is limited to 115% of the total rectifier rating.

4.4.5.5.2 Input Power Walk-In

When the mains are restored following an outage, the UPS modules shall initially draw no power over a period of approximately 15 seconds (known as walk-in time). The input power requirements shall rise to a level dictated by the power required to drive the critical (very essential) load and the additional pre-set power to recharge the batteries as described above.

4.4.5.5.3 Rectifier/Battery Charger Unit

- (1) The rectifier/charger shall be solid state type with relevant electronic control circuit.
- (2) The rectifier/charger shall have sufficient capacity to support a fully loaded inverter and at the same time maintain the battery at fully charged condition. If the battery is fully discharged, the rectifier/charger shall recharge the battery to 95% of its fully charged condition within 16 hours at the same time supplying full load current to the UPS system.
- (3) The unit shall be a complete set manufactured from the factory.
- (4) Electrical characteristics of the unit shall be as listed below:
 - (a) Rated input voltage : 415 Volts ac + 15%, -20%
 - (b) Input frequency : 50 Hz \pm 5%
 - (c) Input power factor : > 0.9 lagging when the system is operating at full load and nominal voltage.
 - (d) Input THDI : < 5% at rated load
 - (e) Input Current limiting : adjustable from 100% to 125%
 - (f) DC output voltage regulation : \pm 1%

4.4.5.5.4 Inverter Unit

- (1) The unit shall be a transistorized solid state type, IGBT, which shall be designed for Pulse Width Modulation technology interconnected with 3 phases isolation transformer and filter capacitor.
- (2) Output terminal of the unit shall be bus-bars type with a neutral bus size not less than 1.4 times of the rated current.
- (3) Electrical characteristics of the unit shall be as listed below:
 - (a) Rated output power (kVA) : As applicable (at power factor 0.92 lagging and up to 0.99)
 - (b) Output voltage, Transient and recovering
 - (i) Steady state : 415 Volts ac \pm 1%, 3 ϕ , 4W with Earth
 - (ii) Transient 0% - 100% step load : + 5% of rated voltage
 - (iii) Transient recovery time load : < 50 ms for non-linear load
and < 20ms for linear

	load	
(vi) Voltage imbalance	: < 1.5%	at 50% unbalance load
(vi) Phase Displacement	: < $\pm 2.0^\circ$	
(c) Output frequency		
(i) Steady state	: 50 Hz \pm 1%	
(ii) Free running	: 50 Hz \pm 0.1%	
(iii) Slew rate (df/dt)	: < 1 Hz/sec	
(d) Output harmonic distortion (THD)		
(i) 100% linear load	: < 1%	
(ii) 100% non-linear load	: < 5%	

4.4.5.5.5 Static Bypass Switch

- (1) The static bypass switch shall be designed to bypass the critical (very essential) load from the inverter to the main power source in the event of UPS malfunctions, without interrupting the critical (very essential) load operation.
- (2) The static bypass switch shall be rated at least to carry full load continuously and shall be able to withstand any internal and external fault current not less than ten (10) times of full load within 20 milliseconds.

4.4.5.5.6 Maintenance Bypass Transfer Switch

- (1) A manually operated maintenance bypass switch shall allow the critical (very essential) load to be fed from the normal power source while providing isolation of the inverter and static bypass switch for safety during maintenance.
- (2) Testing of the maintenance switch may be performed while the load is being fed from the normal power source.
- (3) The bypass switch shall permit the transfer of critical (very essential) loads to the normal power mains during the electrical disconnection of the UPS module for maintenance purpose.

4.4.5.5.7 Battery Bank

The battery bank shall at least consist of the following:-

- (1) Set of batteries, in split banks to facilitate maintenance.
- (2) Battery racks, which shall be coated by acid resistant material from the factory.
- (3) Associated equipment of the battery, panel board and isolators.
- (4) Grounding system
- (5) Battery manager to have interoperability of the battery banks.

4.4.5.5.8 Battery

- (1) The battery shall be maintenance free Valve Regulated Sealed Lead Acid (VRSLA) type and each unit shall be enclosed in battery cabinet equipped with appropriate insulation.

- (2) The battery shall have capability to deliver the output power rating at the output terminal of the UPS for at least 30 minutes in the event of input power to the UPS failure.
- (3) The maximum and minimum voltage of the battery shall be matched with the operating input voltage of the inverter. The minimum final discharge voltage of the battery cell shall be limited at 1.75V or at the recommended value from the manufacturer and as approved by the Engineer.
- (4) Low Battery Voltage Protection: To prevent total discharge or damage to the battery, the UPS shall transfer to standby operation when the battery voltage reaches a set minimum voltage level (programmable). If AC input source has not returned within 10 minutes after “low battery” shutdown, the UPS shall electronically disconnect DC Power from the battery to avoid deep discharge.
- (5) Battery Monitor: Battery function monitor shall be capable of monitoring and defining battery capacity. It shall be possible to program the unit to perform an automatic battery test every 90 days to test the condition of the battery.

4.4.5.5.9 Associated Equipment of the Battery

- (1) The battery cell inter-connectors shall be copper bar and fully insulated. All bolts and nuts shall be of the acid resistant type.
- (2) All battery terminal posts shall be covered with soft rubber pole caps to prevent external short circuit.

4.4.5.5.10 Control and Annunciation System

- (1) The UPS shall incorporate the necessary control, instruments and annunciation to perform the complete function and to allow the operator to monitor the system status and performance as well as to take any appropriate action.
- (2) The control and annunciation system shall be micro-processor based control, complete with LCD display for monitoring of events and measured values.
- (3) The visible and audible alarm for the UPS shall be provided.
- (4) The minimum requirement for the measuring values for monitoring shall be as listed below:

(a) Input	:	Voltage, Frequency, Power,
(b) Output	:	Voltage, Current, Frequency, Power,
(c) Battery Output	:	Voltage, Current, Temperature, Autonomy time
- (5) The minimum requirement for the status and alarm for monitoring shall be as listed below:

(a) Rectifier	:	Off, Over Temperature, Failure
(b) Inverter	:	Off, Over Temperature, Failure

- (c) Battery : On Load, Over Temperature
- (d) Load on Bypass
- (e) Overload

4.4.5.5.11 Network Interfacing

- (1) A Network/Communication Port (RS485 or 10/100 Base-T or etc.) shall be provided within the UPS for remote monitoring and management.
- (2) The interface units shall be provided to interface with M & E SCADA for remote monitoring and management in Station Control Room and OCC respectively.
- (3) The UPS and Battery management software shall be provided complete with license number and documentation.

4.4.5.5.12 Enclosure

The UPS shall be housed in a free-standing enclosure. The enclosure shall be designed to blend into a computer room environment. The cabinet shall be equipped for fork truck lifting. The UPS cabinet shall be painted with the manufacturer's standard colour. All service access shall be from the front and top. Details of forced ventilation if required shall be furnished along with the design submission prior to manufacture. Overall dimensions of the UPS systems as also the battery banks shall be furnished and used for planning the station layout and station design. The weight of the UPS units and battery banks shall also be furnished and used for checking the structural floor loading and for station design.

4.4.5.6 Installation

The UPS and Battery Bank including associated equipment shall be installed in UPS Rooms. The installation, size of cables and conduits shall be as per the instructions and requirements from the manufacturer.

4.4.5.7 Testing and Commissioning

Upon completion of installation, the UPS and associated equipment shall be tested for the minimum requirements as follows:

The system shall be tested involving electrical characteristics as specified above for the following load conditions for a period of not less than 8 hours.

- (a) No Load
- (b) 50% Load (Dummy Load)
- (c) Full Load (Dummy Load)

Input and output voltage/current wave form shall be recorded, which shall be measured in each load condition of 0%, 25%, 50%, 75% and 100%.

The overall efficiency at 100% load shall be measured and recorded for each condition of main power supply from utility line and from batteries.

Grounding of the system shall be tested and results recorded.

Quality Control

All UPS installed shall be of industrial grade quality and the quality control shall be undertaken in accordance with the procedures set out in the

Contractor's Quality assurance and Quality management plan.

4.4.6 Diesel Generator

4.4.6.1 General

The Contractor shall supply, install, connect, test and commission a complete system of Prime duty type diesel generator sets to meet the load requirements for all essential loads as mentioned in these Specifications/Contract.

4.4.6.2 Standard and Reference

The diesel generator sets shall comply with the following codes and standards:

- (1) BS 5000 : Specification for rotating electrical machines of particular types or for particular applications
- (2) BS 5514 : Reciprocating internal combustion engines
- (3) BS 4999 : General requirements for rotating electrical machines
- (4) IS 1460 : Automotive Diesel Fuels
- (5) IS 4722 : Rotating Electrical Machines
- (6) IS 13364 : Specification for ac generators driven by reciprocating internal combustion engine

DG Set system as a whole should satisfy the requirements of Level 1, NFPA 110, Emergency and Standby Power Systems.

In addition to above all relevant Central Control Pollution Board (CPCB) notifications shall be complied & certificate of approval shall be produced by the Contractor.

4.4.6.3 Material Description

4.4.6.3.1 The scope shall include, but not be limited, to Design, manufacture, supply, including all transportation, storage, loading / unloading, insurance, installation, testing, commissioning and safe custody till handing over of the sound attenuated Diesel Generator sets.

The DG sets shall be complete with the following:

- (1) Sound attenuated weatherproof enclosures
- (2) Ventilation and illumination system for acoustic enclosure.
- (3) Engine with Radiator
- (4) Brush less alternator provided with suitable automatic voltage regulator conforming to IS 4722, BS 5000. The alternator shall be self-excited, self-regulated, self-ventilated type
- (5) Residential type of silencer
- (6) Bank of starting batteries with battery charger for trickle boost and charging
- (7) AMF Panel with load switches (one for feeding Essential Power Panel and one for Fire Pump Panel)
- (8) Anti-vibration mounting pads
- (9) All piping system between engine and radiator
- (10) Piping system for fuel line from engine to day tank (internal and external)

tanks both). The pipes shall be MS pipes of 25 mm diameter or braided flexible.

- (11) The day tank with a maximum capacity of 990 litres or sufficient for one shift operation at full load.
- (12) Provision of necessary signals for Station Management System (SMS)/Building Management system(BMS).
- (13) Miscellaneous safety and other items viz. rubber mat in front of AMF Panel, maintenance schedule board, cabinet for spares, danger sign boards, first aid box etc.
- (14) Exhaust piping system including MS pipes, specials, bends, flanges, reducers, etc. connection to silencers and lagging the exhaust pipe as per Environmental standards.
- (15) All wiring / cabling and connections including trenching, resurfacing as required between the following:
 - (a) Engine Control Panel and AMF Panel.
 - (b) Starting battery bank and engine control
 - (c) Engine mounted alternator to static battery charger
 - (d) Electrical Panel and Fuel pumps, etc.
 - (e) Battery charger to batteries
 - (f) Any other cabling required to complete the work

- 4.4.6.3.2 All the cables (power and control) shall be Flame Retardant Low Smoke Zero Halogen-type. The Contractor shall submit cable schedule and plan to the Engineer before executing the work for obtaining a Notice of No Objection. The cables sizing and laying shall be as per manufacture's recommendation. For AMF application, 8/10-core 2.5-sqmm flexible armoured copper cables shall be used. All the cable should be crimped, marked & tagged and routed through proper cable glands in the control panel.
- 4.4.6.3.3 For Earthing of DG set, AMF panel, neutral earthing , the earth stations / electrodes, main earth terminals and connection from the Main Earth Terminal to equipments in the DG room shall be provided by the Contractor. All the requirements of IE Rules, NBC etc. shall be complied for earthing and safety of the system.
- 4.4.6.3.4 All other works, not specifically mentioned but required for satisfactory completion of work shall be done by the Contractor.
- 4.4.6.3.5 Automatic Gas flooding of AMF panel, using linear heat sensing tubes Fire trace or equivalent shall be provided by the Contractor.
- 4.4.6.3.6 If the generator set is available for service, is set to automatic control and has not runs in the last 7 days, the set shall be started and run for a pre-determined period (set in the range 30 to 60 minutes) in the no-load condition. The DG Set shall actuate an alarm to run the DG Set automatically for ½ Hour to 1 Hour in idle condition if the Engine has not been run for the last seven (7) days. A manual bypass shall be provided to bypass automatic idle run.
- 4.4.6.3.7 Through calculation or software simulation it shall be shown that the DG Set Alternator and Engine are able to start the Tunnel Ventilation Motors under

the worst conditions without causing the excessive voltage or frequency drop on other connected loads. The alternator selected should have suitable characteristics for this purpose.

4.4.6.4 Component

4.4.6.4.1 Diesel Engine

(1) Construction

- (a) The Engine shall be internal combustion type direct injection, cold start suitable for diesel fuel, 1500 rpm, turbocharged, with electronic governor suitable for auto synchronization, 4-stroke of suitable rating with provision of 10% overload for 1 hour in every 12 hours of running. Engine shall be multi- cylinder of in-line or V configuration and complete with basic accessories.
- (b) Engine shall be built to comply with BS 5514. The engine shall be complete with cooling fan drive, lubricating oil filters, air cleaners, starter motor/exciter, battery charging, regulator, fuel injector, fuel control solenoid, fuel lift pump, engine speed adjustment, other standard / operational accessories and protective devices.
- (c) The Diesel Engine shall be designed for operation on High Speed Diesel (HSD) Fuel conforming to IS: 1460 – 2005.
- (d) The engine shall be fitted with a heavy, dynamically balanced flywheel suitable for constant speed generator duty to meet the cycle variation requirements as per relevant standard. An electronic speed governor shall be fitted to maintain engine speed at all conditions of load in lines with the requirements of BS: 5514.
- (e) Cylinder housing and crankcase shall be of high-grade cast iron with overhead valves. Housing and heads shall be provided with necessary cooling fins.
- (f) Crankshaft shall be manufactured from solid forging with hardened crank pin and main bearing journals. The entire shaft shall be truly balanced.
- (g) Pistons shall be of aluminium alloy and provided with necessary compression and scrapper rings and a fully floating gudgeon pin.
- (h) Connecting rods shall be H-section steel stampings. Camshaft shall be gear driven (fly-wheel end) and easily removable.
- (i) DG set shall be able to start automatically even in cold condition without any adverse effect on its performance and capable to take full load within 10 seconds (wake up time) of failure of normal supply.
- (j) DG set shall be designed for low specific fuel consumption and shall be ≤ 220 g/kwh, 5 star rated in accordance with BEE labelling.
- (k) The DG set shall be suitable for working in parallel with another DG set by installation of an auto-synchronizing panel.
- (l) The DG set shall be suitable for continuous operation under the ambient conditions without any adverse effect on its performance. The set shall be used only for the standby purposes, supplying rated

load for periods of up to 8 hours continuously, followed by a rest period of not less than 30 minutes.

- (m) The AMF panel shall be connected & provided with suitable interlocking arrangements to ensure automatic starting of the DG set in case of failure of supply from both the sources and interlocking arrangement to avoid any incident of paralleling of normal power supply with DG set supply.

(2) Cooling

- (a) The engine shall be complete with suitable radiator for cooling the machine in tropical ambient temperatures, with engine-driven blower type heavy-duty cooling fan and radiator core.
- (b) Water-cooled with fan and radiator, with engine driven circulating water pump, thermostat, temperature gauge with high temperature alarm / trip. Cooling water circuit shall be fitted with corrosion inhibitors.
- (c) A thermostatic valve should by-pass the coolant in the primary circuit until a pre-set operating temperature is reached.
- (d) The design shall take into account compensation for possible ingress of dirt, which may normally clog the fins. The choice shall take into account the place of installation and the flexibility available for locating cooling system, air circulation and smoke exhaust.
- (e) The DG sets, if installed inside the underground station shall be planned with suitable cooling arrangement and air circulation. A technical study shall be conducted and report prepared showing the amount of smoke generation & its effects in case the DG is installed inside the underground station, cooling air & combustion air needs/ its adequacy and the Contractor's proposal for taking all the mitigation measures related with the issues concerning installation of DG sets inside the underground station and for obtaining the Notice of No Objection from the Engineer and the relevant statutory authorities.

(3) Fuel Tanks

- (a) A Fuel Day tank of capacity of maximum 990 litres or one shift operation at full load inbuilt inside the acoustic enclosure(or at suitable location as agreed by the Engineer) complete with inlet and outlet connections, drain plug, manhole, graduated fuel level indicator etc. shall be provided by the Contractor duly complying the relevant statutory guidelines/requirements.

(4) Filtration

- (a) The engine shall have replaceable fuel oil filters. Lube oil filtration, air filtration shall be through replaceable filters.
- (b) Fuel Filters - A supply line fuel filters shall be fitted and shall be of twin replaceable elements type complying with BS 4552 and relevant IS.
- (c) Air filters - The engine shall be fitted with dry type air filters with replaceable elements. The engine shall be complete with fuel and

lubricating oil filters with replaceable elements.

- (d) Twin heavy-duty air intake filters in accordance with BS 7226 and relevant IS suitable for operating in dust- laden atmospheres shall be fitted. Breathers shall be fitted with washable filters, which are easily accessible for maintenance.

(5) Engine Exhaust

- (a) The engine exhaust piping shall be amply sized for minimum backpressure and connected to the engine manifold through flexible connection or an expansion joint on one side and to a silencer on the other side along with pipe. The silencer shall be package type with adequate attenuation for urban

use, constructed from heavy gauge galvanized steel. The sound absorbent infill shall be non-hygroscopic, vermin proof, non-combustible material. Engine shall be provided with residential type silencers so as to reduce the sound level to 75 dB measured at a distance of 1 meter from the DG set as per norms.

- (b) The exhaust piping from the silencer onward shall be led up to the specified/approved level and discharged through a rain cowl in accordance with CPCB guidelines. Entire exhaust piping and silencer shall be Class 'B' MS pipe and shall be glass wool insulated with 75mm thick 48Kg/cum density fiberglass, white wool. The insulation shall be held in position with 0.63 mm diameter, 20 mesh, galvanized steel wire mesh and finished neatly with 24SWG Aluminium cladding.
- (c) The generator set shall be provided with an exhaust system incorporating residential silencers. If possible, the silencers shall be contained entirely within the Generator building, but if necessary the installation shall comprise two silencers in series, with one located inside the building, and the second located externally on the roof of the generator building. Care shall be taken when locating the exhaust to ensure the exhaust gases are not drawn back into the air inlets of either the generator room or the pump room.
- (d) Flanged connection to the silencer and between pipe sections shall be made. Minimum wall thickness of pipes and the silencer shall be 3 mm. A stainless steel bellows unit shall be provided for connection onto the engine.
- (e) Exhaust pipes within the building shall be lagged and guarded to prevent accidental contact up to a height of 2.5 m. No part of any exhaust system installed outside the building shall be less than 3 m from ground level. Passage of exhaust pipes through walls or the roof shall be sleeved and shall be shrouded to prevent ingress of rain of vermin. Exhaust emission control shall be as per Central Pollution Control Board (CPCB) regulations and all other statutes.
- (f) Exhaust piping shall be fabricated from class 'B' MS pipes upto 150 mm dia conforming to IS 1239 of size suitable to limit backpressure to within permissible limit. The insulation thickness shall be as per

standard to achieve a maximum temperature of 60°C on the outside surface of the insulated pipe and supporting calculations for back pressure shall be furnished. Flanged joints in the exhaust piping shall be covered with removable insulation at suitable intervals for permitting access to the joint, as and when required. All flanged joints shall have high temperature gasket. The piping shall be installed with necessary thermal expansion facility as required. Exhaust piping shall be connected to the engine by means of flexible section or an expansion joint and shall also be graded to a drain pocket inside the building. The pocket shall be fitted with a drain cock.

- (g) The engine exhaust stack shall conform to the latest Regulation of the Central Pollution Control Board (CPCB).
- (6) Hot air exhaust (If Applicable)
 - (a) Hot air duct from DG engine radiator (top of the acoustic enclosure) to atmosphere shall be provided for routing the hot air generated by engine operation to keep the temperature rise of DG room within limits. The duct shall be constructed from GI sheet duct 1.0 mm (20SWG) thick including duct flanges, supports etc as per site layout requirement for radiator hot air outlet. In case the length of the duct is more than 3 meters (as constrained by site condition), an exhaust fan at the atmosphere end of the duct shall be provided.
- (7) Sound Attenuating Acoustic Enclosure
 - (a) Sound Attenuating Acoustic Enclosure should have pleasant and aesthetical looks and should be able to bring the sound noise to tolerable limits of 75 decibels when measured at a distance of 1 meter away from the set.
 - (b) The DG set should be supported on a base frame in an MS Sheet enclosure with suitable ducting for air inlet and outlet. The door and enclosure should be given corrosion resistant treatment and painted to be weatherproof and long lasting. Resin bonded Glass / Mineral / Rock wool of high density (greater than 45 Kg / Cu. M) with minimum thickness of 75 mm covered with perforated MS Sheet should be provided and covered with tissue paper. Enclosures should be provided with durable locking system with doors duly gasketed with neoprene rubber.
 - (c) Exhaust gases should be taken out from the DG Set by means of MS Pipe and a noise suppressor.
 - (d) Proper care should be taken for engine heat rejection in order to have safe working temperature inside the enclosure by provision of fans etc, as required. The design aspect should ensure free and uninterrupted flow of suction and exhaust air in order that the temperature rise of the enclosure with respect to the ambient is less than 7°C .
 - (e) The enclosure shall comply to the latest regulation of the Central Pollution Control Board (CPCB).

(8) Safety Systems

(a) Governor - The performance of the governor under load conditions shall be to Class A1 in accordance with BS 5514: Part 4 (ISO 3046). The governor shall meet the following performance requirements:

- (i) Steady state speed band: + 1% or + 0.25% of nominal speed,
- (ii) Transient frequency change on application or rejection of 60% load: $\pm 8\%$,
- (iii) Recovery time to steady state speed band on application of 60% load: 10 seconds,
- (iv) Maximum speed drop: 5%

The electrical over speed trip provided shall operate at 120% of the rated speed and shall be only be rest only by hand.

(b) Other safety controls and indicating instruments shall be provided.

(9) Engine Starting

(a) The starting system shall comprise a 12/24 V heavy-duty suitable capacity maintenance free high discharge lead acid battery, as required, and electric starting motor. The battery shall be sized to give not less than Ten consecutive starts of the engine at 0°C. The starting system shall be complete with necessary relays, solenoid valves for fuel, control and indicating panels as specified and required.

(b) An engine driven alternator and charging system shall be provided. A mains powered battery charger shall be provided, with sufficient capacity to maintain the battery in a condition to fulfill the starting requirements.

Automatic changeover shall be provided such that battery charging is carried out by the engine driven alternator at all times when the generator set is running.

(c) The mains powered charger shall be suitable for operation on a 240 V single phase supply and shall complete with the following indications and features:

- (i) Battery charge / discharge current,
- (ii) Boost charge / trickle charge selector,
- (iii) On / Off switch,
- (iv) Fault indication.

(d) The battery charge shall have a selector switch by which the rate of charging the batteries can be selected.

(e) If the equipment does not start within three starting cycles with appropriate interval between each attempt, the starting circuit shall be located and audio- visual alarm shall be given.

(10) Mounting and installation

(a) The engine shall be complete with suitable radiator for cooling the machine in tropical ambient temperatures, with engine-driven blower type heavy-duty cooling fan and radiator core.

- (b) A common rigid bedplate shall be provided for the engine and alternator, which shall be directly coupled. The coupling must be done after ensuring proper alignment of generator and engine shafts.
- (c) The entire set shall be housed in soundproof enclosure mounted on suitable Rubber-in-shear type vibration mounts with 6mm static deflection for isolating the building floor. A nominal base concrete pad (if required) shall be provided over which the engine set with its own base frame and vibration mounts shall be mounted.
- (d) DG Set in soundproof enclosure shall be housed in DG room at locations approved by the Engineer
- (e) Radio Interference - All equipments, provided under the scope, shall be so designed that they shall not cause interference with radio equipment. In the event of the inherent characteristics of the equipment being such that radio interference is possible, efficient devices to nullify the same shall be provided.
- (f) The installation of DG set shall be strictly in compliance with the manufacturer's recommendations.

(11). Emissions

The DG set emissions shall confirm to the latest regulation of the Central Pollution Control Board (CPCB).

4.4.6.4.2 Alternator

(1) Type & Rating

- (a) Alternator shall be 3 phase, 4 wire 50 cycles 415 volt, brush-less screen protected drip proof with self contained excitation system and self regulating and conforming to BS 4999/5000, IS 13364 Part-2 and continuously rated in accordance with IS: 4722 and IS: 13364 Part-2. The alternator should have the rated capacity at 0.8 PF. The alternator shall be designed to suppress radio interference in conformity with BS 800. It shall be of heavy-duty single/double bearing design, adaptable for direct coupling with diesel engine including excitation system, automatic voltage regulator, voltage adjusting potentiometer and low speed protection.
- (b) The supply interlocks shall be provided to supply the electricity after stabilization only. The excitation system shall provide an exceptionally rapid response to load change and alternator shall be designed for high motor starting capabilities.
- (c) The alternator shall be tropically insulated with H class insulation and windings shall be impregnated with thermosetting insulated varnish to use in
 - tropical climates. Ample ventilation shall be provided by shaft mounting fan as per manufacturer design.
 - (i) The neutral point shall be brought out separately and earthed permanently.
 - (ii) The band of voltage regulation shall be $\pm 1\%$ from no load to

full load and under varying load conditions.

- (iii) The overload capacity shall be 150-300 % for 10 seconds. Limitation, if any, shall be highlighted by the manufacturer.
- (iv) The Alternator shall be suitable for taking unbalanced load as per IS 13364 Part-2.
- (d) The alternator shall be of fabricated steel construction conforming to IP class specified, dynamically balanced rotor with single / two bearings and damper windings. The unit shall be with a large terminal box for outgoing cable connections specified. Necessary adapter box shall be provided if the terminal box is not adequate to receive the cables.
- (e) Alternator rotor shall be salient pole type with a damper cage and dynamically balanced. Insulation shall be to class 'H'. All winding shall be fully impregnated for tropical climates with high quality of epoxy varnish.
- (f) Ventilation to the alternators shall be by means of fans fitted on the rotor.
- (g) It shall handle 10% overload in one hour in every 12 hrs of operation without exceeding the permissible possible temperature rise for the class of insulation provided.

4.4.6.4.3 Excitation system

- (a) The main exciter shall receive power from a permanent magnet generator through separate auxiliary windings on stator via Automatic Voltage regulator.

The AVR shall be of solid-state circuitry and shall provide regulated voltage to the exciter compensating for all normal variations. The main exciter output is fed to the main motor windings via a rotating 3-ph bridge rectifier assembly, which shall be protected, from voltage surges, short circuit, overload and diode failures. The AVR and control gear shall be mounted in a component box on the side of the machine. Electrical connections to the AVR shall be taken through a multi way plug and socket.

- (b) Voltage regulation shall be within one percent under all conditions of load, power factor and temperature including cold to hot variation. There shall be no radio or television interference. Line voltage waveform shall be as true as possible with a total harmonic distortion not exceeding 3% on 3-Phase load.
- (c) The excitation system and engine governor should be such that the alternator is capable of starting up induction motors having a starting kVA of not less than 1.8 times the alternator rated kVA. Manufacturer should indicate the voltage dip and duration under such conditions as required under equipment data.
- (d) The neutral of each generating set shall be earthed solidly to ground with facility for isolation through a fully rated contactor or manual switch.

4.4.6.4.4 Automatic Mains Failure (AMF) operation

- (a) The AMF panel shall be capable of starting the DG set automatically in the event of unhealthy conditions of the main power supply including power (mains) failure, single phasing or voltage going below 85% or 360 V at the bus bar of MDB or Essential power panel and shall switchover essential load from the main supply to DG set. The voltage on both the incoming mains shall be continuously monitored through adjustable voltage monitor on all the three phases. To avoid unnecessary frequent starting and stopping of the DG set caused by momentary unhealthy condition, an adjustable timer with setting 1 to 10 seconds shall be incorporated in the control system. The DG set shall start automatically within 10 seconds of main supply failure. It shall be idle for three minutes after making change over from DG set supply to main supply, to ensure that the main supply has stabilized. The manufacturer shall specify the adjustable range in both the cases.
- (b) The AMF logic must be achieved through a microprocessor based circuitry to monitor engine controls with an on line mimic giving status of Engine running, voltage built up & other status as required & specified. AMF shall have 3 modes of operations viz. automatic, manual & test. The set shall be capable of starting and taking up the load within the time stipulated
- (c) The sequence of Automatic Mains Failure (AMF) operation shall be as follows:
 - (i). Upon main power failure, the generator shall receive 3 kick-starts and the generator breaker shall close only after building up of requisite voltage.
 - (ii) Hold the Mains Contactor or Breaker open.
 - (iii) On restoration of power, AMF logic should make change over from DG set to main supply and trip the engine after a preset time delay.
- (d) The AMF Panel should therefore comprise:
 - (i) 4 Pole MCCB with 4-pole contactor as main outgoing from AMF Panel, copper bus bar of adequate rating and two nos. 4-pole MCCBs as outgoing for Essential Power Panel (EPP) and Fire Pump Panel (FPP) of adequate rating, duly interlocked.
 - (ii) Battery charger with normal and trickle charging facility and an isolating switch.
 - (iii) Over load and Earth Fault protection for the generator set.

4.4.6.4.5 Protection / Annunciation

Protection and annunciation system conforming to latest standards like BS/IEC or IS with soft control and touch resets shall be designed and provided comprising of following but not limited to:

- (1) Overload and short circuit trip for the DG set
- (2) High temperature for cooling water trip If applicable.
- (3) Alarm in case the DG set is not run for one week at a stretch

- (4) Earth fault
- (5) Reverse power relay
- (6) Low battery voltage
- (7) Fault indication alarm through suitably designed Annunciator with in built hooter
- (8) Fuel low level alarm
- (9) Meters and Indicators shall be as follows

A: Meter generator

Battery 0 - 24V Voltmeter
 0 - 5A Ammeter for charge
 0 - 75mA ammeter for trickle charge

a. Indication and Alarm

annunciation Engine
 side

Additional Indication Alarm

Charger on	Yes	-
Failed to start	Yes	Yes
Additional	Indication	Alarm
Low oil press	Yes	Yes
Gen. on	Yes	-
Mains on	Yes	-

b. Auto-Manual change over switch

Start-Stop Reset

Buttons

Alarm Reset : Buttons

Lamp test

:Buttons

4.4.6.4.6 Battery System

- (1) There shall be a 12/24V Nickel Cadmium stationary battery with an AH capacity suitable for 10 (ten) cranking attempts of (10 seconds each) plus all indicating lamps and alarm before the cell voltage goes down by 1.8V. Battery shall be complete with necessary angle iron stand and multi strand flexible copper leads. The battery charger in the AMF Panel shall be capable of floating the battery with quick and trickle charging facility to maintain a cell voltage of 2 Volts.

4.4.6.4.7 Control System

- (1) The control system shall work on suitably supplied DC / AC operated system

with provision of alarm and operation status available on auxiliary terminal board so as to enable to extend alarm and operation status to operation control center & station control center. The metering system shall be based on digital indication with status on auxiliary contacts. The control system and metering panel shall provide for the following:

- (a) Metering/Indication
 - (i) Voltmeter
 - (ii) Phase sequence indication
 - (iii) Ammeter
 - (iv) KW Meter
 - (v) Frequency Meter
 - (vi) Battery Voltmeter
 - (vii) Common Fault Alarm Signal
 - (viii) KWH meter
 - (ix) Power factor meter
- (b) Counters
 - (i) Hours Run Counter
- (c) Controls
 - (i) Emergency Stop Button
 - (ii) Run/Off-Reset/Auto Control Switch
 - (iii) Lamp Test/Reset Push Button
 - (iv) 3 Attempt Start Timer
 - (v) Terminals for Remote / Emergency Stop
 - (vi) Interface to Remote Annunciator
 - (vii) Voltmeter Phase Selector Switch
 - (viii) Ammeter Selector Switch

4.4.6.4.8 Above or equivalent system shall be designed & provided as industrial standards.

4.4.6.4.9 The annunciation alarm shall be repeated to the station control room through Station Management System (SMS).

4.4.6.4.10 Network Interfacing

The DG system shall be provided to interface with Station Management System (SMS)/Building Management system(BMS) for remote monitoring and management in Station Control Room and/or OCC room (if available) respectively.

4.4.6.5 Installation

The DG including associate equipment shall be installed in the DG Room at locations as approved by the Engineer .

The instructions from the manufacturer shall be followed for the installation, size of cables and conduits .

4.4.6.6 Testing and Commissioning

- (1) The generator shall be thoroughly checked for correct operation and load tested in supplier works before dispatch. All fluid seals, faults, control functions and site load conditions shall be simulated, checked and proved. The equipment shall be dispatched after testing in presence of the Employer / the Engineer or the authorized representative of the Employer.
- (2) After installation, the set shall be run for a minimum period of 0.5 hours continuously on no load. On satisfactory completion of the no-load run the set shall be run for a period of one day at 6 hours a day at 100% full load. All consumables including fuel, lube oil and load banks required for commissioning the set shall be supplied by the Contractor. Test readings together with an hourly log of the running test shall be furnished to the Engineer.
- (3) The trial shall be conducted in the presence of the Employer /the Engineer and the test results shall be recorded in an approved format. Any abnormal condition occurring during trial run of the DG set shall also be recorded. Test results shall be recorded at 30 minutes intervals. All facilities, labour instruments, materials and consumables including fuel and lubricating oil required for the test shall be provided by the Contractor at his cost.
- (4) Test proving the satisfactory performance of all operating gear, safety functions and controls shall be carried out.
- (5) Performance test at site shall include (but not limited to) the following test acceptance criteria:
 - (a) Voltage variation \pm 1%
 - (b) Voltage regulation \pm 1%
 - (c) Frequency regulation \pm 1%
 - (d) Maximum water temperature \pm 5% of guaranteed performance
 - (e) Minimum lube oil pressure \pm 5% of guaranteed performance
- (6) The Contractor shall be required to carry out any further tests/trials that the Employer /the Engineer may desire to satisfy themselves that the Generator Sets and Associated equipments fully comply with the conditions as set out in these Specifications.

4.4.7 Not used

4.4.8 Low Voltage Cables

4.4.8.1 General

The Contractor shall Design, supply and install the low voltage cables and accessories as described and specified herein.

This cable Specification applies to both Station and tunnel area.

4.4.8.2 Standard and Reference

The cabling system and its constituent parts shall comply with the latest version of the relevant European Standards (EN), British Standard (BS), International Electro technical Commission (IEC), local standards, or equivalent national standards

The low voltage cabling system shall comply with the following standards where

appropriate:

(1)	IEC 60228	:	Conductors of Insulated cables
(2)	IEC 60502-1	:	Power cables with extruded insulation and their accessories for rated voltage from 1 kV – Part 1: Cables for rated voltage of 1 kV
(3)	IEC 60332	:	Tests on electric cables under fire conditions
(4)	IEC 61034-2	:	Measurement of smoke density of cables burning under defined conditions – Part 2: Test Procedure and Requirements
(5)	IEC 60754	:	Tests on gases evolved during combustion of electric cables
(6)	BS 6387	:	Specification for performance requirements for cables required to maintain circuit integrity under fire
(7)	IS 694	:	PVC insulated cables for working voltages up to and including 1100 V.
(8)	IS 1554	:	PVC insulated (heavy duty) electric cables
(9)	IS 7098	:	Cross-linked polyethylene insulated PVC sheathed cables
(10)	IS 5578	:	Guide for marking of insulated conductors
(11)	IS 732	:	Code of Practice for Electric Wiring Installations
(12)	IS 1255	:	Code of practice for installation and maintenance of power cables
(13)	IS 8130	:	Conductors for insulated electrical cables
(14)	IS 10418	:	Drums for electrical cable
(15)	IS 10810	:	Methods of test for cables
(16)	IS 3961	:	Recommended current rating
(17)	IS 5891	:	Recommended short circuit rating of high voltage PVC cables
(18)	IEC-332	:	Flammability Characteristics of cables
(19)	SS4241475 class(F3)	:	Flammability Characteristics of cables
(20)	ASTM-D-2843`	:	Determination of smoke generation of outer sheath

4.4.8.3 Submittal

The Contractor shall submit the technical data, catalogues, cable installation drawings, cable routes, cable connection and other necessities of the low voltage cables for Notice of No objection before procurement and installation.

Manufacturers' Routine test reports and Type test reports as necessary for each type of cable in accordance with the standards as mentioned above and Contract Specifications shall be submitted.

4.4.8.4 Material Description

Power cables shall be of single, two, three or four conductors depending on the requirement and are to be rated for 1100V grade, and shall be used in a 3-phase, 4-wire, 50 Hz, solidly grounded system.

All cables shall be suitable for indoor and outdoor installations, wet and dry locations, exposed to sunlight, in conduit, in cable tray as appropriate.

The conductors shall be unbroken for the full length of the reels.

Type of the low voltage cables shall be specified by the category of service as indicated below:

- (1) Cables conforming to BS 7846: "Specification for 600 / 1000V fire resistant armoured cables having thermosetting insulation and low emission of smoke and corrosive gases when affected by fire"
Fire resistant / fire survival power cables shall be provided for the emergency lighting circuits, UPS supply circuits, battery and charger circuits, fire services installations, smoke extraction system, staircase pressurization system, fireman lifts, disable lifts, and those circuits required to maintain circuit integrity under fire conditions. Cables for loads classified as the "Emergency" loads shall be Fire Survival type and shall conform to NFPA requirements.
- (2) Cables conforming to BS 6724: "Specification for 600 / 1000V armoured electric cables having thermosetting insulation and low emission of smoke and corrosive gases when affected by fire "
- (3) Cables conforming to BS 7211. "Specification for Thermosetting insulated cables (Non-armoured) for electrical power and lighting with low emission of smoke and corrosive cases when effected by fire "

The total voltage drop from the Main Low Voltage Switchboard to the end load shall not exceed 5%.

4.4.8.5 Component

4.4.8.5.1 All cables shall be insulated with extruded Cross-linked Polyethylene (XLPE) / complying with the requirements of BS 7655 (Type GP8). The multicore XLPE insulated cables shall be rated for continuous operation at a maximum conductor temperature of 90 °C and for a maximum short circuit temperature of 250 °C. XLPE Cable

- (1) The cables shall be 1100 Volt grade XLPE insulated with PVC inner sheath, steel armouring and with an outer protective sheath of Flame Retardant Low Smoke Zero Halogen type compound, conforming to IS: 7098 (Part I). Cables shall have high conductivity stranded Aluminium or copper conductors and cores colour coded to the Indian Standards.
- (2) The cable shall be helically wrapped over the insulation and copper shielding with non-hygroscopic Mylar or Polyester tape.
- (3) The shielding shall be annealed copper tape of suitable width and shall be helically applied over the inner jacket with a minimum 10% lap. The annealed copper tape shall be of at least 0.1mm thickness and substantially free from burrs.
- (4) Fillers shall be used in the interstice of the multi-core conductor cable where necessary to give the complete cable a substantially circular cross section. Fillers shall be of polypropylene, non-hygroscopic materials.

4.4.8.5.2 Fire Resistant Cable (FR)

- (1) Fire Resistant (FR) cables with the cable size of 6 mm² or less, or branch circuit wire such as emergency circuits, shall be single sheathed and installed in conduit or trunking. FR cables with sizes larger than 6mm² shall be mica or XLPE insulated and sheathed with fire resistant or fire retardant, low smoke zero halogen flame retardant, material.

- (2) Outer sheath shall be of polyethylene or other material that have Flame Retardant Low Smoke Zero Halogen-properties. For multi-core cable spacing between conductors shall be filled with filler.
- (3) Rated voltage of cable shall be 1.1 KV.
- (4) These cables shall be resistant to flame temperature of 250°C for 2 hours (900°C for 2 hours for life safety equipment/systems) minimum and water spray as defined in BS6387.
- (5) Cable shall not generate corrosive gases when burnt.
- (6) Standard for Testing of Fire Resistance shall be conforming to BS 6387 Category C, W, Z.
- (7) Standard for Testing of Flame Retardant shall be conforming to IEC 60332-1.
- (8) Standard for Testing of Low Smoke shall be conforming to IEC 601034-3.
- (9) The Contractor shall submit the test report for Notice of No objection.

4.4.8.5.3 Control Cable

- (1) All control cables shall be suitable for installation in wet and dry locations. The conductor shall be of soft or annealed strand uncoated copper wire.
- (2) The insulation shall be Flame Retardant Low Smoke Zero Halogen, XLPE insulated cables suitable for use on a copper conductor with a maximum operating temperature not less than 70°C.
- (3) Fillers shall be used in the interstice of the multi-conductor cable where necessary to give the complete cable a substantially circular cross section. Fillers shall be Polyethylene (PE) materials.
- (4) The cable shall be helically wrapped over the filler and copper shielding with non-hygroscopic Mylar or Polyester tape.
- (5) The shielding, for control cables, shall be annealed copper tape of suitable width and shall be helically applied with a minimum 10% lap. The annealed copper tape shall be of at least 0.1mm thickness and substantially free from burrs.

4.4.8.6 Installation

All power cables shall be delivered on robust cable drums with cable ends treated to from an effective seal. When a cable is cut from a drum the cable end and the end left on the drum shall be immediately sealed in an approved manner to prevent the ingress of moisture.

In general, the Power cables shall be run in conduits, in cable tray and shall be run concealed in ceiling, floor, and wall.

All cables shall be adequately protected against any risk of mechanical damage to which they may be liable in normal conditions of services. No wire shall be pulled into the conduit system until it is complete in all respect.

Lubricant shall be used to facilitate wire pulling. Lubricants shall be of approved type for using with the insulation specified.

Splicing of wires and cables shall be allowed only in the luminaires, receptacles and proper junction box with an approved method of insulation. No splice shall be made in conductors for instrument circuits or control circuits.

Splicing of large wires and cables shall be by compression type, solder less wire

connectors indented by special hydraulic tool. The splice shall be insulated with plastic insulation tape such as Scotch Brand No.35. Thickness of the tape shall not be less than three layers or at least the same thickness as the wire insulation.

Compression type, solder less lugs indented by proper tool shall be used at the end of all wires and cables and shall be connected to the screw type terminals of the equipment and to the bus bars.

The cut end of cables shall be treated to prevent ingress of water into the cable. When unreeling cable from the cable drums, special care shall be taken to prevent damage to the cables. When removing the cover of the drum, care shall be taken to prevent damage to the cable sheath.

The Contractor shall provide all necessary materials for installation of the cables, such as grounding lead wires, compression type terminals, metal fitting, bolts and nuts including cable identification and felt packing to be inserted between cable and cleats.

The unoccupied space in cable knockouts and conduits after cable insertion shall be filled, with duct seal to prevent insects and rodents from entering the equipment housing.

Where cables are buried in the ground the minimum depth of burial shall be 0.6 m. Cables shall be laid on 0.15 m and covered by a 7.5 cm. layer of clean sand or as indicated in Bureau of Indian Standards. Cables shall be covered with tiles and or marking tape and the trenches backfilled to grade level.

Cables under roads shall be enclosed in ducts supplied and installed by the Contractor.

All cables shall be identified by means of cable tags fitted to each termination point and at 30 metre intervals along cable route.

Cable route markers shall be installed above ground along underground cable routes. These shall be located at 30 metre intervals, at change of direction and at entries to buildings.

The Contractor shall be responsible for the supervision of the cable trench excavation, sanding and backfilling, supply and installation of warning tape, cable tiles and cable marker posts as detailed in these Specifications and/or as required.

Cables shall be laid in one continuous length.

Cable Loops

At the time of the installation approximately 3 metres of surplus cable shall be left at each end of the cable on each side of underground straight through/tee/termination joints, at entries to buildings and such other places as may be decided by the Engineer.

This cable shall be left in the form of a loop. Wherever long runs of cable length are installed cable loops shall be left at suitable intervals as specified by the Engineer.

Conductors with compression type terminals and insulation cover shall be arranged in a neat manner on terminal box or equivalent terminals. The

Contractor shall install plastic cable tie-wraps as required to neatly group cables and to keep the weight of the cable from damaging terminations.

Cable entry into buildings shall be made through RCC pipes recessed in the floor. RCC Hume pipes shall be provided well in advance for service cable entries. The pipe shall be filled with sand and sealed at both ends with bitumen mastic to avoid entry of water. Suitable size manholes shall be provided wherever required to facilitate drawing of cables as per requirements.

Where cables pass through structural elements such as floors and walls, the opening made shall be sealed with the approved fire-resistant material of not less than 2 hours fire rating to prevent spread of fire.

Where cables pass through expansion joints, the cables shall be formed into a loop which shall be of such size that any movement in the joint shall not stress the cables.

Laying and Drawing of Wires Bunching of Wires

Wires carrying current shall be so bunched in conduits that the outgoing and return wires are drawn into the same conduit. Wires originating from two different phases shall not be run in the same conduit.

Drawing of Wires

The drawing of wires shall be done with due regard to the following precautions:-

- No wire shall be drawn into any conduit, until all work of any nature, that may cause damage to wire is completed. Burrs in cut conduits shall be smoothened before erection of conduits. Care shall be taken in pulling the wires so that no damage occurs to the insulation of the wire. Approved type bushes shall be provided at conduit terminations.
- Before the wires are drawn into the conduits, conduits shall be thoroughly cleaned of moisture, dust, dirt or any other obstruction by forcing compressed air through the conduits if necessary.
- While drawing insulated wires into the conduits, care shall be taken to avoid scratches and kinks which cause breakage of conductors.
- The Contractor shall, after wiring is completed, provide a blank metal/sunmica plate on all switch / outlet / junction boxes for security and to ensure that wires are not stolen till switches / outlets etc. are fixed at no extra cost to the Employer. The Contractor shall be responsible to ensure that wires and loop earthing conductors are not broken and stolen. In the event of the wire being partly / fully stolen, the Contractor shall replace the entire wiring along with loop earthing at no extra cost to the Employer. No joint of any nature whatsoever shall be permitted in wiring and loop earthing.

Termination /Jointing of Wires

- Sub-circuit wiring shall be carried out in looping system. Joints shall be made only at distribution board terminals, switches/buzzers and at ceiling roses/connectors/lamp holders terminals for lights/fans/socket outlets. No joints shall be made inside conduits or

junction/draw/inspection boxes.

- Switches controlling lights, fans or socket outlets shall be connected in the phase wire of the final sub circuit only. Switches shall never be connected in the neutral wire.
- Conductors having nominal cross sectional area exceeding 1.5 sq. mm shall always be provided with crimping sockets. Tinning of the strands shall be done wherever crimping sockets are not available as per instructions of the Engineer.
- All wiring shall be labelled with appropriate plastic ferrules for identification.
- Brass nuts and bolts shall be used for all connections.
- Only certified valid license holder wiremen shall be employed to do wiring/jointing work.
- All Cable terminations for conductors upto 10 sq.mm may be insertion type and be terminated through cage claps as required/feasible and all remaining & higher sizes shall have tinned copper compression lugs. The end terminations shall be insulated with a minimum of six half lapped layers of PVC tape. Cable armouring shall be bonded at both ends.
- Soldered jointing / termination shall be totally avoided. Solder-less terminations by using crimping tools, suitable lugs and double compressor brass glands shall be used. In the case of aluminium conductor, it is to be ensured that the conductor oxidation is cleaned by means of emery paper and then a thin coat of tin is applied before termination.

Cable Identification

- (1) All Cables shall be provided with identification markers, at each end of the cable, at entry and points of buried ducts, and in such other positions as are necessary to identify and trace the route of any cable. Where cables are not enclosed in ducts and are of multiple runs, markers shall be provided at 10m intervals.
- (2) Cable identification shall be assembled from elliptical profiled plasticized PVC markers, carrier strip and nylon ties and the complete assembly shall be suitable for a maximum service temperature of 70 degree C.
- (3) Every single core cable and every core of multicore cable shall be provided with identification at its terminations in the form of tapes, sleeves or discs of appropriate colours prescribed in accordance with the requirements of the Engineer .

Load Balancing

The Contractor shall plan the load balancing of circuits in 3 phase installation and get the same approved by the Engineer before commencement of the work.

The conductors in vertical raceways shall be supported if the vertical rise exceeds the values in following table:

Wire size Conduit size	Maximum no of PVC/ <u>Flame Retardant Low Smoke Zero Halogen</u> -PVC insulated 1100 V grade aluminium/copper conductor wires inside conduits conforming to IS : 694				
	Ø 20 mm.	Ø 25 mm.	Ø 32 mm.	Ø 40 mm.	Ø 50 mm.
2.5 Sq.mm.	5	8	12	-	-
4 Sq.mm.	3	6	10	-	-
6 Sq.mm.	2	5	8	10	-
10 Sq.mm.	2	4	6	8	-
16 Sq.mm.	-	2	3	6	10
25 Sq.mm.	-	-	3	5	8
35 Sq.mm.	-	-	-	3	6
50 Sq.mm.	-	-	-	-	5

Spacing for Conductor Supports in Vertical Raceway		
Size of Cable (mm ²)	Maximum Spacing (m)	Remark
50 or smaller	30	If the vertical run are less than 25% of max. spacing in table, cable supports shall not be
70 thru 120	24	
150 thru 185	18	
240	15	
300	12	
over 300	10	

Colour coding for the low voltage cables shall be as follow:

- (1) Phase R : Red
- (2) Phase Y : Yellow
- (3) Phase B : Blue
- (4) Neutral : Black
- (5) Ground : Green or Yellow Strip Green
- (6) Large wires and cables shall be colour coded with tapes as specific colour.

4.4.8.7 Testing and Commissioning

All the materials employed in the manufacture of the cable shall be subjected to tests specified in relevant standards before manufacture of the cable.

- A) The manufacturer must have type test certificates from the third party accredited laboratories certifying compliance to all the type tests mentioned in the relevant clauses of BS 6724 / BS 7211/ BS 7846 and relevant tests mentioned in Clause E02.2.1.1. In case of non – availability of these test certificates, the manufacturer must get these cables type tested at third party accredited laboratory prior to production of cables.

After completion of manufacture and prior to dispatch the cables shall be subjected to routine & acceptance tests as specified in relevant standards.

In addition to the above tests, test certificates from the third party accredited laboratories for the following tests must be supplied. In case of non – availability of these test certificates, the manufacturer must get these cables type tested at third party accredited laboratory prior to production of cables.

1. Accelerated water absorption test for insulation
2. Oxygen Index Test
3. Temperature Index Test
4. Smoke density test

Cable Accessories

- B) The type tests shall include the following tests conforming to the latest IEC 502 and VDE 0278 specifications. Type test certificates shall be furnished along with the offer.

1. AC voltage with stand dry test for 1 minute.
2. Partial discharge test
3. Impulse voltage with stand test with 10 impulses of each polarity.
4. AC high voltage test following load cycling test
5. Thermal short circuit test
6. DC voltage withstand test
7. Humidity test
8. Dynamic short circuit test
9. Salt fog test
10. Impact test

The Contractor shall maintain a record of test results commencing from the Manufacturer's tests conducted at the place of manufacture for comparison with the values obtained at site before and after installation. The cause for any appreciable change shall be investigated and corrective action taken as agreed with the Engineer. This record shall be a submittal at the time of handing over.

Power cables, 1100 volts grade, shall be meggered phase-to-phase and phase-to-ground before the equipment is connected and phase-to-ground after the equipment is connected and all connections are taped.

Insulation resistance tests shall be performed by using a 500 V dc megger on the 400 volts system. Insulation resistance shall be not less than 50 mega-ohms per 1000 volts rating.

Testing of Polarity of Non-Linked Single Pole Switches

In a two wire installation a test shall be made to verify that all non-linked single pole switches have been connected to the same conductor throughout, and such conductor shall be labeled or marked for connection to an outer or phase conductor or to the non- earthed conductor of the supply. In the three or four wire installation, a test shall be made to verify that every non-linked single pole switch is fitted to one of the outer or phase conductor of the supply. The entire

electrical installation shall be subject to the final acceptance of the Engineer as well as the local authorities.

Wiring Continuity Test

All wiring systems shall be tested for continuity of circuits, short circuits, and earthing after wiring is completed and before installation is energised.

Performance

Should the above tests not comply with the limits and requirements as above the Contractor shall rectify the faults until the required results are obtained. The Contractor shall be responsible for providing the necessary instruments and subsidiary earths for carrying out the tests. The above tests are to be carried out by the Contractor without any extra charge to the Employer.

Quality Control

All low voltage cables installed shall be of industrial grade quality and quality control shall be undertaken in accordance with the procedures set out in the Contractor's Quality assurance and Quality management plan.

4.4.9 Conduit, Cable Tray and Wireway

4.4.9.1 General

The Contractor shall furnish and install the conduits, cable trays and wire ways as described and specified herein.

Scope of Work

Cable Main Containment (ducts/Trays/Ladders etc.) in concourse, Mezzanine(where applicable) and platform/Track areas/station under-croft areas(Public and Non Public), tunnel (including cross passages) and ancillary buildings etc for namely signaling and Telecom, PSD, AFC, Lifts and Escalators, OHE/PS , TVS , ECS etc shall be provided by the Contractor along with the cable containments for station building services(all E&M works) except inside the respective plant/equipment rooms. . However, the following shall be provided by the respective Interfacing Contractors (System wide Contractors) and not by the Contractor:

- (1) cable containments for connection to the isolated and individual equipment.
- (2) cable containments within each plant/equipment room .

4.4.9.2 Standard and Reference

The conduits, cable trays and wire ways shall comply with the following codes and standards:

- | | |
|-----------------|---|
| (1) ANSI C80.1 | : Rigid Steel Conduit (RSC) |
| (2) ANSI C80.6 | : Intermediate Metal Conduit (IMC) |
| (3) ANSI C80.4 | : Conduit fitting |
| (4) ASTM A123 | : Hot-dipped galvanized for Steel Cable Tray |
| (5) IS 694 | : PVC Insulated cables for working voltages up to |
| and | including 1100 Volts |
| (6) IS 9537 P-I | |
| IS 9537 P-II | : Conduits for electrical installations |

- (7) IS 3837 : Accessories for rigid steel conduits for electrical wiring
- (8) IS 3480 : Flexible steel conduits for electrical wiring
- (9) IS 732 : Code of practice for electrical wiring installations
- (10) IS: 2667 : Fittings for rigid steel conduits for electrical wiring

4.4.9.3 Material Description

The conduit, cable tray and wire way shall be designed and manufactured in accordance to the Indian Standards or international standards and accepted by the relevant authority and shall be installed to comply with relevant provision in Indian Standards Specifications, Indian Electricity Rules and IE wiring regulation.

4.4.9.4 Component

4.4.9.4.1 Conduits and accessories

- (1) The steel conduits shall be manufactured from steel tubing, produced in electrical resistance welding process with the weld bead on both inside and outside removed and hot-galvanization in accordance with Indian standard IS:9537 or equivalent .
- (2) Size of conduit, fitting and accessories shall be as indicated, specified or as requested by the local utilities and reference standard.
- (3) The finished conduit and fittings shall have smooth surface, free of lumps of excess zinc, inside bead or other injurious defects or such defects detrimental to smooth wire pulling.
- (4) The outside surface and threads on conduit shall have protective coating against corrosion. The threads on the fittings shall have paint, zinc or other protective coating against corrosion.
- (4) Flexible conduit and fittings for life safety equipment shall be galvanized, water-tight pattern, flame retardant, Low smoke and fume, over-sheathed and separate earth wire enclosed within the conduit (if applicable).
- (5) The standard manufactured elbows shall be used for all sizes of conduits diameter larger than 1 inch (25mm), and the field bends to be handled with great care not to damage the conduits, shall be permitted to be used for conduit of 1 inch and smaller.
- (6) The conduits shall be defined in SI units. The table below shows the comparison of diameters of conduit in inches and in mm.

Conduit Diameter in Inches	½	¾	1	1 ¼	1 ½	2	2 ½	3	3 ½	
Conduit Diameter in mm	15	20	25	32	40	50	65	80	90	100

4.4.9.4.2 Cable Tray

- (1) Cable trays used indoors shall be made of hot-dip galvanized to BS 729 or equivalent Indian standards, after fabrication to afford good corrosion resistance during storage, installation and service life. The ventilated type

cable tray, punching, with cover shall be provided with the appropriate dimensions. The fabricated cable trays shall be made of a minimum 2.0 mm thickness steel sheet and shall be capable of being subject to temperatures up to 500°C for 1 hour and shall not support combustion under the same temperature.

- (2) The supports for horizontally run-cable tray shall be provided such that they shall be capable to adjust vertically. Where cable tray and cable ladder systems are supported by drop rods additional restraints shall be included to provide adequate lateral support. Restraints shall be installed at all bends and intersections and at intervals not exceeding 15 metres on straight runs. Support rods shall be at least 6mm diameter. Trapeze or other hangers shall be clamped on the drop rods between two nuts.
- (3) Support brackets shall be of the same type.
- (4) Site cuts or bends to hot dipped galvanized components shall be properly repaired in the field using cold galvanizer.
- (5) Cable drops to equipment shall be rigidly supported using cable tray. Structural steel members, plant pipe work support steelwork or walls may be used for cable drops.
- (6) Each section of the cable tray shall be electrically bonded, with a minimum 6 mm² cross section area earth-bonding strap or wire, to the next section to form an electrically continuous system and bonded to the main grounding system with green/yellow low smoke zero halogen material, sheathed, single core cable. All edges, fittings, or any parts of the cable trays shall be finished free from burr, sharp edges, or projections damaging to the insulation or jacket of the cables.
- (7) The number of cables installed on the cable tray shall be provided in compliance with the requirements of the Indian Standards Specifications, Indian Electricity Rules and IE wiring regulation. And 40% spare space capacity shall be provided for cable laying inside the cable tray.
- (8) Cable tray or ladder shall not be installed across building or structural expansion joints. On horizontal runs the tray or ladder shall be installed with a 20 mm gap at the expansion joint. Supports shall be installed within 150 mm on either side of the joint.
- (9) All cable trays and ladders installed in stations and tunnels shall be capable of being subjected to temperatures up to 500 °C for one hour and conform to National Electrical Code (NFPA 70).
- (10) Widths of cable trays, thickness of steel, flanges of trays, and bends or tees, shall be nominally as follows:

Width of Tray (mm)	Thickness of Steel (mm)	Flanges of Tray (mm)
300 & below	2.0	50
300-450	2.0	50
450-900	2	50
1000	2	50

4.4.9.4.3 Wire way (if applicable)

- (1) Wire way shall be made of hot-dip galvanized after fabrication to afford good corrosion resistance during storage, installation and service life and shall be provided to form the continuous steel sheet troughs with removable covers attached to the wire way by screws for housing the cables. The minimum thickness required for wire ways shall be as per the following table (in millimetre unit):

Size of wireways (width x height)	Thickness (mm)
50 x 50 up to 100 x 50	1.6
100 x 100 up to 150 x 100	1.6
200 x 100 up to 300 x 100	1.6
150 x 150 up to 300 x 150	1.6
Larger than above	2.0

- (2) Wire ways shall be installed so that all Signalling cables wireways are separate from power cables wireway.
- (3) Separated wireway for normal and emergency circuits shall be provided (4) The full length adjust vertically.
- (4) Each section of the wireways shall be electrically bonded, with a minimum 6 mm^2 cross section area earth-bonding strap or wire, to the next section to form an electrically continuous system and bonding to the main grounding system shall be copper with green/yellow, low smoke zero halogen material, sheathed, single core cable. All edges, fittings, or any parts of the wireways shall be finished free from burr, sharp edges, or projections damaging to the insulation or jacket of the cables.
- (5) The number of cables installed in the wireways shall be provided in compliance with the requirements of the Indian Standards Specifications, Indian Electricity Rules and IE wiring regulation. 40% spare space capacity shall be provided for cable laying inside the wireways.

4.4.9.4.4 Boxes and Accessories

- (1) Boxes shall be provided in the conduit work for cable connections, cable pulling, installations of switches, and installation of outlets.
- (2) All boxes provided in the conduit work shall be made of metal. A box provided for cable connections and concealed in or exposed on ceiling shall be a standard galvanized steel square or circular box or a metal box, made of steel sheet with not less than 1.6 mm thickness, with one primer anti-rust coated and two coating finishes.
- (3) All wall boxes on exposed work shall be of die cast aluminium or cadmium-plated cast-iron.
- (4) All boxes and conduit accessories shall be fully weather-proof when used in outdoor locations and other locations as agreed by the Engineer .
- (5) Conduit outlet boxes, for socket outlets, lighting switches, etc., shall be of

hot-dip galvanized steel complete with adjustable lug, ample knockouts, and brass earth terminals fitted in the base.

- (6) Each box shall be covered with a cover plate matching with the box construction and suitable for application condition.

4.4.9.5 Installation

System

The whole conduit system shall be installed to comply fully with the relevant provision in Indian Standard Specifications, Indian Electricity Rules and IE wiring regulations. Conduits shall be laid either recessed in walls and ceilings or on surface on walls and ceilings or partly recessed and partly on surface, as required. Steel wire of suitable size to serve as a fish wire shall be left in all conduit runs to facilitate drawing of wires after completion of conduiting.

Layout

Conduits from different distribution boards shall not be connected to the same junction box. Each run of conduit shall be assembled complete with draw in wires.

Joints and terminations

Where conduits are not jointed or terminated in boxes, they shall be terminated in a screwed brass bush.

Cleaning of Conduit Runs

The entire conduit system including outlets and boxes shall be thoroughly cleaned after completion of erection and before drawing in of cables.

Protection against Dampness

All outlets in conduit system shall be properly drained and ventilated to minimise chances of condensation/sweating.

Expansion Joints

When crossing through expansion joints in buildings, the conduit sections across the joint shall be through approved quality heavy duty metal flexible conduits of the same size as the rigid conduit.

All conduits shall be as specified herein with a minimum size of 15 mm. unless otherwise noted.

Where the conduits enter the cabinets and equipment, conduit bushings and double locknuts shall be used.

The end of all conduits shall be tightly plugged to exclude dust and moisture while the buildings are under construction.

The bending radius of the conduit shall not be less than six times the outer diameter of the conduits. The conduits used shall not have any internal and external defects. Each end of the conduit shall be made smooth with the conduit reamer to prevent damage to the wire.

A short piece of flexible metal conduit shall be used for connecting all motors, vibrating equipment, recess lighting fixtures and junction boxes and as otherwise specified.

The wiring system shall consist of Flame Retardant Low Smoke Zero Halogen

cables drawn into conduit. Wiring shall be loop-in style without joints.

The wiring capacity of conduits shall be as per Table of the current edition of the Indian Standards and as specified.

Conduit shall be run neatly on the surface or buried within the carcass of the buildings as indicated in these Specifications. Conduit shall be run at least 0.15 m. clear of plumbing and mechanical services.

Conduit shall be supported at regular intervals not exceeding 2.5 m. on horizontal runs and 1.5 m. on vertical runs.

The length of thread on the ends of the conduit shall be fixed to the structure or the building independently of the conduit.

The length of thread on the ends of the conduit shall suit the length of internal thread in the end of the fitting or accessory. Excess length of thread shall not be permitted.

Sleeves in floor slabs or beams for conduits shall be made of galvanized sheet steel, securely fastened in position. Floor sleeves shall be with their top and set at least 5 cm. above finished floor. Sleeves in beams shall be finished flush with the surface of the beam. Sleeves in telephone and electric rooms shall be filled with approved materials to provide a fire barrier. Both used and unused sleeves shall be filled.

All openings on floors and walls necessary for cable trays and wireways shall be provided by the Contractor unless indicated as being provided by others.

The conduits, cable trays, wireways and termination boxes for the electrical system shall have to be painted strip colour coding at an interval of 1 m along total length of raceways with;

(1)	Normal Power	:	Orange
(2)	Essential Power	:	Yellow
(3)	Control system	:	Blue
(4)	Network system	:	Grey
(5)	Signalling	:	Pink
(6)	Telecom	:	Purple
(7)	AFC	:	Green
(8)	PST	:	Red

4.4.9.6 Testing and Commissioning

Field inspection and testing for conduit, cable tray and wireway installed shall occur more than 1 week before equipment is energized or tested.

Quality Control

All conduit, cabletray and wireway installed shall be of industrial grade quality and the quality control shall be undertaken in accordance with the procedures set out in the Contractor's Quality assurance and Quality management plan.

Penetration in walls

Where proprietary cable transits are required, they shall be installed strictly in accordance with the manufacturer's recommended procedures. Where cables pass through walls, floors, or fire partitions, sleeves shall be installed to facilitate installation and subsequent withdrawal of the cable.

After installation of the cables, the hole(s) through which the cables pass shall be sealed with fire resisting material to achieve the fire rating as the structure through which they pass. Details of the proposed sealing method shall be submitted for approval prior to implementation. Cables passing through external walls shall additionally be sealed with appropriate additional weather protection to prevent the ingress of water.

The fire resisting material shall intumesce to form a hard char that tightly seals penetrations against flame spread, smoke and toxic fumes. The fire resisting material shall be tested according to ASTM E119, ASTM E814 and ASTM E84. Test certification and test report shall be submitted.

The materials shall not emit toxic gases on exposure to fire. The materials shall be easy to dismantle and replace in case of rearrangement and also withstand vibration due to rail operation and seismic tremor.

4.4.10 ELECTRICAL FITTING AND ACCESSORIES

Galvanized boxes shall be used as junction boxes, pull boxes or terminal boxes in exposed or embedded conduit runs. The boxes used shall be sized to code requirements. Boxes shall be provided where surface mounted cables interface with embedded conduits for proper termination of cable and cable fittings. Watertight cast iron boxes shall be used in wet or damp locations. Outlet, junction and pull boxes for use inside the building shall be zinc-coated.

All junction and pull boxes shall be installed so that covers are readily accessible and removable after completion of the installation. Boxes shall not be installed above suspended ceilings, except where the ceiling is of the removable type of definite provisions are made for access at a point close to each box.

All lighting switches, switched socket outlets, and isolators shall be labelled by an approved means to identify the circuit number and the source of supply to which they are connected.

Interface Terminal Boards

ITB shall be sized to contain terminal blocks which shall be barrier, screw type, rated at 30A per point, 1100V. Each point shall accommodate wire sizes up to 6 mm², and shall be equipped with slotted washer head binding screws. Blocks shall have white marking strips for terminal identification, and hinged covers. Blocks shall be mounted on parallel iron support bars spaced at least 50mm off the back panel. Space between rows of blocks and from row of blocks to panel sides shall be a minimum of 100mm to allow adequate space for wire connections. Removable link switches shall be provided to facilitate isolation between the incoming and the outgoing cables. Terminal boxes shall be of adequate gauge

galvanized steel, with hinged front cover.

Lighting Switches

Lighting switches shall be of silent action type and comply with SS227. They shall be marked or provided with a device indicating clearly whether the switch is in the “ON” or “OFF” position. The finishes for public areas shall be of matt-chrome and in back-of-house areas such as plant rooms, service corridors, etc. metal clad switches shall be provided. All lighting switches shall be rated at a minimum of 10A each.

Lighting switches shall be mounted at a height of 1400 mm above finished floor level to the bottom of the mounting box. All lighting switches shall be mounted on the lock side of the doors. The actual positions shall be determined on Site.

All lighting switches, either flush or surface mounted, shall be mounted on malleable iron or pressed steel boxes to BS 31.

Whenever the number of switches at one location exceeds one, multi-gang switches shall be used. Where more than one phase of a supply are brought into a multi-gang switch box, the switches, accessories and cabling connected to one phase shall be adequately separated from those connected to other phases.

Switches used to control discharge lighting circuit shall have a current rating of not less than twice the total steady load current which it is required to carry.

Where switches are located in exposed situation and wet area, switches shall be non-metallic weatherproof type to IP56. In other areas, switches with the appropriate IP rating shall be provided to suit the particular location.

Contactors

Lighting contactors shall be electrically held and shall be furnished in a general purpose, surface mounted enclosure, with full tungsten lamp rating, without the use of auxiliary arcing contacts. All contacts shall be removable without disturbing line or lead cabling. All coils shall be of moulded construction, replaceable without removing the contactor from its enclosure. Coils shall be suitable for continuous energization.

4.4.11 Luminaires and Associated Equipment

4.4.10.1 General

The Contractor shall Design, supply, install and commission a high efficiency lighting system for all area and buildings of the Underground Station, Tunnel, cross-passages including emergency lighting system. Light fittings for all areas shall be selected to suit various architectural design and finishes and the Contractor shall allow for the design co- ordination process that this shall entail. The light fittings and all associated accessories shall be subject to the Notice of No objection of the Engineer .

The Contractor shall engage a specialist lighting system consultant for carrying out a detailed review of the lighting design proposed by the Contractor in order

to meet the following objectives:

- (a) State of art, lighting system with modern smart luminaires;
- (b) Energy efficiency;
- (c) Integration with Architectural design and finishes of stations including signages;
- (d) Aesthetic appearance.

Lighting fixtures shall be manufactured locally by approved factory or imported from abroad.

The design of mounting details of the light fitting shall take into consideration the ease of maintenance. Where light fittings are mounted at high levels, the Contractor shall provide suitable means to enable the light fittings to be maintained without the use of portable ladders or other portable equipment with minimum interruption to the railway operation.

The Contractor shall design, supply, install and commission all the light fittings for all areas.

Emergency lighting in the Tunnel, cross-passages, escape corridors and staircases shall be un-switched.

Lighting in public areas shall be controlled via Lighting Control System's Workstation/M&E SCADA at station control room. The circuitry shall be designed such that the lighting could be controlled to achieve 25-50 Lux, 33%, 66% and 100% illumination levels as specified in Outline Design Specifications.

Lighting levels shall be uniformly distributed throughout the whole station, and shall be designed such that glare, dark recesses and areas of poor lighting levels are avoided. Highlight of 2 times the general illumination level shall be provided by down lighting for main entrance, lift front doors, tops and bottoms of stairs.

All offices, plant rooms, workshop, stabling yard/stabling sidings and stores shall have local switches to control the lighting in that area. Where six or more luminaires are provided in a single room, circuits shall be split and the multi-gang switches shall be provided.

The street lighting shall consist of luminaries on galvanized steel pole, for road lighting. Illumination levels

The illumination levels for various areas shall be as follows:

Areas	Average Normal (Lux)	Minimum Emergency (Lux)
UG Sump Room	150-200	25-50
Lift Maintenance Room	150-200	25-50
Pump Room	150-200	25-50
Inert Gas Room	200-250	25-50
Medium Voltage Switch Gear (MVSGR)	200-250	25-50
Low Voltage Switch Gear (LVSGR)	200-250	25-50
UPS Room	300	25-50
DG (fenced area) or DG Room	200-250	25-50

Areas	Average Normal (Lux)	Minimum Emergency (Lux)
Transformer Room (ASS Room)	200-250	25-50
Signalling Equipment Room	300-500	50
Signalling Control Panel Room	300-500	50
Communication Equipment Room	300-500	50
Communication Maintenance Room	300-500	50
Telecom closet	200	50
Station Control Room	300-500	50
Excess Fare Office	250-300	25-50
Ticket Issuing Window/Ticket Office	250-300	50
Secure Suite (SS)	200	25-50
Ticket Office Store & safe (TOST)	200-250	25-50
AFC Maintenance Room	200-250	25-50
Station Entrances & Passage ways	250	50
Concourse Public area	200-250	50
Security Room	200-300	25-50
Lift Lobby	200-300	50
Toilets	100-150	25-50
Locker Rooms	200-300	25-50
Lunch Room	200-300	25-50
Cleaners Room	150-200	25-50
Refuse Room	100-150	25-50
Store Room	150-200	25-50
PH Toilet	100-150	25-50
Janitors Closet	150-200	25-50
Retail/Commercial	200-300	25-50
Parking	100-200	25-50
Link Bridge	200-300	50
Corridor/Passage way	200-300	50
Fire Escape staircase	200-300	50
Paid Lobby Area	200-300	50
Unpaid Lobby Area	200-300	50
Platform (General)	200	50
Platform (Edge)	250	50
Tunnel Ventilation room	150-200	25-50
ECS and other plant Rooms	150-200	25-50
Tunnel Area (including cross- passages)	25-50	25-50

4.4.10.2 Standard and Reference

The luminaires and associated equipment shall comply with the following codes and standard:

(1)	IEC 60598-1	:	Luminaires – Part 1: General requirements and tests
(2)	IEC 60598-2	:	Luminaires – Part 2: Particular requirements
(3)	IEC 60400	:	Lampholders for tubular fluorescent lamps and starter-holders
(4)	IS 1913	:	General Safety requirements for luminaires
(5)	IS 1777	:	Industrial luminaires with metal reflectors
(6)	IS 3553	:	Specification for Watertight Electric Lighting Fittings
(7)	NFPA	:	National Fire Protection Association

The LED lighting need to be in compliance with LM79 and LM80.

4.4.10.3 Material Description

The luminaires as specified herein comprise of the lighting fixtures, lamp holders, lamps, ballasts, starters, emergency/exit lights and street lighting fixtures.

The Contractor shall provide lighting fixtures completely factory assembled, wires and equipped with necessary sockets, ballasts, wiring, shielding, reflectors, channels, lenses, brackets, fasteners and other parts necessary to complete the fixture installation.

All lighting fixtures, when installed shall be set true and free of light leaks, warps, dents, and other irregularities. The finish of exposed metal parts of lighting fixtures and finish trims of all recessed lighting fixtures shall be as directed/approved by the Engineer.

Each lighting fixture shall have a manufacturer's label affixed to it in a concealed location and shall comply with the requirements of all authorities having jurisdiction.

All luminaries, in general which are suitable for different applications, shall use LED lights.

After the fixtures are completely installed, the wiring system, wiring and fixtures must be tested against grounds and short circuit.

Power for normal lighting shall be obtained from normal supply lighting panels while the power supply for emergency lighting shall be obtained from UPS lighting panels which are backed-up directly by the Emergency Standby Generator power.

All hanger, cables, supports, channels, frames and brackets of all kinds for safely erecting this equipment in place, shall be furnished and erected in place by the Contractor .

The fixtures shall be supported from the building structure and the hangers shall be adjustable in length.

All luminaries shall be supplied with low loss control gear and electronic ballast unless otherwise stated.

Lighting fixtures fitted with the high frequency or electronic control gear shall be disconnected before the circuit is tested for insulation resistance.

Louvers or diffusers shall be restrained to prevent them from falling out of the body of the luminaires under normal conditions and when re-lamping. Metal louvers shall be connected to the body of the luminaire or the earth terminal by an insulated flexible copper conductor.

In addition to the primary fixing, all high bay luminaries shall be provided with safety chains to prevent them failing during cleaning or re-lamping.

4.4.10.4 Component

4.4.10.4.1 Lighting Fixtures

(a) LED Luminaries

- (1) The lighting fixture shall be made from high grade cold rolled steel sheet, 0.8mm minimum thickness, and be provided with a lamp compatible with the control gear used. All sheet steel components shall be suitably pre-treated and painted using acrylic polyester or epoxy powders, to prevent corrosion, in white colour or otherwise as specified by the Engineer.
- (2) Sheet metal work shall be free from tool marks and dents, and shall have accurate angles bent as sharp as is compatible with the gauge and materials of the required metal. All intersections and joints shall be formed true, of adequate strength and structural rigidity to prevent any distortion after assembly. Return or clean edges shall be free of all burrs or sharp spots.
- (3) Lamp sockets shall conform to IEC standard or equivalent.
- (4) Aluminium reflectors and louvers shall be made from high purity aluminium (99.85% minimum) with low or very low iridescence and a total reflection shall be of 87%. The anodic film shall have a minimum thickness of 2.5 microns.
- (5) Diffusers shall be made from UV stabilized acrylic or light stabilized polycarbonate, injection moulded or equal and as approved by the Engineer.
- (6) The luminaires shall be clearly marked, giving rated voltage method of operation and lamp wattage.
- (7) The 900C heat resistant with a minimum diameter of 1.5mm² cables shall be used inside the luminaries and shall be neatly secured within the fittings to prevent undue looseness and contact with the ballasts.
- (8) Where wiring passes through the edge of any metal section of the fitting, it shall be protected by an endurance tested grommet used in similar installations. All wire connections to terminals shall be of an approved type as approved by the Engineer. All wiring shall be concealed from view when the luminaries are installed.
- (9) The housing shall be fabricated so that all electrical components are

easily accessible and replaceable without removing fixtures from their mountings, or altering adjacent construction.

(b) Emergency Lighting and Exit Sign

- (1) The addition of conversion kits to luminaires specified elsewhere shall only be carried out in the factory of either the original luminaire manufacturer or the suppliers of the conversion kit. In either case the supplier of the conversion kit shall inspect and approve the modification work.
- (2) Self-contained conversion kit shall contain an emergency lighting module and battery pack.
- (3) The Nickel Cadmium battery shall have ample capacity to maintain lamp in the fitting for up to 2 hours after the mains supply fails.
- (4) The module shall contain a battery charger with charge indicator, inverter, low battery voltage disconnect circuit and changeover relay.
- (5) The Solid State charging system shall be capable of recharging the battery to full capacity in 24 hours after a total discharge of the battery.
- (6) An LED charge indicator shall be visible from below. Allowance shall be made to extend the LED circuit and incorporate it into the luminaire body or into the ceiling adjacent to the luminaire using a purpose made ceiling plate.
- (7) The internal temperature of the luminaire shall not exceed the battery manufacturer's recommended ambient temperature for their batteries.
- (8) Where the ambient temperature of the luminaire exceeds that recommended for the batteries then the batteries shall be mounted externally in a ventilated sheet steel enclosure with a minimum rating of IP 20.
- (9) Where remote conversion kits and/or batteries are mounted more than 0.5m from the luminaire, they shall be interconnected using wiring complying with International Standards.
- (10) Conversion kits deriving their emergency supply from a central battery shall contain an inverter ballast and changeover relay.
- (11) Exit signs shall be manufactured to meet the appropriate requirements of the local regulations, or other International Standard, and shall be operated from a single phase, 240V 50Hz system. The units, when installed, shall be concealed.
- (12) Each Exit sign shall be internally illuminated by two separate systems of lighting.
- (13) The housing shall be designed to maintain an internal ambient temperature below that of the lowest temperature rating of any piece of equipment installed therein.
- (14) The control circuits shall be suitable for mains operation and shall be designed to enable the luminaires to operate exactly like normal conventional luminaires. However, irrespective of the status of the light switch or the controlling contactor, the luminaires shall automatically

illuminate or remain illuminated upon mains failure. Upon restoration of the main supply the lamp shall be switched back to mains supply operation and the batteries shall be re-charged again automatically.

- (15) Tunnel lights shall be of IP65 weatherproof type and IK-10 industrial LED type with housing and Fire Resistant low smoke halogen-free type and of non- combustible materials.
 - (16) Tunnel lights shall be spaced at not more than 15 m with a minimum illumination level of 25-50 lux.
 - (17) In Tunnel areas including cross passages area alternate luminaires shall be fed from the circuits of alternate phases to enhance reliability and cater for local system failure.
 - (18) Illuminated Tunnel Evacuation Signage System (ITESS) and Cross Passage Evacuation Signage System (XPES) are to be installed to provide a series of clear and unambiguous illuminated signs to indicate the direction in which the passengers should move, in the event of passengers' evacuation from tunnel due to emergencies requiring evacuation
 - (19) Tunnel lighting control panel shall be provided in the SCR for local control of the Tunnel lighting at SCR.
 - (20) Emergency Luminaires inside the Launch box (including mid-ventilation shaft, where applicable) shall be automatically controlled by Door Contactor Switch. -
- (c) Luminaires and accessories:

The luminaires and accessories shall be as specified and/or of the following types as below

Sl. No.	Room Name	Type of Luminaires
1	Station Control room, Office area, Security room Maintenance room and Staff room.	LEDLED
2	UPS room, Electrical switch room, Escalator panel room, UG tank & pump room, Signalling equipment room, Communication equipment room and Power supply equipment room.	LEDLED
3	Toilet, Cleaners room, Station store room	LEDLED
4	Plant rooms	LEDLED
5	Staff Store room	LEDLED
6	Working area	LEDLED
7	Work Shop Area	LEDLED
8	Turn back sidings / Stabling Lines	LEDLED
9	Street Light	LEDLED
10	Public/Passenger Area	LED, As per the recommendation of the design Architect of the Contractor and as approved by the Engineer

4.4.10.4.2 Lamps

- (1) Lamps shall be of the number and types as calculated/required to meet the specifications All lamps installed shall be new, and shall operate on completion of the job.
- (2) All lamps of the given type shall be supplied by the same manufacturer. And the basic requirements for each lamp shall be as follows :
 - (a) LEDLEDLED
 - (i) LED lights to be provided shall be of energy efficient, high efficacytype (> 100100 lumen/watt for) with Colour Rendering Index(CRI) in excess of 80 and colour temperature of $5700 \pm 300^{\circ}\text{K}$ (approximately) unless specified otherwise.
 - (ii) Power factor > 0.95
 - (iii) Total harmonic distortion of input current (THDI) < 1010% and conforming to IEC 61000-3-2
 - (iv) Lamp current crest factor < 1.7 conforming to IEC 60929
 - (v) Ballast lumen factor > 94 % conforming to IEC 60081
 - (vi) (vii)EMI, EMC, RFI Suppression conforming to IEC 60929

4.4.10.5 Product Handling

The lighting fixtures, components and assemblies shall be delivered in fully sealed protective cartons and identified as to the contents. The fixtures shall be protected from damage from any source. Each lighting fixture shall be sealed at the bottom with easily removable protective plastic to keep dust out during construction.

Each lighting fixture with a ballast shall have the ballast pre-mounted, pre-wired, pre- tailed and factory tested prior to packaging.

Each lighting fixture shall be packaged with complete instructions and illustrations indicating installation method.

The materials shall be stored in accordance with the manufacturer's instructions, properly protected from weather and construction activities.

Handling shall be in a manner to prevent damage to the finished surfaces.

4.4.10.6 Mock-up

If requested mock-up installation shall be provided for review and approval by the Engineer . The mock-up shall simulate lighting system conditions as specified..

For each substitution item which is not specified mock-up installation shall be provided, if desired by the Engineer at no additional cost to the Employer .

4.4.10.7 Installation

Lighting fixtures shall be installed as per the calculations carried out complying to the Specification herein and as approved by the Engineer, and also to the installation instructions of the manufacturer.

The Contractor shall fully coordinate with the other contractors/sub-contractors in planning and execution of installation to ensure that the fixtures furnished are compatible with the ceiling suspension system being installed and not to cause

any damage or deflection to the works of any Project Contractor.

If the lighting fixtures installed by the Contractor cause any damages or deflections to the works of other Contractors, such affected works shall be replaced by the new ones by the Contractor at his own cost/expenses.

The lighting fixtures shall be installed so as to fully effect the light distribution.

Final connections to luminaries in areas where a suspended ceiling is provided shall be in a flexible conduit system.

4.4.10.8 Testing and Commissioning

The lighting system shall be checked at night to ensure that illumination levels as specified have been achieved.

The luminaires and control cables shall be meggered phase-to-phase and phase-to-ground.

The performance of the luminaries and associated equipment shall be tested by switching-on all luminaries in a period of 24 hours, together with measuring of the illumination levels which shall not deviate from the specified levels.

Quality Control

All luminaires and associated equipment installed shall be of industrial grade quality and the quality control shall be undertaken in accordance with the procedures set out in the Contractor's Quality assurance and Quality management plan.

4.4.12 SWITCH AND SOCKET OUTLET

4.4.11.1 General

The Contractor shall Design, supply and install the switch and socket outlet as described and specified herein.

4.4.11.2 Standard and Reference

The switches and socket outlets shall comply with the following code and standard:

- | | | |
|-----------------------|---|--|
| (1) IEC 60529 | : | Degree of protection provided by enclosures (IPCode) |
| (2) IEC 60309 | : | Plugs, socket-outlets and couplers for industrial purposes |
| | | Part 1: General requirements |
| (3) IEC 60884-1 | : | Plugs and socket-outlets for household and similar purposes |
| | | - Part 1: General requirements |
| (4) IEC 60669-1 | : | Switches for household and similar fixed-electrical installations - Part 1: General requirements |
| (5) IS 4615 | : | Switch socket outlets |
| (6) IS 1293 | : | 3 pin plugs and socket outlets upto 250 volts |
| (7) IS 3854 | : | Switches for domestic and similar purposes |
| (8) IS 5133 Part-I&II | : | Boxes for the enclosure of electrical accessories |

4.4.11.3 Material Description

The colour of cover plates for all switches and socket outlets (except power outlets) shall be selected conforming to the decorative finishing of architectural work.

4.4.11.4 Component

Switch

- (1) In general, the switches shall be of the concealed, flush-mounted, toggle type rated 6/16 Amperes at 240 V.
- (2) The cover plates of the switches shall be aluminium anodized or stainless steel. .
- (3) Switches located in wet and outdoor locations shall be complete with waterproof cover plate, housed in a galvanized cast iron or impact resistance molded plastic enclosures providing the minimum degree of protection of IP54.
- (4) The maximum switch number placed at the same location, installed in the same box and covered by the cover plate, shall not be more than 3 gang switches.
- (5) Only lighting switches connected to the same phase shall be allowed to be mounted on a common switch plate and adaptable box for 6/16A single-pole switch otherwise phase shall be physically separated within a switch box. Switches for Normal and emergency lighting circuits shall be housed in separate boxes.
- (6) Lighting switches shall be compatible with the type of conduit system. The types of lighting switches provided shall be metal front plates with appropriate galvanized steel back boxes for offices, control rooms and for public areas metal-clad with heavy-duty pattern front plates and appropriate steel back boxes.

Socket Outlet

- (1) In general, the switch-socket outlets shall be 16 A, 240 V, modular , universal type having flush grid plate mounting, unless otherwise stated, and shall be switched, three pin type fitted with automatic linear safety shutters to finger proof.
- (2) The cover plates of the outlets shall be aluminium anodized or stainless steel . Cover plates shall be of the same manufacture and shall match the switches in the particular room or area in which they are installed.
- (3) Water-proof sockets shall consist of a single outlet in an outlet box with gasket, water-proof, complete with cover plate conforming to IP54 protection for platform area and IP44 for indoor used. The switch-sockets shall be rated 6/16 Amperes at 240 V, 2 wires with third pole grounded (SP&N).
- (4) The power socket outlets for maintenance purpose in stations and Tunnels shall be supplied at 32A, 415V, 3-phase/16A, 240V, 1-phase 50 Hz. The socket outlets shall be 3/5 pole with neutral and earth (TP&N) rated to IP54 protection for platform area and IP44 for indoor use, IP65 for Tunnels,

external use or in wet environment locations.

- (5) In offices, control rooms and public areas, they shall be flush mounted with appropriate galvanized steel back boxes. In workshop, plant room etc, surface mounted, robust heavy duty steel back boxes shall be provided.
- (6) Residual current devices, or ELCB, of 30mA sensitivity shall protect all sockets. RCD shall be housed in an enclosure incorporated into the MCB distribution boards or Load Center Panels.

4.4.11.5 Installation

The switches shall be fixed to wall or column at level 1,350 mm above the finished floor level. The outlets shall be fixed to wall or column at level 300 mm above the finished floor level.

4.4.11.6 Testing and Commissioning

The complete switches and sockets shall be tested to ensure that the operation is in compliance with the requirements.

Quality Control

All switches and socket outlet installed shall be of industrial grade quality and the quality control shall be undertaken in accordance with the procedures set out in the Contractor's Quality assurance and Quality management plan.

4.4.13 Earthing and Bonding and Lightning Protection System

4.4.12.1 General

The Contractor shall Design, supply, install, connect, test and commission a complete system of safety grounding and lightning protection in accordance with the Specifications/Contract stipulations herein for all other contractors(Project Contractors) in the station, tunnels and terminate at respective rooms with earth bus.

All the non-current carrying metal parts of electrical installation shall be earthed properly. All metal conduits, cable trays, trunking, cable sheaths, switchgear, distribution fuse boards, light fittings and all other parts made of metal shall be bonded together and connected by means of specified/approved earthing conductors to an efficient earthing system. All earthing shall be in conformity with Indian Electricity Rules.

Earthing of DG set, body earthing of all equipment, SCADA M&E equipment, and other items shall be carried out as per the Specifications. The Contractor shall lay an earth mesh having not more than 1.00 ohm resistance at each location using copper flats/rods. The same earthing shall also be used by Power Supply and OHE Contractor.

The clean or special earthing system required by Signaling/AFC/Telecom/SCADA equipment etc. shall be supplied and installed by the Contractor. The clean earth mesh shall give not more than 0.5 ohm resistance at each location. The design of Clean/special earth shall be done by the Contractor in coordination with the interfacing Signaling & Telecommunications contractor to meet their systems' requirements and the same shall be installed by the Contractor below base slab or as required. Main Earth Tape (MET)/Clean Earth Tape (CET) (as applicable)

from earth mat to the system rooms shall be provided by the Contractor and the final termination of the system equipments to these MET/CET shall be done by the respective system contractors in their systems' rooms.

All the earthing strips shall be buried in floor or wall as required and all the fastening (by nut bolts) of earthing strips shall be tag welded as well.

The Earthing System shall comprise the following:

- (i) Earth mats and Electrodes as per IEEE 80 and IS:3043
- (ii) Earthing Leads
- (iii) Earth Conductors
- (iv) Residual current earth leakage circuit breakers where applicable as per IE rules 61A. All three phase equipment shall have two separate and distinct body earths and single phase equipment shall have a single body earth.

4.4.12.2 Standard and Reference

The grounding and lightning protection system shall comply with the following codes and standards:

- (i) IS:3043 Code of Practice for earthing
- (ii) Indian Electricity Act, 2003 and IE Rules, 1956 as amended
- (iii) IEEE 80 Guide for Safety in AC Substation Grounding
- (iv) IS: 2309 Amendemnt-1

Code of practice for the protection of buildings and allied structures against lightning

- (v) IS 5216 : Part I Recommendations on Safety Procedures and Practices in Electrical Work - Part I : General
- (vi) IS 5216 : Part II

4.4.12.3 Material Description

The material for earthing and lightning protection system shall consist of ground rods with pits, ground conductors, test boxes, lightning down conductors, lightning conductors, air terminals and accessories interconnected for the complete system.

The Contractor shall coordinate with the Designated/Interfacing Contractors to provide and install the earthing system at each location (Power earth and clean earth).

The earthing system shall primarily be of copper and the earthing configuration shall be Indian TN-S as per IS: 3043 and earth mats shall be designed and constructed in accordance with IEEE 80 to limit the grid resistance, maximum attainable grid potential and step / touch potentials within the safe limits. The Contractor shall ensure that the intents of the earthing configuration are met with, by simulating a single-phase-ground fault current, which is sufficient enough to trip all the circuit breakers and fuses in the system.

4.4.12.4 Component

(1) Earthing System

Earth . Stations

Earth . mats

Earth mats shall be constructed as per IEEE 80 and IS 3043 . Copper round / flats shall be used for constructing earth mat of adequate size (horizontal and vertical conductors) and at a depth of 700 – 1000 mm from ground or as required. Adequate number of risers shall be brought from earth mat for further connection to ASS equipment and down stream equipment. Main earth terminals shall be provided in ASS, DG, pump and other equipment /system rooms as required. The resistance of the earth mat shall not be more than 1 Ohm.

Plate Earthing Station

The plate type earth electrodes shall be provided for clean earth & equipment earth grid. The earth resistance shall be maintained with a suitable soil/ground treatment and watering arrangement. The clean earthing station shall use copper plate earthing of adequate size.

The resistance of each earth station of clean earth system shall not exceed 2 Ohms and the total resistance of the clean earthing system shall not exceed 0.5 ohm.

The earth lead shall be connected to the earth plate through copper/brass bolts.

The resistance of each earth station of Main earth system shall not exceed 5 Ohms. The total resistance of earthing system shall not exceed 1 ohm. The earth lead shall be fixed to the pipe with a clamp and safety set screws. The clamps shall be permanently accessible.

Number of Earth Stations

In all cases the relevant provision of rule 33, 61 & 67 of the Indian Electricity Rules 1956 as amended shall be complied with.

Metallic covers or supports of all electrical equipment shall, in all cases be connected to earthing system having at least two separate and distinct earth path .

Earth leads and connections

The strip earthing leads shall be connected to the Earth Electrode / Earth mat at one end and to the main equipment at the other end. The earthing lead shall connect to the earthing network in the installation.

Earth lead shall be bare copper or galvanized steel as specified with sizes. Strip earthing leads shall be of copper/GI or GS.

The buried strip earthing lead shall be in trench not less than 0.5 m deep. If conditions necessitate use of more than one earthing lead, they shall be laid as widely distributed as possible, preferably in a single straight trench or in a number of trenches radiating from one point.

In the case of plate earth electrode, the earthing lead shall be securely bolted to the plate with two bolts, nuts, check nuts and washers as required by IS 3043 . All

materials used for connecting the earth lead with electrode shall be GI in case of GI Pipe and GI plate earth electrodes or tinned brass in case of Copper plate electrode.

Connection of Earthing Conductors

Main earthing conductors shall be taken from the earth connections at the auxiliary substation to the earth bar at the main switch boards in the TN-S configuration and the earth bar may also be directly earthed as in Indian TN-S.

Sub-mains earthing conductors shall run from the earth bar at the main switch board to the sub-distribution boards and to the final distribution boards/Load centres.

Loop earthing conductors shall run from the final distribution boards and shall be connected to any point on the main/sub-main earthing conductor, or its distribution board.

Metal conduits, cable sheathing and armouring shall be earthed at the ends adjacent to switch boards at which they originate, or otherwise at the commencement of the run by an earth bonding conductor in effective electrical contact with cable sheathing. Switches, accessories, lighting fitting etc shall be effectively connected to the Loop Earthing Conductors. A metallic conduit shall not be considered as the only protective earth conductor.

Point wiring for lights, fans, ceiling fans, exhaust fans, 6A & 16A and 32A, 3 phase sockets and likewise and sub-main wiring, shall have an earth continuity conductor (ECC) with the same cross section and type of wires used, the minimum in this case being 2.5-sqmm copper.

Prohibited Connections

Neutral conductor, sprinkler pipes, or pipes conveying gas, water, or inflammable liquid, structural steel work, metallic enclosures, metallic conduits and lightning protection system conductors shall not be used as a means of earthing an installation or even as a link in an earthing system. However, these are to be effectively earth bonded.

Resistance To Earth

The main power earth mat and clean earth system shall have a resistance not more than 1 ohm and 0.5 ohm respectively. The electrical resistance measured between earth connection at the main switchboard and any other point on the completed installation shall be low enough to permit the passage of current necessary to operate fuses or circuit breakers.

Equipment earthing

All apparatus and equipment transmitting or utilizing power shall be earthed. The earth continuity conductor may be drawn inside the conduit in which case, it shall be insulated.

Metallic conduit shall not be accepted as an earth continuity conductor. A separate insulated/bare earth continuity conductor of size related to phase conductor shall be provided. Non-metallic conduit shall have an insulated earth

continuity conductor of the same size as above. All metal junction and switch boxes shall have an inside earth stud to which the earth conductor shall be connected. The earth conductor shall be distinctly coloured (green) for easy identification.

Armoured cables shall be earthed by 2 bonding earth connections to the armouring at both the ends and the size of connection being as above. In multiple cables entering a panel/DB, the cable joints shall be bonded together using a bonding wire selected on the basis of the largest size of cable in the group. In the case of unarmored cable, an earth continuity conductor shall be run outside along the cable. Three phase power panels and distribution boards shall have 2 distinct earth connections of the size correlated to the incoming cable size. In case of single phase DB's a single earth connection is adequate. Similarly for 3-Phase and 1-Phase isolating switches there shall be 2 and 1 earth connections respectively, sizes being correlated to the incoming cable.

Three Phase motors and other 3-Phase apparatus shall have 2 distinct earth connections of size equal to incoming feeder size. For 1-Phase motor and 1-Phase apparatus, the single earth connections shall be provided.

Artificial treatment of soil/ground

If the earth resistance is too high and the multiple electrodes do not give adequate low resistance to earth, as specified above, then the soil/ground resistivity immediately surrounding the earth electrodes shall be reduced by adding sodium chloride, calcium chloride, sodium carbonate, copper sulphate, salt and soft coke or charcoal in suitable proportions

4.4.12.5 Lightning Protection System

Air Terminations

The air termination shall be multiple point type of copper/brass material. The stem and multi-point head shall be erected on the roof with a 150 x 150 x 6mm stainless steel (SS) base plate with a threaded socket of the same material welded to it. The base plate shall be embedded in a concrete block to hold the elevation rod in a vertical position. The elevation rod shall be one single rod without any joints.

Down Conductor

The down conductor shall follow the most direct path possible between the air termination and the earth termination. The down conductor shall be free of sharp bends, upturns and kinks and clamped to the stem of the air termination by means of gun metal clamps. Each down conductor shall have an independent earth termination. Minimum size of the down conductor shall be 25 x 3 mm stainless steel (SS).

The down conductor shall be clamped to the building outer wall at 600-mm centres. Joints in the down conductors shall be avoided as far as possible. However, in any case, joints shall not be made below ground level. Where joints are made care shall be taken so as to exclude any moisture. Bimetallic connectors shall be used where dissimilar metals are to be jointed. All joints

shall be tinned, soldered or double-riveted.

A testing link shall be provided for each down conductor. Testing links shall be of gun metal or SS 304 or as specified.

Earth termination

The earth terminals and earth leads shall be as specified for earth station and earthing leads under section 'EARTHING'.

Testing

The entire installation shall be tested in accordance with the Indian Standard Code (IS 2309) and the ground resistance values shall be recorded for each earthing station and earthing system as a whole.

Testing Points

Each down conductor shall be provided with a testing point in a position convenient for testing but inaccessible for interference. No connection other than one direct to an earth electrode shall be made below a testing point. Testing points shall be of GI.

Design Considerations

The entire lightning protection system shall be mechanically strong to withstand the mechanical forces produced in case of a lightning stroke.

The lightning protection system shall be so installed that it does not spoil the architectural or aesthetic beauty of the buildings.

A vertical air termination where provided need not have more than one point and shall project at least 30 cm above the project, salient point or network on which it is fixed.

Horizontal air terminations shall be so interconnected that no part of the roof is more than 9 m away from the nearest horizontal termination.

Horizontal air terminations shall be coursed along contours such as ridges, parapets and edges of flat roof, and where necessary over flat surfaces in such a way as to join each air termination to the rest and shall themselves form a closed network.

All metallic finials, chimneys, ducts, vent pipes, railings, gutters, metallic flag staff etc. on or above the main surface of the roof of the structure shall be bonded to, and form part of the air-termination network. If portions of a structure vary considerably in height, any necessary air termination or air termination network of the lower portions shall be in addition to their own conductors, be bonded to the down conductors of the taller portions.

All air terminals shall be effectively secured against overturning either by attachment to the object to be protected or by means of substantial braces and fixings which shall be permanently and rigidly attached to the building. The method and nature of the fixings shall be simple, solid and permanent, due attention being given to climatic conditions and possible corrosion.

Earth Terminations

Each down conductor shall have an independent earth pit. The interconnection of all the earth termination shall be preferable. It shall be capable of isolation for testing purposes by “testing joints” of GI provided in suitable enclosures.

Earth electrode

Earth electrodes shall be constructed and installed as specified.

The whole of the lightning protection system shall have a combined resistance to earth not exceeding 10 Ohms before any bonding has been effected to metal in or on a structure or to surface below ground.

4.4.12.6 Installation

All equipment shall be installed at the required locations and conforming to the standard as specified.

4.4.12.7 Testing and Commissioning

Following Earth resistance values shall be measured with an approved earth megger and recorded.

- (i) Each earthing station / mat
- (ii) Earthing system as a whole
- (iii) Earth continuity

Quality Control

All Earthing & Bonding and Lightning protection system installed shall be of industrial grade quality and the quality control shall be undertaken in accordance with the procedures set out in the Contractor’s Quality assurance and Quality management plan.

4.4.14 Lighting Control System

4.4.13.1 General

The Contractor shall provide and install the lighting control system specified herein.

The Lighting Control System shall be integrated with the SCADA M & E. Each lighting circuit from the lighting control panels (LCP) shall be controlled by the SCADA M & E between the LCP and the RTU. The Schedule for control and monitoring of lighting circuits and graphic of lighting control floor plan shall be from the SCADA M & E.

The lighting control system configuration such as graphic, layout, setting, etc., shall be adjusted to harmonize with Architectural finishes. This shall be also applied to third party vendors interfaces with the system.

4.4.13.2 Standard and Reference

The lighting control system shall comply with the following codes and standards:

- (1) IEEE 802 : Standard for Information Technology
– Telecommunications and Information exchange between systems

- (2) IEC 60529 : Degree of protection provided by enclosures (IP Code)
- (3) IEC 60255 : Electrical Relay
- (4) IEC 60364 : Electrical Installation of Buildings

4.4.13.3 Material Description

The lighting control system as specified herein shall be to control and manage the switching function of lighting fixtures.

The lighting control panel (LCP) shall consist of the enclosure with separate power section and control section, relay unit, power supply unit, interconnected wirings and accessories.

The system shall allow added switching configurations. Any number of switches shall be able to be programmed for a common load or loads and all switches shall indicate the load status on SCADA M & E.

Each LCP shall be provided manual override switch of any of its zone for maintenance purpose.

The relay unit and accessories shall be housed inside an enclosure of LCP and installed adjacent to the MCB board (or Load centre) from which power shall be obtained. Supply source for control circuit shall be derived from the MCB board (or Load centre) where the power for the lighting circuits shall be obtained.

4.4.13.4 Component

Relay unit

The relay unit shall be an extra low voltage (24 or 36 V.) single pole High Intensity Discharge (HID) relay. The HID relay shall be used for lighting circuit switching, which have a contact rating > 20 A, 240 V.AC.

Power supply unit

The power supply unit in the system which transforms the nominal power supply voltage at 240 V.AC to the equipment required voltage, shall have adequate capacity for power consumption of all connected equipment.

Enclosure

The enclosure for the equipment shall be cabinet with flush key lock, which is fabricated from 2mm electro-galvanized steel sheet and complying with IP 42 protection class.

Each enclosure shall be sufficiently equipped with relay unit with 30% spare space for future expansion.

4.4.13.5 Installation

All equipment and accessories shall be installed in accordance with the manufacturer's recommendation.

4.4.13.6 Testing and Commissioning

The Contractor shall test the system to full functions.

The Contractor shall prepare instruction manual of the system.

The Contractor shall provide training to maintenance staff covering the

function and maintenance.

Quality Control

Lighting Control System installed shall be of industrial grade quality and the quality control shall be undertaken in accordance with the procedures set out in the Contractor's Quality assurance and Quality management plan.

4.4.15 M & E SCADA Interface Work

4.4.14.1 General

The Contractor shall provide and install the M & E SCADA Interfacing system as indicated in the specification herein and as required.

The Contractor shall fully coordinate with the Engineer and/or Interfacing Contractors in collecting all necessary technical interface details and information to produce the necessary interface document between Underground station contractor (the Contractor) and Signaling and Telecommunication contractor.

4.4.14.2 Standard and Reference

The M & E SCADA system and its components shall comply with the following codes and standards.

Sl. No	Standard/ Code No	Title
1	IEC 445	Identification of equipment terminals and terminations of certain designated conductors, including general rules for an alphanumeric system
2	IEC 571-1	General requirements and tests for electronic equipment
3	IEC 571-3	Components, programmable electronic equipment and electronic system reliability
4	IEC 617-12	Binary logic elements-Graphical symbols to represent dependency notation, combinative and sequential element, as well as complex-function elements
5	IEC 801-3	Radiated electromagnetic field requirements
6	IEC 870-1-1	Tele-control considerations equipment and systems-General
7	IEC 870-2-1	Operating conditions
8	IEC 870-4	Performance requirements
9	IEC 870-5-4	Definition and coding of application information elements-Transmission protocols
10	IEC 1082-1	Preparation of document (Signals, Diagrams)
11	ISO/IEC 4873	Information technology ISO 8-bit code for information interchange-Structure and rules for implementation
12	IEC 60848	Preparation of function charts for control systems

Sl. No	Standard/ Code No	Title
13	IEC 61175	Designations for signals and connections
14	IEC 61346 (All parts)	Industrial system installation, equipment and industrial products-Structuring principles and reference designations
15	IEC 61850-Part 2	Glossary
16	IEC 61850-Part 3	General requirements
17	IEC 61850- Part 4	Communication networks and systems in substations-System and Project management
18	IEC 61850- Part6	Substation automation system configuration description language
19	IEC 61850-7-1	Basic communication structure for substation and feeder equipment- Principles and models
20	IEC 61850-10	Conformance testing
21	BS 4737: Part 2	Specification for installed systems for deliberate operation
22	BS 4737: Section 4.1	Code of practice for planning and installation
23	BS 4737: Section 4.2	Code of practice for maintenance and records
24	BS EN 14908-1	Open data communication in building automation, controls and building management, building network protocol, protocol stack.
25	BS EN 50090-2-1	Home and building electronic systems-System overview, Architecture
26	BS EN 50090-2-2	Home and building electronic systems-System overview, General technical requirements
27	BS ISO/IEC 6592	Information technology. Guidelines for the documentation of computer-based application systems
28	BS 5839-1	Code of practice for system design, installation, commissioning and maintenance for fire detection and alarm systems for buildings
29	BS EN 54-2	Specification for control and indicating equipment
30	BS 6266	Code of practice for fire protection for electronic data processing installations
31	BS EN ISO 9000-3	Development, supply, installation and maintenance of computer software
32	IS: 1765	Direct current potentiometers
33	IS: 3043	Code of practice for Earthing

Sl. No	Standard/ Code No	Title
34	IS: 3700	Essential rating and characteristics of semiconductor devices
35	IS: 4007 Part1	Terminals for electronic equipment- General requirements
36	IS: 5051 Part 1	Relays for electronic and telecommunication equipment- General requirements
37	IEEE 802 series	Local area network
38	ISO 3511	Process measurement control functions and instrumentation-Symbolic representation-Part 1 Basic requirements
39	IEC 947-7-1	Low-voltage switchgear and control gear – Part 7-1: Ancillary equipment – Terminal blocks for copper conductors
40	IEC 60529	Degree of protection provided by enclosures (IP code)

4.4.14.3 Material

Description

The M & E SCADA interfacing system for E & M service shall consist of the following equipment:

- (1) Microprocessor based distributed controllers interface directly with sensors, actuators and environmental delivery systems, i.e. electrical system, Plumbing & drainage, Fire alarm system, Fire Fighting System, Air Conditioning and Tunnel Ventilation system
- (2) Remote Processor units required for interface with different stations.
- (3) A serial link communication network shall be provided by other contractor to allow data exchange between devices in the system, i.e. Fire alarm system, Fire Fighting system, Lifts and Escalators, TVS and ECS systems , Plumbing and Drainage System, Lighting System, Low Voltage Power Supply System, Uninterruptible Power Supply (UPS), AFC, S&T , PSD, PST etc.
- (4) Marshalling Cabinets (MS) shall be provided for termination of all M & E SCADA interface monitor and control signal wiring.
- (5) Associated Power & Control Cables.

4.4.14.4 Technical Requirement

4.4.14.4.1 Remote Processing Unit (RPU)

- (a) The RPU shall be microprocessor based design for performing control, alarm and monitoring programs.
- (b) Each RPU shall be sufficiently equipped with input/output points including 30% spare capacity. Expansion by at least 50% shall be possible simply by

adding more I/O modules and reconfiguring the software.

- (c) The RPU shall be provided for interfacing with the equipment to be monitored and controlled via hardwired cables and shall be located in proximity of the equipment in order to minimize the amount of hardwired cables. Alternatively Programmable Logic Controllers (PLC) shall be installed with equipment to be monitored and controlled.
- (d) The RPU shall be provided for interfacing with systems through serial or LAN data interface. The RPU shall communicate with the M & E SCADA workstation via the Ethernet LAN.
- (e) The RPU shall be capable of control on-off command, mode change, status input and digital alarms etc. The RPU shall also include energy management program for time of the day program, optimum start/stop and duty cycling, etc.
- (f) RPU shall be installed in electrical room or mechanical room or as required. It shall be possible to expand each RPU by additional input/output modules.
- (g) The RPU shall accept the following type of inputs and outputs.

Input	Output
Analog 4 – 20 mA	Analog 4 – 20 mA
Dry contact (NO or NC)	Dry contact (NO or NC), 20A, 250V
Pulse accumulator	Momentary-pulsed and Mechanically latched
Override switch	
Photocell contact	
Transducer sensors	
Etc.	

- (h) If the CPU transmission network fails but power to RPU does not, the RPU shall continue to monitor all changes of state or value and shall retain the most recent values for 30 minutes and the RPU shall also maintain all analog set points and command positions.

4.4.14.4.2 Sensors and operating equipment

The Contractor shall supply the sensors, transmitters and relays necessary for the M & E SCADA system, where necessary. Monitoring points shall include but not limited to the following:

- (a) Filter pressure drop of each filter bank shall be sensed by means of a diff. pressure sensing device which shall close a contact when the filter pressure differential exceeds a typical pressure.
- (b) Air proving switches shall utilize a differential pressure activated, diaphragm actuated, snap acting Single Pole Double throw (SPDT) switch.
- (c) Pressure transmitters shall have a linear output of 0-10V. Pressure transmitters shall be a span of not greater than twice the static pressure at maximum flow or differential pressure at shutoff as applicable.
- (d) Water flow for pumps shall be indicated by means of diff. pressure or flow switches which open a contact as the diff. pressure or flow falls below a

typical value. Water flow switches shall have a paddle actuated, snap acting SPDT switch.

- (e) Humidity sensors shall be suitable for operating ranges of 10 to 100% RH and shall incorporate a solid state sensing element. Sensor accuracy shall be 3% over a range of 5 to 95% RH. Humidity sensors shall also incorporate a transducing circuit for conversion of the sensed variable to a voltage level for digital conversion.
- (f) Water-flow measuring devices shall be consisting of annular averaging pilot tube flow elements having the following minimum Specifications. The Annular shall be selected for the operating flow range, pipe size and fluid temperature.
 - (i) Accuracy - 2%
 - (ii) Repeatability - 1.2%
 - (iii) Pressure Drop - 1.5 kPa maximum
 - (iv) Operating Temperature Range - 0 to 95 °C [140 °F to 203 °F]
 - (v) Operating Pressure Rating - 174 kPa [250 psig]

The Contractor shall provide weld couples of Model 1440, 25 mm. [1"] carbon steel coupling with MPE stainless steel cap for future Annubar corrections. The Contractor shall also Install the annubar flow device in accordance with the manufacturer's recommendations and locate it with sufficient upstream and downstream straight pipe without any obstructions.

- (g) Pressure sensing elements to be provided shall be of bourdon tube, bellows or diaphragm type with adjustable set point and differential set point. Pressure switches shall be snap action type rated at 220 volts, 10 amp AC or 24 volts DC.
- (h) Temperature sensing elements to be provided shall be of liquid, vapour or bimetallic type with supply adjustable set point and differential set point, snap action type rated at 220 volts, 10 amps or 24 volts DC and the Sensors shall be able to operate and reset automatically.

Temperature switches sensing elements shall be of the following types.

- (i) Room type shall be suitable for wall mounting on standard electrical box with or without protective guard.
- (ii) General purpose duct type shall be suitable for insertion into air ducts, insertion length of 450 mm. [18"].
- (iii) Thermoweld type shall be complete with compression fitting for 20 mm. [0.8"] NPT well mounting of length of 100 mm. [4"]. Immersion wells shall be stainless steel.
- (iv) Strap-on type shall be complete with helical screw stainless steel clamps.
- (i) Start/stop relay modules shall if possible provide either momentary or maintained switch actions as appropriate for the unit being started and depending on the fact

whether the units are subjected to a power fail restart program or not. All

relays shall be mounted in interface panels and/or starter panels.

4.4.14.4.3 Control Cable and Cable Connection

Type of cable shall be as per manufacturer recommendations or as follows:-

- (a) Multi-core-twisted pair with shielded cable shall be used between CPU and RPU.
- (b) Twisted pair with aluminum shielded cable shall be used for analogue input/output point between RPU and Marshalling box or Marshalling cabinet.
- (c) Multicore cable shall be used for digital input/output points between RPU and Marshalling box or Marshalling cabinet.
- (d) Terminal blocks shall be provided in panel for RPUs to load points.
- (e) If screen is required, aluminum tape laid longitudinally and in contact with the un- insulated drain wire or un-insulated circuit protective conductor (cpc) shall be provided.

All field control wiring associated with analogue inputs/outputs shall be run in screened cable with a minimum cross sectional areas of 0.5 mm^2 .

All field control wiring associated with digital inputs/outputs shall be wired in unscreened cable with a minimum cross sectional areas of 1.0 mm^2 .

All field control wiring shall be wired, contained in trunking or conduits

All field control wiring for equipment used for life safety shall be of fire resistant low smoke zero halogen cable.

4.4.14.4.4 Control RPU Software

(a)General:

The RPU shall be capable of fully stand-alone operation and shall be independent of any central computer for all specified control or communication applications. The software shall include all necessary routines and modules required to implement any control strategy and shall be user programmable. The programming language shall be English and shall use standard controls terminology.

(b)Input and Output point processing shall include:

- (i) Continuous update of input and output values, conditions and status. All connected points are to be updated at a maximum of 5 second intervals, under worst conditions.
- (ii) Analog to digital conversion of input values shall be carried out with at least 11 bit resolution with typically 40 dB series mode rejection @50 Hz. It shall be possible to calibrate the inputs by means of movable jumpers or links to suit the sensor type in use, to achieve a high accuracy reading.
- (iii) Input reading shall be automatically checked to determine that the reading is within the sensor's range and within the range of the input circuit, i.e. 0-10V or 4- 20mA. Should this not be the case then an alarm status shall be indicated.
- (iv) All sensor readings shall be in engineering or user-definable units. These units shall be calculated by the sensor scaling type assigned to

each sensor.

- (v) Each sensor shall have, in addition to the checks specified above, operator adjustable High and Low alarm limits. If the sensor reading is outside these limits then an alarm shall be generated. It shall be possible to delay these alarms by a user-defined amount so that spurious alarms are not reported.
- (vii) All inputs shall be filtered to reject mains frequency interference. The mains frequency of 50 Hz shall be selectable in software.
- (c) Each RPU is to be configured to run the control strategies called for in the sequence of operation. Each RPU shall have the required software modules available for arithmetic calculations, logical decisions and relational operators necessary for the implementation of these control sequences.
 - (i) RPU data such as set points, sensor values, loop parameters etc., shall be available to the operator for display and modification at the main supervisor, the portable supervisor or the display panel.
 - (ii) The reschedule time of control loops shall be adjustable, in 5 second intervals.
- (d) Each RPU shall provide five independent time zones, each of which shall have three separate start and stop periods within each 24 hours.
 - (i) Unique time program shall be provided for each day of the week, plus a unique holiday schedule. Each RPU time zone may be provided with unique time programs, or they may be grouped and assigned a common time program as configured by the operator.
 - (ii) For each time program, the main supervisor shall have a calendar available which may be used to make simple modifications up to a year in advance. The calendar shall allow these modifications to be permanent or to execute only once and then return to the previous (permanent) schedule.
 - (iii) Calendar days which are intended to operate as Holidays shall also be definable up to a year in advance.
- (e) All control strategies shall be held in RAM, battery backed up for at least 2 years. All data shall be available for review and modification from the main or portable supervisors.

4.4.14.4.5 Marshalling Cabinets (MS)

- (1) The terminal blocks shall be provided for termination of all M & E SCADA interface monitor and control signal wiring. Terminal blocks shall be designed and tested in complying with IEC 60947-7-1. Terminal block shall have ability to receive unprepared conductors.
- (2) Terminal block shall be single terminal type. Each terminal shall be exchangeable without dismounting adjacent terminals and also suitable for designative labeling.
- (3) Terminal blocks shall be of the rail-mounted type and shall be of screwless type terminals 600V a.c. moulded block type with molded insulating barrier between terminals. Terminal connections shall be such that the

conductors shall be connected with the necessary maintained contact pressure. Terminals shall be so constructed that the conductors can be clamped between suitable surface without any significant damage either to conductors or terminals.

- (4) Terminal blocks shall have test probe facilities for connections of test leads and an integral disconnecting device to facilitate testing.
- (5) The rated cross-section of a terminal block shall be 0.5-2.5 mm² of round copper conductor. No terminal can carry more than two conductors simultaneously connectable on each incoming/outgoing side.
- (6) The spare terminating block in all MS shall be provided with a capacity of at least 20% of the number of I/O points.
- (7) The Marshalling Cabinet shall be of 1.6 mm thick galvanized sheet steel with gray colour epoxy and electrostatic powder coated. The protection class shall be IP 31.

4.4.14.4.6 M & E SCADA Interfacing Cables

- (1) Digital input (DI) and Digital output (DO) signals shall use multi-core Flame Retardant Low Smoke Zero Halogen FRLS cables via conduits or cabletrays.
- (2) Analog input (AI) and Analog output (AO) signals shall use multi core flame retardant low smoke zero halogen screened cables via conduits or cable trays.
- (3) M & E SCADA interfacing cables for life safety lifts, fire alarm system and fire pumps shall use multi-core Flame Retardant Low Smoke Zero Halogen screened Fire Resistant cable tested to BS 6387 category CWZ via conduits only.

Field Control Wiring

- (1) If screen is required, aluminum tape laid longitudinally and in contact with the un- insulated drain wire or un-insulated circuit protective conductor (cpc) shall be provided.
- (2) All field control wiring associated with analogue inputs/outputs shall be run in screened cable with a minimum cross sectional areas of 0.5 mm².
- (3) All field control wiring associated with digital inputs/outputs shall be wired in unscreened cable with a minimum cross sectional areas of 1.0 mm².
- (4) All field control wiring shall be wired, contained in trunking or conduits.
- (5) All field control wiring for equipment used for life safety shall be of fire resistant cable.

4.4.14.4.7 M & E SCADA Control and Communication Protocol

The International standard open protocol system shall be adopted for various communication links .The communication Protocol can be classified as per following requirements:

- (a) The communication between E&M equipment to RPU such as preferably RS-485, MODBUS, BACnet, Lontalk, ARCNET etc.
- (b) The communication between RPU to the SCR Workstation should adopt an universally adopted open protocol such as OPC.

- (c) RPU to the server: the requirements for control, monitoring & parameters' measurement of each field and also the format of display at the SCR & OCC and mode of control shall have to be agreed between all the Interfacing contractors and with the Engineer;
- (d) The communication between Multifunction Meters and Energy meters and their communication to RPU/Workstation such as MODBUS, BACnet, Lontalk, ARCNET, etc on RS 232/485 port.
- (e) The communication between Dimming Light Control Panel, Fire Alarm Control Panel, MDB & Electrical panels, Escalator Panel, AMF Panel etc to the RPU/SCR Workstation such as MODBUS, BACnet, Lontalk, ARCNET etc on RS 232/485 port.

4.4.14.5 Installation

All equipment and accessories shall be installed in accordance with the manufacturer's recommendation and in the locations as indicated on the approved Design and Drawings.

4.4.14.6 Testing and Commissioning Type of tests

- Factory Acceptance test for RPU - During the test all logics shall be demonstrated with simulator and sample RPU.
- Installation test- After delivery of the RPU at the site, this test shall be arranged to check the physical healthiness of the hardware.
- Functional test- This test shall be arranged to test the functioning of RPU, workstation and printer and communication network.
- System acceptance test- This test shall be arranged to test all automation and i/o list, with integration of communication network.

It is the Contractor's responsibility to submit the separate test documents for each type of test to Engineer for the Notice of No objection. All tests shall be in sequence and on completion of previous test, the next test shall be arranged. Before installation test, all QA/QC document shall be submitted to the Engineer for the Notice of No objection.

- The Contractor shall test the system to full function.
- The Contractor shall prepare instruction manual of the system for users.
- The Contractor shall provide training to maintenance staffs covering the function and maintenance.

Quality Control

All equipment and accessories installed shall be of industrial grade quality and the quality control shall be undertaken in accordance with the procedures set out in the Contractor's Quality assurance and Quality management plan.

4.4.16 Fire Barrier Work

4.4.15.1 General

After erection of materials and equipment, through wall and opening, has been completed, it shall be the responsibility of the Contractor to fill up voids and openings with fire resistant materials which conform to NEC article 300-21 and ASTM equivalent Indian Standards (IS) to protect fire or smoke from spreading

out from one room to another room through these voids and openings.

4.4.15.2 Standard and Reference

The fire barrier shall comply with the following codes and standards.

- (1) NEC 300-21 : Spread of Fire or Products of Combustion
- (2) ASTM E814 : Standard Test Method for Fire Tests of Through-Penetration Fire Stops

4.4.15.3 Material Description

The material that is applied to the wall shall be considered to be a fire or acoustical protection wall, unless otherwise specified. Cover plates shall be provided, wherever exposed, and shall be neatly placed to the satisfaction of the Engineer .

The fire resistant rating of the material shall be in accordance with the fire rating of construction walls or slabs and shall be not less than 2 hours.

4.4.15.4 Component

The fire barrier materials shall have properties as follows:

- (1) The fire barrier materials shall be of a minimum 2-hour fire resistant rating or higher in accordance with type of construction walls or slabs.
- (2) The fire barrier materials must not be toxic during installation or incase of fire.
- (3) Easy to be dismantled and replaced in case of rearrangement.
- (4) Withstand vibration.
- (5) Easy installation.
- (6) The fire barrier materials shall be strong enough both before and after fire spreads,

4.4.15.5 Installation

At all voids and openings, fire barrier materials shall be installed where:

- (1) Voids, sleeves, and openings which appear on wall, floor, beam and shaft, provided for raceway installation, which must be sealed after the erection work has been completed.
- (2) Voids, sleeves, and openings which are provided for future installation.
- (3) Voids which exist between electrical conduits and sleeves.
- (4) Voids which exist between electrical cabling and raceway on fire wall and floor.
- (5) Voids which exist between raceway and sleeves on fire wall and floor.

4.4.15.6 Testing and Commissioning

The testing method shall be as provided by the manufacturer.

Quality Control

Fire Barrier materials installed shall be of industrial grade quality and the quality control shall be undertaken in accordance with the procedures set out in the Contractor's quality assurance and management plan.

4.5 PLUMBING

4.5.1 GENERAL REQUIREMENT

4.5.1.1 Scope of Work

The scope of work of the Contractor shall include design, manufacturing, supply, installation, testing, balancing and commissioning of equipment and accessories as shown on the Drawings and Specifications to achieve a complete Plumbing system.

The system shall include the following :

- a) Cold Water Supply Piping Work,
- b) Cold Water Supply Pump,
- c) Sewage Pump Sets,
- d) Waste Water Pump Sets,
- e) Drainage Piping Work,
- f) Storm Drain Piping Work,
- g) Valves and Accessories,
- h) Hangers and Supports for Plumbing Piping,
- i) Sanitary Fixtures and Fittings,
- j) Electrical and Control Works,
- k) Fire Barrier Work,
- l) Painting,
- m) Tests and Sterilizations.

It shall be the Contractor's responsibility to design and provide a completely safe and workable system in accordance with the requirements of the Technical Specifications/Contract stipulations and to the Engineer's Notice of No Objection.

The Contractor shall coordinate with the other Designated/Interfacing Contractors to ensure that the system and its components furnished form a complete Plumbing and Drainage system with the established construction schedule.

4.5.1.2 Nameplates and Identifications

All parts of the installation, which relate to operation and maintenance procedures, shall be provided with nameplates, tags or arrows, especially in enclosed areas, such as ceiling, shafts, and other places accessible for maintenance service.

4.5.1.3 Corrosion Protection

All ferrous components and fittings exposed to the atmosphere shall be hot-dip galvanized unless specified otherwise.

4.5.1.4 Acoustic Criteria

Noise emanating from the equipment / service installations shall not exceed 55dB for the static machines and 65dB for rotating machinery at a distance of one metre to match or exceed the relevant international standards for each of the equipment /service.

4.5.1.5 Field Testing

All equipment shall be tested upon completion of installation to ensure that the equipment operates satisfactorily and to conform to the Contract Documents.

Field testing shall be required for all Plumbing System equipment furnished, installed or connected by the Contractor to ensure proper installation, setting, connection, and functioning in accordance with the plans, specifications and manufacturer's recommendations.

Testing shall be conducted in the presence of the Employer / Engineer and, when necessary, under the supervision of equipment manufacturer's field Engineer.

All tests recommended by the equipment manufacturer whether specified in this specification or not, shall be included, unless specifically waived by the Employer / Engineer in writing.

Testing shall include any additional tests asked by the Employer / Engineer to determine the conditions of that equipment, material and system to meet requirements of the specifications.

The Contractor shall maintain in quadruplicate , a written record of all tests showing date, personnel making test, equipment or material tested, tests performed and results. Two copies of test records shall be given to the Employer / Engineer within the following day.

The Contractor shall notify the Employer / Engineer two weeks prior to commencement of any testing, except for metering.

The Contractor shall be responsible for any damage to equipment or material due to improper test procedures or handling test apparatus, and shall replace or restore any damaged equipment or material to original condition.

Safety devices such as rubber gloves and blankets, protective screens and barriers, danger signs, etc. shall be provided by the Contractor and shall be used to protect and warn adequately all personnel in the vicinity of the test location .

The Contractor shall furnish all testing equipment and provide proper temporary power source for testing purposes when normal supply is not available at the time of testing.

4.5.1.6 Additional Standards, Codes and Regulations for Plumbing

In addition to the standards listed in Section 4.2 "STANDARDS, CODES and REGULATIONS", all the design, equipment, supply, erection, testing and commissioning shall comply with the requirements of Indian Standards and code of practices given below as amended up to the design phase. All equipment and materials being supplied by the Contractor shall meet the requirement of IS, the Codes / Publications as given below:

General	
IS: 27	Pig Lead
IS: 554	Dimensions for pipe threads where pressure tight joints are
IS: 779	Specification for water meters (domestic type)
IS: 782	Specification for caulking load

IS: 800	Code of practice for general construction in steel
IS: 1068	Electroplated coatings of nickel plus chromium and copper plus nickel plus chromium
IS: 1172	Code of Basic requirements for water supply drainage and sanitation
IS: 1367 (Part 1)	Technical supply conditions for threaded steel fasteners: Part 1 Introduction and general information
IS: 1367 (Part 3)	Technical supply conditions for threaded steel fasteners: Part 3 Product grades and tolerances
IS: 1726	Specification for cast iron manhole covers and frames
IS: 1742	Code of practice for building drainage
IS: 2064	Selection, installation and maintenance of sanitary appliance code of practice
IS: 2065	Code of practice for water supply in buildings
IS: 2104	Specification for water meter for boxes (domestic type)
IS: 2373	Specification for water meter (bulk type)
IS: 2379	Colour code for identification of pipe lines
IS: 2527	Code of practice for fixing rainwater gutters and down pipes for roof drainage
IS: 2629	Recommended practice for hot dip galvanizing on iron and Steel
IS: 3114	Code of practice for laying of cast iron pipes
IS: 4111	Code of practice for ancillary structures in sewerage system: Part 1 manholes
IS: 4127	Code of practice for laying glazed stoneware pipes
IS: 4853	Recommended practice for radiographic inspection of fusion welded butt joints in steel pipes
IS: 5329	code of practice for sanitary pipe work above ground for buildings
IS: 5455	Cast iron steps for manholes
IS: 6159	Recommended practice for design and fabrication of material, prior to galvanizing
IS: 7558	Code of practice for domestic hot water installations
IS: 8321	Glossary of terms applicable to plumbing work
IS: 8419 (Part 1)	Requirements for water filtration equipment: Part 1 Filtration medium sand and gravel
IS: 8419 (Part 2)	Requirements for water filtration equipment: Part 2 under drainage system

IS: 9668	Code of practice for provision and maintenance of water supplies and fire fighting
IS: 9842	Preformed fibrous pipe insulation
IS: 9912	Coal tar based coating materials and suitable primers for protecting iron and steel pipe lines
IS: 10221	Code of practice for coating and wrapping of underground mild steel pipelines
IS: 10446	Glossary of terms relating to water supply and sanitation
IS: 11149	Rubber Gaskets
IS: 11790	Code of practice for preparation of butt-welding ends for pipes, valves, flanges and fittings
IS: 12183 (Part 1)	Code of practice for plumbing in multistoried buildings: Part 1 water supply
IS: 12251	Code of practice for drainage of building basements
IS: 5572	Code of practice for sanitary pipe work
BS: 6700	Specification for design, installation, testing and maintenance of services supplying water for domestic use within buildings and their cartilages
BS: 8301	Code of practice for building drainage
BSEN: 274	Sanitary tap ware, waste fittings for basins, bidets and baths General technical specifications
Pipes and Fittings	
IS: 458	Specification for precast concrete pipes (with and without reinforcement)
IS: 651	Salt glazed stone ware pipes and fittings
IS: 1239 (Part 1)	Mild steel, tubes, tubular and other wrought steel fittings: Part 1 Mild Steel tubes
IS : 1239 (Part 2)	Mild Steel tubes, tubular and other wrought steel fittings : Part 2 Mild Steel tubular and other wrought steel pipe fittings
IS: 1536	Centrifugally cast (spun) iron pressure pipes for water, gas and sewage
IS: 1537	Vertically cast iron pressure pipes for water gas and sewage
IS: 1538	Cast Iron fittings for pressure pipes for water, gas and sewage
IS: 1879	Malleable cast iron pipe fittings
IS: 1978	Line pipe
IS: 1979	High test line pipe
IS: 2501	Copper tubes for general engineering purposes

IS: 2643 (Part 1)	Dimensions for pipe threads for fastening purposes: Part 1 Basic profile and dimensions
IS: 2643 (Part 2)	Dimensions of pipe threads for fastening purposes: Part 2 Tolerances
IS: 3468	Dimensions for pipe threads for fastening purposes: Part 3 Limits of sizes
IS: 3468	Pipe nuts
IS: 3589	Seamless or electrically welded steel pipes for water, gas and sewage (168.3 mm to 2032 mm outside diameter)
IS: 3989	Centrifugally cast (spun) iron spigot and socket soil, waste and ventilating pipes fittings and accessories
IS: 4346	Specifications for washers for use with fittings for water services
IS: 4711	Methods for sampling steel pipes, tubes and fittings
IS: 6392	Steel pipe flanges
IS: 6418	Cast iron and malleable cast iron flanges for general engineering purposes
IS: 7181	Specification for horizontally cast iron double flanged pipe for water, gas and sewage
Valves	
IS: 778	Specification for copper alloy gate, globe and check valves for water works purposes
IS: 780	Specification for sluice valves for water works purposes (50 mm to 300 mm size)
IS: 1703	Specification copper alloy flat valves (horizontal plunger type) for water supply fittings
IS: 2906	Specification for sluice valves for water works purposes (350mm to 1200mm size)
IS: 3950	Specification for surface boxes for sluice valves
IS: 5312 (Part 1)	Specification for swing check type reflux (non return) valves: Part 2 Multi door pattern
IS: 5312 (Part 2)	Specification for swing check type reflux (non return) valves: Part 2 Multi door pattern
IS: 12992 (Part 1)	Safety relief valves, spring loaded: Design
IS: 13095	butterfly valves for general purposes
Sanitary Fittings	
IS: 771 (Part 1 to 3)	Specification for glazed fire clay sanitary appliances
IS: 774	Specification for flushing cistern for water closets and urinals (other than plastic cistern)

IS: 775	Specification for cast iron brackets and supports for wash basins and sinks
IS: 781	Specification for cast copper alloy screw down bib taps and stop valves for water services
IS: 1700	Specification for drinking fountains
IS: 2548 (Part 2)	Specification for plastic seats and covers for water closets: Part 1 Seats and covers
IS: 2556 (Part 1)	Specification for vitreous sanitary appliances (Vitreous china): Part 1 General requirement
IS: 2556 (Part 2)	Specification for vitreous sanitary appliances (Vitreous china): Part 2 Specific requirements of wash-down water closets
IS: 2556 (Part 3)	Specification for vitreous sanitary appliances (Vitreous china): Part 3 Specific requirements of squatting pans
IS: 2556 (Part 4)	Specification for vitreous sanitary appliances (Vitreous china): Part 4 Specific requirements of wash basins.
IS: 2556 (Part 6 Sec 4)	Specification for vitreous sanitary appliances (Vitreous china): Part 6 Specific requirements of urinals, section 4 partition slabs.
IS: 2556 (Part 6 Sec 5)	Specification for vitreous sanitary appliances (Vitreous china): Part 6 Specific requirements of urinals, section 6 water spreaders for half stall urinals.
IS: 2556 (Part 7)	Specification for vitreous sanitary appliances (Vitreous china): Part 7 Specific requirements of half round channels.
IS: 2556 (Part 8)	Specification for vitreous sanitary appliances (Vitreous china): Part 8 Specific requirements of siphoning wash down water closets.
IS: 2556 (Part 11)	Specification for vitreous sanitary appliances (Vitreous china): Part 11 Specific requirements for shower rose.
IS: 2556 (Part 12)	Specification for vitreous sanitary appliances (Vitreous china): Part 12 Specific requirements for floor traps.
IS: 2556 (Part 15)	Specification for vitreous sanitary appliances (Vitreous china): Part 15 Specific requirements of universal water closets.
IS: 2692	Specification for ferrule for water services
IS: 2717	Glossary of terms relating to vitreous enamelware and ceramic metal systems
IS: 2963	Specification for waste plug and its accessories for sinks and wash basins
IS: 3311	Specification for waste plug and its accessories for sinks and wash basins
IS: 5961	Specification for cast iron gratings for drainage purposes
IS: 6249	Specification for gel-coated glass fibre reinforced polyester resin bath tubs

IS: 9758	Specification for flush valves and fitting for water closets and urinals
Water Quality Tolerance	
IS: 3025 (Parts 1- 44)	Method of sampling and test (physical & chemical) for water and waste water
IS: 4764	Tolerance limits for sewage effluents discharged into inland surface waters
IS: 10500	Drinking Water
Pumps & Vessels	
IS: 1520	Specification for horizontal centrifugal pumps for clear cold fresh water
IS: 2002	Steel plates for pressure vessels for intermediate and high temperature service including boilers
IS: 2825	Code for unfired pressure vessels
IS: 4648 (Part 1)	Code of practice for lining of vessels and equipment for chemical processes Part 1: Rubber lining
IS: 5600	Specification for sewage and drainage pumps
IS: 8034	Specification for submersible pump sets for clear, cold, fresh water
IS: 8418	Specification for horizontal centrifugal self priming pumps

The design of Station Services for this Project shall be governed by all latest applicable local codes, regulations, standards and requirements issued by all the applicable local authorities and statutory bodies.

4.5.2 COLD WATER SUPPLY PIPING WORK

4.5.2.1 General

The Contractor shall furnish and install all piping work including all necessary parts. The cold water piping shall be of the types and models, which are suitable for the working fluid in the system.

The rated working pressure of the cold water piping system for the working fluid shall be at least 1.5 times of the actual working pressure, but not less than 1,034 kPa (150 PSIG.).

4.5.2.2 Piping

Cold Water Pipe

- (1) Cold water pipe underground shall be of Ductile Iron with cement lining to IS 8329 or as per the Notice of No Objection by the Employer / Engineer ,
- (2) Cold Water pipe inside building shall be PE-Lined or PVC-Lined steel pipe or as per the Notice of No Objection by the Employer / Engineer,
- (3) G.I. pipes and fittings with anti-corrosive paint and sand filling around.

Fittings for Ductile Iron pipes

Fitting for Ductile Iron pipes shall be Ductile Iron as required or recommended by the manufacture.

Fittings for PE-Lined or PVC-Lined steel pipe.

Fitting for PE-Lined or PVC-Lined steel pipe shall follow requirement or recommendation of the manufacturer.

4.5.2.3 Piping Installation

- (1) All piping shall be installed parallel to, or at right angles with, the building walls and partitions. A pitch in the direction of flow and drain shall be not less than 1: 500. Branches from water mains shall be taken in a manner to facilitate venting and draining. Reductions in bore shall be formed eccentrically to facilitate venting, except on vertical pipes where concentric reduction may be used.
- (2) All water piping shall be installed in such a way that all circuits can be completely drained off and all air pockets in the water circuits shall be suitably vented.
- (3) Clearance between pipe works and equipment or machinery shall be adequately provided to facilitate maintenance. Overhead clearance shall be at least 600 mm. over access ways, and where possible the projection of valve stems into access ways shall be avoided. Pipe works and pumps shall be so arranged that the removal for maintenance of the equipment can be carried out with minimum dismantling. Provision of all pipe fittings and accessories necessary for the efficient functioning of the various systems shall be included.
- (4) Pipes shall be installed in continuous lengths as long as possible. Except where required to be connected to fitting outlets or headers, they shall be joined by welding, solvent welding, screwing or soldering as per these Specifications and as per the Notice Of No Objection by the Employer / Engineer .
- (5) The equipment or piping shall be installed such that it will not provide a cross connection or interconnection between a distributing supply for drinking or domestic purposes and a polluted supply such as a drainage system or a soil or waste pipe that will permit or make possible the backflow of sewage, polluted water or waste into the water supply system. Where crossing a sewer or waste line is inevitable, the water line shall not be less than 0.30 metre above the sewer line, which shall be cast-iron soil pipe for not less than 30 metre on each side of the crossing.
- (6) All pipes shall be installed in an appropriate manner to present a neat and orderly appearance, using fittings for all changes of direction, and arranging pipe run parallel to or at right angles with structural members of the building, to provide utmost head-room and to clear lights and other obstructions. In general, suspended pipes shall be installed as closely as possible to the overhead structure.

4.5.2.4 Workmanship

All pipes shall be cut accurately to measurements established at the site, and

shall be worked into place without springing or forcing.

Piping shall be installed so that it may expand and contract freely without injury to itself or other work. Steel and wrought-iron pipe shall be cut with pipe cutters and threaded with sharp, clean dies. All cut sections shall be reamed to remove all burrs and to restore the pipe to full diameter. All changes in size shall be made with reducing fitting.

Pipe bends and bushings shall be prohibited.

Location of Device

All valves, cleanouts, equipment, accessories, and devices shall be so located that they are accessible for repair and replacement.

Storage and Cleaning

Pipes shall be delivered and stored with plugged ends. Ends shall be kept closed with temporary covers during erection. Before any pipe is installed, it shall be opened and pounded to remove any foreign substances, or swabbed, if necessary, for thorough cleaning.

Pipes shall be stored on racks in a suitable warehouse or cover to avoid rusting. If necessary, carbon steel pipes shall be coated with anodic rust converter or red lead primer.

During the course of installation, the Contractor shall take every precaution to prevent any debris from being left in the pipes. The Contractor shall be responsible for any damage that may occur.

Immediately after erection, exposed threads at all fittings shall be painted with zinc- chromate paint, and after welding each joint shall be wire-brushed and then painted with zinc-chromate paint.

Before start-up, all piping systems shall be thoroughly flushed with water until it runs clear.

Fixtures and equipment shall be lightly covered and protected against damage. At the completion of the work, fixtures, materials and equipment shall be thoroughly cleaned and delivered in a satisfactory condition.

Connection to Equipment

Connections to coils, pumps and other equipment shall be made in such a manner that undue strains between pipes and equipment are eliminated. Unions and / or flanges shall be used to facilitate the removal of the equipment.

Expansion and Contraction

The piping systems shall be installed so that there will be no damage due to expansion and contraction during operation.

Packless type expansion connectors shall be used where the expansion and contraction of the pipe is excessive or cannot be compensated by expansion loops or offsets.

Differential Settlement

The piping systems shall be installed so that there will be no damage due to differential settlement of the pipe supports after installation. The problems could be avoided by providing flexible connections.

Sleeves

Vertical pipes passing through floors shall be provided with sleeves of black steel pipes. Sleeves shall be of a proper length to pass through the entire floor construction and shall terminate 50 mm. above the finished floor level.

Horizontal pipes passing through walls and partitions shall be provided with full thickness sleeves made of standard weight black steel pipes.

Sleeves shall be large enough to leave not less than 12.5 mm. clearances around the pipe and covering insulation, if there is any. Sleeves shall be set in place when the walls and partitions are built.

Sleeves in concrete work shall be flanged at the bottom or provided with temporary centering caps and securely nailed or screwed to formwork before the concrete is poured.

Chromium-plated escutcheon shall be provided, where exposed pipes pass through walls or floors.

When sleeves are installed through a fire wall, the clearance between sleeves and pipes shall be filled with fire-resistant material. The fire rating of the fire-resistant material shall be at least equivalent to that of the fire wall.

When pipes pass through waterproof walls, water retaining rings with approved type of sealant shall be applied.

Joints for Threaded Pipes

Joints for threaded pipes shall be made with an approved Teflon tape or graphite compound applied to the male threads only. Threads, exposed after joints are made up, shall be mopped with compound.

Threads shall be of the cleanout, tapered threads with the ends being reamed before installation.

Flanged Pipe Joint

Flanged joints shall be installed at all valves larger than 50 mm. and at other places where necessary.

Jointing flanges shall be truly parallel to each other so that bolts are used only to tighten joints, rather than to correct alignment. Flanges shall be chosen to suit the maximum working pressure of the system. Bolts, nuts and washers shall be cadmium-plated steel.

Welded Pipe Joint

The edges of the pipe to be welded shall be machine-beveled wherever possible. Gas cuts shall be true and free of all burnt metal. Before welding, the surfaces shall be thoroughly cleaned and degreased. The welding technique shall be such as to ensure penetration to the full thickness of the pipe wall and through fusion of the deposited metal with the parent metal. During welding the ends of the pipes shall be held firmly together by suitable lugs, welded-on-bridge pieces or adequate tack welding. Special care shall be taken to prevent formation of welded obstructions and lodgment of welding residue inside the pipes. Cracks, pinholes, excessive under-cutting, etc. shall be removed and the joints re-welded. Welding materials and workmanship shall be in accordance with the requirements of American Welding Society (AWS).

Welders must be entirely competent and may be required to perform site tests. Should the Employer / Engineer not be satisfied, the welder must be replaced. The Employer / Engineer reserves the right to order the cutout for inspection of up to 1 percent of the total number of welds. In the event of any inspected welds being, in the Employer / Engineer opinion, unsatisfactory he reserves the right to order the removal of further welds which in his opinion indicate faulty workmanship. Welds removed for inspection shall be reinstalled at no additional cost to the Employer .

Either the electric arc or the oxy-acetylene welding method may be used. Welding rods or electrodes shall have such composition that the welds produced by them shall have the same analysis as the parent metal and shall be of an approved type and brand.

Floor, Wall and Ceiling Plate

Plates on all entry and exit openings shall be furnished and installed for all exposed pipes passing through finished walls, finished partitions, finished ceilings, and floors above grade.

Plates shall be large enough to completely close the hole around the pipe. Wall and ceiling plates shall have set screws; spring clips shall not be acceptable.

Where necessary to cover beads of fittings, special deep escutcheons shall be provided.

Cutting and Repairing

The work shall be carefully laid out in advance. Cutting of structural works shall be done only with the Notice of No Objection by the Employer / Engineer. Damage from the cutting shall be carefully repaired by skilled workmen of the trade involved.

Termination of Water and Drainage Piping

Water and drainage pipes extended to points 1.50 metres beyond the building structure shall be capped or plugged for future connection, or connection under other sections of these Specifications.

If trenches are closed, or the pipes are otherwise covered before being connected to the utility systems, the locations of the end of each pipe shall be marked with a stake properly tagged or otherwise identified.

Underground Pipes

All steel pipes to be buried underground shall be externally coated in the mill of the fabricator. Material shall conform to AWWA C 203. Sequence of application shall be as follows :

- (a) Sandblast,
- (b) Apply coat of plasticized coal tar primer,
- (c) Apply flood coat of hot plasticized coal tar enamel, 2.4 mm. minimum thicknesses,
- (d) Apply spiral wrap with 20 mil fiberglass,
- (e) Apply flood coat of hot plasticized coat for enamel, 2.4 mm. minimum thicknesses,

- (f) Apply spiral wrap with 6.8 kg asbestos felt,
- (g) After the top coat has been cured at approximately 20⁰C for not less than 16 hours, the external protective coating shall be tested electrically using an approved holiday detector and shall be free of missed spots,
- (h) Pipe shall be painted with two coats of anti corrosive paint and sand around.
Underground pipe supports attached to the building structure shall be made of stainless steel.
Back fill and under-fill shall be made with sand.

Flashing

Vent pipes shall be flashed and made watertight at the roof with 4-pound sheet lead. Flashings shall extend not less than 200 mm from the vent pipes in all directions and shall extend up the vent pipe not less than 150 mm at which point threaded standard cast-iron or malleable-iron recess roof couplings shall be installed to form counter-flashing or rain guards.

Valve

The location of the principal valves shall be as required, but, whether or not so indicated, shutoff gate valves shall be furnished and installed in each supply main where it enters the building. All valves used for pipe or equipment drains shall, if possible, be changed to gate valve type. All valves shall be installed in accessible locations or otherwise

access panels shall be provided. No valve shall be installed with its stem below the horizontal. These valves shall be rated for 10 kg/cm² working pressure or more.

The Contractor shall furnish and install a trap on each fixture and each piece of equipment requiring connection to the sewer system, except fixtures or equipment having an integral trap or seal. Each trap shall be placed as close to the fixture as possible and no fixture shall be double-trapped. All traps installed in accessible locations shall have cleanout plugs or as per the Notice Of No Objection by the Employer / Engineer means for cleaning. Slip joints in traps will be permitted only on the inlet side or in the trap seal.

Water Pipe

All pipes shall be installed with a pitch to drain. Where branches are connected to vertical risers, each branch shall drain back to its respective riser. Drain valves shall be provided at all low points of the system to permit complete draining.

Branches from service lines may be taken from the top, bottom or side of the main, using such cross over fittings as may be required as per site conditions.

Unions shall not be concealed in walls or partitions nor covered with insulations.

4.5.2.5 Testing and Commissioning

Cold water piping shall be tested with water pressure of not less than specified or 1 ½ times the maximum working pressure, whichever is greater, at the lowest point in the system. Care shall be taken to avoid putting excessive pressure on safety devices, etc. These delicate control mechanisms shall be removed during the tests to prevent shock damage. The system shall be tested when water temperatures and average ambient temperatures are approximately equal and

constant. Test pressure shall be maintained for not less than 30 minutes without an appreciable drop after the force pump has been disconnected.

Piping may be tested for a section at a time in order to facilitate the construction.

Leaks in screwed fittings shall be corrected by remaking the joints. Leaks in welded joints shall be cut out and re-welded. Caulking of leaks will not be permitted.

After pressure tests have been made, the entire water-distribution system to be sterilized, shall be thoroughly flushed with water until all entrained dirt and mud have been removed before introducing chlorinating material. The chlorinating material shall be either liquid chlorine or hypochlorite. The chlorinating material shall provide a dosage of not less than 50 PPM and shall be introduced into the system in an approved manner. The treated water shall be retained in the pipe long enough to destroy all non-spore forming bacteria. Except where a shorter period is approved, the retention time shall be at least 24 hours and shall produce not less than 10 PPM of chlorine at the extreme end of the system of the retention period. All valves in the system being sterilized shall be opened and closed several times during the period.

The system shall then be flushed with clean water until the residual chlorine is reduced to less than 0.2 PPM. During the flushing period all valves and faucets shall be turned on and off several times.

4.5.3 COLD WATER SUPPLY PUMP

4.5.3.1 General

Pumps used for the same function shall be from the same manufacturer.

The unit shall be especially selected to meet the project requirements, from reputed manufacturers.

The cold water supply pump in this section shall include packaged hydro pneumatic system and water transfer pump set (if applicable).

Water Supply Pump-Constant Pressure Booster Pump Set

- (1) The water supply pumps shall be of constant pressure with continuous running operation sequence and of low energy consumption. The booster pump set shall be pressure switch controlled or variable speed drive controlled,
- (2) The entire booster system shall be factory prefabricated on a common structural steel stand with all interconnection piping, anti-vibration mounting and wiring completed and operationally tested prior to shipment. The complete package shall also include isolation valves on the suction and discharge at each pump. Galvanized steel suction and discharge pipe manifolds as well as copper tubing with shut-off cocks for gauges and pressure switch shall be furnished and assembled,
- (3) The booster pump set shall be complete with pump starter and control panel with all automatic control functions which can interface to the M&E SCADA and the SCR.

Pumps shall be selected for a total efficiency of not less than 75 percent and comply with TAC standard.

4.5.3.2 Centrifugal Pumps

(1) Split Case Centrifugal Type

- (a) Pumps shall be of the non-overloading, centrifugal, volute type. They shall be of the horizontally split or vertically split, double suction type with suction and discharge connections in the lower half of the casing,
- (b) The pump shall allow removal of the rotating element without disturbing pipe connections and operating at not over the speed of 2900rpm.

(2) End Suction Centrifugal Type

- (a) Pumps shall be of single-stage horizontal end suction centrifugal type, operating at not over the speed of 2900rpm,
- (b) The pumps shall be designed so that removal of the pump impeller shall not interfere with the piping system (back pull out pump).

(3) In-line Centrifugal Type

- (a) Pumps shall be of the single-stage vertical mounted, split coupled (for all capacity) or close coupled (capacity not more than 500gpm) design, in-line centrifugal type, single suction with volute type casing operating at a speed of not over 1500 rpm,
- (b) The pumps shall be so designed that removal of the pump impeller shall not interfere with the piping system (back pull-out pump).

4.5.3.3 Centrifugal Pump Component

(1) Casings

- (a) Casings of all pumps shall be designed for a working pressure of 16 kg/cm² or 1.5 times the actual discharge pressure, whichever is greater,
- (b) Pressure classification of flange connections shall correspond to casing working pressures,
- (c) Casing material shall be cast-iron, precision manufactured for best performance and long-term duty,
- (d) Water discharge diffusers shall be included to reduce radial torque to the impeller.

(2) Wearing Rings

- (a) All pumps having discharge connections larger than 50 mm and operating at more than 2 kg/cm² total dynamic head shall be provided with casing wearing rings,
- (b) These rings shall be suitable for an individual application. Rings shall be replaceable, and positively keyed to prevent rotation.

(3) Impellers

- (a) Impellers shall be one-piece, zinc free bronze and dynamically balanced. Impellers of pumps having 40 mm and larger discharge connection shall be fully enclosed and hydraulically balanced,
- (b) Impellers shall be accurately keyed to the shaft and fixed in an axial position by shaft sleeves and separate snap rings. Impellers shall be fully protected against damage due to reverse rotation.

(4) Shafts

- (a) Shafts for pumps with stuffing boxes shall be of stainless steel, (chrome-iron or nickel-iron) extending through the stuffing boxes. Where stuffing boxes are used, shafts shall be provided with water slingers. Shafts shall be designed with high safety precautions to withstand easily the torsional loads with other stresses to which they may be subjected. They shall be so designed that there shall be no detrimental vibrational stresses. All shaft threading shall be external to the water passage and stuffing boxes,
- (b) Shafts sleeves shall be keyed to the shaft and extended through the stuffing box. "O" rings or gaskets shall be provided at sleeve ends to protect the shaft from water corrosion. They shall be so designed that no dismantling of the pump casing is required to replace the sleeves.

(5) Bearings

- (a) Bearings shall be heavy-duty ball bearing with a minimum average life of 100,000 hours,
- (b) The bearings shall be self-sealed, and housed in malleable-iron housing aligned to a bearing bracket by means of large precision registers,
- (c) Bearing shall be removable without dismantling any rotating element inside the pump.

(6) Stuffing Boxes

- (a) Stuffing boxes shall be deep enough for not less than 4 rings of packing and shall have bronze glands,
- (b) Packing shall be suitable in all cases for the service required with proper consideration of water pressure, temperature, temperature changes and sediment carried in the water,
- (c) Mechanical seals shall be provided in lieu of stuffing boxes. Balance type mechanical seals shall be used when the casing working pressure exceeds 10 kg/cm^2 .

(7) Couplings

- (a) All pumps, other than close coupled pumps, shall be provided with urethane flexible couplings or steel pins and bushing with a service factor of at least 1.5 for an individual application,
- (b) Spacer couplings shall be required for back pull out end suction pumps,
- (c) Couplings shall impose no restriction on normal end play or expansion. Suitable coupling guards shall also be provided.

(8) Base Plates

- (a) Each flexible coupled pump shall be provided with a cast-iron or fabricated mild steel base plate to hold both the pump and the motor in correct alignment,
- (b) Pumps and motors shall be accurately aligned.

(9) Miscellaneous Fittings

- (a) High points of pump casings shall be provided with air vent cocks. These cocks shall be extended outside of any insulation. Low points of casings shall be provided with valve drains and both inlet and outlet connections with properly located gauge tapings,
- (b) Casing brackets of pumps equipped with stuffing boxes shall be arranged to form drip pockets. A drip pipe shall be run from each drip pocket to the nearest drip funnel or floor drain.

(10) Motors

- (a) Each pump shall be driven at the required speed by 415V / 3 phase / 50 Hz. totally enclosed fan-cooled, insulation class F, protection class IP54 for indoor and IP 55 for outdoor electric motor,
- (b) The rated kW shall be at least 1.15 times the maximum power required,
- (c) The motors shall be of high efficiency design and shall be supplied as an integral part of the pump. The Contractor shall submit technical data for the Notice of No Objection by the Employer / Engineer,
- (d) Bearing of each motor shall be of anti-friction type ball bearing or roller bearing,
- (e) Motor terminal box shall be waterproof.

(11) Instrumentation and Control Panel

Instrumentation and Control Panel for Transfer Pump.

The transfer pump shall include the following instrument and control features

- (1) Main selector switch “Auto-Off-Manual”,
- (2) Pressure gauge and pressure switch,
- (3) Over temperature protection,
- (4) Flow sequencing,
- (5) Standby pump sequence and alarm,
- (6) Lead-lag pump selector switch,
- (7) Thru the door pump disconnect switch,
- (8) Pump run light,
- (9) External overload reset,
- (10) Control power light and switch,
- (11) Audible alarm horn,
- (12) Water storage tank low level system shut down,
- (13) High system alarm,
- (14) Control panel,
- (15) Pressure regulating valve,
- (16) Gate valve, check valve,
- (17) Strainer,
- (18) Flow switch,

- (19) Pump overload light,
- (20) Flexible Connectors,
- (21) Storage tank level switch,
- (22) Roof tank level switch.

Instrumentation and Control Panel for Constant Pressure Booster Pump Set

The booster pump set shall include the following instrument and control features :

- (1) Main selector switch “Auto-Off-Manual”,
- (2) Pressure gauge and pressure switch,
- (3) Over temperature protection,
- (4) Flow sequencing,
- (5) Standby pump sequence and alarm,
- (6) Lead-lag pump selector switch,
- (7) Thru the door pump disconnect switch,
- (8) Pump run light,
- (9) External overload reset,
- (10) Control power light and switch,
- (11) Audible alarm horn,
- (12) Water storage tank low level system shut down,
- (13) High system alarm,
- (14) Variable speed drive (for Variable Speed Booster Pump Set only),
- (15) Pressure transmitter (for Variable Speed Booster Pump Set only),
- (16) Control panel,
- (17) Pressure regulating valve,
- (18) Gate valve, check valve,
- (19) Strainer,
- (20) Anti-Vibration pads,
- (21) Flow switch,
- (22) Pump overloads light,
- (23) Flexible Connectors,
- (24) Diaphragm tank, pre-charged diaphragm type closed pressure tank.

4.5.3.4 System Control

4.5.3.4.1 Cold Water Transfer Pump (If Applicable)

- (1) The transfer pump shall be controlled by storage tank and roof tank level switch,
- (2) The transfer pump control shall be parallel and alternate, when the lead pump cannot handle the volume flow rate of the system then the lag pump shall automatically start to run in parallel.

4.5.3.4.2 Constant Pressure Booster Pump Set

- (1) System pressure control shall be maintained within + 5% by pilot operated

diaphragm type, combination pressure regulating and non-slam check valve on each pump discharge line, or stabilized and controlled by a pressure reducing valve station using a small pressure regulating valve for low flow requirements and a large valve for medium to large capacities,

- (2) The booster pump set shall be controlled by storage tank level switch and differential pressure switch.

4.5.3.4.3 Variable Speed Booster Pump Set

- (1) System pressure shall be maintained within + 5% by variable speed drive (Inverter) and pressure transmitter (At the longest point of riser) and non-slam check valve on each pump discharge line,
- (2) Pump shall be stabilized and controlled by a pressure reducing valve station using a small pressure regulating valve for low flow requirements and a large valve for medium to large capacities,
- (3) The booster pump set shall be controlled by the pressure switch in the distribution line.

4.5.3.5 Installation

Pumps shall be installed by following the manufacturer recommendations.

Each pump shall be mounted on approved vibration isolators which are, in turn, placed on a concrete base. The isolators shall be selected and installed in accordance with the manufacturer's recommendations such that no disturbing vibration and noise is being transmitted to the nearby structure.

The Contractor shall ensure that no cavitations occur at the eye of the impeller.

Any suction and discharge pipes, which are bigger than the pump connections shall be equipped with eccentric reducers.

Flexible connections shall be installed on both the suction and on the discharge pipe.

Shut-off valve and strainers shall have the same size as the suction pipe. Check valve and shut-off valve shall have the same size as the discharge pipe.

Drainage from each pump shall be discharged to the nearest drain. Each drain pipe shall be of galvanized steel pipe as detailed within this specification.

Where suction lift or negative suction occurs in the installation, self-priming pump of adequate NPSH shall be installed. The maximum speed of self-priming pump shall not exceed 3,000 rpm.

4.5.3.6 Testing and Commissioning

Operating test run method shall be provided by the manufacturer.

Before start-up, grease or lubricating oil shall be applied to the pump and motor.

After installations are completed, all pumps shall undergo test run. Any adjustments that are needed shall be made to ensure that all pumps shall operate with the required performance. Report forms shall contain following minimum data listings including design and actual conditions for each item mentioned below :

- (1) Date and time of test,
- (2) Ambient conditions at the time of test,

- (3) Pump maker, type, name and serial number,
- (4) Pump rpm,
- (5) Pump amperage (Individual Operation),
- (6) Pump amperage (Multiple Operation),
- (7) Rated motor amperage, starter relay number and amperage rating,
- (8) Pump inlet pressure (Individual Operation),
- (9) Pump inlet pressure (Multiple Operation),
- (10) Pump outlet pressure (Individual Operation),
- (11) Pump outlet pressure (Multiple Operation),
- (12) Water flow rate GPM.

4.5.4 SEWAGE PUMP SETS

4.5.4.1 General

Pumps used for the same function shall be of the same manufacturer.

The unit shall be especially selected to meet the project requirements, from reputed manufacturers.

The sewage pump in this section shall include drainage pump, sewage pump, and aerator.

Submersible Drainage Pump

- (1) Submersible drainage pump shall be of the automatic, electrical-motor-driven submerged type, complete with all necessary control equipment,
- (2) The guide rail with fitting with the pumps in the sump shall be used to make the removal and installation easier by suspending with the chain,
- (3) The submersible drainage pump shall be completed with pump starter and control panel with all automatic control functions that can interface with the M&ESADA.
- (4) The submersible sewage stationary pump shall meet the following requirements, submersible sewage pump with cutter device, with torque-flow impeller and submersible chemical pump.
- (5) The submersible pump shall be constructed such that motor is the integral part of the unit and shall be capable of operating in submerged condition without any damage.
- (6) The submersible sewage pump shall be completed with pump starter and control panel with all automatic control function that can interface with the M&ESADA.

4.5.4.2 Components

4.5.4.2.1 Submersible Drainage Pump

(1) Drainage Pump

The pump shall be of the automatic, electrical-motor-driven submerged type, complete with all necessary control equipment. The guide rail with fitting for the pumps in the sump shall be to make the removal and installation easier by suspending with the chain. Pump impeller shall be non-

clog, single or double channel of specified/required solid passage.

(2) Motor

Pump shall be directly connected to a vertical electrical motor having continuous oiling device on packed bearing sealed against dirt and moisture.

The motor shall be class F insulation with built-in thermal protection.

(3) Control

The motor shall be operated by a float switch adjusted to start and stop the motor at predetermined water levels. The switch shall be completely enclosed in a rain tight cast-aluminum case. Duplex pumps shall be equipped with automatic alternator to allow for the change in operation from one pump to the other and for starting the second pump if the flow to the sump exceeds the capacity of the first pump.

(4) Discharge Line and Accessories

The discharge line from each pump shall be provided with a check valve and union in an accessible location near the pump.

4.5.4.2.2 Submersible Sewage Pump

- (1) The submersible sewage stationary pump shall meet the following requirements, submersible sewage pump with cutter device, with torque-flow impeller and submersible chemical pump,
- (2) The submersible pump shall be constructed such that motor is the integral part of the unit and shall be capable of operating in submerged condition without any damage,
- (3) The shaft shall be of mechanical type, lubricated with oil. The sealing effect shall be kept for a long usage,
- (4) The pump impeller shall have adequate passage to handle solids, it shall be hydraulically balanced,
- (5) The pump with cutter device shall have a rotating cutting edge and a stationary cutting edge. The rotating cutting edge shall be made of tungsten carbide. The stationary cutting edge shall be surface-hardened,
- (6) The motor shall be submersible type and capable of running in submerged condition without any damage,
- (7) The motor shaft shall be common to the pump shaft,
- (8) The bearing shall be capable to sustain pump thrust and shall maintain its function for long usage,
- (9) The pumps of more than 22 kW output shall have a leak sensing probe inside the oil chamber,
- (10) The pumps of more than 22 kW output shall have a water jacket by which the motor is cooled by itself,
- (11) The cable entry shall be constructed such that water does not leak into the terminal box even along the cable conductors if the sheath is damaged,
- (12) Motor protector shall be as follows:

- a) D.O.L. start motor shall have a motor protector which is connected in the main circuit of single phase motor winding or neutral point of three phase motor winding. The protector shall be such that, if it senses overheating and/or over current, it automatically cuts the circuitry to stop the motor. The protector shall automatically reset to re-start the pump when cooling has occurred,
- b) Star-Delta start motor shall have three miniature protectors (thermostat) which are connected in series and embedded on the motor windings. The protectors shall sense motor overheating and give a signal through the cabtyre cable, to actuate the magnetic contactor in control panel or starter to cut the power supply circuit. The type of contactor of the miniature protectors shall be of Form-B contact.

(13) Material

Pump casing : Iron casting, Stainless steel casting, Bronze casting, Impeller : Iron casting, Stainless steel or casting, Bronze casting, Mechanical Seal : SiC (silicon carbide) or WC (tungsten carbide) seal, Shaft : Stainless steel, Cabtyre cable : P.V.C. Sheathed, Chloroprene sheathed, Motor frame : Iron casting, Stainless steel or casting.

(14) Accessories

- (a) Automatic discharge connection components; Duckfoot bend, support, Guide pipes (Galvanized steel, Stainless steel) and Lifting chain (Galvanized steel, Stainless steel),
- (b) Free-standing type components; Discharge bend, Pump stand (strainer),
- (c) 5 metres of cabtyre cable,

(15) Painting

The painting shall be epoxy-tar painting, chloroprene rubber painting or other painting recommended by the manufacturer. Stainless steel components shall not be painted.

4.5.4.3 Submersible Aerator & Ejector Aerator

The submersible aerator & ejector aerator shall meet the following requirements:

- 1) The aerator shall consist of an integral submersible electric motor and an aerator, and shall be capable of operating in the submerged condition without any damage,
- 2) The aerator shall have an impeller and a casing. The operation shall be such that the rotation of impeller shall create a centrifugal force in the casing and through this centrifugal force negative pressure areas shall be created at the periphery of the impeller, which draws air from the atmosphere. The air sucked down into the water shall be subject to an air/water collision within the guide vane, and then this mixed air-water current is forcibly discharged

through the discharge outlets. The numbers of discharge outlets shall not be less than six (6),

- 3) The shaft seal shall be mechanical seal running in an oil bath. A dust seal shall be furnished between the mechanical seal and the impeller, by which dust in the sucked air shall not come in contact with the mechanical seal,
- 4) The sucked air shall pass through an air passage made between the mechanical seal and the back of impeller,
- 5) The motor shall be submersible type capable of running in submerged condition without any damage,
- 6) The motor shaft shall be common to pump shaft,
- 7) The bearing shall be capable to sustain the pump thrust and shall maintain its function for a long usage,
- 8) The cable entry shall be constructed such that water does not leak into the terminal box even along the cable conductors if the sheath is damaged,
- 9) The motor protector shall be as follows :
 - (a) D.O.L. standard or shall have a motor protector which is connected in the main circuit of single phase motor or neutral point of three phase motor winding. The protector shall such, that if it senses overheating and / or overcurrent, it automatically cuts the circuitry to stop the motor. The protector shall automatically reset to re-start the pump when cooling has occurred.
 - (b) Star-delta start motor shall have three miniature protectors (thermostat) which are connected in services and embedded on the motor windings. The protectors shall sense motor overheating and give a signal through the cabtyre cable, to actuate the magnetic contactor in a control panel or starter to cut the power circuit. The type of contactor of the miniature protectors shall be 'B-contact',
- 10) Material
Pump casing -iron casting, Stainless steel or casting, Suction cover- Stainless casting (#304, #316), Impeller -Stainless casting (#304, #316), Mechanical Seal- SiC (Silicon Carbide), or WC (Tungsten Carbide), Shaft -Stainless steel, Cabtyre cable- P.V.C. sheathed or Chloroprene sheathed, Motor frame- Iron casting, Stainless steel or casting,
- 11) Accessories
Completed with silencer, air control valve, air inlet pipe, long flexible vinyl suction delivery, stainless steel lifting chain, cabtyre cable.
- 12) Painting
The painting shall be epoxy tar, chloroprene rubber, or other painting recommended by the manufacturer. Stainless steel components shall not be painted.

4.5.4.4 Installation

Installation shall follow the instruction manual from the manufacturer.

4.5.4.5 Testing and Commissioning

Before start-up, grease or lubricating oil shall be applied to the pump and motor.

After installations are completed, all pumps shall undergo test run. Any adjustments that are needed shall be made to ensure that all pumps shall operate -with the required performance. Report forms to contain following minimum data listings shall include design and actual conditions for each item mentioned below

- (1) Date and time of test,
- (2) Ambient conditions at the time of test,
- (3) Pump maker, type, name and serial number,
- (4) Pump rpm,
- (5) Pump amperage (Individual Operation),
- (6) Pump amperage (Multiple Operation),
- (7) Rated motor amperage, starter relay number and amperage rating,
- (8) Pump inlet pressure (Individual Operation),
- (9) Pump inlet pressure (Multiple Operation),
- (10) Pump outlet pressure (Individual Operation),
- (11) Pump outlet pressure (Multiple Operation),
- (12) Water flow rate GPM.

4.5.5 DRAINAGE PIPING WORK

4.5.5.1 General

The Contractor shall furnish and install all piping work including all necessary parts. The sanitary piping shall be of the types or models, which are suitable for the working fluid in the system.

4.5.5.2 Piping

Soil, Waste and Drain Pipes

Soil and waste pipe inside building shall be cast-iron pipe as per IS 3989 with joints,

Soil and waste pipe outside building shall be vitrified clay pipe and fittings conforming to IS 4129.

Vent Pipe

Vent Pipe inside building shall be Galvanized Steel Pipe Class B conforming to BSI Standard,

Underground vent pipe shall be Ductile Iron pipe with cement lining conforming to IS 8329.

Waste Pipes from Drainage Pumps

Pipe from drainage pump shall be Ductile Iron pipe with cement lining conforming to IS 8329.

Fittings for Galvanized Steel Pipes

Fittings for galvanized steel pipes shall be galvanized malleable cast-iron, conforming to ASTM A120-73 and IS 1879.

Fittings for Cast-Iron Pipes

Fitting for cast-iron pipes shall be cast-iron waste and drain pipe fittings,

conforming to ASTM A74-42.

Fittings for Polyvinyl Chloride Pipes

Fittings for polyvinyl chloride pipes shall be rigid, unplasticized polyvinyl chloride (PVC) as designated in ASTM D2241, ASTM D1785, Schedule 40.

Fittings for Ductile Iron

Fitting for Ductile Iron pipes shall be Ductile Iron as required or recommended by the manufacturer.

4.5.5.3 Installation

All piping shall be installed parallel to, or at right angles with, the building walls and partitions. A pitch in the direction of flow and drain shall be not less than 1:500. Branches from water mains shall be taken in a manner to facilitate venting and draining. Reductions in bore shall be formed eccentrically to facilitate venting, except on vertical pipes where concentric reduction may be used.

All water piping shall be installed in such a way that all circuits can be completely drained off and all air pockets in the water circuits shall be suitably vented.

Clearance between pipe works and equipment or machinery shall be adequately provided to facilitate maintenance. Overhead clearance shall be at least 600 mm. over access ways, and where possible the projection of valve stems into access ways shall be avoided. Pipe works and pumps shall be so arranged that the removal for maintenance of the equipment can be carried out with minimum dismantling. Provision of all pipe fittings and accessories necessary for the efficient functioning of the various systems shall be included.

Pipes shall be installed in continuous lengths as long as possible. Except where required to be connected to fitting outlets or headers, they shall be joined by welding, solvent welding, screwing or soldering as per the Notice Of No Objection by the Employer / Engineer or indicated in these Specifications.

The equipment or piping shall be installed so that it will not provide a cross connection or interconnection between a distributing supply for drinking or domestic purposes and a polluted supply such as a drainage system or a soil or waste pipe that will permit or make possible the backflow of sewage, polluted water or waste into the water supply system. Where crossing a sewer or waste line is inevitable, the water line shall not be less than 0.30 metres above the sewer line, which shall be cast-iron soil pipe for not less than 30 metres on each side of the crossing.

All pipes shall be installed in an appropriate manner to present a neat and orderly appearance, using fittings for all changes of direction, and arranging pipe run parallel to or at right angles with structural members of the building, to provide utmost head-room and to clear lights and other obstructions. In general, suspended pipes shall be installed as closely as possible to the overhead structure.

4.5.5.4 Workmanship

All pipes shall be cut accurately to measurements established at the site, and shall be worked into place without springing or forcing.

Piping shall be installed so that it may expand and contract freely without injury to itself or other work. Steel and wrought-iron pipe shall be cut with pipe cutters and threaded with sharp, clean dies. All cut sections shall be reamed to remove all burrs and to restore the pipe to full diameter. All changes in size shall be made with reducing fitting.

Pipe bends and bushings shall be prohibited.

Location of Device

All valves, cleanouts, equipment, accessories, and devices shall be so located that they are accessible for repair and replacement.

Storage and Cleaning

Pipes shall be delivered and stored with plugged ends. Ends shall be kept closed with temporary covers during erection. Before any pipe is installed, it shall be opened and pounded to remove any foreign substances, or swabbed, if necessary, for thorough cleaning.

Pipes shall be stored on racks in a suitable warehouse or cover to avoid rusting. If necessary, carbon steel pipes shall be coated with anodic rust converter or red lead primer.

During the course of installation, the Contractor shall take every precaution to prevent any debris from being left in the pipes. The Contractor shall be responsible for any damage that may occur.

Immediately after erection, exposed threads at all fittings shall be painted with zinc- chromate paint, and after welding each joint shall be wire-brushed and then painted with zinc-chromate paint.

Before start-up, all piping systems shall be thoroughly flushed with water until it runs clear.

Fixtures and equipment shall be lightly covered and protected against damage. At the completion of the work, fixtures, materials and equipment shall be thoroughly cleaned and delivered in a satisfactory condition.

Connection to Equipment

Connections to coils, pumps and other equipment shall be made in such a manner that undue strains between pipes and equipment are eliminated. Unions and / or flanges shall be used to facilitate the removal of the equipment.

Expansion and Contraction

The piping systems shall be installed so that there will be no damage due to expansion and contraction during operation.

Packless type expansion connectors shall be used where the expansion and contraction of the pipe is excessive or cannot be compensated by expansion loops or offsets.

Differential Settlement

The piping systems shall be installed so that there will be no damage due to differential settlement of the pipe supports after installation. The problems could be avoided by providing flexible connections.

Sleeves

Vertical pipes passing through floors shall be provided with sleeves of black steel pipes. Sleeves shall be of a proper length to pass through the entire floor construction and shall terminate 50 mm. above the finished floor level.

Horizontal pipes passing through walls and partitions shall be provided with full thickness sleeves made of standard weight black steel pipes.

Sleeves shall be large enough to leave not less than 12.5 mm. clearances around the pipe and covering insulation, if there is any. Sleeves shall be set in place where the walls and partitions are built.

Sleeves in concrete work shall be flanged at the bottom or provided with temporary centring caps and securely nailed or screwed to formwork before the concrete is poured.

Chromium-plated escutcheon shall be provided, where exposed pipes pass through walls or floors.

When sleeves are installed through a fire wall, the clearance between sleeves and pipes shall be filled with fire-resistant material. The fire rating of the fire-resistant material shall be at least equivalent to that of the fire wall.

When pipes pass through waterproof walls, water retaining rings with approved type of sealant shall be applied.

Joint for Cast - Iron Pipe

Joints for cast-iron pipes, hubs or bell-and spigots shall be made by tightly packing and caulking oakum gaskets or braided or twisted jute into the annular space between a spigot and hub or a bell to within 1 1/2 inches (3.75 cm) of the face of the hub or the bell, and filling the remaining space with molten lead at one pouring. The lead shall then be caulked to produce a watertight joint without overstraining the hub or the bell. When finished, the lead shall be flush with face of the hub or the bell.

Joints for No-Hub cast-iron pipes shall be made by Neoprene rubber sleeve conforming to ASTM D-15 and couplings with 304 stainless steel shaft and nut screw. Pipes and joints shall be plain ends.

When cast-iron pipe is used for pump suction or discharge pipe, the joint shall be flanged joint.

Joint for Threaded Pipe

Joints for threaded pipes shall be made with an approved Teflon tape or graphite compound applied to the male threads only. Threads, exposed after joints are made up shall be mopped with compound.

Threads shall be of the cleanout, tapered threads with the ends being reamed before installation.

Flanged Pipe Joint

Flanged joints shall be installed at all valves larger than 50 mm. and at other places where necessary.

Jointing flanges shall be truly parallel to each other so that bolts are used only to tighten joints, rather than to correct alignment. Flanges shall be chosen to suit the maximum working pressure of the system. Bolts, nuts and washers shall be cadmium-plated steel.

Joint for PVC Pipes

All PVC pipe works shall be strictly installed in accordance with the manufacturer's instructions. It shall be joined with a push fit, sealed rubber rings (or equal and approved jointing method), to allow for expansion. They shall be fixed with PVC or PVC-coated wrought iron brackets at distances specified/required below.

Welded Pipe Joint

The edges of the pipe to be welded shall be machine-beveled wherever possible. Gas cuts shall be true and free of all burnt metal. Before welding, the surfaces shall be thoroughly cleaned and degreased. The welding technique shall be such as to ensure penetration to the full thickness of the pipe wall and through fusion of the deposited metal with the parent metal. During welding the ends of the pipes shall be held firmly together by suitable lugs, welded-on-bridge pieces or adequate tack welding. Special care shall be taken to prevent formation of welded obstructions and lodgment of welding residue inside the pipes. Cracks, pinholes, excessive under-cutting, etc. shall be removed and the joints re-welded. Welding materials and workmanship shall be in accordance with AWS.

Welders must be entirely competent and may be required to perform site tests. Should the Employer / Engineer not be satisfied, the welder must be replaced. The Employer / Engineer reserves the right to order the cutout for inspection of up to 1 percent of the total number of welds. In the event of any inspected welds being, in the Employer / Engineer's opinion, unsatisfactory he reserves the right to order the removal of further welds which in his opinion indicate faulty workmanship. Welds removed for inspection shall be reinstalled at no additional cost to the Employer.

Either the electric arc or the oxy-acetylene welding method may be used. Welding rods or electrodes shall have such composition that the welds produced by them shall have the same analysis as the parent metal and shall be of an approved type and brand.

Cast-Iron Pipe : Horizontal maximum distance between supports shall be 3.00 m, with atleast one hanger for each pipe section. Hangers shall be located adjacent to joints, changes in direction and branch connection.

Floor, Wall and Ceiling Plate

The Contractor shall furnish and install plates on all entry and exit openings for all exposed pipes passing through finished walls, finished partitions, finished ceilings, and floors above grade.

Plates shall be large enough to completely close the hole around the pipe. Wall and ceiling plates shall have set screws; spring clips will not be acceptable.

Where necessary to cover beads of fittings, special deep escutcheons shall be provided.

Cutting and Repairing

The work shall be carefully laid out in advance. Cutting of structural works shall be done only with the Notice of No Objection by the Employer / Engineer. Damage from the cutting shall be carefully repaired by skilled workmen of the trade involved.

Termination of Water and Drainage Piping

Water and drainage pipes extended to points 1.50 metres beyond the building structure shall be capped or plugged for future connection, or connection under other sections of these Specifications.

If trenches are closed, or the pipes are otherwise covered before being connected to the utility systems, the locations of the end of each pipe shall be marked with a stake properly tagged or otherwise identified.

Underground Pipes

All steel pipes to be buried underground shall be externally coated in the mill of the fabricator. Material shall conform to AWWA C 203. Sequence of application shall be as follows:-

- (a) Sandblast,
- (b) Apply coat of plasticized coal tar primer,
- (c) Apply flood coat of hot plasticized coal tar enamel, 2.4 mm. minimum thicknesses,
- (d) Apply spiral wrap with 20 mil fiberglass,
- (e) Apply flood coat of hot plasticized coat for enamel, 2.4 mm. minimum thicknesses,
- (f) Apply spiral wrap with 6.8 kg asbestos felt,
- (g) After the top coat has been cured at approximately 20°C for not less than 16 hours, the external protective coating shall be tested electrically using an approved holiday detector and shall be free of missed spots.

Underground pipe supports attached to the building structure shall be made of stainless steel.

Back fill and under-fill shall be made with sand.

Flashing

Vent pipes shall be flashed and made watertight at the roof with 4-pound sheet lead. Flashings shall extend not less than 200 mm from the vent pipes in all directions and shall extend up the vent pipe not less than 150 mm at which point threaded standard cast-iron or malleable-iron recess roof couplings shall be installed to form counter-flashing or rain guards.

Valve

The location of the principal valves shall be as specified/required, but in any case , shutoff gate valves shall be furnished and installed in each supply main where it enters the building. All valves used for pipe or equipment drains shall be gate valve type. All valves shall be installed in accessible locations or otherwise access panels shall be provided. No valve shall be installed with its stem below the horizontal. These valves shall be rated for 10 kg/cm² working pressure or more.

The Contractor shall furnish and install a trap on each fixture and each piece of equipment requiring connection to the sewer system, except fixtures or equipment having an integral trap or seal. Each trap shall be placed as close to the fixture as possible and no fixture shall be double-trapped. All traps 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.

Floor Cleanout

Floor cleanouts shall have an iron body ferrule with raised head brass plug or with spanner wrench sockets.

Drain

Outside Floor Drain

Floor drains shall be of the cast-iron type and provided with trap, chromium-plated brass inlet grating and round removable cast-brass strainer. They shall, furthermore, be threaded or have caulked connection.

Floor and Area Drain

The size of the drains shall be determined by the branch size indicated/required. Drains and backwater valves installed in connection with waterproofed floors shall be equipped with bolted-type clamping devices. Floor drain for mechanical room shall be of tunnel floor drain type .

Grease Trap (If Applicable)

Grease trap shall be installed be of the sizes and dimensions as per the Contractor's design. They shall be constructed of complete sets from the manufacturer.

Soil, Waste and Drain Piping

Slope

Horizontal lines shall be installed with a minimum slope in the direction of flow of 2 cm per metre (1:50) for pipes of 80 mm and smaller sizes and with 1 cm. per metre (1:100) for larger pipe sizes.

Fitting

All changes in pipe sizes shall be made with reducing fittings or recessed reducers while changes in direction shall be made with "Y" fittings, combination Y and 1/8 bends, long sweep 1/4 bends, 1/6, 1/8, and 1/16 bends. Sanitary "Tee" branches shall be used when the direction of flow is from a horizontal line to a vertical line, and short sweep 1/4 bends shall be used on the discharge from a water closet. Union connections shall be made with tucker or hub drainage fittings.

Vent Line

Slope

Horizontal lines shall be pitched to drain back to the drainage system without forming traps, using fittings as required.

Arrangement

Except where otherwise indicated, main vertical soil and waste stacks shall be extended full size to and above the roof line as vents. Where practicable, two or more vent pipes shall be connected together and extended as one pipe through the roof. Vertical vent pipes shall be connected together and extended as one pipe through the roof. Vertical vent pipes may be connected into main vent riser above vented fixtures. Unless otherwise indicated, sanitary piping shall form

circuit or loop vents with no dead ends or inverted siphons. Circuit or loop vent lines shall be connected at a height of not less than 300 mm. above the highest fixture served. Horizontal waste lines receiving the discharge from two or more fixtures shall be provided with end vents unless separate venting of fixtures is shown. Where a vent is taken from a horizontal drain line, the vent connection shall be made above the centerline of the drain, either on the top or at an angle of not more than 45 degrees from the vertical. The bottoms of vent stacks shall be so connected that any dirt or scale from the inside of the stacks will be flushed out through the soil or waste piping. All vent stacks shall be extended to a minimum of 300 mm above the roof and equipped with a flashing fitting and special waterproof hood.

4.5.6 STORM DRAIN PIPING WORK

4.5.6.1 General

The Contractor shall furnish and install all piping works including all necessary parts. The storm drain piping shall be of the types or models, which are suitable for the working fluid in the system.

4.5.6.2 Rain Water Piping

Rain Water Pipes

Rain water pipes inside building shall be galvanized steel pipes medium weight, conforming to BSI and IS Standard.

Underground rain water pipe shall be Ductile Iron pipe with cement lining conforming to IS 8329.

Storm Drain Pipe

Storm drain pipe shall be Reinforced Concrete pipe, Tongue & Groove Joint Type, conforming to IS 456 and IS 3114.

Fittings for Galvanized Steel Pipes

Fittings for galvanized steel pipes shall be galvanized malleable cast-iron, conforming to ASTM A120-73 and IS 1879.

Fittings for Ductile Iron

Fitting for Ductile Iron pipes shall be high density polyethylene as required or recommended by the manufacturer.

4.5.6.3 General Piping Installation

All piping shall be installed parallel to, or at right angles with, the building walls and partitions. A pitch in the direction of flow and drain shall be not less than 1: 500. Branches from water mains shall be taken in a manner to facilitate venting and draining. Reductions in bore shall be formed eccentrically to facilitate venting, except on vertical pipes where concentric reduction may be used.

All water piping shall be installed in such a way that all circuits can be completely drained off and all air pockets in the water circuits shall be suitably vented.

Clearance between pipe works and equipment or machinery shall be adequately provided to facilitate maintenance. Overhead clearance shall be at least 600 mm. over access ways, and where possible the projection of valve stems into access ways shall be avoided. Pipe works and pumps shall be so arranged that the

removal for maintenance of the equipment can be carried out with minimum dismantling. Provision of all pipe fittings and accessories necessary for the efficient functioning of the various systems shall be included.

Pipes shall be installed in continuous lengths as long as possible. Except where required to be connected to fitting outlets or headers, they shall be joined by welding, solvent welding, screwing or soldering as approved or indicated in these Specifications.

The equipment or piping shall be installed so that it will not provide a cross connection or interconnection between a distributing supply for drinking or domestic purposes and a polluted supply such as a drainage system or a soil or waste pipe that will permit or make possible the backflow of sewage, polluted water or waste into the water supply system. Where crossing a sewer or waste line is inevitable, the water line shall not be less than 0.30 metres above the sewer line, which shall be cast-iron soil pipe for not less than 30 metres on each side of the crossing.

All pipes shall be installed in an appropriate manner to present a neat and orderly appearance, using fittings for all changes of direction, and arranging pipe run parallel to or at right angles with structural members of the building, to provide utmost head-room and to clear lights and other obstructions. In general, suspended pipes shall be installed as closely as possible to the overhead structure.

4.5.6.4 WORKMANSHIP

All pipes shall be cut accurately to measurements established at the site, and shall be worked into place without springing or forcing.

Piping shall be installed so that it may expand and contract freely without injury to itself or other work. Steel and wrought-iron pipe shall be cut with pipe cutters and threaded with sharp, clean dies. All cut sections shall be reamed to remove all burrs and to restore the pipe to full diameter. All changes in size shall be made with reducing fitting.

Pipe bends and bushings shall be prohibited.

Location of Device

All valves, cleanouts, equipment, accessories, and devices shall be so located that they are accessible for repair and replacement.

Storage and Cleaning

Pipes shall be delivered and stored with plugged ends. Ends shall be kept closed with temporary covers during erection. Before any pipe is installed, it shall be opened and pounded to remove any foreign substances, or swabbed, if necessary, for thorough cleaning.

Pipes shall be stored on racks in a suitable warehouse or cover to avoid rusting. If necessary, carbon steel pipes shall be coated with anodic rust converter or red lead primer.

During the course of installation, the Contractor shall take every precaution to prevent any debris from being left in the pipes. He shall be responsible for any damage that may occur.

Immediately after erection, exposed threads at all fittings shall be painted with zinc- chromate paint, and after welding each joint shall be wire-brushed and then painted with zinc-chromate paint.

Before start-up, all piping systems shall be thoroughly flushed with water until it runs clear.

Fixtures and equipment shall be lightly covered and protected against damage. At the completion of the work, fixtures, materials and equipment shall be thoroughly cleaned and delivered in a satisfactory condition.

Connection to Equipment

Connections to coils, pumps and other equipment shall be made in such a manner that undue strains between pipes and equipment are eliminated. Unions and / or flanges shall be used to facilitate the removal of the equipment.

Expansion and Contraction

The piping systems shall be installed so that there will be no damage due to expansion and contraction during operation.

Pack less type expansion connectors shall be used where the expansion and contraction of the pipe is excessive or cannot be compensated by expansion loops or offsets.

Differential Settlement

The piping systems shall be installed so that there will be no damage due to differential settlement of the pipe supports after installation. The problems could be avoided by providing flexible connections.

Sleeves

Vertical pipes passing through floors shall be provided with sleeves of black steel pipes. Sleeves shall be of a proper length to pass through the entire floor construction and shall terminate 50 mm. above the finished floor level.

Horizontal pipes passing through walls and partitions shall be provided with full thickness sleeves made of standard weight black steel pipes.

Sleeves shall be large enough to leave not less than 12.5 mm. clearances around the pipe and covering insulation, if there is any. Sleeves shall be set in place where the walls and partitions are built.

Sleeves in concrete work shall be flanged at the bottom or provided with temporary centering caps and securely nailed or screwed to formwork before the concrete is poured.

Chromium-plated escutcheon shall be provided, where exposed pipes pass through walls or floors.

When sleeves are installed through a fire wall, the clearance between sleeves and pipes shall be filled with fire-resistant material. The fire rating of the fire-resistant material shall be at least equivalent to that of the fire wall.

When pipes pass through waterproof walls, water retaining rings with approved type of sealant shall be applied.

Joint for Threaded Pipe

Joints for threaded pipes shall be made with an approved Teflon tape or graphite compound applied to the male threads only. Threads, exposed after joints are made up shall be mopped with compound.

Threads shall be of the cleanout, tapered threads with the ends being reamed before installation.

Flanged Pipe Joint

Flanged joints shall be installed at all valves larger than 50 mm. and at other places where necessary.

Jointing flanges shall be truly parallel to each other so that bolts are used only to tighten joints, rather than to correct alignment. Flanges shall be chosen to suit the maximum working pressure of the system. Bolts, nuts and washers shall be cadmium-plated steel.

Joint for PVC Pipes

All PVC pipe works shall be strictly installed in accordance with manufacturer's instructions. It shall be joined with a push fit, sealed rubber rings (or equal and approved jointing method), to allow for expansion. They shall be fixed with PVC or PVC-coated wrought iron brackets at distances specified/ required.

Welded Pipe Joint

The edges of the pipe to be welded shall be machine-beveled wherever possible. Gas cuts shall be true and free of all burnt metal. Before welding, the surfaces shall be thoroughly cleaned and degreased. The welding technique shall be such as to ensure penetration to the full thickness of the pipe wall and through fusion of the deposited metal with the parent metal. During welding the ends of the pipes shall be held firmly together by suitable lugs, welded-on-bridge pieces or adequate tack welding. Special care shall be taken to prevent formation of welded obstructions and lodgment of welding residue inside the pipes. Cracks, pinholes, excessive under-cutting, etc. shall be removed and the joints re-welded. Welding materials and workmanship shall be in accordance with AWS.

Welders must be entirely competent and may be required to perform site tests. Should the Employer / Engineer not be satisfied, the welder must be replaced. The Employer / Engineer reserves the right to order the cutout for inspection of up to 1 percent of the total number of welds. In the event of any inspected welds being, in the Employer / Engineer opinion, unsatisfactory he reserves the right to order the removal of further welds which in his opinion indicate faulty workmanship. Welds removed for inspection shall be reinstalled at no additional cost to the Employer.

Either the electric arc or the oxy-acetylene welding method may be used. Welding rods or electrodes shall have such composition that the welds produced by them shall have the same analysis as the parent metal and shall be of an approved type and brand.

Floor, Wall and Ceiling Plate

The Contractor shall furnish and install plates on all entry and exit openings for all exposed pipes passing through finished walls, finished partitions, finished ceilings,

and floors above grade.

Plates shall be large enough to completely close the hole around the pipe. Wall and ceiling plates shall have set screws; spring clips will not be acceptable.

Where necessary to cover beads of fittings, special deep escutcheons shall be provided.

Cutting and Repairing

The work shall be carefully laid out in advance. Cutting of structural works shall be done only with the Notice of No Objection by the Employer / Engineer. Damage from the cutting shall be carefully repaired by skilled workmen of the trade involved

Invert Elevation

The Contractor shall verify the proposed invert elevations prior to laying pipes.

Termination of Water and Drainage Piping

Water and drainage pipes extended to points 1.50 metres beyond the building structure shall be capped or plugged for future connection, or connection under other sections of these Specifications.

If trenches are closed, or the pipes are otherwise covered before being connected to the utility systems, the locations of the end of each pipe shall be marked with a stake properly tagged or otherwise identified.

Underground Pipes

All steel pipes to be buried underground shall be externally coated in the mill of the fabricator. Material shall conform to AWWA C 203. Sequence of application shall be as follows :

- (a) Sandblast,
- (b) Apply coat of plasticized coal tar primer,
- (c) Apply flood coat of hot plasticized coal tar enamel, 2.4 mm. minimum thicknesses,
- (d) Apply spiral wrap with 20 mil fiberglass,
- (e) Apply flood coat of hot plasticized coat for enamel, 2.4 mm. minimum thicknesses,
- (f) Apply spiral wrap with 6.8 kg asbestos felt,
- (g) After the top coat has been cured at appropriate temperature for not less than 16 hours, the external protective coating shall be tested electrically using an approved holiday detector and shall be free of missed spots.

Underground pipe supports attached to the building structure shall be made of stainless steel.

Back fill and under-fill shall be made with sand.

Flashing

Vent pipes shall be flashed and made watertight at the roof with 4-pound sheet lead. Flashings shall extend not less than 200 mm from the vent pipes in all directions and shall extend up the vent pipe not less than 150 mm at which point threaded standard cast-iron or malleable-iron recess roof couplings shall be installed to form counter-

flashing or rain guards.

Valve

The location of the principal valves shall be as specified/required, but in any case , shutoff gate valves shall be furnished and installed in each supply main where it enters the building. All valves used for pipe or equipment drains shall be of gate valve type. All valves shall be installed in accessible locations or otherwise access panels shall be provided. No valve shall be installed with its stem below the horizontal. These valves shall be rated for 10 kg/cm² working pressure or more.

The Contractor shall furnish and install a trap on each fixture and each piece of equipment requiring connection to the sewer system, except fixtures or equipment having an integral trap or seal. Each trap shall be placed as close to the fixture as possible and no fixture shall be double-trapped. All traps 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.

Floor Cleanout

Floor cleanouts shall have an iron body ferrule with raised head brass plug or with spanner wrench sockets.

Drain

Outside Floor Drain

Floor drains shall be of the cast-iron type and provided with trap, chromium-plated brass inlet grating and round removable cast-brass strainer. They shall, furthermore, be threaded or have caulked connection.

Floor and Area Drain

The size of the drains shall be determined by the branch size indicated/required. Drains and backwater valves installed in connection with waterproof floors shall be equipped with bolted-type clamping devices. Floor drain for mechanical room shall be of tunnel floor drain type.

4.5.7 VALVES AND ACCESSORIES

4.5.7.1 General

Valves and accessories shall be provided as specified/required.

Shut-off valves shall be furnished as necessary for a satisfactory operation of all apparatus.

Valves of the same type shall be supplied by the same manufacturer.

4.5.7.2 Material Description

The valves shall be of the types or models which are suitable for the working fluid in the system. The rated working pressure of the valve as specified for the working fluid shall be at least 1.5 times of the actual working pressure, but not less than 1,034 kPa (150 psig).

The diameter of hand wheels for valves shall be of a suitable size so as to allow tight closure by hand with the application of reasonable force so that neither additional leverage nor damage shall be imposed upon the stem, seat and disc. Where indicated or required, for inaccessible overhead valves, chain-operated

hand wheels including rustproof chain and chain guide shall be provide.

4.5.7.3 Gate Valves

Valves of size up to 50 mm. (2") shall be bronze where appropriate, with threaded ends, solid wedges and nonrising stems.

Valves of sizes 65 mm. (2 ½") and larger shall be cast-iron or ductile iron where appropriate, with flanged ends, solid wedges and rising stems.

4.5.7.4 Globe Valves

Valves of sizes up to 50 mm. (2") shall be bronze where appropriate with threaded ends and union bonnets.

Valves of 65 mm. (2 ½") and larger shall be cast-iron or ductile iron, bronze-trimmed where appropriate, with flanged ends.

4.5.7.5 Swing - Check Valves

Valves shall be of the swing type suitable for the horizontal or vertical operation with a two-piece hinge and accessible disc cover. Valves of sizes up to 50 mm. (2") shall be bronze where appropriate, with threaded ends and full area Y pattern bodies.

Valves of sizes 65 mm. (2 ½") and larger shall be cast-iron, swing pattern and bronze- trimmed where appropriate, with flanged ends.

4.5.7.6 Lift - Check Valves

Lift-check valves or silent-type check valves shall be installed as specified/required and at the location where noise and water hammer would cause a problem. The valves shall be of spring closed type.

Seats, discs, and springs shall be bronze or stainless steel, whichever is appropriate.

Valves of sizes up to 50 mm. (2") shall be bronze where appropriate, with threaded ends.

Valves of sizes 65 mm. (2 ½") and larger shall be cast-iron where appropriate, with flanged ends.

4.5.7.7 Butterfly Valves

A butterfly valve can be used instead of a gate valve if its size is over 100 mm. (4"); it shall have flange bolt centering holes for easy installation and drilled to suit precisely the piping flange (Full Lug type).

The body shall be cast-iron or ductile iron with aluminum-bronze disc where appropriate of sufficient rigidity and strength to resist distortion. The stem shall be through-shaft design to provide high strength and positive disc control.

Compound rubber seat rings shall have excellent elasticity as well as wear resistance to ensure positive water shut-off under the designed working pressure. Moulded-in "O" rings shall provide positive flange sealing to eliminate need for gaskets. All rubber parts shall be of the type suitable for the specified working fluid.

Lever-operated valves shall be used for sizes up to 150 mm. (6"). Gear-operated valves shall be used for sizes larger than 150 mm. (6"). Position indicators shall be provided to indicate valve disc position.

4.5.7.8 Ball Valves

Valves shall be ball pattern of the square head type with stainless steel ball conforming to AISI 304.

Valves of sizes up to 50 mm. (2") shall be bronze with threaded ends conforming to ASTM B62 and for valves of sizes larger than 50 mm (2") Valve body shall be carbon steel conforming to ASTM A216.

4.5.7.9 Float Valve

The valve shall be hydraulically operated, diaphragm-actuated globe or angle pattern valve. Operation of the main valve shall be controlled by a two-level remote float control.

The body shall be cast-iron with flanged ends and shall have a pressure rating of 1,206 kPa. (175 psi [class 125]). A stilling well must be provided around the float for protection against water surface turbulence.

4.5.7.10 Pressure Regulating Valve

The valve shall automatically reduce a higher inlet pressure to a steady lower downstream pressure regardless of changing flow rate and/or varying inlet pressure. This valve is an accurate pilot-operated regulator, capable of holding downstream pressure to a pre-determined delivery pressure.

The body of main valve shall be cast-iron with screwed or flanged ends and have a pressure rating of 1,206 kPa. (175 psi [class 125]).

4.5.7.11 Pressure Reducing Valve

The Pressure Reducing Valve is a hydraulically operated, single seated globe valve controlled by a direct acting spring and diaphragm pilot valve. It is available in globe or angle body.

The main valve shall be operated by the downstream pressure passing through the pilot system. It will reduce a high pressure of upstream to a predetermined lower pressure of downstream.

(h) Pressure ratings	:1,034 kPa. (150 PSI.)
(i) Pressure adjust ranges	:170 to 550 kPa. (25 to 80 PSI.)
(j) Materials:	
(i) Main Valve	:Cast iron
(ii) Body & Bonnet	:Cast iron
(iii) Seat	:Stainless Steel
(iv) Stem	:Stainless Steel
(v) Diaphragm	:Reinforced Synthetic Rubber

4.5.7.12 Pressure Relief Valve

Pressure relief valve shall be installed at the pump discharge line to provide protection against high surge when pump is shut down. It shall be of globe pattern diaphragm valve, hydraulically-operated, pilot-controlled and modulating type.

The body of main valve shall be cast-iron with screw or flanged ends of pressure

rating class 125.

4.5.7.13 Water Hammer Arrestors (Air Rechargeable)

This water hammer arrestor shall be installed at discharge pipe of water pump. It shall contain only one moving part; a spherical piston which floats inside the surge copper chamber, built in valve and gauge assembly simplifying charging and recharging procedure.

4.5.7.14 Flexible Connections

Where it is considered necessary, and with the Employer / Engineer's Notice of No Objection, flexible connections at inlets and outlets of pumps shall be of stainless steel flexible connector.

The flexible connectors shall be designed for excellent vibration and noise protection. Isolated tension members shall be provided to prevent excessive elongation.

Flexible connections shall be suitable for the specified working fluid, and specified working pressure and temperature.

4.5.7.15 Expansion Joints (For Steam and Hot Water System)

Packless type expansion connectors shall be used where the expansion and contraction of the pipe is excessive or cannot be compensated by expansion loops or offsets.

Anchors and pipe guides shall be provided and installed at the recommended locations.

All expansion connectors shall have flanged ends with working pressure corresponding with the piping system.

4.5.7.16 Strainers

Water strainers shall be of the Y type. Strainers of 50 mm. (2") and smaller shall have bronze or iron bodies with screwed connections while 65 mm. (2 ½") strainers and larger shall have iron bodies and flanged connections. They shall have the same rating as the piping system.

Water strainers shall comply with the requirements of the ASTM Standards.

The free area of each screen shall not be less than three times the area of the strainer inlet pipe. Strainers of 65 mm. and larger shall be provided with 15 mm. valve drains.

4.5.7.17 Air Vents and Drains

Manual air vents shall be furnished as required for purging air or other gases from the water circuit during filling-up. The outlet piping shall be done up to the nearest drain.

Automatic air vents, conforming to ASA standards, shall be furnished at the top of main water risers, supply and return pipes.

A shut-off valve shall be provided at the inlet of each automatic air vent. The outlet piping shall be done up to the nearest drain.

A plug-type drain cock shall be provided at all low points of pipe work systems. Drains shall be installed to ensure easy access and convenience for maintenance and removal of all piping, valves, fittings and equipment without

undue spillage.

Drainage facilities shall be provided and suitably sized to drain expeditiously the entire system and equipment involved.

4.5.7.18 Thermometers

Thermometers shall be of the adjustable-angle glass tube-type in a 230 mm. (9") case, accurate to $\pm 1/2^\circ\text{C}$. The scale range shall be suitable for the specified working fluid temperature and shall be of 230 mm. (9") scale case, dual scale with F and C.

Thermometers and socket wells shall be selected, subject to the Notice of No Objection by the Employer / Engineer, with their stem length suitable for the size of pipes where they are to be installed.

4.5.7.19 Pressure Gauges

Pressure gauges shall be of the bourbon type, stainless steel casing, round type of 100 mm. dial and scale range of approximately 150 per cent of the normal operation. Pressure readings shall be in dual scale with psi and kg/cm^2 .

A needle valve and snubber with working pressure corresponding with the piping system shall be provided for each pressure gauge.

Pressure gauges, exposed to corrosive liquid, shall be of the chemical type with diaphragm liquid separator.

4.5.7.20 Flow Measuring Equipment

Flow measuring devices shall be annular flow measuring stations with a portable meter set, provided complete with master chart for direct conversion of meter readings to m^3/h , carrying case, two 4 m. hoses, equalizer manifold, check seal, installation and operating instructions.

Meters shall be factory assembled eagle eye flow meters or equivalent duly approved.

Each station shall be complete with safety shut-off valves and quick connect coupling connections.

Annular elements shall be made of stainless steel where appropriate and rated to $20 \text{ kg}/\text{cm}^2$ at 66°C .

Each station shall be tagged by means of brass tag, attached with a chain that indicates the station number, meter setting and m^3/h .

Welding sockets shall be supplied by the flow meter manufacturer.

Where required, the flow meters shall be equipped with a built-in electronic totalizer, a square-root extractor, and a power unit for the transmitter to the Station Control room.

4.5.7.21 Water Meters

Water meters shall be of the displacement and accumulative reading type, conforming to the Local Standard with working pressure corresponding to the piping system.

4.5.8 HANGERS AND SUPPORTS FOR PLUMBING PIPING

4.5.8.1 General

All pipes shall be securely supported. Horizontal piping shall be supported by adjustable clevis type hangers with solid rods securely attached to the building

structure. Where several pipes run in a parallel fashion, trapeze hangers may be used in lieu of separate hangers. All hangers shall have turnbuckles or other approved means of adjustment. Where pipes, such as those from individual toilet rooms to main stacks, are not low enough to permit the use of turnbuckles, other means of adjustment shall be used. Chains, straps, perforated bars, or wire hangers will not be accepted. All hangers and supports shall be hot-dip galvanized. The maximum distances between hangers and supports for horizontally mounted and vertically mounted pipes shall be as indicated below.

For all pipes where the hanger clips bear directly on pipes and for hangers of dissimilar metals, suitable apposition with a layer of felt shall be provided to prevent corrosion. Hangers on structural steel shall be absolutely prohibited.

Anchors for steel pipes shall be welded directly to the pipe wall and securely bolted to the building structure. Anchors for copper and PVC pipes shall be of the split ring type. Hangers in the plant room shall be supported on springs.

Supporting brackets shall be fastened to concrete by means of inserts or expansion bolts, to brickwork by means of expansion bolts, and to hollow masonry by means of toggle bolts.

Two fixings per bracket shall be provided as follows:

Nominal Pipe Size (mm.)	Fixing Size (mm.)
Up to 65 (2 ½")	6.4 (1/4")
80 (3") to 150 (6")	9.5 (3/8")
200 (8") to 300 (12")	12.7 (1/2")

All hangers and steel supports shall have zinc coating.

The thickness of coating shall not be less than 300 grams of zinc per square metre (1 oz per sq.ft.) of the surface covered. Underground pipe support and hanger shall be all stainless steel.

4.5.8.2 Schedule of Pipe Supports

Schedule of Pipe Supports are shown in the following table:

SCHEDULE OF PIPE SUPPORTS							
Nominal	Hanger Rod	Maximum Interval (m.)					
Pipe Size	Min. Size	Steel Pipe		PVC Pipe		Copper Pipe	
(mm.)	(mm.)	Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
15 (1/2")	9	2.0	2.4	0.9	1.2	1.5	1.8
20 (3/4")	9	2.4	3.0	1.0	1.2	1.8	2.4
25 (1")	9	2.4	3.0	1.0	1.2	1.8	2.4
32 (1 ¼")	9	2.4	3.0	1.2	1.8	2.0	3.0
40 (1 ½")	9	3.0	3.6	1.3	1.8	2.4	3.0
50 (2")	9	3.0	3.6	1.5	1.8	2.4	3.6
65 (2 ½")	12	3.0	4.5	1.8	2.4	3.0	3.6
80 (3")	12	3.6	4.5	2.0	2.4	3.0	3.6

SCHEDULE OF PIPE SUPPORTS							
Nominal	Hanger Rod	Maximum Interval (m.)					
Pipe Size	Min. Size	Steel Pipe		PVC Pipe		Copper Pipe	
(mm.)	(mm.)	Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
80 (3")	15	4.0	4.5	2.4	2.4	3.6	3.6
100 (4")	15	4.8	4.5	2.4	3.0	4.1	4.2
125 (5")	22	4.8	4.5	2.4	3.0	4.3	4.4
150 (6")	22	6.0	4.8	3.0	3.6	4.5	4.6
200 (8")	22	6.0	4.8	4.7	4.7	4.8	4.9
250 (10")	22	6.0	4.8	4.1	4.10	4.11	4.12
300 (12")	22	6.0	4.8	4.13	4.13	4.14	4.15

Cast-Iron Pipe : Horizontal maximum shall be 3.00 m, with at least one hanger for each pipe section. Hangers shall be located adjacent to joints, changes in direction and branch connection.

4.5.9 SANITARY FIXTURES AND FITTINGS

4.5.9.1 General

The Contractor shall get the installation along with associated water supply distribution system and drainage system approved by the PUNE Water Supply and Sewerage authority or other licensing authorities / owner.

All sanitary wares and CP fittings shall be new, best of quality and of make, type and colour for which the Employer / Engineer has given the Notice Of No Objection. All samples of materials with specifications/ catalogues, performance data, shall be submitted for obtaining the Notice of No Objection by the Employer / Engineer before use on the Works. Samples with Notice of No Objection by the Employer / Engineer along with other approved equipment / materials shall be neatly displayed on a board and such a display board of samples shall always be in exhibition in the construction office of Engineer-. Such display shall be used for the day-to-day checking of the materials on site.

All the sanitary fixtures shall be of water conserving type and the flush tank for the water tanks shall be of dual flush type.

Wherever multiple choices of fixtures are offered, the Engineer shall have the final choice.

All fixtures shall be complete with all accessories as required for the working of the said fixture.

The Flush valves shall have in built vacuum breaker.

4.5.9.2 European Water Closet

European WC shall be wash down, floor mounted in white glazed vitreous chinaware with integral P or S trap as required. Wash down WC shall be supported on floor. The WC shall be with 32mm diameter C.P. brass flush valve or with Flush Tank (concealed or exposed). Each WC shall be provided with a solid plastic seat. The seat shall be fixed to the WC with CP brass pillar bar hinges. Rubber buffers shall be provided for the cover. The flush tanks shall have dual flush and shall be of water conserving type.

4.5.9.3 Asian Water Closet

Asian Water Closet shall be provided if applicable. They shall be of approved type and shall be in vitreous chinaware with P or S trap as required. AWC shall be installed on floor. The WC shall be with 32mm diameter C.P. brass flush valve or with Flush Tank (concealed or exposed). The flush tanks shall have dual flush and shall be of water conserving type. The flush valves shall be of water conserving type with limited volume per flush.

4.5.9.4 Urinals

Urinals shall be flat back wall hung urinal in white glazed vitreous chinaware. Urinals shall be provided with:

- a) 15 mm diameter spreader,
- b) 32 mm diameter CP dome waste,
- c) 32 mm diameter CP P-trap with unions,
- d) CP wall flange and pipe,
- e) CP Pipe manifolds.

All exposed pipes and fittings shall be of CP. The urinals shall be fixed with CP brass screws. Urinal flushing shall be through an auto flush valve with electrically operated solenoid valve activated by infra red sensor. Auto flush shall be concealed in wall and flush pipe shall be of copper or GI except the specified exposed part. Urinal partitions shall be white Marble 25mm thick, 1050 x 600mm size fixed in wall by cutting chase and making good in cement mortar (1:2) finished to match the surroundings.

4.5.9.5 Wash Basin

Wash basins shall be white glazed vitreous chinaware, wall mounted type / pedestal type / counter top type of size, shape, Colour and type for which the Employer / Engineer has given the Notice of No Objection. Each basin shall be complete with:

- a) CI or galvanized steel supporting brackets & clips as required,
- b) 32 mm diameter CP waste and overflow,
- c) Waste with rubber plug and CP chain as specified,
- d) One no. pillar tap or Basin Mixer of 15 mm size,
- e) One / Two nos. 15 mm CP brass angle cock 15 mm size with CP brass rigid connection from angle cock to taps / Mixers.

The tap shall be automatic in operation. Necessary solenoid valve (electrically operated) activated by infrared sensor shall be included.

4.5.9.6 Kitchen Sink / Pantry Sink

Kitchen / Pantry sinks shall be of stainless steel construction. Each sink shall be complete with:

- a) CI or galvanized steel supporting brackets & clips as required,
- b) 40mm diameter CP waste,
- c) Waste with rubber plug and CP chain specified,
- d) One no. pillar tap or Sink Mixer of 15 mm size,

- e) One / Two nos. 15 mm CP brass angle cock 15 mm size with CP brass rigid connection from angle cock to taps / Mixers.

4.5.9.7 Janitor's Sink

Janitor's sinks shall be of vitreous china or as other materials as per the Notice Of No Objection by the Employer / Engineer . Each Janitor's sink shall be complete with :

- a) CI or galvanized steel supporting brackets & clips as required,
- b) 40mm diameter CP waste,
- c) Waste with rubber plug and CP chain specified,
- d) One no. pillar tap or Sink Mixer of 15 mm size,
- e) One / Two nos. 15 mm CP brass angle cock 15 mm size with CP brass rigid connection from angle cock to taps / Mixers.

4.5.9.8 Toilets for The Mip

Where specified in washroom facilities designed to accommodate Mobility Impaired Persons, accessories shall be provided as directed by the Engineer. Stainless steel grab bars of required size suitable for concealed or exposed mounting and preened non-slip gripping surface shall be provided in all washroom. The flushing cistern / valve shall be provided with chromium plated long handles.

4.5.9.9 Drinking Water Fountain

Drinking water fountain shall be wall mounting type / surface mounting type made of stainless steel or any other material and the details shall be submitted to the Employer / Engineer for Notice of No Objection. The drinking water fountain shall be with anti-squirt bubble less, self closing valve type with automatic volume regulator. The drinking water fountain shall be provided with an anti-splash back and integral strainer with 32mm or 40mm cast brass trap.

4.5.9.10 Toilet Paper Holder

Toilet paper holder shall be white glazed vitreous china or chrome plated of size, shape and type for which the Employer / Engineer has given the Notice of No Objection.

Vitreous China toilet paper holders shall be fixed in walls and set in cement mortar 1:2 (1 cement: 2 coarse sand) and fixed in relation to the tiling work. The latter (chrome) shall be fixed by means of screws / capping having finish similar to the toilet paper holder in wall/temper partitions with rawal plugs or nylon sleeves.

4.5.9.11 Liquid Soap Dispenser

Liquid Soap Dispenser shall be wall/counter mounted suitable for dispensing liquid soaps, lotions, detergents. The cover shall lock to the body with concealed locking arrangement, opened only by the key provided. Liquid soap dispenser body and shank shall be of high impact resistance material. The piston and spout shall be stainless steel with 1 litre capacity polyethylene container and/or as per the Notice of No Objection by the Employer / Engineer.

4.5.9.12 Coat Hook

Coat hook shall be glazed vitreous china or chrome plated of size, shape, colour and type for which the Employer / Engineer has given the Notice of No Objection.

4.5.9.13 Towel Rail or Ring

Towel Rail or ring shall be glazed vitreous china or chrome plated of size, shape, colour and type for which the Employer / Engineer has given the Notice of No Objection.

4.5.9.14 Hand Drier

Hand Drier shall be of colour and type for which the Employer / Engineer has given the Notice of No Objection.

4.5.9.15 Mirror

Mirrors shall be of type for which the Employer / Engineer has given the Notice of No Objection.

4.5.9.16 Waste Bins

Waste bins shall be of type for which the Employer / Engineer has given the Notice of No Objection.

4.5.9.17 Tissue Dispenser

Tissue dispenser type shall be submitted to the Employer / Engineer for Notice of No Objection.

4.5.9.18 Installation

All sanitary ware and CP fittings shall be installed in accordance with the interior requirements. Neat workmanship and maintaining exact position and level of each fixture shall be ensured during installation. Care shall be taken to fix inlet and outlet pipes at correct positions. Faulty positioning shall be made well without any damage to the finished floor or wall tiling and any damage to the finished surfaces shall be made good by the Contractor at no additional cost to the Employer .

In order to ensure quality of workmanship and compliance with interior requirements, one or two mock-up installations shall be done and the Notice of No Objection by the Employer / Engineer obtained for the same. Fixtures used in the mock-up may be reused with the Notice of No Objection by the Employer / Engineer .

All fixing accessories like bolts, nuts, brackets etc. as required shall form part of the installation. All such accessories shall be CP brass or galvanized or stainless steel as per the Notice Of No Objection by the Employer / Engineer . All exposed pipes and bends shall be of CP brass.

Wall-hung European WC shall be mounted on CI chairs, which are fixed to the wall and floor using Anchor fasteners. The bolts and nuts used for fixing the chairs shall be stainless steel and the fixing bolts for the WC and chairs could be CP brass or stainless steel. Floor-mounted WC shall be fixed with Anchor fasteners using stainless steel bolts and nuts. The gap between the WC and floor or wall shall be neatly sealed with waterproof non-hardening sealant of approved colour. The sealant should not extrude beyond the footprint or WC

outline.

All WC's shall be aligned and leveled with the floor and wall tiles so as to present an integrated look. Utmost care and skill shall be exercised to achieve a good installation in keeping with the interior designs.

Urinals shall be fixed to the wall using anchor fasteners and stainless steel bolts and nuts. The urinals shall be held in line and level according to the interior designs and tile modules. Partitions, wherever required to be provided, shall also maintain line and level as required. Supply spreader and drain piping and P-trap shall be of CP brass and installed in a neat and workman like manner. No unseemly bends or wooden support pieces shall be permitted.

Wall-mounted wash basins shall maintain line and level as per the requirements of the interior drawings and also with the tile modules. The supply connections shall be of CP brass from the angle stop valves to the pillar taps and shall display good workmanship. Drain connections shall have a CP trap with unions and exposed CP drainpipe and a wall flange. In the case of counter mounted basins extreme care shall be taken to independently and adequately supporting the basin and aligning with the opening in the counter slab. Supply and drain connections shall be same as for wall mounted basins. The gaps between basin and wall or counter shall be neatly sealed with a non-hardening sealant of approved colour.

All accessories like the mirror, soap dish etc shall be neatly fixed as per interior designs. Good workmanship shall be the essence of all sanitary installation for achieving the interior design objectives.

During the construction period, the Contractor shall protect all the sanitary fixtures from damage due to accidental or even intentional mechanical impact with hard objects and also misuse and vandalism. Any damaged items shall be replaced by the Contractor at no additional cost to the Employer .

4.5.9.19 Testing And Acceptance

The sanitary fixtures form the final terminal units of the water supply and drainage system and should meet the performance needs as a terminal unit. Each fixture shall be inspected for scratches or chippings and alignment before acceptance. The following design flows shall be verified and validated for Notice of No Objection by the Employer / Engineer:

WC Flush Valve	9 liters to 12 liters per flush	Provide 32 diametre test valve connection at the lowest floor and highest floor
Pillar taps / Mixers	15 lpm max.	6lpm min
Wash Basin	Full basin drain time 3 min	To be measured and validated
Urinal Flush Valve	2 Liters per flush.	1 Liter per flush

All tests shall be conducted at each and every fixture except for flush valves which shall be at the lowest and highest test connections to be made on each riser / down take. The Contractor shall make the temporary valve connections which shall be plugged with a brass.

4.5.9.20 Mock Up

The Contractor shall install all pipes, fixtures, clamps and accessories and fixing devices in mock-up shaft and room so constructed as directed by Engineer without any additional cost to the Employer. The materials used in the mock-up may be reused in the works if found undamaged.

Any tiles or finished surfaces or floors damaged by the Contractor while doing his work shall be made good with new tiles and finishing materials at no additional cost to the Employer.

4.5.10 ELECTRICAL AND CONTROL WORKS

4.5.10.1 General

This section describes all electrical equipment and installations including connections for the aforementioned systems.

Unless items are factory-finished, one prime coat shall be provided on all raceways, hanger assemblies, equipment and accessories furnished under this section. Prime coating on steel and iron shall be synthetic red lead, or other materials, the details of which shall be submitted to the Employer / Engineer for the Notice of No Objection.

Scratches in factory-finished surfaces shall be touched up to match the original. The colours of Finished coat shall be as per the Notice Of No Objection of the Employer / Engineer .

The Contractor shall be responsible for bringing in the supply cable or wiring to the Contractor's distribution / control panels (or junction boxes or enclosed circuit breakers or safety switches). The Contractor shall connect the cable from the envisaged location to the isolator or circuit breaker in the panels or to the equipment. The connections and installation thereof shall form part of the Contract.

The equipment rating shall be based on the following electrical system :

- | | | | |
|-----|-----------------|---|-----------|
| (1) | Rated Voltage | : | 415V/240V |
| (2) | Rated Frequency | : | 50 Hz. |

All electrical conductors such as bus-bars, cables, wires, terminals, etc. shall be colour- coded as follows :

(1)	Phase R	:	Red
(2)	Phase Y	:	Yellow
(3)	Phase B	:	Blue
(4)	Neutral	:	Black
(5)	Ground	:	Green or Yellow Strip Green

- (6) Large wires and cables shall be colour coded with tapes of specific colour.

4.5.10.2 Component

Motor Control Centres

This provision covers the design and construction of motor control centre of floor or wall mounting type.

The requirement of electrical characteristics for equipment in Motor Control

Centres shall be as followed :

(a)	Voltage and Frequency	415V/240V, 50 Hz 3-phase, 4-wires with Earth or 1-phase,
(b)		2-wires with Earth in accordance with type of the equipment
(c)	Insulation Class :	600V (Minimum)
(d)	Rated Continuous Current :	As per Specifications/ Drawings
(e)	Rated Short Circuit Current :	As per Specifications/ Drawings (at 415 V.)

If ratings of the equipment in the motor control centre are not indicated on the drawings and in these Specifications, they shall be calculated in compliance with IEC Standard.

The Construction of Motor Control Centre (MCC)

- Enclosure of the motor control center shall be made of electro-galvanized steel sheet (minimum thickness of 2 mm.) and finished with epoxy-powder coating (minimum 60 micron) and coloured, the details shall be submitted to the Employer / Engineer for the Notice of No Objection. The enclosure shall consist of four compartments via bus-bar, cable, terminal and control unit compartment, which shall be separated by steel sheet barrier.
- Each control unit compartment shall be the combination of starter, circuit breaker and other accessories for each motor. The unit shall be completely enclosed and isolated from all other units. Unit side plates shall be permanently attached so much that they cannot be accidentally discarded. Each unit shall have a single door mounted on removable pin hinges. Each door shall be provided with a removable panel suitable for mounting push button, select or switches and pilot lamp. The door of each control unit shall be interlocked so that it cannot be opened while the circuit breaker is in "ON" position.
- Efficient vent opening shall be provided on the panel. The opening shall be screened so as to be insect-proof.
- Each panel shall undergo a treatment of degreasing and de-rusting by electro- galvanized or other equivalent method for anti-rust and shall be coated by an oven- baked enamel paint finished.
- All doors shall be provided with dust-protection gaskets of neoprene or any other materials as per the Notice of No Objection by the Employer / Engineer , positively retained in a rebate. All doors shall be equipped with locks operated by keys.
- Plastic nameplate with engraved letters of at least 3 mm thick shall be placed at every circuit breaker and starter indicating their uses.

Circuit Breakers

- Moulded case circuit breakers shall be applied in the system which shall comply with IEC 60947-1, IEC 60947-2 standard with appropriate rated short-circuit breaking capacity at 415V. The short circuit performance categories shall depend on the application of the breaker. All MCCB shall be of triple-pole or double-pole as required, thermal magnetic type, with

magnetic adjustable for MCCB's rated at 400A and above, independent manual operated to provide quick-make, quick-break, trip free mechanism so that the unit cannot be held closed against overload and short- circuit,

- (b) All circuit breakers shall be equipped with operating handles.

Motor Starters

- (a) Motor starters shall comply with IEC 60947-4-1 standard equipped with AC3 duty magnetic contactors,
- (b) Thermal overload relays with auxiliary contacts for shut down and monitoring shall be provided. The relays shall be manually preset / reset,
- (c) Phase failure relays with auxiliary contact for shut down and monitoring shall be equipped with the starter,
- (d) At least 2 normally open and 2 normally closed free contacts for both starting and tripping signals shall be provided. These free contacts shall be wired to the terminal blocks for remote indicator,
- (e) Direct-on-line starters are allowable for various motor sizes up to 3.75 kW
- (f) Motor bigger than 3.75 kW shall be equipped with Y-D starter.

Measuring Instrument and Current Transformer

- (a) All metering shall be the flush-mounted type with a dimension approximately 96 x 96 mm. accuracy classes 1.5 or better. The overload capacity is 1.20 times of the normal continuous load, except for motor circuit where the overload capacity of ammeter shall be 2 times the normal continuous load. The voltmeters shall be provided with selector switch,
- (b) Current transformers shall be the single phase insulated type and can withstand a continuous overload of 20%. The accuracy class of the transformer shall be class 1 for metering winding and class 3 for instrument winding. The insulation of the current transformer shall be of class 600 volts.

Bus-bar & Bus-bar Holder

- (a) Bus-bar shall be of bare copper conductor (purity 98%) the size and ampere rating of the bus-bar shall comply with DIN standard and also shall comply with the relevant Authority regulation,
- (b) Bus-bar spacing shall comply with the relevant Authority regulation,
- (c) Bus-bar holders shall be of Fiberglass reinforced polyester or epoxy resin (flame- proof material) and shall withstand the short-circuit stresses,
- (d) Each bus-bar shall have color identification, conforming to the color coding of the cable.

Control Wiring

- (a) Control wire in the motor control center shall be flexible annealed copper wire 600V Flame Retardant Low Smoke Zero Halogen, PVC insulated cables,
- (b) The size of control wire shall be as follow :
 - (i) 2.5 mm^2 for voltage/current circuit
 - (ii) 1.5 mm^2 for control circuit
- (c) All control wiring shall be run in cable trunking or flexible conduit without any

jointing

(d) Wire markers shall be applied at both ends of the control wiring.

4.5.10.3 Motors

All motors shall comply with IEC 60034-1, IEC 60034-12 standards and/or as per the Notice of No Objection by the Employer / Engineer. They shall have ample margin on their rating for the required duty with due allowance for ambient temperature. All motors shall be induction type suitable for 50 Hz. Motors shall be of totally enclosed fan cooled squirrel cage screen-protect drip-proof type. High starting torque motors and low speed machines shall be started by reduced voltage starters.

The rated kW shall be at least 1.15 times the maximum power required.

Control devices shall be provided for all motors. Single-or double-pole snap switches, specifically designed for alternating current operation only, may be used as manual controllers for single-phase motors having a current rating not in excess of 80 percent of the switch rating. Automatic control devices such as thermostats may control the starting and stopping of motors directly, provided the devices used are designed for that purpose and have such a rating. Otherwise, magnetic starters shall be used, with the automatic control device actuating the control circuit.

Overload protection shall be provided with running-over current (overload) protection in accordance with the NEC. The overload protection device shall be provided either integrally with the motor or controller, or shall be mounted in separate enclosure. Unless otherwise specified, the protective device shall be of the manually reset type.

4.5.10.4 Safety Switch

The safety switches shall be either Fused Safety Switches or Non-Fused Safety Switches as required.

The switches shall be heavy duty type equipped with switch blades, a quick-make and quick-break operating handle and mechanism which shall be an integral part of the box. Service door of each safety switch shall be interlocked so that it cannot be opened while the switch is in "ON" position.

Current rating of the switches shall be as required.

All fuses for "fused safety switch" shall be of the high rupturing capacity (HRC) type of voltage rating up to 600 volts. Current rating shall be specified.

The switches shall be IP31 general purpose enclosure with knockouts unless otherwise noted or required. Switches located outdoor or in wet areas shall have IP55 enclosures.

Low Voltage Cable and Fire Resistant (FR) Cable

The technical requirements have been specified in Electrical Section.

Conduits and Accessories, Boxes and Accessories and Equipment Grounding

The technical requirements have been specified in Electrical Section.

4.5.10.5 Installation

The Works shall be executed to completion and in conformity with the drawings and these Specifications.

Motor Control Centres.

All control centres shall be mounted 1.80 m. above the finished floor level and in accordance with the manufacturer's recommendation.

The Contractor shall supply, adapt and install a steel work at the top and / or the bottom of the equipment to permit where necessary the incoming or outgoing of the cables, conduits, and wires.

Low Voltage Cables

The technical requirements have been specified in Electrical Section.

Conduits

The technical requirements have been specified in Electrical Section.

4.5.10.6 Testing and Commissioning

All motor control centres shall be not only tested at the manufactory but also checked at the site for the follow performances :

- a) Insulation of all cables,
- b) Operating and protecting of the equipment,
- c) Grounding.

All cables fed to the equipment shall be meggered phase-to-phase and phase-to-ground before the equipment is connected and phase-to-ground after the equipment is connected and all connections are tapped.

Cable insulation resistance tests shall be performed by using a 500 V D.C megger on the 400 volts system. Insulation resistance shall not be less than 50 mega-ohms per 1000 volts rating.

4.5.11 FIRE BARRIER WORK

4.5.11.1 General

After erection of materials and equipment through wall and opening have been completed, it is the responsibility of the Contractor to fill up voids and openings with fire resistant material which conform to NFPA AND NEC article 300-21 or equivalent Indian Standard to protect fire or smoke from spreading out from one room to another room through these voids and openings.

The wall shall be considered to be a fire or acoustic protection wall, unless otherwise specified. Cover or escutcheon plates shall be provided, wherever exposed, and shall be neatly placed to the satisfaction of the Employer / Engineer .

Also, after the erection of all pipes, ducts conduits, wirings, and raceways in the shaft, block-out or any floor openings, the voids must be sealed with 2 hour fire rating material, the proposal for which shall be submitted to the Employer / Engineer for the Notice of No Objection.

The fire barrier materials shall be based on the standards of Underwriter's Laboratory Inc.

The fire resistant rating of the material shall be in accordance with the fire rating of construction walls or slabs and shall not be less than 2 hours rating.

4.5.11.2 Component

The fire barrier materials shall have the following properties :

- a) The fire barrier materials shall be of a minimum 2-hour fire resistant rating or higher in accordance with type of construction walls or slabs,
- b) The fire barrier materials must not be toxic during installation or in case of fire,
- c) It shall be easy to be dismantled and replaced in case of rearrangement,
- d) it shall be able to withstand over vibration,
- e) Easy installation shall be possible,
- f) Before and after fire spreads, the fire barrier materials must be strong enough,
- g) The proposal for the fire barrier materials shall be submitted to the employer / Engineer for the Notice of No Objection, before installation.

4.5.11.3 Installation

At every voids and openings, fire barrier materials shall be installed where:

- a) Every voids, sleeves, and openings on wall, floor, beam and shaft, provided for piping and raceway installation, must be sealed after the erection works have been completed,
- b) Voids, sleeves, and openings which are provided for future installation,
- c) Voids between electrical conduits and sleeves,
- d) Voids between electrical cabling and raceway on fire wall and floor,
- e) Voids between raceway and sleeves on fire wall and floor.

4.5.12 PAINTING

4.5.12.1 General

The following clauses specify the material or paint system (where permitted by the Engineer), preparation and application requirements for painting of all equipment, housing, vessels, containers, pipelines, pipe supports, and other structural steelworks which are not protected by galvanizing or a protective coating (as agreed by the Engineer) as per the Notice Of No Objection by the Employer / Engineer .

The Contractor shall also be responsible for cleaning, brushing and painting work. When surface cleaning, blasting and painting is done in the factory, the proposal for such preparation and painting shall be submitted to the Employer / Engineer for the Notice of No Objection. If necessary or required by the Engineer, the Contractor shall arrange for the inspection of the Employer / Engineer at the factory.

All painting shall be completed before applying of pipe insulation and commissioning.

Prior to equipment installation all metal surfaces shall be treated with anti-corrosive materials and / or painted according to these Specifications.

The preparation and application of the painting materials shall adhere strictly to the manufacturer's recommendations.

The equipment or materials that have previously been treated with anticorrosive materials and painted from the factory must be inspected for their workmanship. Any defects, such as scratches, peels and rust shall be repaired and repainted, the proposal for which shall be submitted to the Employer / Engineer for the Notice of No Objection.

During the progress of the painting work, the Contractor shall avoid spotting of the floors, walls, and other adjacent equipment. All spotting, if any, shall be cleaned immediately. Any damages, which may result from painting, shall be Contractor's responsibility.

4.5.12.2 Surface Preparation and Cleaning

Metal or ferrous Metal Surfaces

Rust at welding joints and other defects shall be removed by scraping. Wire brushes or sandpaper shall be used to clean the surfaces and to remove rust. Sand-blasting may be used to remove loose rust and other foreign substances. Mordant solution such as thinner, gas, turpentine shall be used to remove grease, oil or organic coating. Then the surfaces shall be cleaned with water and thoroughly dried or blow-dried.

The application of prime coats shall adhere strictly to the manufacturer's recommendations.

Old paint coats shall be removed by scraping before application of new paint.

4.5.12.3 Brush or Spray Painting

Each paint coat shall be left until completely dry before subsequent applications. Painting can be classified into 2 coats :

- a) Prime coat for rust prevention and/or adhesion of the finishing coats,
- b) Finishing coat for final appearance or for symbolizing the system codes.

Types of paint used shall depend on the material as well as on the environmental conditions,

4.5.12.4 Paint System

For Equipment

All of the manufacturer's applied coating or painting surfaces of all equipment such as pump, valve, and other accessories or fittings, etc., which have been damaged, or have been applied with inappropriate paint system for the services and environment of the equipment, shall be corrected or removed and repainted at the Contractor's expenses without any additional cost to the Employer.

The above requirements shall also be applied to all damaged galvanized surfaces of the equipment and materials.

Paint system for equipment, valves, etc. shall be of the same grade as specified for pipe work connected, except that the surface cleaning may be mechanical wire brushing.

4.5.12.5 Types of Paint for Various Surface and Environment

	Type of Surface	Normal Area	Humid/Corrosive Area
(a)	Black steel pipe, Black steel sheet, Switchboard, Panel	1 st coat: Red lead primer. 2 nd coat: Red lead primer. 3 rd coat: Alkyl finishing paint. 4 th coat: Alkyl finishing paint.	1 st coat: Epoxy red lead primer. 2 nd coat: Epoxy red lead primer. 3 rd coat: Epoxy finishing paint. 4 th coat: Epoxy finishing paint.
(b)	Galvanized steel pipe, Galvanized steel sheet duct work exposed to view. If colour coding is not specified, bronze colour shall be used for finishing coat	1 st coat: Wash primer. 2 nd coat: Zinc chromate primer. 3 rd coat: Alkyl finishing paint. 4 th coat: Alkyl finishing paint.	1 st coat: Wash primer. 2 nd coat: Epoxy red lead primer. 3 rd coat: Epoxy finishing paint. 4 th coat: Epoxy finishing paint.
(c)	PVC pipe, Plastic pipe	1 st coat: Wash primer. 2 nd coat: chlorinate rubber finishing paint. 3 rd coat: chlorinate rubber finishing paint.	1 st coat: Wash primer. 2 nd coat: chlorinate rubber finishing paint. 3 rd coat: chlorinate rubber finishing paint.
(d)	Cast-iron pipe inclusive of underground pipe	1 st coat: Coal tar Epoxy. 2 nd coat: Coal tar Epoxy.	1 st coat: Coal tar Epoxy. 2 nd coat: Coal tar Epoxy.
(e)	Copper tube, Stainless steel sheet, Aluminium steel sheet, Light alloy, Lead	1st coat: Wash primer. 2nd coat: Alkyd finishing paint. 3rd coat: Alkyd finishing paint.	1st coat: Wash primer. 2nd coat: Alkyd finishing paint. 3rd coat: Alkyd finishing paint.
(f)	Closed cell foam plastic. Use colour tape strips to Indicate colour codes.	-	-

Note: In cases where there is a necessity/ requirement of paint repairs resulting from welding, cutting, drilling, polishing, or threading, zinc rich primer shall be used prior to the application of finishing paint.

4.5.12.6 Colour Code

All pipes shall be colour coded except insulated pipes where only priming coats shall be applied to the pipe surface.

In the electrical system, colour coding shall be only at the conduit clamps

and the cover of junction boxes.

Strip sizes of colour codes (for insulated pipes) and the letter size shall be as follows:

Pipe Size (mm.)	Width of Colour Strip(mm.)	Letter Size (mm.)
20 (3/4") – 32 (1¼")	200 (8")	12 (1/2")
40 (1½") – 50 (2")	200 (8")	20 (3/4")
65 (2½") – 150 (6")	300 (12")	30 (1¼")
200 (8") – 250 (10")	300 (12")	65 (1½")
300 (12") and larger	500 (20")	100 (4")

Location of symbols and arrows indicating directions shall be as follows:

- Every 6 metre (20 ft.) interval of straight line pipe,
- Near all valves,
- Every change of direction and/or separation,
- Where pipes passing through walls or floors,
- Near service pipe.

Colour Codes of Various Systems

The identifications previously mentioned shall have colour as required by NBC and IS standard.

4.5.13 TEST AND STERILIZATIONS

4.5.13.1 General

All piping shall be tested by the Contractor, the proposal for which shall be submitted to the Employer / Engineer for the Notice of No Objection.

All equipment, materials, labour, etc. required for testing of the plumbing Works shall be furnished/arranged by the Contractor at no additional cost to the Employer.

All new, altered, extended or replaced plumbing work shall be left uncovered and unconcealed until it has been tested and the Notice of No Objection from the Employer / Engineer has been obtained by the Contractor.

Where such work has been covered or concealed, before it is tested or before obtaining the Notice of No Objection from the Employer / Engineer, it shall be exposed for testing.

Underground plumbing shall be tested and the Notice of No Objection from the Employer / Engineer obtained before back filling.

4.5.13.2 Field Testing

All electrical equipment shall be tested upon completion of installation to ensure that the equipment operates satisfactorily and conform to the Contract documents.

Field testing shall be required for all cables and electrical equipment furnished, installed or connected by the Contractor to ensure proper installation, setting, connection, and functioning in accordance with the plans, specifications and

manufacturer's recommendations.

Testing shall be conducted in the presence of the Employer / Engineer and, when necessary, under the supervision of equipment manufacturer's field engineer.

All tests recommended by the equipment manufacturer whether specified in these Specifications or not, shall be included.

Testing shall include any additional tests deemed necessary by the Employer / Engineer

, because of field conditions, to determine that equipment, material and system meet the requirements of these specifications.

The Contractor shall maintain in quadruplicate a written record of all tests showing date, personnel making test, equipment or material tested, tests performed and results. Two copies of test records shall be given to the Employer / Engineer.

The Contractor shall notify the Engineer two weeks prior to commencement of any testing, except meggering.

The Contractor shall be responsible for any damage to equipment or material due to improper test procedures or test apparatus handling, and shall replace or restore any damaged equipment or material to the original condition.

Safety devices such as rubber gloves and blankets, protective screens and barriers, danger signs, etc. shall be provided by the Contractor to adequately protect and warn all personnel in the vicinity of the tests.

The Contractor shall furnish all testing equipment, and provide proper temporary power source for testing purposes when normal supply is not available at the time of testing.

The conduit and wiring system shall be checked to ensure that the system has been installed in such a way as to provide a safe and reliable system.

The lighting system shall be checked at night to ensure that illumination levels as specified have been met.

Operation of interlocks, control and alarm circuits shall be tested. The grounding system test shall not be more than 5 ohms.

All miscellaneous equipment circuit breaker, low voltage switchboard, motor, etc shall be tested as recommended by equipment manufacturers.

All additional tests that the Employer / Engineer deems necessary because of field conditions, shall be conducted to determine that equipment and material and systems meet requirements of these Specifications.

The Cost incurred for testing i.e, electricity, city water, labour, etc, shall be borne by the Contractor.

4.5.13.3 Piping Test

Flushing of Pipes

Underground mains and lead-in connections to system risers shall be completely flushed before connection is made to sprinkler piping.

The flushing operation shall be continued for a sufficient time to ensure thorough cleaning.

The minimum rate of flow shall not be less than one of the following:

- (a) Hydraulically calculated water demand flow rate of the system, including any hose requirements.
- (b) Flow necessary to provide a velocity of 3.1 m/sec (10 ft/sec).
- (c) Maximum flow rate available to the system under fire conditions.

Piping between the Breeching Inlet and the check valve in the inlet pipe shall be flushed with sufficient volume of water in order to remove any construction debris and trash accumulated in the piping prior to the completion of the system and prior to the installation of the Breeching inlet connection.

Hydrostatic Test

All piping and fittings subjected to system working pressure shall be hydrostatically tested at 13.8 kg/cm^2 (200 psi) or 3.5 kg/cm^2 (50 psi) in excess of the system working pressure, whichever is greater, and shall maintain that pressure without loss for 2 hours.

The hydrostatic test pressure shall be measured at the low elevation point of the individual system or zone being tested.

The inside standpipe system, piping shall show no leakage.

Piping between the Breeching Inlet connection and the check valve in the inlet pipe shall be tested hydrostatically in the same manner as the balance of the system.

During the hydrostatic test, the pressure gauge at the top of each standpipe shall be observed and the pressure recorded.

Flow Tests

Water flow tests shall be carried out in accordance with NFPA 13 and NFPA 14 to verify the following :

Mains water supply.

All water flow alarm devices.

Flow rate at the hydraulically most remote sprinkler. Flow rate at the hydraulically most remote hose reel.

The arrangement of piping work and fittings to facilitate these tests shall be as illustrated in NFPA 13 and NFPA 14, with safety shut-off valves and quick-action couplings for connection of the portable meter set.

4.5.13.4 Equipment Tests

In addition to the tests required by NFPA 20, the Contractor shall carry out functional tests on all flow switches, monitoring points and interface connections with the fire alarm and Building Management systems.

Packaged pump units shall be tested at the manufacturer's works, and a detailed test certificate shall be provided.

4.5.13.5 System Operational Tests

Water flow detecting devices including the associated alarm circuits shall be flow tested through the inspector's test connection to result in an alarm on the premises within 5 minutes after such flow begins.

The main drain valve shall be opened and remain open until the system pressure stabilizes. The static and residual pressures shall be recorded on the Contractor's test certificate.

Operating tests shall be conducted after ensuring exposure protection systems are provided upon completion of the installation, where such tests do not risk water damage to the building on which they are installed or to adjacent buildings.

4.5.13.6 Defective Work

If the inspection or test shows defects, such defective work or material shall be replaced or repaired as necessary. Then inspection and tests shall be repeated.

Repairs of piping shall be made with new materials. No caulking of screwed joints or holes shall be acceptable.

4.5.13.7 Cleaning and Adjustment

Equipment, pipes, valves, fittings, and fixtures shall be cleaned without grease, metal cuttings, or sludge that may have accumulated from operation of the system during the test. Any stoppage, discolouration, or other damage to the finish, furnishings, or parts of the building, due to the Contractor's failure of cleaning the piping system properly, shall be repaired by the Contractor properly, at his own expense. When the Works are completed, the water system shall be adjusted for uniform circulation. Flush valves and automatic control devices shall be adjusted for proper operation.

Works to Completion

The Contractor shall commission, clean down, and leave in full working order the works as specified.

The Contractor shall operate the systems in such a manner to be able to and ready to operate at full load, anytime within a period of 24 consecutive hours. The cost incurred during this operation shall be borne by the Contractor.

As the installation proceeds the Contractor shall prepare record drawings of the Electrical Installation, ('as built drawing') to be submitted to the Employer / Engineer for the Notice of No Objection.

The Contractor shall deliver to the Employer / Engineer on completion of the works, manufacturer's literature, specifications, technical information and record drawings for all equipment installed.

4.5.13.8 Reports

After installations are completed, all equipment shall be test run. Any adjustments that are needed shall be made to ensure that all equipment shall operate with the required performance. Test run reports with all necessary data such as pressure, temperature, flow rate, current, voltage, etc., shall be recorded.

4.6 FIRE DETECTION & ALARM SYSTEM

4.6.1 GENERAL REQUIREMENT

4.6.1.1 Scope Of Work

The scope of work of the Contractor shall include design, manufacturing, supply, installation, testing, balancing and commissioning of equipment and accessories as per the Specifications to achieve a complete Fire Detection & Alarm System.

The system shall include the following:

- a) Fire Detection & Alarm system including VESDA,
- b) Public Address & Voice Alarm System,
- c) Emergency Lighting System,
- d) ECS and TVS Systems (AHUs / FAHUs / Fire Dampers / Staircase Pressurization / Fans, Station – Tunnel Ventilation-Smoke Exhaust),
- e) Fire Fighting Systems (Fire Pumps / Sprinkler Valves),
- f) Clean Agent Fire Suppression System (Total Flooding & Panel Flooding),
- g) Doors with access control ,
- h) Systems not listed above but that require interfacing with the Main Fire Alarm System.

Standards

Relevant Codes and Standards

BS 4683: Electrical Apparatus for Explosive Atmospheres

BS 5445: Components of Automatic Fire Detection Systems

BS 5839: Fire Detection and Alarm Systems for Buildings

BS 6387: Performance Requirements for Cables required to Maintain Circuit Integrity under Fire Conditions

BS EN 54-1: Fire Detection and Fire Alarm Systems

BS EN 55104: Electromagnetic Compatibility

BS EN ISO 9000: Quality Management and Quality Assurance Standards

BS EN ISO 9001: Quality Systems Model for Quality Assurance in Design, Development, Production, Installation and Servicing

BS EN ISO 9002: Quality Systems Model for Quality Assurance in Production, Installation and Servicing

BS EN ISO 9003: Quality Systems Model for Quality Assurance in Final Inspection and Test

BS EN ISO 9004: Quality Management and Quality Assurance Standards

BS 7846: – Code for Fire Survival Cables.

NFPA-72: National Fire Alarm Code

Codes and regulations of the jurisdictional authorities

4.6.1.2 Design and Verification And Validation to be Provided by The Contractor

The Technical Specifications and the Employer's Drawings shall form the basis upon which the Contractor shall develop and generate his detailed design and shop drawings for the Works. The Contractor shall be responsible for preparation of the CSD / SEM drawings to ensure that the Plant layouts are installed in such a manner that they do not clash with their surrounding installations and that sufficient space is provided for access and maintenance.

The Contractor's responsibility for design, verification & verification of the Works shall be as follows :

- a) Selection of plant to meet performance criteria and specification with supporting calculations,
- b) Pipe sizes, sprinkler/hose-reel pumping capacities and hydraulic pressure drop in accordance with the actual characteristics of the pipe work and equipment installed,
- c) Automatic clean gas total flooding system and or panel flooding system,
- d) Cable sizes, cable containment, voltage drop and electrical protective devices in accordance with the coordinated cable routing and the actual rating of plant,
- E) 24V DC battery sizing calculations,
- f) Fault level discrimination,
- g) EMC analysis and EMI control measures for the works,
- h) Acoustic and vibration isolation,
- i) All software design.

4.6.1.3 Harmonics

The Contractor shall ensure that equipment selection and installation of all the Plant and Equipment are such that harmonics in the power distribution system are kept to minimum. The installation shall comply with the latest edition of "UK - G5/4 – Planning levels for harmonic voltage distortion and the connection of non-linear equipment to transmission systems and distribution networks in the United Kingdom" as published by Electricity Association of UK.

The Contractor shall provide necessary information of their Plant for carrying out a harmonics study for the whole electrical power distribution network. When the overall harmonics at the point of common coupling with Electricity Grid exceeds the limits required by G5/4 due to the Contractor's Plant, the Contractor shall be responsible for reducing the harmonics with the appropriate means subject to the Notice of No Objection by the Employer / Engineer .

4.6.2 ANALOGUE ADDRESSABLE INTELLIGENT FIRE ALARM SYSTEM

4.6.2.1 Main Alarm Panel

- a) The Main Fire Alarm panel shall meet BS EN 5889 & BS EN 54 part 2 & part4, and UL and FM listed.
- b) The MAP construction shall be wall type suitable for recessed installation and of dust proof construction,

- c) The cabinet of all MAPs shall be fabricated from minimum 2mm thick electrogalvanized steel sheet, epoxy powder coated (signal red in colour to BS 381c requirements) to a minimum thickness of 60 microns. All angles and channels shall also be hot dip galvanized and painted signal red,
- d) The cabinet shall be fitted with a lockable door of hardened tempered glass panel,
All alarm group indicators and associated switches shall be visible behind the locked door without opening the door. The door shall be provided with appropriate hinges and lockset and shall not sag when opened, due to its own weight,
- e) The manufacturer's name, together with any other appropriate means of Identification of the alarm system shall be clearly and permanently marked on the MAP. The above information shall include the type of board and the model number. All brand names, model numbers and other identifications of components shall be left intact to facilitate ease of replacement. A control circuit diagram shall be laminated and housed within the board.

4.6.2.2 Features of The Main Alarm Panel

- a) The MAP shall be of microprocessor based and controlled by a program contained in non-volatile memory (ROM or EPROM). The MAP shall allow adaptation to the stations requirements by entry of user data via keypad or built-in keyboard provided on the MAP,
- b) The MAP shall have capability to process and evaluate incoming signals from individually addressable devices such as :
 - 1. Analogue addressable smoke detectors, heat detectors Combined optical smoke & heat detectors, Aspirating smoke detectors and linear heat detection cables,
 - 2. Addressable manual call points, alarm bells, beacon lights,
 - 3. Addressable interface unit for sprinkler flow switches,
 - 4. Addressable interface unit for fire sprinkler and hose-reel Pumps,
 - 5. Addressable interface unit for sprinkler/hose-reel tanks,
 - 6. Addressable control unit for control function.
- c) The following shall be provided on the MAP with LED indicators :
 - 1. Fire and jockey pumps "ON / OFF / TRIP" status,
 - 2. Fire water tank high and low level alarm,
 - 3. Control valve status,
 - 4. Electricity supply per phase failure indication alarm zones "ALARM / FAULT / ISOLATE",
 - 5. Electrically supervised gate valves "CLOSED",
 - 6. Clean gas panels "ALARM / FAULT / ISOLATE",
 - 7. Mute switch status.
- d) The MAP shall have at least 25% spare capacity on each detection / module Device loop for future expansion,

- e) Each addressable line card shall have its own micro processor-based circuit, working independently from the central processor board in the MAP. The addressable line card shall have each addressable line working independently in order to maintain full autonomous operation in the event of fault in any of the line circuit,
- f) By entering user-data via the keyboard provided at the MAP, it shall be possible to assign one or more detectors to a zone and display it accordingly. It shall also be possible to generate zones consisting of a single detector only,
- g) An alarmed or troubled condition of any detection device within a programmed zone shall result in the same condition for the entire zone. Should a detection device respond with either an alarmed or troubled condition, it shall be possible to determine the exact device location from the liquid crystal display screen in plain english text. These texts shall be user definable. The LCD screen shall be able to display sufficient characters with back lighting capacity,
- h) The MAP shall be field programmable. All programming inputs shall be via simple numeric code by using the keyboard on the MAP. All operation functions and programming shall follow guided operations via flashing keys or display,
- i) Alarm Test Mode
It shall be possible to switch each zone or each detector selectively and/or all detector zones together into test mode. In this mode, it shall be possible to initiate any detector by means of actual smoke or test gas. If the detector responds, this shall be indicated by the response indicator of the detector. The MAP shall automatically issue a reset command to the detector after 10 seconds. It shall be possible for a single person to perform detector testing without having to return to the MAP for reset action. When a zone is in test mode, all remote signaling and control outputs of the zones to be tested shall automatically be inhibited. The test alarm shall only trigger the internal silent alarm indicator of the MAP,
- j) Self Monitoring of MAP
The MAP shall be designed and programmed to perform extensive automatic self monitoring. If the MAP detects a fault, it shall reflect a fault status, indicated by liquid crystal display (LCD) with plain English text of the location and nature of the fault. The following shall be continuously monitored :
 1. Fault in microprocessor unit,
 2. Fault in ROM / EPROM memory,
 3. Fault on power supply/charger/battery,
 4. Fault in communication system/modem,
 5. Error in software (program) configuration,
 6. Error in hardware configuration.

For accurate location of faulty parts within the MAP, each plug-in card shall be equipped with dedicated (LED) indicators. The audible signal used for giving fault

Warning shall be distinctive and of a different tone from the audible fire alarm. Provision shall be made for cancelling the audible signal only while the fault visual indication remains on. Upon removal of the fault, the MAP shall automatically reset the fault signal.

k) Signal Display and Operating Terminal

The MAP shall be designed to operate with an operating and display terminal. Each terminal shall allow complete display and operation of the MAP. The display and operating terminal shall be equipped with a liquid crystal display (LCD) screen to provide plain English text of the following information:

1. Current date, month, year and time,
2. Current status summary for:
 - i. Number of alarms remaining in system,
 - ii. Number of faults remaining in system,
 - iii. Number of zones isolated,
 - iv. Number of zones in test mode,
 - (a) Display of FAULT condition with detailed description of Zone location, device location, type and time of fault,
 - (b) Display of ALARM condition with detailed description of Zone location, device location (including devices monitored by the SAPs), and time of activation of alarm,
 - (c) Display of ISOLATE condition with detailed description of Zone location, device location and time of isolation,
 - (d) Display of guided text for system programming functions,
 - (e) Hydrant / sprinkler / jockey pumps status,
 - (f) Power supply (individual phase) to sprinkler/jockey pumps,
 - (g) Fire tank compartments high / low levels,
 - (h) ALARM signal text display,
 - (i) FAULT signal text display,
 - (j) Clean gas system signal.

In addition to the LCD screen, the following master LED indications shall be provided:

1. "SYSTEM ON" with green LED,
2. "SYSTEM FAULT" with yellow LED,
3. "ISOLATE" with yellow LED,
4. "ALARM" with red LED.

The terminal shall also be provided with the following control and programming features:

1. Alarm and Fault Acknowledge button,
2. Alarm Reset button,
3. Function buttons for recalling of details of current status,

4. Keypad for the following functions :
 - i. To key in password,
 - ii. To program and edit user data,
 - iii. To perform lamp test (for all LEDs),
 - iv. To isolate zone,
 - v. To isolate a detector(s) within zone,
 - vi. To switch zone to test mode,
 - vii. To simulate zone alarm condition,
 - viii. To simulate alert condition,
 - ix. To simulate zone fault condition.
5. To create zones within each addressable loop,
6. To form cross zoning operation between zones,
7. To form alarm verification function for specific zone(s),
8. To define priority level of individual zone or stage,
9. To define access passwords.

The basic operation of the MAP in case of an alarm or fault shall be in a guided mode by means of visual indicators on the operation buttons. Clear distinction shall be provided between unacknowledged and acknowledged alarm status. Upon depressing the acknowledge button the audible alarm shall cease, however, the alarm or trouble visual indication shall remain lighted. Should an alarm be subsequently activated by a different device, even when it is from the same acknowledged zone, the audible alarm shall be reactivated until acknowledged. The acknowledge button shall be normally operational at all times.

A reset button shall also be provided which will set the MAP into normal (quiescent) condition. This reset button shall normally be locked. It shall only be operational by means of an access code via the built-in keyboard.

Both acknowledge and reset buttons shall incorporate user prompting that clearly guides the operator through the sequence of alarm acknowledgement and MAP reset. All troubled indications shall be no cancelling except by an actual clearing of the troubled condition at which time the troubled indications shall clear automatically with no requirement for reset at the MAP. There shall be a clear distinction between the alarm audible and fault audible signals at the terminal. Operator access to the terminal shall be restricted by means of passwords which have to be entered via the built-in keyboard.

l) Printer Unit

A strip printer unit (built-in type) shall be incorporated in the MAP and RP only. The printer shall register time and location of any alarm or fault. The printer unit shall be emergency power operated and paper run-out shall be indicated as a fault. The paper provided by the Contractor shall be sufficient for one year usage. The MAP and RP shall have a serial port and be configured for connection interface to a common dot matrix printer

m) Power Supply Unit

The storage batteries shall be 24V DC sealed and maintenance free dry type and compatible with the charger. Calculations to substantiate the compatibility with the charger shall be provided. The mains supply shall be 240V, 1 phase, 50 Hz and terminating in a fuse connection unit outside the MAP / SAP / RP. The capacity of the storage battery used to energize the alarm system shall be such that in the event of mains failure, the battery is capable of maintaining the system in normal working condition for 24 hours. Thereafter it shall be capable of supplying an additional load, resulting from an alarm originating in two separate alarm zones for a period of half an hour. In addition it shall be capable of supplying the full emergency evacuation alarm load for a period of at least 10 minutes. The Contractor shall submit detailed calculations to justify the capacity of the battery and the battery charger and their compatibility. A switch for disconnection of the battery shall be provided

n) **Battery Compartment**

Batteries shall be kept in a separate cool, dry, well ventilated compartment. They shall be kept in a locked cabinet or a container that can be opened only by the use of a key which shall be similar to that used for the main panel door. Such cabinet or container shall be readily accessible for inspection and shall not be above the control cabinet. The interior of the cabinet or container shall be protected against corrosion. The battery compartment shall be appropriately earthed. Cable entry to the battery compartment shall be rimmed and bushed

o) **Fire Alarm Signaling Transmission**

Upon receipt of an alarm signal, the MAP shall send the various summary alarm signals to SCR / OCC through M&E SCADA via ITB..

4.6.2.3 Sub Alarm Panel

A) Construction

The sub alarm panel shall be similar in construction to the MAP,

B) SAP shall be fully standalone complete with power supply, charger / batteries. The SAP shall have its own micro-processor, software, and memory capabilities and provide indication for alarmed and troubled/faulted condition in each loop. All software (i.e. Programs and data system configuration) shall be held in non-volatile ROM / EPROM. The signal display at each SAP shall be by means of LCD with back-lighting capability and sufficient display characters which are user definable. All alarm signal display shall include zone location and point location in plain English text. Test, acknowledge, alarm silence, re-set switches, local programming, switches or keypad and buzzer shall be provided in each SAP.

4.6.2.4 Repeater Panel (RP)

a) **Construction,**

The repeater panel (RP) shall be similar in construction to the MAP.

b) **The RP shall be a monitoring panel which shall be fully stand alone function complete with power supply, charger / batteries,**

c) **The RP shall have its own micro-processor, software, and memory**

capabilities and provide indication for alarmed and troubled / faulted condition in each loop. All software (i.e. Programs and data system configuration) shall be held in non-volatile read only memories. The signal display at the RP shall be by means of 640 Characters LCD with back-light capability and sufficient display characters which is user definable. All alarm signal display shall include zone location and point location in plain English text, Each detector of each circuit loop shall carry out self-verification indicated by the panel for re-confirmation before sending out the fire alarm signal.

Test, acknowledge, alarm silence, re-set switches, local programming, switches or keypad and buzzer shall be provided in the RP. A mute switch shall be provided in the repeater panel to silence the bells when necessary.

The mute switch in SCR shall be provided with indicating light and labelling. The installation and operation of the mute switch shall comply with the emergency voice communication being provided for the station and the proposal for the same shall be submitted to the Employer / Engineer for Notice of No Objection.

4.6.2.5 Interface Terminal Board (ITB)

ITBs shall be located within 1.4 to 2 metres above the finished floor level such that it is readily accessible to operational personnel for maintenance purposes. ITBs shall be opened using a key which is similar to that used for the main panel door. The terminal diagram shall also be provided on the panel door of the ITB.

4.6.2.6 Mimic Panels

- a) The Contractor shall supply and install all coloured mimic panels with LED indications of the station's layout and details relating to the fire alarm zones, breeching inlets, standby hoses, alarm bells, call points, electrically supervised gate valves, landing valves, flow switches and sprinkler control valves, MAPs, SAPs and RP locations etc. The proposal for mimic panels shall be submitted to the Employer / Engineer for Notice of No Objection prior to their fabrication,
- b) The mimic panels shall be of Perspex sheet silk screened on the reverse side. The mimic panels shall be installed within a locked enclosure. Where space permits, the mimic diagram shall be installed within a recessed space besides the MAP. The mimic panel shall not fade on exposure to sunlight and ultra-violet light,
- c) One red LED light each shall be provided on the mimic panels for each zone to flash when fire or smoke is detected in that zone. One red LED light each shall also be provided on the mimic panel for each clean gas cylinder room and to flash when clean gas leakage is detected in that room or low pressure in the clean gas cylinder bank (which signifies clean gas leakage from the gas cylinder). One red LED each shall also be provided for all the system panels /devices / components including the VESDA that are interfaced with the Fire Alarm System.

4.6.2.7 Alarm Bells

All alarm bells shall be iron clad, corrosion proof, 24V DC, 150mm round red

gong pattern suitable for 20mm conduit entry except otherwise stated. All outdoor alarm bells shall be of weatherproof construction and shall be at least rated to IP55. The alarm bells shall be labelled 'FIRE ALARM BELLS' in English, the bell circuits shall be 'interleaved' and separately fused at the control unit. The sound pressure level measure at 3m away shall be at least 85 dBA.

The Alarm bells shall be provided in the Mechanical Plant Room Areas only. The station shall be provided with the Public Address and Voice Alarm System.

4.6.2.8 Beacon Light

Flashing beacon lights shall operate on 24V DC and shall be of wall-mounted type. These lights shall be mounted within the noisy rooms to provide visual warning. The beacon light shall be visible when operated within a lighted room.

4.6.2.9 Manual Call Point

- a) Manual call points shall be addressable type. Manual call points shall be arranged to operate automatically upon breaking of the glass and shall comply with the requirements of BS 5839 part 2 and as acceptable to the local authorities. The cover shall have sealing facilities to prevent vandalism and locked in position with a special key with the glass panel being clipped firmly into place. The unit shall be of pleasing appearance and styling and finish enamelled red. The words: 'IN CASE OF FIRE - BREAK GLASS' shall be included. The voltage and current ratings of the contacts shall be marked within the unit,
- b) Contacts shall be of silver or approved non-deteriorating alloy; for normally closed alarm system. A concealed 'test' device shall be included,
- c) The units shall be of flush mounting type and suitable for direct connection to the addressable loop, therein specified without the addition of unsightly surface boxes, glands, addressable interface unit, adapters, etc. where special boxes are necessary for installation, the boxes shall be provided. Boxes for recessing in concrete or plaster shall be of galvanized steel,
- d) Manual call-points installed outdoors shall be of weatherproof construction and installation and shall be at least rated to IP55. Those installed within the commercial space shall be vandal-proof type.

4.6.2.10 VESDA System (Very Early Smoke Detection & Alarm)

The VESDA system shall be provided for the Electrical Rooms & Signal and Communication Equipment Rooms and rooms where Sensitive equipment are installed as agreed by the Engineer.

The components of the VESDA systems are as follows :

A) Aspirating Smoke Detector

Smoke detector, in which air and aerosols are drawn through a sampling device and carried to one or more smoke sensing elements by an integral aspirator (e.g. Fan or pump). Each smoke sensing element may contain more than one sensor exposed to the same smoke sample. It shall meet the UL standard and comply with BS EN 54 part 20 or equivalent.

B) Sampling device

Component or series of components or dedicated device (e.g. a pipe

network, dedicated duct, probe or hood) which forms part of the ASD and transfers samples of air to the smoke sensing element(s). The sampling device may be supplied separately.

C) Sampling point

The point at which an air sample is drawn into the sampling device.

D) Response threshold value (RTV)

The measure of the aerosol concentration in the proximity of the smoke sensing element at the moment that the specimen generates an alarm signal, when it is tested.

E) Transport time

The time it takes for aerosols to transfer from a sampling point to the smoke sensing element.

F) Recovery

Treatment of a specimen, after conditioning, so that the properties of the specimen may be stabilized before measurement of the said property as required by relevant standards.

Detection Technology

Light Source

The Detection Chamber shall employ a highly sensitive, short wavelength LASER light source.

Detection Method

The detection sensing method shall use both a two-dimensional image sensing array and at least 5 photodiodes spaced inside the chamber to detect various scattering angles.

The output data from the sensing method shall include particle size and mass scattering measures,

A particle counting method shall be employed for the purposes of:

1. Minimizing the effect of large dust particles on the true smoke obscuration.
2. Monitoring contamination of the filter (dust & dirt, etc.) to automatically notify when maintenance is required.

Analytics

The detector shall apply analytics algorithms based on output data from the sensing method to determine the nature of sampled airborne material. Such algorithms shall provide probabilities of sampled air containing dust, diesel particulate and smoke from overheating PVC wire.

Absolute Calibration

The detection chamber shall be factory calibrated and shall not use adaptive algorithms or drift compensation techniques to adjust the sensitivity or detector output from that established during commissioning.

Detector Features

The detector shall incorporate the following features.

1. The Detector, Filter, Aspirator and Relay Outputs shall be housed in a

mounting box and shall be arranged in such a way that air is drawn from the fire risk area by an aspirator and a sample passed through a sample filter and detection chamber.

2. The Detector shall employ a short wavelength LASER light source and incorporate particle imaging and light scattering using a two-dimensional image sensing array and scatter pattern measurement using photodiodes.
3. The detector shall have an obscuration sensitivity range of 0.005-20% obs/m (0.0016–6.25% obs/ft) with a resolution of 0.0002%obs/m (0.00006%obs/ft).
4. The Detector shall have four independent field programmable smoke alarm thresholds across its sensitivity range with adjustable time delays for each threshold between 0-60 seconds.
5. The detector shall employ modular construction allowing field replacement of the filter, chamber and aspirator.
6. The detector shall allow future hardware expansion via stackable modules placed either on top or below the detector.
7. The Detector shall also incorporate facilities to transmit the following fault categories:
 - Detector
 - Air flow
 - Filter
 - System
 - Zone
 - Network
 - Power
 - Chamber
 - Module

The detector shall support the generation and transmission of urgent and minor faults. Minor faults shall be considered as servicing or maintenance signals. Urgent faults indicate the unit may not be able to detect smoke.

The single and four pipe VEP shall include one and four in-line sample pipe inlets respectively, and must contain a flow sensor for each pipe inlet. Both Minor and Urgent flow faults can be reported

The flow sensors in each pipe shall use ultrasonic flow sensing technology.

The filter shall be a disposable filter cartridge and shall be capable of filtering particles in excess of 20 microns from the air sample.

A second filter shall be ultrafine, removing more than 99% of contaminant particles of 0.3microns or larger, to provide a clean air barrier around the detector's optics to prevent contamination and increase service life.

The aspirator shall be a purpose-designed impeller air pump. It shall be capable of allowing for branched pipe networks up to 130m (427ft) and 560m (1,837ft) (branched) in total for single and four pipe VEP respectively, with a transport time per applicable local codes.

The Assembly must contain relays for alarm and fault conditions. The relays shall be software programmable to the required functions. The relays must be rated at 2 Amp at 30 VDC. Remote relays shall be offered as an option and either configured to replicate those on the detector or programmed differently.

The detector shall have built-in event and smoke logging. It shall store smoke levels, alarm conditions, operator actions and faults. The date and time of each event shall be recorded. Each detector (zone) shall be capable of storing up to 20,000 events and does not require the presence of a display in order to do so.

The detector shall incorporate a galvanically isolated General Purpose Input (GPI) which activates in the event of an applied voltage of 5 to 50VDC and can be assigned by configuration to activate one of several functions (Reset, Disable, Reset/Disable, Stand-by, Mains OK, Day/Night).

The detector shall incorporate a monitored voltage-free input, to be used with isolated relay contacts, which is supervised using a 10k Ohm terminating resistor.

The detector shall have seven or more relays for remote indication of alarm, fault and other status. The assignment of relay functions shall be configurable.

Displays

For the single pipe ASD, a display module may be located in a remote mounting box or a 19 inch remote rack. For the four pipe ASD, a display module may be located within the detector, a remote mounting box or a 19 inch remote rack.

Each Display shall provide the following features at a minimum:

1. Color LCD touch screen user interface
2. A bar graph display.
3. Four independent high intensity alarm indicators, Alert, Action, Fire 1 and Fire2, which correspond to the four alarm thresholds of the detector.
4. Alarm threshold indicators for Alert, Action and Fire 1.
5. Fault icons indicating faults for the categories: detector, chamber, filter, flow, aspirator, network, power and external module where applicable.
6. A remotely mounted Display may be optionally equipped with 7 configurable relays for signaling alarm and fault conditions.
7. A single mechanical button to support RESET and DISABLE commands
8. A touch screen interface to allow scrolling through status screens on the LCD.

Monitoring

The system shall have available software for the purpose of monitoring all devices connected to a system. Such software shall be provided to run on:

1. PC-based hardware
2. Android-based hardware
3. iOS-based hardware

4. A dedicated monitoring device built into a detector
5. A dedicated monitoring device mounted remotely from any detector

Configuration

Configuration Software Tools

The system shall have available software for the purpose of commissioning and configuring all parts of the system. Such software shall be provided to run on:

1. PC-based hardware
2. A dedicated monitoring device built into a detector
3. A dedicated monitoring device mounted remotely from any detector

Programming Device

Programming may be performed using a Windows® application running on a PC connected through a High Level Interfacing unit (PC-Link HLI) or by direct connection to a detector.

Each Programmer shall support the following features at a minimum:

1. Programming of any device on the ASD system.
2. Viewing of the status of any device in the system.
3. Adjustment of the alarm thresholds of a nominated detector.
4. Setting of Day/Night, weekend and holiday sensitivity threshold settings.
5. Initiation of AutoLearn™, to automatically configure the detector's alarm threshold settings to suit the environment.
6. Multi-level password control.
7. Programmable latching or non-latching relay operation.
8. Programmable energized or de-energized relays.
9. Programmable high and low flow settings for airflow supervision.
10. Programmable aspirator speed control for four pipe ASD.
11. Programmable maintenance intervals.
12. Facilities for referencing with time dilution compensation.
13. Testing of relays assigned to a specific zone to aid commissioning.

Security

The following security measures shall be provided.

1. Connectivity via wireless access shall support WPA2 encryption with encryption key.
2. Access to a detector via Ethernet or WiFi shall be protected using a detector password specific to the detector and in addition to the WiFi encryption key.
3. All software connecting to a detector or peripheral shall support an authentication protocol to verify that it has been supplied by the manufacturer of the system.

Upgrading

There shall be provision for field upgrading the firmware in the system using a USB memory key connected directly to the detector, avoiding the need for a separate PC for this function.

Peer-to-peer detector communications network ports.

A peer-to-peer networking facility shall be provided for the purposes of reporting alarms, faults and monitoring status, history and for configuration of devices.

The peer-to-peer network shall:

1. Comprise a physical layer that shall:

- comply with the ANSI/TIA/EIA-485-A-1998 electrical specifications
- employ asynchronous serial data transfer
- operate at a baud rate no less than 19.2 kBaud.
- detect communications errors due to interference, open and short circuit
- detect ground faults

Be able to support up to 200 devices (detectors, displays and programmers), of which 100 detectors can be supported.

Be capable of being configured in a fault tolerant loop for short circuit, open circuit and ground fault. Any communication faults shall be reported unambiguously and shall be clearly attributable to an individual device or wire link in the fault messages.

Be configurable by PC based configuration tools that are available to configure and manage the network of detectors.

Secondary communications

Detectors shall provide inbuilt secondary communications for monitoring and configuration using the following physical media:

- USB
- 10/100 BaseT Ethernet
- WiFi (802.11b/g)

Application

Detection Alarm Levels

The system shall have four (4) independently programmable alarm thresholds. The four alarm levels may be used as follows:

- Alarm Level 1 (Alert) - Activate a visual and audible alarm in the fire risk area.
- Alarm Level 2 (Action) - Activate the electrical/electronic equipment shutdown relay and activate visual and audible alarms in the Security Office or other appropriate location.
- Alarm Level 3 (Fire 1) - Initiate an alarm condition in the Fire Alarm Control Panel to call the Fire Brigade and activate all warning systems.
- Alarm Level 4 (Fire 2) - Activate a suppression system and/or other

suitable countermeasures.

Notes!

The alarm level functions as listed are possible scenarios. Consideration should be given to the best utilization of these facilities for each application and the requirements of local authorities (e.g. Authorities Having Jurisdiction).

Initial Detection Alarm Settings

Initial settings for the alarm levels shall be determined by the requirements of the protected environment. However, the setting for Fire 1 (Alarm Level 3) shall always appear as 100% on the bar graph scale. Default settings of the unit shall be:

1. Alarm Level 1 (Alert) 0.08% obs/m (0.025% obs/ft)
2. Alarm Level 2 (Action) 0.14% obs/m (0.0448% obs/ft)
3. Alarm Level 3 (Fire 1) 0.20% obs/m (0.0625% obs/ft)
4. Alarm Level 4 (Fire 2) 2.0% obs/m (0.625% obs/ft)

Initial (factory default) settings for the alarm/fault delays

1. Alarm Level 1 (Alert) 10 seconds
2. Alarm Level 2 (Action) 10 seconds
3. Alarm Level 3 (Fire 1) 10 seconds
4. Alarm Level 4 (Fire 2) 10 seconds
5. Air Flow Fault 5 seconds

Faults

The Detector Fault relay shall be connected to the appropriate alarm zone on the Fire Alarm Control Panel (FACP) in such a way that a Detector Fault would register a fault condition on the FACP. The Minor Fault and Isolate relays shall also be connected to the appropriate control system.

(Check local Codes, Standards or Regulations to determine whether compliance with this set up is required).

Power Supply and Batteries

The system shall be powered from a regulated addressable power supply of nominally 24V DC. The battery charger and battery shall comply with the relevant Codes, Standards or Regulations. Typically 24 hours standby battery backup is required followed by 30 minutes in an alarm condition.

Local Power Supply Standards that may apply:

1. UL 1481 Listed - provided the power supply and standby batteries have been appropriately sized / rated to accommodate the system's power requirements.
2. US Telecommunication Central Office Power Supply - the system shall operate on negative 48 VDC (provided continuously from the telephone central office power source) converted to 24VDC.
3. EN 54-4 approved power supply for use in Europe.
4. In accordance with AS 1670.1-2004 and NZS4512: 2003.

Sampling Pipe Design

Sampling Pipe

The sampling pipe shall comply with the following requirements.

1. The sampling pipe shall be smooth bore. Normally, pipe with an outside diameter (OD) of 25mm or 1.05" and internal diameter (ID) of 21mm or ¾" should be used.
2. The pipe material should be suitable for the environment in which it is installed, or should be the material as required by the specifying body (UL 1887 Plenum rated CPVC).
3. All joints in the sampling pipe must be air tight and made by using solvent cement, except at entry to the detector.
4. The pipe shall be identified as Air Sampling/Aspirating Smoke Detector Pipe (or similar wording) along its entire length at regular intervals not exceeding the manufacturer's recommendation or that of local codes and standards.
5. All piping should be supported at centers of the lesser of 1.5m (5ft) apart or that specified by local codes or standards.
6. The end of each trunk or branch pipe shall be fitted with an end-cap and made air-tight by using solvent cement. Use of a hole in the end-cap will be dependent on the network design (as per Software calculations).

Sampling Holes

The sampling holes shall comply with the following requirements.

1. Sampling holes shall not be separated by more than the maximum distance allowed for conventional point detectors as specified in the local codes and standards. Intervals may vary according to calculations. For NFPA the maximum allowable distance is 30ft.
2. Each sampling point shall be identified in accordance with Codes or Standards.
3. Consideration shall be given to the manufacturer's recommendations and standards in relation to the number of sampling points and the distance of the sampling points from the ceiling or roof structure and forced ventilation systems.
4. Sample point size shall be as specified by Software calculations.
5. Calculations shall be rub from the listed software of OEM.

Installation

The Detection system

The contractor shall install the system in accordance with the manufacturer's System Design Manual.

Mounting

The detector shall be capable of vertical mounting with sample air inlet port(s) directed up toward the ceiling (normal mounting) or down towards the floor (inverted mounting).

The detector shall be capable of mounting directly to a wall using screw fasteners or by using a stainless steel mounting bracket..

Where a mounting bracket is used, it shall be marked or engraved with the correct locations of inlet port sample pipe(s) and cutting guide and electrical conduit locations.

The Capillary Sampling Network

The capillary sampling network shall comply with the following requirements:

1. Where false ceilings are installed, the sampling pipe shall be installed above the ceiling, and Capillary Sampling Points shall be installed on the ceiling and connected by means of a capillary tube.
2. The typical internal diameter of the capillary tube shall be 5mm or 3/8", the maximum length of the capillary tube shall be 8m (26 ft) unless the manufacturer in consultation with the engineer have specified otherwise.
3. The Capillary tube shall terminate at a Ceiling Sampling Point specifically designed and approved by the manufacturer. The performance characteristics of the Sampling Points shall be taken into account during the system design.

Air Sampling Pipe Network Calculations

Air Sampling Pipe Network Calculations shall be provided by Air Sampling Pipe Network modelling program . Pipe network calculations shall be supplied with the proposed pipe layout design to indicate the following performance criteria:

Transport Time

Wherever possible the transport time (i.e. the time taken by smoke sampled to reach the detector) for the least favourable sampling point shall be less than 60 seconds for open hole sampling and less than 90 seconds for capillary tubes. Longer transport times may be tolerated where long pipe runs are required and where local codes and standards permit.

Local codes and standards may also apply. For example:

AS1670, Part 1	Australia	90 Seconds
FIA Code of Practice	UK	120 Seconds
NFPA 72	The Americas	120 Seconds
NFPA 76	The Americas	60 Second

Balance %

The balance is the ratio of lowest sample hole flow rate to the highest, expressed as a percentage. The sample point balance for the pipe shall not be less than 70% as indicated by Software calculations.

Tools/Software shall be used to calculate the balance for a protected area as part of the outputs for modelled pipe sampling network.

System Commissioning

Detector commissioning

The detector shall incorporate a push button to invoke self-learning modes to simplify commissioning including:

1. a learning mode that ensures the best selection of appropriate alarm thresholds during the commissioning process

2. a learning mode that determines the optimum flow fault thresholds based on environmentally induced flow changes during the commissioning process. Additionally, there shall be provision for a PC software tool to configure all user modifiable parameters of the all system devices.

Commissioning Tests

The contractor shall allow for the manufacturer's representative to attend commissioning of the entire installation in the presence of the owner and/or their representative.

All necessary instrumentation, equipment, materials and labor shall be provided by the Contractor.

The Contractor shall record all tests and system configuration and a copy of these results shall be retained on site in the System Log Book.

All the ASD units shall be integrated with a network and display be provided on the ASD works station to be provided at Fire Command Center. Work station shall be provided with listed software and all applicable controls available.

System Checks

Visually check all pipes to ensure that all joints, fittings, bends, sampling points, etc., comply with the Specification.

Check the system to ensure the following features are operational and programmed in accordance with the specification.

1. Alarm threshold levels (for both day and night settings),
2. Time delays,
3. Pipes in use for four pipe VEP,
4. Detector address,
5. Display address where applicable,
6. Clock time and date,
7. Air flow fault thresholds,
8. Reset button operable,
9. Touch screen operable where applicable,
10. Referencing
11. Units set to U.S./S.I. (for US only) or metric for other regions
12. Check to ensure that all ancillary warning devices operate as specified.
13. Check interconnection with Fire Alarm Control Panel to ensure correct operation.

Final Tests

The contractor shall:

1. Introduce smoke into the detector assembly to provide a basic Go / No-Go functional test.
2. Verify that transport time from farthest sampling port does not exceed the local code requirements.
3. Activate the appropriate Fire Alarm zones and advise all concerned that the

system is fully operational. Fill out the logbook and commissioning report accordingly.

Maintenance

Sample Filter

The detector shall incorporate a replaceable cartridge-style filter to remove large contaminants from the sampled air.

The filter shall be accessible by opening the cover to the field wiring terminal area.

Once accessible, the filter shall be removable and replaceable by hand without the need of a tool.

The filter shall incorporate an electronic circuit which identifies it uniquely and maintains status information such as the percent of filter life remaining.

4.6.2.11 Optical Smoke Detector

The optical smoke detector shall be of the analogue addressable type, which continuously measures the element of combustion in the air and generates a proportional analogue output to the SAPs / MAP via the addressable detection cable loop. It shall meet the UL standard and comply with BS EN: 54 Part 7 or equivalent, and is FM / UL listed or LPC approved. The detector shall react to the whole range of fire products of both visible and invisible products of combustion.

The Optical smoke detectors shall be installed in the Public Circulation / Staff Circulation areas.

4.6.2.12 Multi Sensor Detectors

The intelligent addressable multi sensor detector shall be a microprocessor based and operate on light scattering principle, containing an emitter and photo sensor. The scattered light reaching the photo sensor shall be proportional to the smoke density inside the detection chamber. It will combine both optical smoke and heat detector technology to detect clear burning fire products, which hitherto could only be easily detected by ion-chamber detectors. The detectors will not operate on a rate of rise of temperature alone. It shall meet the UL standard and comply with BS EN: 54 Part 15 or equivalent as appropriate. The integral microprocessor shall employ time based algorithms to dynamically examine values from the two sensors simultaneously and initiate an alarm based on that data.

The detector shall utilize advanced algorithms with time based analysis to provide early warning and an accurate analysis of alarm situations.

Under normal ambient conditions, the optical detector will behave as a normal optical detector. Only when a rapid rise in temperature is detected, the sensitivity of the detector shall increase together with the presence of smoke shall confirm a fire condition, which will be transmitted as a fire alarm level.

The detector will be fully compensated for temperature, humidity and barometric changes in the environment. All electronic components shall be hermetically sealed to prevent their operation from being impaired by dust, dirt, humidity, corrosion or mechanical shock. All circuitry must be

protected against typical electrical transients and electromagnetic interference according to BS 6667: Part 3. The detector will be fully operable between -20oC and + 70oC and up to 95% relative humidity non-condensing.

The Sensitivity shall be adjustable by means of a pre-set control only accessible by use of a special tool. Built-in wind-shields will be provided to ensure that air velocity of up to 10 meters / second do not affect the proper operation of the detector. The Combined Optical smoke & Heat detectors will be installed in the Mechanical Plant room areas.

4.6.2.13 Duct Smoke Detector

- a) Probe type smoke detectors shall be installed in the supply or return air duct of all AHU / PAU and ventilating fans as stipulated in the relevant Specification, and/or as shown on the Drawings.
- b) Installation details shall comply with NEMA and NFPA standards.
- c) An audible and visual alarm signal shall be provided at the Station Control Room of the respective station which upon receipt of a signal from the probe type smoke detector shall initiate the audible and visual alarm on the FS control panel and shut off the corresponding ventilating fans, fan units of the AHU and/or fan units of PAU.
- d) Detectors shall be supplied with intelligent addressable multi sensor heads and complete with, but not be limited to, the following:-
 - (1) Housing base and cover assembly;
 - (2) Sampling tube filters;
 - (3) Test and reset switch;
 - (4) Drilling template;
 - (5) O-rings;
 - (6) Tube bushing seals;
 - (7) Sampling tube.
 - (8) Filter adaptor; and
 - (9) Tube end plug.
- e) Each smoke probe unit shall comprise a perforated inlet tube across the inside of the duct at 90° to the air flow and an expansion chamber containing photo electronic smoke detector.
- f) The smoke probe unit shall contain a clear polycarbonate cover for convenient visual inspection.
- g) The smoke probe units shall be either of the same addressable analogue type or conventional type ionization/photoelectric smoke detectors as specified with a suitably designed duct adapters. The whole assembly shall be suitable for monitoring air movement of up to 25 m/s.
- h) For conventional type smoke probe unit, it shall be designed for standalone operation and powered by 240 V AC, or 24 V AC or DC power source.
- i) The complete assembly (smoke detector with duct adapter) shall be supplied

as a single unit.

- j) Connection of remote indicator shall also be available and compatible with the smoke probe unit so that the operation of the indicator shall not impair or affect the brightness of the detector's built-in LED.

4.6.2.14

4.6.2.15 Heat Detectors

Heat Detectors shall be of analogue addressable type and a combined rate of rise of 10°C per minute and fixed temperature suitable for 24V DC operation. It shall meet the UL standard and comply with BS EN: 54 Part 5 or equivalent.

The detectors shall meet UL / FM standard or LPC approved.

The electronic circuits shall be solid state type. The quiescent current consumption of the unit shall be minimal and shall not exceed 100 microampere.

All electronic circuitry in the detecting head and base unit shall be hermetically sealed to prevent their operation from being impaired by dust, dirt or humidity. The detectors shall be capable of performing accurately when subjected to relative humidity up to 95%.

A LED visible alarm indication of sufficient brightness shall be provided on the detectors to identify the unit in alarm.

Detectors shall be housed in a corrosion proof plug-in unit designed to be mounted pendent, surface or semi recessed.

The complete unit shall consist of a base unit with a detecting head, which can be simply "plugged" into the operating position. A fault signal shall be activated when the detecting head is detached from its base unit or when it is not attached properly.

Removal of the unit from its base shall cause a fault signal to be transmitted to the fire alarm panels.

The detector electronic circuitry shall be of highest possible reliability and protected against voltage spikes and surges. The detector shall be capable of operating satisfactorily under a reasonable variation in supply voltage, such as may normally occur in service due to charge and discharge of the alarm system battery. Reverse polarity or faulty wiring shall not damage the detector.

Tools to facilitate the removal of detectors, especially at high level shall be provided. Two (2) sets of tools shall be provided.

The Heat detectors shall be installed in all Electrical Rooms.

4.6.2.16 Combined Optical Smoke & Heat Detector

The detector shall operate on light scattering principle, containing an emitter and photo sensor. The scattered light reaching the photo sensor shall be proportional to the smoke density inside the detection chamber. It shall combine both optical and heat detector technology to detect clear burning fire products, which hitherto could only be easily detected by ion-chamber detectors. The detectors shall not operate on a rate of rise of temperature alone. It shall meet the UL standard and comply with BS EN: 54 Part 15 or

equivalent.

Both the optical components and the detection chamber shall be protected from the environment but still allow smoke to enter freely into the chamber for sampling. Stainless steel wire mesh with very fine openings shall be designed and provided to keep out the insects. However, the mesh shall not impede the entry of smoke particles or clog with dust easily.

Under normal ambient conditions, the optical detector shall behave as a normal optical detector. Only when a rapid rise in temperature is detected, the sensitivity of the detector shall increase together with the presence of smoke and then only it shall confirm a fire condition, which shall be transmitted as a fire alarm level.

The detector shall be fully compensated for temperature, humidity and barometric changes in the environment. All electronic components shall be hermetically sealed to prevent their operation from being impaired by dust, dirt, humidity, corrosion or mechanical shock. All circuitry must be protected against typical electrical transients and electromagnetic interference according to BS6667: Part 3. The termination shall be so designed that the terminals are polarity insensitive to simplify wiring and to reduce incorrect field termination.

The detector shall be fully operable between -20°C and $+70^{\circ}\text{C}$ and up to 95% relative humidity non-condensing.

Detectors shall be housed in a corrosion proof plug-in unit designed to be mounted pendent, surface or semi recessed.

The complete unit shall consist of a base unit with a detecting chamber, which can be simply 'plugged' into the operating position. A fault signal shall be activated when the detecting chamber is detached from its base unit or when it is not attached properly.

Removal of the unit from its base shall cause a fault signal to be transmitted to the fire alarm panels.

The detector electronic circuitry shall be of highest possible reliability and protected against voltage spikes and surges. The detector shall be capable of operating satisfactorily under a reasonable variation in supply voltage, such as may normally occur in service due to charge and discharge of the alarm system battery. Reverse polarity or faulty wiring shall not damage the detector.

Sensitivity shall be adjustable by means of a pre-set control only accessible by use of a special tool. Built-in wind-shields shall be provided to ensure that air velocity of up to 10 metres / second do not affect the proper operation of the detector. Each unit shall be fitted with an alarm condition indication lamp.

A LED visible alarm indication of sufficient brightness shall be provided on the detector to identify the unit in alarm.

Approved wind-shields shall be fitted to smoke detectors installed at locations where air movement will adversely affect the proper operation of the detector.

Tools to facilitate the removal of detectors, especially at high level shall be provided. Two (2) sets of tools shall be provided for each station.

Detectors shall not be installed such that they are obstructed by other

equipment, ductwork, etc.

The Combined Optical smoke & Heat detectors shall be installed in the Mechanical Plant room areas.

4.6.3 ELECTRICAL WORKS

- All electrical works shall comply with relevant standards as stated in the electrical requirements,
- All wiring shall be of minimum size, 1.5mm² copper conductors and 2.5mm² cables for power circuit. All cables in the concealed area shall be PVC and cables in exposed area shall be installed enclosed in galvanized threaded metal conduits.

4.6.4 CABLES/ WIRING

4.6.4.1 General

The Contractor shall be responsible for bringing in the supply cable or wiring to the Contractor's distribution / control panels (or junction boxes or enclosed circuit breakers or safety switches) at the required locations and as per the Specification. The Contractor shall connect the cable from the envisaged location to the isolator or circuit breaker in the panels or to the equipment. The connections and installation thereof shall form part of the Contract.

The equipment rating shall be based on the following electrical system :

- (1) Rated Voltage : 415 V / 240V
- (2) Rated Frequency : 50 Hz.

All electrical conductors such as bus-bars, cables, wires, terminals, etc. shall be colour- coded as follows :

(1)	Phase R	:	Red
(2)	Phase Y	:	Yellow
(3)	Phase B	:	Blue
(4)	Neutral	:	Black
(5)	Ground	:	Green or Yellow Strip Green

- (6) Large wires and cables shall be colour coded with tapes as specific colour.

Low Voltage Cable

The technical requirements shall be as specified in Electrical Section.

Fire Resistant Cable (FR)

The technical requirements shall be as specified in Electrical Section.

Conduits and accessories

The technical requirements shall be as specified in Electrical Section.

Boxes and Accessories

The technical requirements shall be as specified in Electrical Section.

Equipment grounding

The technical requirements shall be as specified in Electrical Section.

4.6.4.2 Installation

The works shall be executed to completion and in conformity with the Drawings and these Specifications.

Low Voltage Cables

The technical requirements shall be as in Electrical Section.

Conduits

The technical requirements shall be as specified in Electrical Section.

- a) All cables shall be in conduits, trucking and trays as appropriate. All cable runs shall be continuous and without joints. They shall also be run neatly and vertically, horizontally or match the features of the building,
- b) All control and power cables shall be of the 1100V grade .

4.6.5 INTERFACE TERMINAL BOARD (ITB)

Interface terminal board shall be of the Insulation Displacement Connection (IDC) type, which complies with the IEC 947-7-1 standard. The IDC interface terminal board shall use a C-shaped jaw working in an elastic warping zone to pierce through the insulation of a cable to form an electrical connection capable of absorbing shocks and vibrations (exceeding VDE 0611 standard's requirement).

The elastic nature of this C-shaped jaw shall also ensure that electrical connections with copper core(s) remain secure and maintenance-free even after many years of use in varying temperature cycles. The C-shaped jaw shall be of iron-free copper alloy material thereby giving minimal bimetallic or galvanic effects when connected to copper core(s). Cable connections to an IDC interface terminal board shall be vapour - tight; with the only exposed copper surfaces from the cable in contact with the C-shaped jaw, which is tightly wrapped round by the insulating material of the cable. Insertion of cables into IDC interface terminal boards shall be done with a semi-automatic full cycle tool which guarantees consistent quality electrical connections.

The interface terminal board shall also be provided with switch connection, disconnect link bar and heavy duty switch blade. At least 3 sets of tools necessary for connection and extraction of the wire shall be provided in a lockable toolbox.

4.6.6 ELECTRICAL REQUIREMENT IN THE CONTROL PANEL

- a) All wiring inside the control panel shall be colour coded, neatly bundled and tagged for easy identification,
- b) All terminal blocks/connectors shall be of the type suitable for mounting on DIN rail,
- c) A circuit diagram shall be laminated and mounted on the internal side of the door panel indicating clearly the schematics and function of each outgoing terminal.

4.6.7 ELECTROMAGNETIC COMPATIBILITY REQUIREMENTS

4.6.7.1 General

- a) This section defines the minimum EMC requirements for the electronic and electrical equipment supplied.
- b) The Contractor shall be responsible for ensuring that all equipment supplied conform to the following requirements in terms of their electromagnetic compatibility with the environment, with all existing equipment and with all equipment to be installed:
 - 1) Prevailing EMC requirements as specified in, but not limited to, IEC, CISPR, EN, BSI, VDE, ITU-T or their equivalents,
 - 2) Prevailing EMC requirements applicable to general, scientific and industrial equipment specified but not limited to IEC, CISPR, EN, BSI, VDE, ITU-T or their equivalents,
 - 3) Generic EMC requirements specified but not limited to IEC, CISPR, EN, BSI, VDE, ITU-T or their equivalents,
 - 4) The order of compliance shall be as described above. It should be noted that the standards given herein are by no means exhaustive and compliance with standards described herein shall not absolve the Contractor of his liability/responsibility in ensuring EMC compliance with the environment, all existing equipment and all equipment to be installed.
 - 5) Any other special requirement as determined by the Employer /Engineer .
- c) The Contractor shall be responsible for implementing corrective actions to rectify any EMC problems identified during on-site testing and/or when the whole system is in operational service with the approval of the Employer/Engineer.
- d) The Contractor shall be fully aware of the EMC requirements and any modifications to systems and/or equipment carried out by the Contractor during warranty period shall not reduce the immunity levels or increase the emission levels for the installed system and/or equipment. EMC documentation shall be provided as a result of modifications carried out.
- e) EMC requirements shall cover but not be limited to conducted, induced and radiated emissions as well as immunity to conduct, induced and radiated emissions
- f) The maximum levels of conducted, induced and radiated electromagnetic emissions shall not be higher than:
 - 1) Those specified by the prevailing EMC standards,
 - 2) General requirements imposed on similar equipment operating in similar environment, or
 - 3) Requirements specified in the Contract documents , whichever is the lowest .
- g) The minimum levels of immunity to conducted, induced and radiated electromagnetic emissions shall comply with or be better than :
 - 1) Those specified by the prevailing EMC standards,
 - 2) General requirements imposed on similar equipment operating in similar environment, or requirements specified in the Contract documents ,

whichever is the highest .

- h) All tests shall be conducted at levels and using instruments and measurement procedures according to the relevant codes and standards. The Contractor shall obtain prior written permission from the Employer / Engineer where deviations in terms of instrumentation or measurement procedures are necessary due to environmental factors or limitations in laboratory equipment.
- i) For systems or equipment where no international EMC standards exist, the Contractor shall ensure that :
 - 1) The said equipment conforms to generic EMC standards and standards applied to similar equipment operating under similar environment,
 - 2) A technical construction file is developed as described by guidelines provided by CENELEC directives. The technical construction file shall be certified by a relevant competent body where applicable,
 - 3) The Contractor shall obtain prior written acceptance of the Employer / Engineer before deciding on the pass / fail criteria for the equipment.
- j) This section specifies the requirements for the electromagnetic compatibility of the electrical services with its environment and with all the components, sub-systems, systems, etc. installed by the Contractor :
 - 1) The electromagnetic environment of the PUNE Metro Rail Line-3 includes emissions from the transit system, high voltage transmission and distribution equipment, TV and radio broadcasting equipment, telecommunication equipment and many types of domestic or publicly carried electrical equipment. All equipment and systems supplied shall neither interfere with nor be interfered by the PUNE Metro Rail Line-3 environment,
 - 2) The Contractor's system shall not produce intolerable emissions within the operational environment and shall comply with the following EMC standards :
 - i. EN 50121-4 part 4: emission and immunity of the signaling and telecommunication apparatus,
 - ii. EN 50121 – 5 part 5: emission and immunity of fixed power supply installations and apparatus,
 - iii. EN 50121-1: railway applications – electromagnetic compatibility part1: general,
 - iv. EN 50121-2: railway applications – electromagnetic compatibility part 2 : emission of the whole railway system to the outside world,
 - v. EN 50122-1 part 1: railway applications: fixed installations; protective provisions relating to electrical safety and earthing,
 - vi. EN 50122-2 part 2: railway applications: fixed installations; protective provisions against the effects of stray currents caused by D.C traction systems,
 - vii. ENV 50204:1996 radiated electromagnetic field from digital radio telephones immunity test,

- viii. The Contractor may propose alternative EMC standard provided that the Contractor can demonstrate that the proposed standard is equivalent or better than the specified standard. The Contractor shall submit details to the Employer / Engineer for Notice of No Objection.
- 3) The Contractor shall liaise to update and submit the EMC control plan. This plan shall comprise :
 - i. Description of all main sub-systems to be supplied, in relation to EMC aspects,
 - ii. Detail the overall EMC management philosophy and EMC process,
 - iii. EMI hazard analysis,
 - iv. Provide EMC organization and name the staff responsible for the management of EMC,
 - v. List the EMC standards to be applied,
 - vi. Activities / tasks to be carried out at different stages of the project on demonstration and assurance of EMC performance,
 - vii. List documentation to be submitted to the Employer / Engineer for Notice of No Objection,
 - viii. List the tests to be carried out to demonstrate intra system EMC and EMC between system and the external environment,
 - ix. Outline any EMC related design and installation guidelines to be applied,
 - x. Outline the contents of test plan,
 - xi. Outline any maintenance requirements which result from the ongoing need to ensure system EMC.
- 4) The Contractor shall ensure that all his components and subsystems are electromagnetically compatible with other interfacing contractors' system. The Contractor shall achieve this by the selection and coordinated application of current applicable EMC standards to ensure compliance with these standards and to submit evidence and testing to demonstrate it. Conducted (including transients), radiated, capacitive coupled, inductively coupled and electrostatic interference shall be considered.

4.6.7.2 Specific Requirements

A) Cabling

All cables used shall be adequately protected against external interference. Additional protective measures, including but not be limited to the use of metallic conduit, armour, ferrite choke, EMI filters shall be used to reduce such external interference wherever required.

Assessments shall be carried out to determine that the cables are installed at a safe separation from potential interfering sources, including power cables, LCX, etc.

The Contractor shall develop and follow the cable routing plan so that there are least likelihood of coupling between the cables and the potential sources. The Contractor should also refer to guidelines recommended by IEC61000-5-2 wherever possible.

All cables shall be adequately protected from the effects of inducing fields generated by the rolling stock and power supply system. The cable sheaths shall be earthed to provide maximum protection from any inducing field affecting the safety and reliability of the system. The earthing system shall prevent any longitudinal voltage which could cause touch potential hazards to personnel as specified by the CCITT.

B) Radiated immunity levels

All equipment will be subjected to radiated energy from hand held communication equipment. The equipment will also operate in an environment with a substantial amount of radiated interference present. Therefore the equipment shall operate without degradation when subjected to a field strength of 20 V/m 80% AM in the frequency range 80 to 2,000 mhz. Test shall be carried out in accordance with EN 61000-4-3.

C) Magnetic Field Immunity Levels

The Contractor shall ensure that any static or alternating magnetic fields, generated in the environment, does not affect the operation of the equipment. The equipment shall be tested to applicable standards. All CRT monitors, if supplied by the Contractor, shall be adequately protected against picture distortion from external interference and adjacent monitors.

4.6.7.3 ISM Band

The Contractor shall be responsible to ensure that there is sufficient protection and robustness built into the system to prevent possible interference to/from other equipment operating in the ISM band (for example Bluetooth and WLAN devices) which will affect the safe and proper operations of the system. The Contractor shall undertake the necessary assessments and testing in terms of safety, system immunity and system performance to demonstrate that there shall be no interference affecting the performance of his system as well as emission from his system affecting other systems in the same environment.

4.6.7.4 Non-Safety-Related Systems Interference

The Contractor shall take appropriate measures to ensure that EMC is achieved between the electrical services equipment and all other system equipment. The UPS shall be designed with particular attention to the suppression of harmonic voltages. All radiated emission, either via the power cables, rectifiers and transformers from switching supplies (of UPS) or any other system components, shall be minimized such that they conform to the appropriate international standards. Special reference shall be made to the compliance of EN50121-5, EN50123, and IEC61000-2.

All power cables shall be properly shielded where applicable, not only to reduce radiated emissions from the cables, but also to reduce the possibility of the cable picking up unwanted RF noise. Reference shall be made to EN61000-4-6

and EN61000-4-16.

The Contractor shall ensure that all conducted emissions, including but not limited to harmonics, shall not interfere with telephone, communications, supervisory and control, automatic fare collection, train protection and control, and other PUNE Metro Line-3 system equipment either through the transformer to primary 33kV system . Reference shall be made to EN50121-5, EN50123 and IEC61000-2.

To reduce emissions , the Contractor shall also co-ordinate with other contractors whose equipment are connected to electrical services that are likely to inject unwanted emissions into the system . Reference must be made to EN50121-2, EN50121-4, EN50121-5, and IEC61000-3.

4.6.7.5 Earthing

An earthing system should be designed to assure personnel safety and protection of installations against damage. It should also serve as a common voltage reference and to contribute to the mitigation of disturbances.

To achieve the primary goal of assuring personnel safety and preventing damage, a low impedance path shall be made available to the large current generated due to lightning or power system fault. The potential differences (touch and step voltages) between any two points shall be as low as possible. Safety considerations also require the chassis/body or enclosure to be earthed to minimize shock hazards to passengers and transit system staff.

To achieve the secondary goal of providing protection for sensitive and interconnected electronic and electrical systems, earthing should be designed to minimize the noise voltage generated by currents from two or more circuits flowing through common earth impedance and to avoid creating earth loops susceptible to magnetic fields and differences in earth potentials.

Earthing shall also be designed to accomplish the following minimum requirements :

- 1) Protect personnel and equipment from electrical hazards, including lightning, where practical,
- 2) Reduce potential to system neutrals,
- 3) Reduce or eliminate the effects of electrostatic interference and electromagnetic interference,
- 4) Provide a single-point earthing method for all equipment enclosures, cabinets, drawers, assemblies and sub-assemblies,
- 5) Provide a clean zero-volt reference point for signals in computer and related equipment.

4.6.7.6 Bonding

Bonding shall be provided for all exposed metallic parts of all equipment and connecting them to the earthing network for meeting safety requirements and minimize noise voltage due to potential differences.

Direct bonding shall be used wherever practical. Where indirect bonding via bonding straps are used, to connect two isolated items, the bond shall satisfy

the following minimum requirements and prevailing international standards, for example IEC 61000-5- 2.

4.6.7.7 Electro-Magnetic Interference (EMI) Suppression / Shield

In the event that the immunity of installed systems is proven to be deficient or that their emissions exceed the levels specified, the Contractor shall implement measures either to reduce the emissions or to improve the immunity of the system.

4.6.7.8 EMC Organisation

The Contractor shall be responsible for coordination with other System-wide Contractors to obtain relevant information to ensure EMC with other systems.

The name of an EMC Coordinator, who shall be responsible for all aspects of ensuring EMC, shall be given to the Engineer. The Contractor shall submit the Curriculum Vitae of the EMC Coordinator showing details of his previous experience within the field.

4.6.7.9 EMI Impact Analysis

The Contractor shall liaise with the Employer / Engineer , to update EMI Impact Analysis. This analysis shall identify equipment susceptible to EMI, equipment / systems that are a source of EMI, the likely consequences if interferences take place, and the proposed EMI mitigation measures.

The Impact Analysis shall address inter-system compatibility between the Contractor's systems and other Interfacing Contractor's and intra-system compatibility between the Contractor's systems. The Contractor shall also provide a quantitative estimation of EMI severity case by case for different situation once identified as the design progresses.

4.6.7.10 Verification By Testing

The testing shall be split into two phases : pre-delivery testing and post-delivery testing. Pre-delivery testing shall be carried out at an EMC testing laboratory or at the manufacturers own laboratories subject to the Notice of No Objection by the Employer / Engineer .

Post-delivery testing to ensure no compatibility problems shall be carried out on the installed equipment to confirm that the specified level of EMC has been achieved in the PUNE Metro Line 3 environment. The tests shall be coordinated with other interfacing Contractors. Any EMC problems identified during this testing shall be rectified by the responsible Contractor. Where there is a dispute between Contractors this shall be brought to the Employer / Engineer attention for resolution. The decision of the Employer / Engineer shall be final and binding on the Contractor.

Where the system is too large, or no relevant international EMC standard exists the Contractor may follow a Technical Construction File (TCF) route. The TCF shall describe the apparatus and set out procedures used to ensure the apparatus conforms to the protection requirements. During the development of the TCF, it shall be submitted to the Employer / Engineer at regular intervals for comments. Notice of No Objection of the TCF shall be obtained before construction of the system commences. Acceptance of the TCF shall not relieve

the Contractor of his responsibility to carry out on-site tests, nor to take any remedial steps to ensure EMC when the system is commissioned.

4.6.7.11 Test Documentation

a) Test Plan

The purpose of the Test Plan is to provide the relevant information so that the in-house test departments of the Contractor, or external test houses engaged by the Contractor, will be able to perform and certify the tests in accordance with the requirements of the EMC objectives. The Test Plan shall provide assurance that all testing is fully defined and hence that repeatability of measurement can be achieved.

The contents of the Test Plan shall be in the form of a checklist such that it can be used as an aid in the preparation, monitoring and obtaining Notice of No Objection of the various plans from the Engineer.

The EMC site testing shall be included in the Test Plan. This shall include testing to the specified EMC standards at equipment level; the Contractor shall develop a TCF at sub-system level. The TCF shall be certified by a competent body or equivalent, the proposal for which shall be submitted to the Employer / Engineer for Notice of No Objection.

b) Test Report

Test reports presenting the test results and providing evidence of compliance with the EMC requirements shall be produced.

The test report shall include, as a minimum, the following sections :

- 1) Applicable standards,
- 2) Equipment tested,
- 3) Equipment and cable configuration,
- 4) Location of test site,
- 5) List of test equipment,
- 6) Units of measurement,
- 7) Measurement procedure,
- 8) Reporting measurement data,
- 9) General and special conditions,
- 10) Summary of results,
- 11) Required signatures,
- 12) Test report appendices.

4.6.8 INTERFACE REQUIREMENTS

4.6.8.1 General

The Contractor shall be responsible to ensure that the various E&M systems supplied are properly interfaced and integrated with that of others throughout the Contract Period.

The Contractor shall liaise and coordinate with other SWCs (System wide Contractors) to mutually agree the protocols to be used for all necessary data exchange.

4.6.8.2 Interface with M & E SCADA

The Contractor shall provide hardware, software, data etc. to interface with M & E SCADA via the ITBs for the monitoring of the Fire Protection System.

a) MAP shall be interfaced via serial link data interface.

- 1) Standard RS 485 shall be used with baud rates of up to 19.2kbps. C955 shall provide data cable terminated with male connector plug,
- 2) Standard ISO 3309/4335 high-level data link control (HDLC) protocol format shall be adopted unless otherwise accepted by the Engineer . Such acceptance would not be given unless the Contractor can demonstrate that the proposed protocol is fully compatible and meets the performance requirements of the interface. Open and widely used non-proprietary industrial communication protocols shall be preferred,
- 3) Any change in the field data shall be updated within 0.5 second of occurrence,
- 4) Apart from the system initialization, the communication shall generally be event driven with information that has changed being transmitted. However the interface shall maintain regular checks of the integrity of the link with any failure detection indicated with alarms.

b) Information to be provided

The Contractor shall provide information which includes but not limited to the following:

- 1) Exact number of points and its addresses,
 - 2) Equipment identifiers / Labels and locations,
 - 3) Fire Zone schematic drawings (in hard copy and soft copy) and Man Machine Interface (MMI) design,
 - 4) Functional description of protection scheme,
 - 5) Communication protocol.
- c) This information shall be provided in a format within a time frame coordinated well in advance. This shall be submitted to the Employer / Engineer for Notice of No Objection,
- d) Work demarcation

The Contractor shall be responsible to supply and terminate the cable from the MAP to the ITB. The ITB shall be located adjacent to the MAP but its exact location shall be coordinated by the Contractor.

4.6.8.3 Interface With Active Voice Communication System

The ITB between Fire Protection System and Active Voice Communication System shall be provided and installed. The Contractor shall provide, install and terminate all wiring between the ITB and MAP / SAP.

The fire detection system shall provide voltage free fire alarm signal through voltage free contact to activate the Active Voice Communication system. The interface and operation requirement of the fire alarm system and Active Voice Communication System shall comply with the SFSRTS Code.

The Contractor shall determine and co-ordinate for the interfacing

requirements including the ITB locations, number and detail of different types of fire alarm signals for the activation of Active Voice Communication System.

4.6.8.4 Interface With Air Monitoring System (AMS)

The ITB between Fire Protection System and AMS System shall be provided and installed. The Contractor shall provide, install and terminate all wiring between the ITB and MAP / SAP. The fire detection system shall provide voltage free fire alarm signal through voltage free contact normally open to activate the AMS.

The Contractor shall determine and co-ordinate for the interfacing requirements including the ITB locations, number and detail of different types of fire alarm signals for the activation of AMS.

4.6.8.5 Interface with AFC and Emergency Gates

The ITB between Fire Protection System and AFC gates / emergency exit gates shall be provided and installed. The Contractor shall provide, install and terminate all wiring between the ITB and MAP / SAP. The fire detection system shall provide voltage free fire alarm signal through voltage free contact normally open to activate the AFC and emergency gates.

The Contractor shall determine and co-ordinate for the interfacing requirements including the ITB locations, number and detail of different types of fire alarm signals for the activation of AFC and emergency gates.

4.6.8.6 Interface with Maintenance Management System(MMS)

In case the Employer decides to implement a MMS, the Contractor shall be required to work to register all equipment and spares data with the format and methodology to be defined.

4.6.8.7 Interface with Local Sequential Controller(LSC)

- A) The LSC shall interface with the fire detection system to shut down the respective ECS equipment and operate the smoke control system, and/or clean gas extraction system (serving the clean gas protected rooms) and the associated equipment in the event of a station fire,
- B) The fire detection system shall provide voltage free fire alarm signals through voltage free contacts normally open and terminate the signal/cables interfaces at the ITBs of the LSC in Chiller plant rooms. The Contractor shall provide the wiring and connections between the MAP / SAP / CGP and ITBs,
- C) The Contractor shall determine and co-ordinate for the interfacing requirements including the ITB locations, number and detail of different types of fire alarm signals for operation of ECS and smoke purging system in public and non-public areas.

4.6.8.8 Interface With Lifts and Escalators

The ITB between Fire Protection System and lifts/escalators shall be provided and installed by the Lift and Escalator contractor. The Contractor shall provide, install and terminate all wiring between MAP/SAP and ITB. The Fire Alarm System shall provide voltage free fire alarm signal through voltage free contact normally open to each lift/escalator machine via ITB for lift homing/escalator operation in case of fire. The Contractor shall determine and co-ordinate for the

interfacing requirements including the ITB locations, number and detail of different types of fire alarm signals for activation of lifts homing and escalator operation.

4.6.9 SURFACE TREATMENT

4.6.9.1 Corrosion Protection

All materials and equipment supplied under this Contract shall be suitable for being delivered, stored and operated under tropical conditions of high temperature, high humidity, heavy rainfall and mildew and fungus-conductive environment.

The process for tropicalising shall be in accordance with the best modern design and manufacturing practices.

4.6.9.2 Metals

- a) Iron and steel shall be painted or galvanised or metal sprayed as appropriate. Indoor parts may alternatively have chromium or other suitable protective finish. When it is necessary to use dissimilar metals in contact, these shall be selected such that the potential difference between them in the electro-mechanical series will not cause galvanic corrosion. If this is not possible, the contact surface of one or both of the metals shall be electroplated or otherwise finished in such a manner that the potential difference is reduced within the required limits or, alternatively, the two metals shall be insulated from each other by a suitable insulating material or a coating of varnish compound.

- b) Bolts, screws, nuts

Threaded components like bolts, screws, washers and nuts, when used, shall be sherardised to BS 7371: Part 8, Class s1. Where plating is not possible owing to thickness tolerance limitations of corrosion resisting steel type shall be used.

Corrosion-resisting steel, copper-nickel alloy or bronze shall also be used for bolts and nuts throughout the works, when they are subject to frequent adjustment or removal.

Connections shall be such that potential differences do not cause galvanic corrosion.

- c) Fabrics, cork, paper and similar materials, which are not subsequently protected by impregnation, shall be adequately treated with suitable fungicide. Sleeveings and fabrics treated with linseed oil varnish shall not be used.

- d) Adhesives

Adhesive shall be especially selected to ensure the use of tapes which are impervious to moisture, resistant to mould growth, and not subject to the ravages of insects.

- e) Electrical material and equipment

Material and components which are inherently fungus resisting or are protected by hermetic sealing or oil immersion need not to be treated. Other elements shall be protected by additional varnish for high humidity

and given an anti-fungus treatment.

4.6.9.3 Painting

- f) All steel surfaces, except stainless steel and the interiors of all compartments permanently sealed by welding shall be prepared and shall receive protective coating. In general, unless galvanized, all exposed piping, ductwork (including colour coding), metallic equipment cases, equipment cabinets, junction boxes and terminal cases shall be painted. Non-ferrous metals, stainless steel and protected metals will normally not be painted,
- g) Wherever possible, all painting shall be undertaken before delivery to site. The Contractor shall ensure that all surfaces have been properly prepared for application of paint including cleaning, priming and drying. The application of the paint shall be in accordance with the manufacturer's recommendations and undertaken in appropriate conditions,
- h) The dry film thickness of primed surfaces shall be generally 50 microns with an allowed ponding not greater than 60 microns in areas such as covers, welds and bolts. The total dry paint film thickness of the paint system on bare steel surfaces and on metal coated surfaces shall not be less than 130 microns,
- i) Painted surfaces which have been damaged shall be cleaned to bare metal, or metal coating where this has been applied, and the edges of the undamaged paint abrasively beveled. Where a metal coating has been damaged, the affected area shall be rubbed down to remove excessive roughness, cleaned and an additional coat of zinc rich primer applied. Where there is a damaged galvanized surface, cold galvanized paint shall be applied first before the zinc rich primer. The paint shall be re-applied to the full specification to the affected area and overlapping the surrounding area,
- j) The Contractor shall ensure that the finished painted surfaces meet the thickness requirements without discontinuities or voids using appropriate equipment and undertake re-painting where necessary,
- k) Metalizing
 - 1) If the item will not be provided with finish paint the zinc coating shall have a minimum thickness of 500g/m^2 coated surface,
 - 2) Any electrical boxes or other housing enclosure used in outdoor condition shall be hot-dipped galvanised, unless stated otherwise.

4.6.9.4 Schedule of Colours for Identification

Sl. No	Service Description	Colour
1	Fire protection services	Signal Red, colour other than signal red subject to Engineer's acceptance
2	Drains and overflows	
2.a	Outside plant rooms	Black Lacquered
2.b	In plant room	Polished copper
3	Fire protection conduit	Signal Red
4	Pumps :-	Signal Red
4.a	Casing	Light Orange

4.b	Motor Belt guard	Signal Red
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Sl. No	Service Description	Colour
4.c	Base	Signal Red
5	Valves :-	
5.a	Bodies	Signal Red
5.b	Hand wheel	Black
6	Bases and Supports	Signal Red
7	Control panel including clean gas control panels, pump control panels	Signal Red
8	MAPs and SAPs :	Signal Red
9	Electrical including motors, conduits and cable trays	Signal Red
10	Battery Charger Cabinets	
10.a	Exterior	Signal Red
10.b	Interior	Gloss white
11	Tool box	Signal Red

4.6.10 TESTING, COMMISSIONING & VALIDATION

4.6.10.1 Testing, Commissioning and Validation Plan

The Contractor shall be required to submit the Testing and Commissioning Plan which shall include a schedule of tests with the identified standards to which the tests are to be carried out. The Contractor shall update the Plan as necessary. The Plan shall include the following :

- A detailed description of the testing and commissioning philosophy and the testing & commissioning process including the demonstration of successful interfaces with other systems,
- Details of the testing & commissioning organization set up, including staff responsible for testing & commissioning activities,
- Descriptions of methods and procedures for testing & commissioning, procedure for the set up of all test equipment with necessary supporting documentation,
- Details of the testing & commissioning schedule, management and coordination requirements,
- Details of how safety shall be addressed for all personnel and equipment during testing and commissioning,
- Details of all testing & commissioning standards and guidelines that the Contractor shall follow.

The Contractor shall submit test specifications for all tests including integrated tests to the Employer / Engineer for Notice of No Objection prior to the commencement of the tests.

4.6.10.2 Tests of Acoustic and Vibration

- Sound level readings and vibration tests shall be conducted in DG, fan and

pump rooms during construction of the works and at any other time as requested by the Employer / Engineer,

- b) Sound level readings shall be taken with correctly calibrated octave band sound level meter at designated spaces as desired by the Employer / Engineer.

4.6.10.3 Electrical Test

The following tests shall be carried out to the satisfaction of the Employer / Engineer :

- 1) Verification of polarity

To ensure that all fuses and single pole control devices are connected to the live conductor only.

- 2) Insulation resistance tests

Insulation resistance shall be carried out at 240V single phase and at 415V three phase circuits for :

- i. Line to line,
- ii. Line to earth,
- iii. Neutral to earth,
- iv. Line to neutral.

- 3) Earth continuity tests

The test shall be carried out by means of a line-earth loop test or neutral-earth loop test in accordance with IEE regulations.

- 4) Earthing tests

The earthing resistance of equipment shall be measured with loop impedance test in accordance with latest IEE regulations

- 5) Battery capacity shall be tested by tripping the ac supply (normal and emergency) and setting the entire system under alarm condition. Time period up to when the battery can support the system shall be recorded.

4.6.10.4 Test at Manufacturer's Factory and On Site

Manufacturer's factory test shall include all tests in accordance with the relevant standards and any tests called for by the Employer / Engineer to ensure that the Plant being supplied meets the requirements of the Specification. For material / equipment not covered by any standard or specifically mentioned in this Specification, the tests shall be done as agreed by the Employer / Engineer.

The Contractor shall supply and install all materials, supplies, labour and equipment / instrument required for testing. The Contractor shall make preliminary tests and prove the Works as satisfactory. The Contractor shall notify the Employer / Engineer by giving ample advance time to be present for final testing of all materials / equipment. The Contractor shall replace defective work with new work for defects identified by tests or, if required by the Employer / Engineer. The Contractor shall conduct tests in stages if so directed by the Employer / Engineer to facilitate work of others.

For all pipe work, all necessary testing junctions and bends shall be supplied and

installed and sealed off or removed as directed by the Employer / Engineer .

4.6.10.5 Site Tests during Construction

- a) The pressure tests shall be carried out on site in convenient sections during the construction of the Works,
- b) Before the tests are carried out, the Contractor shall remove connected equipment and components which are liable to be damaged under test, and shall provide and fix all necessary gauges, blanking flanges etc.

4.6.10.6 Preliminary Commissioning Checks

- a) The Contractor shall ensure that all equipment are thoroughly cleaned, lubricated and checked for serviceability immediately before setting to the Works. The Contractor shall pay particular attention to the removal of building debris from the pipe work systems,
- b) The Contractor shall pay special attention to the need to thoroughly flush out all pipe work systems to ensure that all foreign matters are removed,
- c) The Contractor shall inspect and check all automatic controls and safety devices for serviceability before the working fluid or electricity is applied to the system.

4.6.10.7 Commissioning

When the various installations have been completed and the preliminary commissioning checks carried out, the Contractor shall set to work, regulate and calibrate all systems in the entire installation. Special attention shall be paid to the following items :

- a) That all valves, switches, controls etc. are regulated and capable of proper operation and in the case of isolation valves that they are capable of tight shut off,
- b) That all instruments are correctly calibrated and read accurately,
- c) That all services are tested in accordance with the details in the relevant clauses of the Contract Specification and relevant standards,
- d) Pumps, pressure reducing sets, etc. shall be operated to ensure that all control systems are functioning correctly and are properly set, sequenced or interlocked.

4.6.10.8 Performance Tests

- a) After the Works have been completed, the Contractor shall be required to carry out or assist in carrying out the performance tests,
- b) Performance tests for all installations shall be carried out to demonstrate that they function in accordance with the intent of the Contract Specification,
- c) Should the performance tests prove that the equipment do not comply with the requirements of the Contract Specification, the Contractor shall be responsible for the rectification, modification or replacement of the equipment and / or system as required by the Employer / Engineer.

4.6.10.9 Final Acceptance Tests

- a) Following commissioning of the entire installation the Contractor shall carry

out final acceptance tests in accordance with a programme to be submitted to the Employer / Engineer for Notice of No Objection,

- b) Should the results of the acceptance tests show that plant, systems and / or equipment fail to perform to the efficiencies or other performance figures as given in the Contract Specification, the Contractor shall adjust, modify and if necessary replace the equipment without any additional cost implications to the Employer in order that the required performance be obtained,
- c) Where acceptance tests are required by the relevant authorities having jurisdiction, these tests shall be carried out by the Contractor, the proposal for which shall be submitted to the Employer / Engineer for Notice of No Objection.

4.6.10.10 Integrated Testing and Commissioning (ITC) with the Civil Works and SWCs

- a) Before the commencement of integrated tests, the Contractor shall complete his own local tests. The Contractor shall submit test specifications for integrated tests to the Employer / Engineer for Notice of No Objection prior to the commencement of the tests,
- b) The Contractor shall coordinate with the civil works and SWCs in preparing an integrated system test plan to test all the points/installations. All testing tools and manpower required for the tests, which will be witnessed by the Employer / Engineer, shall be provided by the respective Contractors. The integrated system test plan shall at least include:
 - 1. The scope of the integrated testing,
 - 2. The objective of the tests and the associated design and operating criteria to be proved / demonstrated,
 - 3. The pass / fail criteria of the test,
 - 4. The inter-dependency and interaction with all systems supplied and those supplied by other Interfacing contractors and their integrated testing programme,
 - 5. The systems / equipment required to be completed by other Interfacing Contractors for each test,
 - 6. A schematic diagram of the integrated tests in the sequence they are to be carried out,
 - 7. A narrative explaining the integrated testing process and methodology, with cross-reference to the schematic diagram,
 - 8. The write-up format on a test-by-test basis,
 - 9. Estimated duration of the Contractor's involvement in each test.
- c) The Contractor shall generate or emulate data signals for the points/installations being tested. Emulation shall be used only if real time signal generation is not possible or impracticable,
- d) On completion of tests or test cases, both interfacing Contractors shall endorse the test records for submission to the Employer / Engineer. Where a failure is recorded in any test cases, the interfacing Contractors shall

reschedule another test regardless of where the fault or defect lies,

- e) The Contractor shall be responsible for taking the lead in conducting the ITC of fire alarm system, clean gas system, pre-testing the activation and re-setting the associated fire alarm devices and panels of the clean gas room,

- f) Fire alarm tests

The objectives of the fire alarm test are to verify and validate the correct operations of interface between automatic fire alarm system and:

- 1) Active voice communication system,
- 2) AMS(Air Monitoring System),
- 3) AFC gates,
- 4) M&E SCADA,
- 5) ECS,
- 6) Fire roller shutters,
- 7) Lifts and escalators.
- 8) TVS,
- 9) Door Access Control System and security system,
- 10) Power Supply and Traction
- 11) Signaling, Telecommunications and PSD

- g) Clean gas test including the VESDA system

The objectives of the clean gas test are to verify and validate the correct sequences and operations of the flooding system, ventilation and extraction system within a clean gas protected room in the event of a fire alarm within the protected area.

4.6.10.11 Integrated Factory Acceptance test(IFAT)

The Contractor shall undertake an Integrated Factory Acceptance Test (IFAT) which will be held in factory. Such IFAT shall be done in the presence of the Employer/Engineer..

A 100% input/output check simulated data may be used subject to the Notice of No Objection by the Employer / Engineer. The Contractor shall be responsible for planning, programming, coordinating, preparing, managing and executing the IFAT.

This IFAT will be the final proving of the interface design prior to on site interface tests and commissioning. The Contractor is required to co-ordinate and agree on the schedule of IFAT and provide input on the preparation of IFAT plan and procedures.

The Contractor shall provide the Employer / Engineer the Testing, Commissioning & Validation Certificate after the successful Installation, Testing Commissioning & Validation of the systems in accordance with the applicable standards.

4.7 FIRE FIGHTING SYSTEM

4.7.1 GENERAL REQUIREMENT

4.7.1.1 Scope of Work

The scope of work of the Contractor shall include design, manufacturing, supply, installation, testing, balancing and commissioning of equipment and accessories as shown on the approved Shop Drawings of the Contractor and Specifications to achieve a complete Fire Fighting System.

The system shall include the following :

- Fire Detection & Alarm System Including VESDA ,
- Public Address & Voice Alarm System,
- Emergency Lighting System,
- Exit and emergency signage system
- Conveying Systems (Lifts & Escalators),
- TVS and ECS Systems (AHUs, FAHUs, Fire Dampers, Staircase Pressurization, Smoke Extraction Fans, Tunnel Ventilation Fans, Chillers, Motorized Dampers, Exhaust Fans, FCU's etc.),
- Fire Fighting Systems (Fire Pumps / Sprinkler Valves),
- Clean Agent Fire Suppression System (Total Flooding & Panel Flooding-only for the Electrical Panels supplied under this Contract eg- Fire Pump, UPS, DG etc.),
- Linear Heat Detector Cable for tunnels (including train turn-back or stabling sidings)
- Automatic Fare Collection System
- Doors with access control system,
- Traction SCADA
- M&E SCADA
- TVS SCADA
- Rolling Shutters
- PSD
- Systems Not Listed Above But That Require Interfacing With The Main Fire Alarm System/ Fire Protection System.

The Works shall be governed by all applicable local codes, regulations, standards and requirements issued by all the local authorities, agencies and services providers.

- i) Local authorities, agencies and services providers
- ii) Local code, standard, rules and regulations
 - (a) Nation Building Code of India
 - (b) NFPA 2001 Standard for clean agent Fire Extinguishing System
 - (c) NFPA 130 Standard for Fixed Guideway Transit System

Relevant Codes and Standards

ANSI B16.9: Factory –Made Wrought Steel Buttwelding Fittings

ANSI B16.21: Nonmetallic Gaskets for Pipe Flanges

ANSI B31.1: Power Piping

ANSI B16.5: Pipe flanges and flanged fittings

ASTM A53: Standard specification for Pipe, Steel, Black and Hot Dipped, Zinc-Coated, Welded and Seamless

ASTM A 135: Standard specification for Electric resistance welded steel pipe.

ASTM A 795: Standard specification for black and hot dipped zinc coated (Galvanized) welded and seamless steel pipe for fire protection use.

ASTM D2000: Standard Classification System for Rubber Products in Automotive Applications

BS 21: Pipes threads for tubes and fittings where pressure tight joints are made on the threads.

BS 143 & 1256: Malleable Cast Iron and Cast Copper Alloy Threaded Pipe Fittings

BS 476: Fire tests on Building Materials and Structures

IS 1239 & 3589: Steel tubes and tubulars suitable for screwing to BS 21 pipe threads.

BS 1560: 1989 Circular flanges for pipes, valves and fittings (Class designated). Steel, cast iron and copper alloy flanges. Specification for steel flanges.

BS 1965: Butt welding pipe fittings for pressure purposes

BS 2494: 1990 Specification for elastomeric seals for joints in pipe work and pipelines.

BS 2633: 1987 Specification for Class-I arc welding of ferritic steel pipe work for carrying fluids.

BS 2971: 1991 Specification for Class-II arc welding of carbon steel pipe work for carrying fluids.

BS 3600: Specification for Dimensions and Masses Per Unit Length of welded and Seamless Steel Pipes and Tubes for Pressure Purposes.

BS 3601 : 1987 Specification for carbon steel pipes and tubes with specified room temperature properties for pressure purposes

BS 3974: Pipe Supports

BS 4504: Circular Flanges for Pipes, Valves and Fittings (PN designated)

BS 4865: Dimension of Gaskets for Flanges to BS 4504

BS CP 2010: Codes of Practice for Pipelines

IS : 817: Part 1: Approval Testing of Welders for Fusion Welding: steels.

BS EN 499 : 1995: Welding consumables. Covered electrodes for manual metal arc welding of non-alloy and fine grain steels. Classification.

BS EN 970: 1997 Non-destructive examination of fusion welds. Visual examination.

BS EN 1092-2: 1997 Flanges and their joints. Circular flanges for pipes, valves fittings and accessories, PN designated. Cast iron flanges.

BS EN ISO 1461: 1999 Hot dip galvanised coatings on fabricated iron and steel articles. Specifications and test methods.

ISO 7483: 1991 Dimensions of gaskets for use with flanges to ISO 7005.

BS 21: Pipe Threads for Tubes and Fittings where Pressure-Tight Joints are made on the Threads (Metric Dimensions)

BS 1010: Draw off Taps and Stopvalves for Water Services
(Screwdown Pattern)

BS 1212: Float Operated Valves (Excluding Floats)

BS 2456: Floats (Plastics) for Floated Operated Valves for Cold Water Services

BS 2879: Draining Traps (Screw – Down Pattern)

BS 4504: Circular Flanges for Pipes, Valves and Fittings (PN Designated)

BS 5150: Cast Iron Gate Valves

BS 5152: Cast Iron Globe and Globe Stop and Check Valves for General Purposes

BS 5154: Copper Alloy Globe, Globe Stop and Check, Check and Gate Valves

BS 5155: Butterfly Valves

BS 5163: Predominantly Key–Operated Cast Iron Gate Valves for Waterworks Purposes

NFPA 14: NFPA standard for fire hydrant system

NFPA 20 : NFPA standard for installation of fire pumps

NFPA-13: Standard for the installation of sprinkler systems

NFPA-15: Standard for water spray fixed systems for fire protection

NFPA-25: Standard for the inspection, testing and maintenance of water based fire protection systems

NBC- National Building Code of India

4.7.1.2 Design and Verification and Validation to be provided by The Contractor

The Technical Specification and the Employer's Drawings shall form the basis upon which the Contractor shall develop and generate his detailed design and shop drawings for the Works. The Contractor shall be responsible for preparation of the CSD / SEM drawings to ensure that the Plant layouts are installed in such a manner that they do not clash with their surrounding installations and that sufficient space is provided for access and maintenance.

The Contractor's responsibility for design, verification & verification of the Works shall be as follows :

- Selection of plant to meet performance criteria and specification with supporting calculations,
- Pipe sizes, sprinkler / hose-reel pumping capacities and hydraulic pressure drop in accordance with the actual characteristics of the pipe work and equipment installed,

- Automatic clean gas total flooding system and or panel flooding system-only for the Electrical Panels supplied under this Contract eg- Fire Pump, UPS, DG etc.,
- Cable sizes, cable containment, voltage drop and electrical protective devices in accordance with the coordinated cable routing and the actual rating of plant,
- 24V DC battery sizing calculations,
- Fault level discrimination,
- EMC analysis and EMI control measures for the works,
- Acoustic and vibration isolation,
- All software design.
- Liaising with the Local Authority & getting their approvals

The sizes of all Plant and equipment specified in the Contract documents are of minimum sizes and capacity. The Contractor shall carry out their system design based on these guidelines provided and shall coordinate with the respective Interfacing contractors for the actual space requirements for their individual installations..

4.7.2 PORTABLE FIRE EXTINGUISHERS

The Contractor shall supply and install fire extinguishers in all stations in compliance with relevant BS EN Codes and Regulations.

Fire extinguishers supplied by the Contractor shall be of Clean gas type (e.g. CO2 type etc.) particularly for electrical rooms and dry powder type for other areas as approved by the relevant Authority with the label affixed. The selection of the extinguishers for a given room shall be determined by the hazard anticipated and its occupational content.

Each extinguisher shall have a tag or label securely attached that indicates the date of inspection and maintenance that was performed and also shall identify the name of the person and organization performing the service. The same record tag or label shall indicate if recharging was also performed and when the next pressure test is to be conducted. The date of inspection and maintenance shall be well within a month prior to the date of installation / handing over.

Operating instructions in accordance with the local code shall be located in front of the extinguisher.

The extinguishers shall not suffer from corrosion at the interface between the cylinder body and nozzle assembly due to galvanic action between dissimilar metals. All fire extinguishers in the public area shall be recessed in wall or partition. The Contractor shall be responsible to provide the right location of recess, access doors and signage for this purpose to the approval of the local fire authority. Where extinguishers are required to be installed exposed (i.e. non-recessed) within public areas, they shall be housed within stainless steel grade 316 cabinets with spring lock or lever type lock.

The location and design of the extinguisher cabinets provided shall comply fully to the local fire authority requirements. Fire extinguishers in non-public areas shall be installed exposed without cabinets.

Extinguishers shall be conspicuously located in positions where they will be readily accessible and immediately available in the event of fire. They shall be

located near to room exits, corridors, stairways, lobbies and landings. Extinguishers shall be installed at a height of 1 metre above the floor level and shall be placed in a manner such that the extinguisher operating instructions face outward

Portable extinguishers shall be installed at the locations as approved by the local fire authorities and Employer/Engineer .

4.7.3 WET MAINS SYSTEM

4.7.3.1 General

The Contractor shall design, supply and install Wet Mains system based on BS-9990 & BS-9999 , NBC, NFPA and in accordance with the codes and standards specified previously.

The wet mains system shall comprise pipe work, breeching inlets, landing valves, automatic air release valves, standby hoses, etc.

The Contractor shall verify and validate the hydraulic pressure drop based on the fittings and valves selected and characteristics of the piping system to be installed to ensure adequate water pressures and flow.

4.7.3.2 Pipe Work

The Wet Mains and associated pipe work shall be of galvanized steel conforming to BS EN: 10255 (for all sizes). The pipe work and fittings shall be galvanized. All pipe joints for the Wet rising mains shall be of mechanical groove coupling. The Contractor shall allow for additional joints to suit tunnels alignment which are curved.

The supply and installation of the pipe work, fittings and valves for the Wet Mains system shall comply with the relevant standards.

The pipe supports, brackets, hangers etc. shall be of hot dipped galvanized steel.

Suitable automatic air release valves shall be installed in each Wet rising main to allow air in the pipes to discharge to atmosphere at the high points of the pipe line (especially breeching inlet location).

Pipelines shall be properly graded to ensure draining of the whole system when required. Minimum 25mm drain valves) shall be provided at the low points of the pipe line.

The Wet Mains pipe shall be electrically isolated from its supporting brackets by means of neoprene rubber of adequate thickness and electrical resistance.

The piping system shall also be designed to withstand water hammer when the water is being charged at the breeching inlet by Fire Department.

4.7.3.3 Breeching Inlets

The requirement for breeching inlets shall be in accordance with the relevant BSI Standards.

4.7.3.4 Landing Valves

The landing valves shall be constructed of gunmetal screw bonnet, bronze spindle. Such valves shall have a purpose made fitting comprising a 64mm bore gun-metal valve, with BS Table 'C' flanged or BSP screwed inlet, 64mm instantaneous female coupling outlet fitted with a removable brass cap secured

by a stainless steel chain, 165mm diameter hand wheel, 64 mm bore renewable valve washer for screw down valves, 22 mm minimum diameter spindle, tested to 2070kPa and marked with the manufacturer's name or mark.

All landing valves shall be strapped shut, the strap being secured with padlocks constructed of brass. 2 sets of keys shall be provided per padlock

Name plates fabricated with aluminium plate with the appropriate words 'WET MAINS OUTLET' painted in block letters of height not less than 50mm shall be provided and fixed on the wall where the landing valve is located and on a level directly just above the valve. The lettering shall be in black colour against a white background.

4.7.3.5 Standby Fire Hoses

- The fire hose shall be of approved type by and acceptable to Maharashtra Fire Safety & Rescue Department/ concerned local authority,
- Non-recessed fire hose shall be housed within stainless steel (grade 316) cabinet or as per the Notice of No Objection by the Employer / Engineer finish cabinets.

4.7.3.6 Fire Hose Reels

The hose reels shall meet the requirements of BS 5306.1 & BS EN 671 – 3

- Hose-reels shall be of the swing-recessed type. Each hose-reel shall be an integral unit consisting of a stop valve, reel, hose, and shut-off assembly. It shall be designed so as to facilitate the swift withdrawal of the hose in any direction with the reel axis horizontal. Non-recessed hose-reels in the public area shall be housed within stainless steel (grade 316) material cabinets as per the Notice Of No Objection by the Employer / Engineer and galvanized steel material cabinet as per the Notice Of No Objection by the Employer / Engineer for non-public areas. The door of the hose- reel cabinet shall include the following features :
 1. Fastened only by means of spring lock,
 2. The door shall be labeled 'fire hose-reel' and the proposal for label shall be submitted to the Employer / Engineer for Notice of No Objection.
- The hose-reels shall be of approved type by the local fire authority,
- Drums shall be constructed of die-cast light alloy, hydraulically balanced, free from denting and twisting, and finished in red enamel. The hub and shaft shall be of brass, fitted with a device to prevent overrun of the hose, having glandless centre seal. The whole unit shall be drip free,
- The length of the hose shall be 45 metres and bore 25mm. it shall be terminated in 'shut-off' branches with 6.5mm jet spray nozzle. Nozzles made of plastic shall not be accepted. Nozzle holders shall be cast aluminium type and firmly secured to the wall using bolts and nuts. Nozzle holder shall be provided in a readily accessible position at a height in accordance with the requirements of local fire authority. Hoses shall be of no kinking reinforced rubber tubing. The hose shall be a flame retardant compound. Hoses shall not suffer any deformation when it is fully reeled into the drum,
- Hose-reels shall be of the non-automatic type with separate isolating valve

mounted in a readily accessible position,

- Hose-reel brackets shall be firmly fixed to the wall and the stresses incurred during use for fire-fighting, will not prevent the unimpeded use of the hose-reel,
- An indication of the open and shut positions shall be fixed or marked on the wheel and the body of the valve, except for the gate valve, which shall be marked with a directional arrow indicating the direction of flow through the valve,
- Every hose-reel shall be marked with the following information in a prominent position :
 1. The manufacturer's name, trade name or mark or the name, trade name or mark of the responsible vendor,
 2. Instructions for operation,
 3. The year of manufacture,
 4. The test pressure in kn/cm^2 ,
 5. The recognized standard (BS EN 671).
- All burrs and sharp edges shall be removed. Water ways shall have a smooth finish. The exterior of all components shall be rounded and smoothed to prevent injury during use. All threaded parts of aluminium alloy components shall be coated in molybdenum grease.

4.7.3.7 Miscellaneous

All other aspects of the hose-reel system shall be provided in accordance with the BS 5306.1 and BS EN 671 – 3 .

4.7.4 AUTOMATIC FIRE SPRINKLER SYSTEM

4.7.4.1 General

The automatic fire sprinkler system shall be based on BS EN: 12845 + Appendix-2 with Ordinary Hazard Group I for ancillary areas and Ordinary Hazard Group III for commercial spaces and maintenance workshop areas.

Sprinkler Heads

Tools shall also be provided to facilitate removal of sprinkler heads. Two (2) sets of tools shall be provided for each station.

Sprinklers shall be of UL/FM standard or listed with BRE.

Sprinkler heads shall be glass bulb type with temperature rating of 68°C and shall be colour coded according to the approved standards. In areas of above normal temperature, high temperature sprinklers suitable for the temperature condition shall be provided.

Sprinklers shall be of conventional pattern designed to produce a spherical type of discharge with a portion of water being thrown upwards to the ceiling. Sprinkler shall be designed with universal deflector enabling the sprinkler to be installed in either the upright or pendant position. Where applicable, the sprinkler heads shall be fitted with water shields and/or protective guards of an approved type.

Sprinklers shall have 15mm nominal orifice size with a K - Factor of $8 \pm 5\%$ where

the water volumetric flow rate and pressure are in litres per minute and kilopascals respectively.

Exposed sprinklers for areas with false ceiling such as shops, offices, corridors etc. shall be designed for use with pipe work within the ceiling space and shall be installed complete with ceiling plate (rosette) flush to the false ceiling. Sprinklers shall be of standard chrome finish. Ceiling plates shall be chrome plated or finish to the Notice of No Objection by the Employer / Engineer. 'Split type' demountable ceiling plate shall be used to enable changing of damaged ceiling without having to remove sprinkler head.

Protective guards of approved type shall be fitted to each sprinkler head in the area where sprinklers are located less than 2 metres above floor level and where they are liable to accidental and mechanical damage.

The Contractor shall ensure that the regulations in BS and / or BS EN, where applicable are complied with in his installation with regards to maximum and minimum spacing between sprinklers on range pipes and between adjacent rows of sprinklers, maximum distance of sprinklers from walls or partitions, maximum distance of sprinkler heads below ceiling or roofs, minimum horizontal distance of sprinklers from beam etc.

Sprinkler heads in bin points / centres or corrosive environment shall be of corrosion proof type, to meet the BS and / or BS EN's requirement.

Approved typed water shields shall be provided for the sprinkler heads where necessary.

Easily accessible flushing facilities shall be provided for each zone to discharge to the nearest drainage outlet. The Contractor shall co-ordinate with regards to the location of the drainage outlets

4.7.4.2 Sprinkler Control Valve Set, Electrically Supervised Gate Valve and Accessories

- a) The contractor shall supply and install sprinkler control valves. Each sprinkler control valve set shall comprise the following :
 1. Main stop valve,
 2. Alarm valve,
 3. Alarm devices including water motor alarm gong, pressure switch, etc.,
 4. Facilities for testing to suit the BS EN requirements,
 5. Glycerine filled pressure gauges to indicate 'upstream' and 'downstream' system pressures,
 6. Electrically - supervised device for valve closures,
 7. Other equipment as necessary.
- b) The stop valves must be 'right handed' and the controlling wheels shall be clearly marked showing in which direction the wheels are to be turned to close the valves. There must be individual indicators, which shall show whether the respective valves are open or shut. The stop valves controlling water supplies shall be secured open by individual pad-locked straps.
- c) The alarm valve shall be fixed on the main supply pipe immediately above the main stop valves. The alarm valves shall be of an approved type and shall have

all necessary connections of the correct size for connections to glycerine filled pressure gauges, water motor alarm, combined drain and test valve etc. The operating pressures of all pumps shall be engraved on bakelite and installed at the test rack

- d) Approved equipment for proving of water supplies shall be provided for all control valves and this shall comply with the requirement of the BS and / or BS EN.
- e) The electrically supervised gate valves shall be with integral limit switches.

4.7.4.3 Alarm Gong

Water motor alarms of approved type shall be supplied and fitted close to the sprinkler control valve set. Each water motor alarm shall comprise a fire alarm gong with a turbine to operate whenever the alarm check valves are being operated. The water motor alarms shall be suitably mounted on the wall above the alarm valves and all pipe connections shall not be less than 20mm diameter.

Each water motor alarm shall be arranged to drain through a non-ferrous fitting with an orifice. Drain lines shall be connected to water drain or sump pit such that the water shall ultimately be discharged out suitably

4.7.4.4 Pressure Switches

- a) Pressure switches shall be provided for the control of the pumps. They shall be of the approved type and in compliance with the requirements of the relevant standards and codes. Pressure switches shall have adjustable settings which shall be set to comply with the requirements of the relevant codes and standards,
- b) Settings of pressure switches shall be labeled for all pumps in a chart. The chart shall be made of perspex complete with reverse colour silk-screen printing and labels indicating clearly the pressure settings. The chart is to be located near to the pressure switches.

4.7.4.5 Flow Switches

- a) Flow switches shall be of paddle type and of approved type. The paddle shall be suitable for the pipe size installed. Flow switches shall be complete with addressable interfacing unit,
- b) The flow switch shall have a single pole double throw (SPDT) mechanism which makes or breaks the electric circuit when water flows. All components of the flow switch that come in contact with the water shall be made of copper alloy,
- c) Contacts shall be suitable for the working voltage and current of the circuits controlled, and shall be of silver or approved alloy,
- d) Adequate space shall be allowed above the pipe work for the installation of flow switches,
- e) Flow switches shall be of the self resetting type and shall be installed in accordance with the manufacturer's recommendations,
- f) Flow switches shall incorporate retards or time delay devices to avoid false alarms due to surges,
- g) The electrical contact block shall be completely sealed from the water in the

pipeline,

- h) Where flow switches are installed within ceiling spaces, the Contractor shall ensure that access panels are provided to facilitate maintenance of the flow switch. The location of each flow switch shall be clearly identified on the access panel. The flow switch interfacing module shall be provided with enclosure of IP rating 55,
- i) Test valves shall be installed immediately downstream of each flow switch to enable local testing. Short drain pipe shall be provided after each test valve and properly terminated with cap.

4.7.4.6 Pressure Gauges

Glycerine filled pressure gauges shall be provided. Pressure gauges shall be of minimum 100mm diameter, threaded chromium plated brass ring with heavy glass, bronze spring tube, precision movement and micrometer adjustment. Pulsation dampeners, steel pipe fittings and shut off cocks of needle point globe type, all brass, rated for 1035kPa working pressure shall be provided. Pressure gauges shall be installed with gauge cocks mounted in a location where they can be easily read. Pressure gauges shall be complete with built-in compensators for fluctuation in external factors such as temperature, humidity and etc.

4.7.4.7 Flow Meter

Flow meters with direct readings shall be provided for control valve installation. They shall be suitable for the system operating range. Data on flow rate and operating pressure shall be engraved on metal plate and installed near the equipment subject to the Notice of No Objection by the Employer / Engineer.

4.7.4.8 Fire Water Tank

- a) The Contractor shall construct the reinforced concrete fire water tank in all stations. The Contractor shall coordinate to achieve the required effective storage capacity. All pipe works and embedded items within the tank wall shall be provided,
- b) The Contractor shall also be responsible for providing water pipe line to the fire water tank. ,
- c) Air vents and overflow fittings shall be provided for each compartment,
- d) The ladders, concrete platforms hand railings and access doors shall be supplied and installed,
- e) Visual water level indicators, with the necessary levels and lettering neatly and clearly marked, shall be provided. The indicator shall show high level at the upper end and low level at the lower end. Visual water level indicators shall not be glass tube type. Electrode type high/low water level sensors shall be provided and these shall be wired back to the pump control panels and MAP by the Contractor,
- f) Anti-vortex device for the fire water tank shall be incorporated so that the effective capacity can be maximized,
- g) All pipe penetrations provided shall be complete with puddle flanges and cast in the tank wall,

- h) The Contractor shall co-ordinate to determine the pipes penetration through the tank wall and the position of the cat ladders and concrete platforms so as to avoid any clashes with the fire protection system and to ensure that they are suitable for their intended purposes,
- i) All exposed openings for the tank and pipe ends shall be completed with insect screen,

4.7.4.9 Wet Main Breeching Inlets

- a) Breeching inlet shall be provided to enable the Fire Department to pump water into the wet main system,
- b) The breeching inlets shall be approved by the local authorities and batch certified by the relevant authority,
- c) All fittings shall be on the external wall and enclosed in a glass fronted stainless steel cabinet complying with the requirements of BS 5041: part 5 and BS 9990 . The breeching inlet shall be recessed. The Contractor shall coordinate and provide the recess, access door and signage,
- d) The breeching inlet connection shall be electrically earthed and it shall be properly earthed to ground using properly sized copper tapes. The Contractor shall provide the required earthing system. A weep hole or drain outlet shall be provided to drain off any residual water within the breeching inlet box. The earthing continuity across pipe joint shall be maintained using copper tape with proper metal to metal contact. The maximum allowable earth impedance shall be less than 10 ohms,
- e) Caps for the breeching inlet shall be of approved brass type and held close by means of a spring lock with a sufficient length of stainless steel chain,
- f) The Contractor shall provide the required signage or indications,
- g) The Contractors will provide breeching inlet cabinet together with the labeling and signage.

4.7.4.10 Earthing And Isolation

The Wet Mains, Hose Reels and Sprinkler systems shall be electrically earthed using appropriately sized copper conductors. The earthing continuity across pipe joint shall be maintained using copper tape with proper metal to metal contact. The maximum allowable earth impedance shall be 10 ohms. Each Wet Mains system shall be independently earthed at the breeching inlet.

4.7.5 PUMPS

4.7.5.1 General

The fire pumps shall be provided in compliance with the BS EN 12845 + APPENDIX-2 . This part specifies the furnishing and installation of wet riser and jockey pumps.

Pumps shall be capable of achieving the nominal flow rate against the head of the system.

The Contractor shall design and verify, validate the operating head based on the equipment selected and upon the characteristics of the pipe work system actually installed.

Calculations together with certified performance curves of the pumps with the operating range indicated shall be submitted to the Employer / Engineer for Notice of No Objection.

Pumps shall be furnished by experienced manufacturers normally supplying this type of equipment, and who can show evidence of having furnished such equipment that has been in successful operation for at least five years.

The make and type of the Pumps shall be submitted to the Employer / Engineer for Notice of No Objection.

Standards

Reference Codes and Standards

BS 599: Methods of Testing Pumps.

BS 970: Wrought Steels for Mechanical and Allied Engineering Purposes.

BS 1400: Copper Alloy Ingots and Copper Alloy and High Conductivity Copper Castings.

BS 1452: Flake Graphite Cast Iron.

BS 3100: Steel Castings for General Engineering Purposes.

BS 4504: Circular Flanges for Pipes, Valves and Fittings.

BS 5316: Parts 1 and 2 : Acceptance Tests for Centrifugal Mixed Flow and Axial Pumps

BS EN ISO 5198: Centrifugal, Mixed Flow and Axial Pumps - Code for Hydraulic Performance Tests - Precision Class.

NFPA 20 : NFPA standard for installation of fire pumps

Fire pump shall comply with NFPA-20, and where applicable shall also comply with BS 5257.

4.7.5.2 Pump Construction

Material of Construction: The pumps shall be constructed with materials specified below or approved equal, unless otherwise specified.

Fluid to be Handled : Clear Water

Material:

Casing	Cast iron to BS 1452 Grade 260
Impeller	Bronze to BS 1400 LG2
Shaft	Stainless steel to BS 970: Part 1 Grade 316 S 16 or chromium steel
Shaft sleeve	Stainless steel to BS 970: Part 1 Grade 316 S16
Wear rings	Bronze to BS 1400 LB1
Bolts, studs, dovels, nuts, washers and other fixing accessories	Stainless steel to BS 970: Part 1 Grade 316 S 16

- a) The main pumps shall be of the centrifugal volute, constant speed, single stage, single end suction, base or frame mounted and flexible coupled to motor drive. The casing shall be arranged for easy removal of impeller, bearings and seals without dismantling connecting piping. Casing shall be provided with drain and vent cocks.
- b) Jockey pumps shall be of centrifugal type. The sprinkler jockey pumps shall have rated capacities not less than any normal leakage rate and not more than the flow rate when any one of the sprinkler is burst. They shall have discharge pressures sufficient to maintain the desired system pressure.
- c) The pump casings shall be of close grain cast-iron accurately machined and assembled with metal to metal joint.
- d) The impellers shall be made of bronze and designed to give no overloading characteristics over a large range of head variations. The impeller shall be statically and dynamically balanced. Impeller rings shall be of cast-iron and removable, secured from relative movement by stainless steel and rotation ring. The shaft shall be of machine ground stainless steel.
- e) Bearings shall be self aligning, radial and thrust ball type, grease lubricated and designed for not less than 100,000 hours average life. Bearings shall be of the silent type.
- f) Pump glands shall be packing seal type. Shaft sleeves shall be bronze removable type. Drainpipe shall be provided to drain any leakages through the pump seal into the nearest floor waste or sump pit.
- g) Pumps shall be capable of running under conditions of zero or low 'draw off' continuously without overheating. This shall be achieved by an automatic bypass circuit arrangement i.e. an automatic pressure relief valve and pipe at the pump discharge side.
- h) The pumps shall be directly driven by a totally enclosed fan cooled motor. Motors shall be equipped with sleeve bearings and speed shall be compatible with pump speed and shall not exceed 2900 r.p.m.
- i) Flexible coupling shall be provided between the pump and motor, and shall be of the steel pin / rubber bush type, accurately aligned. It shall be noted that the coupling is required to reduce shock, excessive wear and tear to the bearings etc. and is not there to compensate for misalignment. The pin and bush coupling require the same accuracy of alignment as rigid couplings, and the Contractor shall demonstrate correct alignment.
- j) Removable hot dip galvanized sheet metal coupling guard shall be provided.

4.7.5.3 Pump Base Plate and Plinth

- a) The pump and motor combination shall be mounted on a substantial machined base plate of fabricated steel and a suitable inertia block and the complete unit mounted on a suitably reinforced concrete plinth with antivibration mounting. The concrete plinth of at least 150mm shall be provided. The casting of the inertia block with concrete shall be provided.
- b) The base depth shall be as recommended by the pump manufacturer for mass or rigidity, but shall not be less than 150mm.

- c) The inertia block shall be sized to obtain minimum 1:1 ratio (inertia block/equipment mass ratio). Thickness of the inertia block shall be at least 150mm and not exceeding 300mm. The inertia blocks shall support the pipe work up to and including the first elbow before the vertical riser. The minimum total static deflection shall be 20mm
- d) Holes for foundation bolts, or the bolts shall be cast into the block. Foundation bolts shall be painted with anti-rust primer before installation
- e) Vibration isolators shall be selected in accordance with the weight distribution so as to produce reasonably uniform deflection during pump running
- f) Spring type isolators shall be free standing and laterally stable without any housing and complete with 6mm neoprene acoustical friction pads between the base plate and support.
- g) All mountings shall have leveling bolts that must be rigidly bolted to the equipment.

4.7.5.4 Maintenance Facilities

Pump installation shall be complete with adequate facilities for maintenance and future replacement of Plant. Lifting eyes shall be provided for pumps and motors.

4.7.5.5 Guards

All moving parts of the pump and motor shall be adequately guarded by a wire mesh screen of sufficient strength to avoid distortion under normal usage.

4.7.5.6 Flexible Connectors

- a) Flexible connectors shall be used on the pump outlet and inlet.
- b) Flexible connectors shall be of stainless steel convoluted bellows type expansion compensators complete with all necessary guides, etc.
- c) All connectors shall be rated at a minimum of 1.5 times of the working pressure of the system.
- d) All connections shall be made with flanged sphere properly pre-extended as recommended by the manufacturer to prevent additional elongation under pressure

4.7.5.7 Automatic Pressure Relief Valve

- a) Each pump shall be provided with an automatic pressure relief valve set slightly below the shut-off pressure of the pump. It shall provide circulation of sufficient water to prevent the pump from overheating when operating with no discharge. Provisions shall be made for a discharge back to the sump. The relief valve shall be labeled with the setting pressure.
- b) When the jockey pumps have a shut-off pressure exceeding the working pressure of the fire protection equipment, a suitable relief valve shall be installed on the pump discharge to prevent damage to the fire protection system. An orifice plate shall be installed at the discharge pipe of the jockey pump.

4.7.5.8 Electric Motor For Fire Pumps

- a) The correct selection of the electric motors for the fire pumps shall be the responsibility of the Contractor.

- b) Motors shall be totally enclosed fan cooled type and motor insulation shall be BS EN: 600085 class b or better.
- c) Motors shall be suitable for continuous operation on voltages within 10% of the supply voltage. Motors above 2.2kw shall be three phase 415v, 50hz. Motors up to and including 2.2kw shall be single phase 240v, 50hz.
- d) Bearings shall be precision grade, anti-friction, deep grooved ball type and extra quiet.
- e) All motors shall be suitably earthed to comply with I.E. Rules' requirements.

4.7.6 FIRE PUMP CONTROL PANEL

4.7.6.1 General

The Contractor shall design, verify, validate, supply and install fire pump control panels. The Fire Pumps controls shall be incorporated within the same fire pump control panels.

The fire pump control panels and the associated components, accessories, instruments and relays shall comply with British Standard Specifications or IEC.

The control panel shall be of the self-contained; metal clad, cubicle type with flush hinged doors lined with rubber gaskets for front access. Doors shall be provided with car type lockable handles with standardized key locks and 3 sets of keys. The panels shall be suitable either for floor or wall mounting. The panel shall be isolated before the door can be opened for access or maintenance purposes. Floor trunkings supported on C- Channels between the control panel and pump are strictly prohibited.

LEDs shall be used to indicate various functions on the control panel. A test and selector switch and ammeter for each pump shall be included in the panel.

The control system shall be capable of both manual and automatic operation of the installation.

Manual / Off / Auto, manual duty pumps selector and pressure switches, and start/stop push button shall be provided. A visual and audio alarm shall also be provided to raise an alarm when the pump is tripped.

The panels shall comprise standardized items, enabling easy exchange or replacement of faulty equipment.

There shall be no magnetic and thermal overload trips for the fire pumps.

Any no volt release mechanism must be of the automatic resetting type such that on restoration of the supply to the motor the same can restart automatically.

Each panel shall include an incoming section equipped with load switch and feeder section furnished with HRC fuse rated to provide protection for the connected cables in accordance with the definition in IE Rules.

HRC fuses must be capable of the following :

- a) Protecting the cable connections to the motor.
- b) Carrying the stalled current of the motor for a period of not less than 75% of the period when such a current would cause the motor windings to fail.

Single line diagram complete with control circuitry shall be laminated and affixed to the interior of all door panels

4.7.6.2 Motor Starters

- a) Motors up to and including 9.32.2kw shall have direct online starter. The starting current shall not exceed 6 times of the full load current when direct-on-line starting at full voltage is applied.
- b) All motors over 9.3kw shall be equipped with automatic air cooled star delta starters to limit the starting current so that it shall not exceed 2.5 times of full load current of the motor.
- c) Not Used.
- d) Starters and contactors contained therein shall comply with the local and/or British Standards. Starters shall be classed for intermittent duty. Contactor type motor starters shall conform to BS 5856-1, BS EN 60947-4-1: 1992 & BS EN 60470,
- e) The starters shall be housed in the appropriate control cabinet board and arranged for automatic and manual control as required. The starters shall have flush mounting START / STOP push buttons, 'on load' integral isolating switch mechanically interlocked with the access door, auxiliary contacts, red pilot lamp to indicate motor 'running' and control circuit fuses.
- f) All starters shall be of electrically held on pattern with no volt release characteristics but shall not release until the voltage falls below 85% of nominal. Any no volt release mechanism must be of the automatic resetting type and that on restoration of the supply the motor can restart automatically.
- g) All contactors shall comply with IEC 158, utilization category AC-3.

4.7.6.3 Cabinet Construction

- a) The cabinet shall be of dead front type and manufactured from minimum 2mm thick electro-galvanized steel sheet using folded sections or angle iron bracing for rigidity of construction.
- b) The cabinet shall have adequate ventilation, double layer enclosure, IP rating 55 for station areas and IP 65 for the tunnel areas, weatherproof and be dust, drip and vermin proof. The construction shall be such that it allows for ready access to the interior of the cubicles for operation and maintenance purposes. The opening of a door or the withdrawing of a circuit breaker shall allow access to that compartment only. Continuous galvanized steel sheets shall be provided to completely separate adjacent cubicles or switchgear.
- c) The cabinet shall be provided with non-ferrous gland plates for the entry of all incoming and outgoing cables. The gland plates shall be drilled on site to suit each appropriate cable.
- d) Instruments, led indicating lights, switches, etc. Shall be mounted directly on a fixed fascia panel suitably stiffened to hold such items firmly in position under all conditions of operation.
- e) All sheet steel, angles and channel for construction of the panel shall be galvanized and epoxy coated to a minimum thickness of 60 microns.
- f) The front doors shall be electrically interlocked such that doors can only be opened after the power supply is isolated.

4.7.6.4 Bus Bars

- (a) The panels shall be provided with 3 phase tinned copper conductor bus bars. All panels shall also be furnished with neutral (n) having the same rating as the phase bus bars.
- (b) Bus bars shall be of equal size, rectangular HDHC copper section capable of carrying for 3 seconds a through fault current equivalent to the prospective 3 phase short circuit level of 25 MVA.
- (c) Current ratings shall comply with BS 158 and BS 159 for a temperature rise not exceeding 45°C. Phase indication shall be provided on all bus bars.
- (d) All connections in bus bars shall be bolted or clamped with contact surfaces suitably prepared to prevent oxidation in service, and all through joints and contact parts shall be tinned before connection.
- (e) All bolts shall be tightened with an even tension. Approved washer shall be used at all joints. Sherardised (BS 7371: part 8, class s1) high tensile steel bolts with BSP threads and plated lock nuts shall be used.
- (f) A copper earthing bar shall be provided and installed at the base of the full length of the panel. A tee connection from the earthing bar shall project into each breaker compartment for automatic grounding of the chassis when the breaker is inserted into the compartment. The cross-sectional areas of these earthing bars shall be sized for fault currents for faults of negligible impedance in accordance with BSI standards.
- (g) Sharp right angle bend and twisting of copper bars shall not be allowed.
- (h) Minimum spacing between copper bars shall not be less than 60mm.
- (i) All copper bars must be hard drawn and tinned and insulated coloured PVC sleeveings to indicate their respective phase.

4.7.6.5 Earthing

- a) All metal raceway (conduit / trunking / cable tray) systems, supports, cabinets, panels, equipment cases and motor frames shall be permanently, solidly and effectively grounded (earthed). Continuity of equipment grounding shall be maintained throughout the system. Ground clamps shall be approved type, specifically designed for grounding.
- b) Copper clad strap metal is unacceptable for earthing or bonding purposes.
- c) All non-current carrying metal parts of electrical equipment installations shall be connected to the ground loop as required. These will include wire way, bus ways, raceways, switchgear enclosures, motor control centre enclosures, pushbutton stations, motors and any other non-current carrying metal parts which may become energized by accidental contact with line electrical conductors.
- d) The grounding (earth continuity) system shall be fully tested in strict conformance with IEE rules.

4.7.6.6 Instruments

- a) Instruments shall be suitable for flush mounting and shall have square or rectangular type face with moulded plastic escutcheons.

- b) The ammeters and voltmeters shall be of the moving coil type and shall have accuracy class of the instruments of 3 or better.
- c) The voltmeter shall be provided with a selector switch for reading the values of the 3 phases i.e. Phase to phase, and phase to neutral voltages.
- d) The scales width shall not be less than 240 angular degrees and the designation shall be in amperes or volts on matt white plate. Anti-parallax and anti-reflecting types of platform/covers shall be used. Ampere meter shall have compressed scale to cater for motor starting where necessary.
- e) Hour count meters shall be provided to measure the operating period of each individual pump.
- f) A minimum of 2 nos of anti-condensation heaters shall be installed inside the panel. The power rating of these heaters shall be equivalent to the power dissipated by the panel during normal operation. These heaters shall only be activated when the process system is shut down or inoperative.

4.7.6.7 Indicator Lights

- a) All indicator lights shall be of pilot light and shall be provided in duplicate. The pilot light when lighted shall be visible in lit rooms.
- b) Light emitting diode (LED) indicator (green) shall be provided to show that there is electrical supply available to the control panel and this shall be labeled 'MAINS SUPPLY ON'.
- c) LED indicator (red, yellow, blue) shall be provided to indicate clearly each phase of the electrical power supply for both incoming and outgoing and to indicate the status of each electric motor.
- d) LED indicator (orange) shall be provided to show the failure of any one phase of the electric power supply to the electric motor driven pump which shall be labeled 'pump fail'.
- e) LED indicator (red) shall be provided to show that the pumps are not operating and shall be labeled 'pump stop'.
- f) LED indicator (green) shall be provided to show that the pumps are running and shall be labeled 'pump running'.

4.7.6.8 Relays

- a) Relays shall be of first grade, with continuously rated coils and contacts to suit voltages and currents concerned. Relay holders for 24V DC and 240V AC shall have different pin configurations and placed at a distance apart.
- b) Care shall be taken in the selection of relays with regard to the use of cables. The Contractor shall ensure that there is no possibility of cable insulation breakdown due to surge voltages which may occur when inductive circuits are opened and closed. If necessary, limiting devices shall be installed and connected.
- c) The phase failure relay shall be of the star capacitor type, arranged to close its contacts in the event of failure of one or more phases under any condition.
- d) Time delay relays, shall be of synchronous motor type, with adjustable time setting up to five (5) minutes and instantaneous reset. The minimum setting

shall be one (1) second.

- e) Earth leakage protective relays shall be of the instantaneous type with adjustable settings from 5% to 40% in 5% steps.

4.7.6.9 Nameplates

Each circuit, equipment and instrument of the control panel as well as the control panel itself shall be clearly identified and designated according to its function. The nameplate shall be of white trifoliate laminated white/black/white engraved with black lettering and affixed with stainless steel screws. Details of the labels shall subject to the Notice of No Objection by the Employer / Engineer before fabrication.

4.7.6.10 Internal Wiring

- a) Wiring within the control panel shall be neatly arranged laced into forms and suitably clamped. All internal wiring shall be installed in wiring channels or conduits as far as possible. Exposed wiring shall be kept to a minimum but where necessary, the wires shall be formed into compact groups suitably spiral bound together and properly supported. Non-metallic material shall be preferred for the channels or conduit. Adhesive cable supports shall be the high bond type and shall not be easily dislodged.
- b) All conductors shall be terminated with suitable pressure type terminal lugs of proper sizes for terminal studs at the terminal blocks or shall be terminated in a manner compatible with the terminals of the instruments. Terminal block shall be appropriately rated. Plug-in type of terminal blocks shall not be used.
- c) All conductors shall run continuously between terminal studs without splices or tape
- d) All conductors shall be identified by colour coding and labeled at each termination using numbered ferrules with wire number to correspond with circuit diagrams. Terminal strips shall also be clearly numbered to conform to the wiring diagram and they shall be provided for all incoming and outgoing cables. In addition, all cable terminations and component circuit references shall be properly labeled.
- e) Terminals shall be of the tunnel type of suitable size for the wire it is to accommodate. Terminals shall be installed in readily accessible positions.
- f) The following conductor colour coding shall be used:

(1) AC SYSTEM

Phase	Colour
R	Red
Y	Yellow
B	Blue
Neutral	Black
Protective Earthing	Green or yellow
Control or measuring	Light grey

Circuits

(2) DC SYSTEM

Phase : Colour

Positive (+) : Red

Negative (-) : Black

4.7.6.11 Switches

- a) Push button controls shall be of the momentary contact type, and suitable for current of 15 amperes at 240V AC.
- b) Key-operated switches shall be of a rotary type such that the key can only be removed in the normal position. Alternatively, a rotary selector switch may be used with an integral lock, the key of which shall only be removable in the normal position. Rotary switches, with shafts that wear off easily during operation, shall not be used.
- c) Toggle switches shall be of a two position switch of robust construction and have silver contacts having minimum rating of 5 amperes for 240V AC and 3 amperes for 30V DC.

4.7.6.12 Miscellaneous

The Contractor shall supply and install the following in the pump room :

- a) Non-fading single line / control wiring diagram etc., shall be framed in a non- reflective transparent plastic/glass board.
- b) Operation / maintenance instruction to be framed in a non-reflective transparent plastic/glass board.
- c) Fibre boards shall be transparent type and provided at the front and rear of each panel to prevent accidental contact with all live parts. Suitable protection shields shall also be provided at the rear of all front panels with lamps/instruments. Danger signs shall be provided on all protective shields and/or barriers. Carrying handles shall be provided for all removable covers.

4.7.7 PUMP CONTROLS

The automatic control of the Fire Pump sets shall provide for the complete system pipe work to be pressurized at the adjustable pre-set pressure level. When the system pressure falls, initially the jockey pump shall come into operation to bring the pressure to the required value and then stop when the high limit pressure is reached. Adjustable time delay shall be provided.

If the system pressure continues to fall despite of the jockey pump operating, the duty Fire Pump shall come into operation when the pressure falls to another pre-set level. The jockey pump shall stop when the duty Fire Pump or standby Fire Pump come into operation. Once started the Fire Pump shall run continuously until stopped manually.

If the duty pump fails to operate, the standby pump shall also automatically come into operation. The pump shall continue to operate and shall not automatically cut-out until it is manually switched off.

Suitable pressure switches and gauges complying with requirements shall be provided to activate the pumps and to monitor the system pressure.

Means shall be provided for the sprinkler and hose-reel pumps to be set for lead lag duty (with changeover) and for the standby pump to operate should the duty pump fail to function after a time lapse (adjustable) upon closing of the starting circuit.

Light indicators showing the status of the pumps and the water level in the Fire water tank shall be provided on the sprinkler and hose-reel pump control panels and MAPs.

The pumps shall be fully operational within 30 seconds after starting. The control of the hose-reel pumps shall be arranged, as follows :

- The duty pump shall come into operation automatically with a drop in pressure in the system.
- Both pumps shall be automatically primed at all times.
- The standby pump shall operate automatically on a failure of the duty pump.
- The duty pump or standby pump shall stop automatically when the system pressure is re-stored.
- The pumps shall also be capable of being started or stopped manually.
- Means shall also be provided for starting the pumps when manually simulating a pressure reduction.

4.7.8 PIPE WORK

4.7.8.1 General

This section specifies the Works for the sprinklers, hose-reels, wet Mains and automatic clean gas total flooding systems.

The Wet Mains, associated pipe work shall be of galvanized steel, BS EN: 10255 (for all sizes). The pipe work and fittings shall be galvanized. All pipe joints for the Wet rising mains shall be of mechanical groove coupling.

The pipe supports, brackets, hangers etc. shall be of hot dipped galvanized steel. Suitable automatic air release valves shall be installed in each Wet rising main to allow air in the pipes to discharge to atmosphere at the high points of the pipe line (especially breeching inlet location).

Pipelines shall be properly graded to ensure draining of the whole system when required. Minimum 25mm drain valves shall be provided at the low points of the pipe line.

The Wet Mains pipe shall be electrically isolated from its supporting brackets by means of neoprene rubber of adequate thickness and electrical resistance.

Due to the long length of the Wet Mains pipes in the tunnel, the piping system shall be designed to allow for expansion and contraction to prevent excessive stress to the pipe work. The piping system shall also be designed to withstand water hammer when the water is being charged at the breeching inlet by Fire Department.

All pipe work delivered to Site shall be new, cleaned, capped, deburred, free

from scale, rust, grease and colour banded to identify different grade. All black steel pipes and fittings shall be cleaned and thoroughly wire brushed and prime coated prior to

installation. All galvanized steel pipes and fittings shall be cleaned and prime coated prior to installation.

Pipe work shall be installed with correct fall to ensure adequate venting and draining.

Pipe work installed in trenches, ducts, voids and inaccessible places shall have welded joints except where screwed or flanged joints are necessary for connecting to valves etc. The pipe work shall be inspected and tested for Notice of No Objection by the Employer / Engineer prior to concealment.

No pipe joints or fittings shall be permitted within the thickness of walls or floors etc.

When pipes pass through walls, floors or ceilings, liquid tight puddle flanges shall be supplied and fixed by the Contractor.

All exposed pipe works shall be installed so that minimum clearance of 100mm is left between the outside of the pipe and the nearest wall equipment surface and minimum 100mm from ceiling or slab. Pipes shall be run at a minimum distance apart to enable them to be individually painted.

Pipe sleeves shall be provided and installed by the Contractor. The gap between pipes sleeve and pipe shall be fire stopped using approved fire stopping material having fire resistance not less that required for fire compartment wall.

All pipe work shall be installed in accordance with the relevant standards, codes and to the approval of the local authorities. The Contractor shall check and ensure that the design meets the requirements of the local authorities having jurisdiction.

The Contractor shall submit manufacturer's printed installation, operation and maintenance instructions, consisting of installation and operation procedures, detailed parts list, recommended spare parts list, and complete maintenance procedure of all valves and piping accessories.

The Contractor shall submit pipe support and anchor details to the Engineer for obtaining the Notice of No Objection.

The Contractor shall submit pipe testing and cleaning procedures to the Employer / Engineer for Notice of No Objection.

No pipe shall be installed at low level across route of egress or maintenance access routes causing obstruction to access.

All angle support brackets installed at low level shall be padded and warning signs shall be provided.

All angle brackets and supports for pipes in the under platform void shall have all sharp edges padded. The direction of flow shall be painted onto the pipe with white arrows at suitable intervals

All sprinkler pipe passing through un-sprinklered non-public areas, shall be encased in fire rated duct with the same fire rating as the fire compartmentation.

4.7.8.2 Piping Installation

- a) All pipes shall be installed parallel to walls, clear of obstructions, preserving head room and keeping passageways clear.
- b) All pipes shall be cut in a neat and workman like manner without damage to the pipe. Cutting shall be done with an approved type mechanical cutter. The Contractor shall use wheel cutters where practicable. Pipe ends shall be reamed to remove burrs. Cutting of pipes and fittings with gas torch shall not be acceptable.
- c) Welding of pipes shall only be undertaken by welders holding a minimum national trade certificate - two in welding issued by institute of technical education or its predecessor or equivalent acceptable by the Employer / Engineer. The Contractor shall submit qualification of all welders who will undertake the welding work for obtaining the Notice of No Objection from the Engineer.
- d) All pipes shall be so installed that the system can be thoroughly drained. Sprinkler pipe work shall be arranged to drain to the installation drain valve. Auxiliary drain valves shall be provided for the trapped section of the system.
- e) Automatic air vents shall be provided at each high point of each water pipe line and where necessary, it shall be complete with isolating cock.
- f) All pipes shall be stored with closed ends, which shall not be opened until erection. All pipes shall be flushed to prevent foreign material being left in the pipe.
- g) As soon as pipe lines have been installed, openings shall be covered to prevent entrance of debris and materials that would obstruct the pipes. Covers shall be left in place until necessary for completion of works.
- h) Supports shall be attached only to structural framing members. Where supports are required between structural framing members, a suitable intermediate metal frame shall be provided.
- i) Screwed joints shall be made with tapered threads properly cut. Joints shall be made with polytetra-fluoroethylene tape, or other approved thread joint compound applied to the male threads only. Not more than three threads shall show after the joint is made up. However, the thread shall not be cut too deep where leakage might occur.
- j) Flanges and unions shall be faced true and provided with approved gasket, and made square and tight. Union or flange joints shall be provided in each pipe immediately preceding the connection to each piece or equipment or material requiring maintenance, such as pumps, control valves, and other similar items. Gaskets shall conform to ANSI b16.21 and ASTM d2000.
- k) Pipe grooving and coupling shall be installed in accordance with the manufacturer's recommendations. The pipe grooving shall be formed and not cut, which will weaken the pipe joint and also the pipe.
- l) Valves installed in horizontal pipes with stems horizontal or above shall have isolation valves at any points indicated or required for draining, isolation, or sectionalizing purposes.

- m) Pipes connected to equipment shall be supported independently such that the equipment is not stressed by piping weight or expansion.
- n) Unions or flanges shall be provided to facilitate maintenance, repair and replacement
- o) Drawn bends shall not be used unless otherwise accepted by the Employer / Engineer .
- p) Where pipes pass through a building expansion joint, and/or are subjected to movement, approved flexible connections shall be provided to eliminate any stress
- q) All drainage pipe work shall be installed plumb, level or true to the gradient and shall be neatly grouped with the minimum number of crossovers and adequate provision for venting, expansion, contraction and movement. Pipe work shall be substantially supported to the Notice of No Objection by the Employer / Engineer, and shall not be located less than 100mm above finished floor levels. Adequate clearances shall be maintained from all other services and from the building structure.

4.7.8.3 Installation of Pipe Hangers and Supports

The proposal for all necessary hangers and supports, including rods, angles, channels and plates shall be submitted to the Employer / Engineer for Notice of No Objection.

Vertical piping shall be guided or supported in the centre of each main with approved steel brackets to prevent swaying, sagging, vibration and resonance. Strains shall be avoided that may cause pipe works to snake or buckle between supports or anchors.

Anchors and guides shall be provided for all horizontal and vertical piping for proper control of thermal movement, this is required to prevent undue strain on branches, provide proper performance of expansion loops and to avoid overloading of hangers and supports

Spacing of supports (center to center) shall not exceed the values given in the table below unless otherwise agreed by the Employer / Engineer:

Piping Material	Nominal Bore	Centres Of Support (m)	
		Vertical	Horizontal
Steel	15 – 40	2.5	1.8
	50	2.7	1.8
	65 – 80	3.5	3.5
	100	4.0	4.0
	150	4.5	4.5
	200	5.0	5.0

Pipe hangers shall be placed not more than 600mm from each change of direction where possible.

All hangers and supports shall be of hot dipped galvanized mild steel of adequate dimensions and approved design. The pipe shall be restrained to prevent movement by a horizontal thrust when flexible fittings are used.

However, threaded components, including bolts, nuts, inserts and washers shall be sheradised to BS 7371 Part 8, Class S1

4.7.8.4 Protection of Pipe Works

All piping work shall be protected during and at the end of each day's work to prevent entrance of moisture or dirt or contamination of the systems.

4.7.8.5 Pipe Work Materials

Pipe work Specification for the fire protection system shall be as follows :

Sl. No	Description	Materials
1	Hose Reel Pipes	Galvanized Steel to BS-1387 Class B (For all sizes)
2	Wet Main Pipes	Galvanized Steel to BS-1387 Class C (For all sizes)
3	Sprinkler Pipes	
	25mm Dia to 150mm Dia	Black Steel ASTM A53 Or Black Steel BS-1387, Class B (25mm Dia to 150mm Dia)
	200mm Dia & Larger	Black Steel ASTM A 53 Schedule 40 (200mm Dia & Larger)
4	Clean Gas Piping	
	Downstream	Galvanized Steel Pipes to ASTM A53 / A 106 Grade-B Schedule 40
	Upstream	Galvanized Steel Pipes to ASTM A53 / A 106 Grade-B Schedule 80
5	Underground Pipes	Ductile Iron Cement Lined BS EN 545 Class K12

4.7.8.6 Pipe Joints

For steel pipe work, all joints up to and including 65mm diameter shall be made by means of screwed socket connections. Pipes of 80mm diameter and above shall be joined by means of mechanical groove coupling.

All pipe works within pump rooms shall be of flanged joints or mechanical groove coupling only. Joints shall not be closer than 3000mm except where necessitated by fittings. Flanges shall be wrought iron or annealed steel, machined full face, suitable for the working pressures to which they will be subjected. Flanges shall conform to the relevant ANSI Standard and pressure rating.

4.7.8.7 Pipe Fittings

- Pipe fittings shall be provided as specified in the following table and conform to the requirements of the relevant standards for the various pipe materials.

Piping Materials Specification of Fittings

Sl. No	Description	Materials
1	Hose Reel Pipes	Galvanized Steel to BS-1387 Class B (For all sizes)
2	Wet Main Pipes	Galvanized Steel to BS-1387 Class C (For all sizes)
3	Sprinkler Pipes	
	25mm Dia to 150mm Dia	Black Steel ASTM A53 or Black Steel BS-1387, Class B (25mm Dia to 150mm Dia)
	200mm Dia & Above	Black Steel ASTM A 53 Schedule 40 (200mm Dia & Larger)
4	Clean Gas Piping	
	Downstream of Pressure Reducer	Galvanized Steel Pipes to ASTM A53 / A 106 Grade-B Schedule 40
	Upstream of Pressure Reducer	Galvanized Steel Pipes to ASTM A53 / A 106 Grade-B Schedule 80
5	Underground Pipes	Ductile Iron Cement Lined BS EN 545 Class K12

- Eccentric reducing sockets shall be used where a reduction in pipe size is required, to ensure proper drainage or elimination of air pockets and at the pump suction and outlet. Concentric reducing sockets shall be used for vertical pipes only.
- Long sweep bends shall be used in preference to round elbow bends whenever practicable. Mitre elbows shall not be used.
- Long radius elbow and sweep or 'pitcher' tees shall be used on all changes of direction. Bends and off-sets formed by welding together of segmented pieces shall not be used.
- Pipe fittings for joining pipes of 80mm diameter and larger shall be standard mechanical groove coupling. Pipe fittings for joining pipes of 65mm diameter and smaller shall be of screwed socketed connection. Welding for such shall not be allowed unless accepted by the Employer / Engineer.
- Pipes installed in inaccessible areas shall be welded at joints.

4.7.8.8 Gaskets

- Gaskets shall be suitable for temperature, service and pressure of system, installed in accordance with manufacturer's recommendations. All gaskets for flanged joints shall be of one-piece ring, 1.5mm thick and neoprene.
- Insulating gaskets, washers and sleeves shall be provided for flanged joints in between dissimilar metals.

4.7.8.9 Vertical and Riser Pipe Isolation

- Risers shall be suspended from or supported by hangers or mountings. In general, all riser pipes in duct shafts shall be resiliently suspended at the top of the pipe duct shafts. "duck foot" supports for pipe elbows connecting to equipment shall rest on resilient mounts having minimum deflection not less

than that of the isolators for the respective equipment.

- b) In general, all resilient mounts and hangers shall have a minimum static deflection of 20mm.

4.7.8.10 Horizontal Pipe Isolation

- a) Vibration hangers shall be provided generally for pipes inside the pump room.
- b) Minimum static deflection of hangers for the first three supports for pipes from equipment shall be as follows :

Pipe Sizes (mm)	Minimum	Static
Deflection (mm) Up to 75	20	
Up to 150	38	

All other hangers and mounts shall have a minimum of 20mm deflection.

4.7.8.11 Sleeves And Covers

- a) The Contractor shall provide the location and size of pipe sleeves for a right installation of them. Pipe sleeves shall be provided where pipes pass through walls, floors etc. All sleeves shall be of short pipe lengths and galvanized. Pipe sleeves fitted in walls or partitions shall be flush with the plaster or other surface finish. Pipe sleeves fitted in floors shall generally end 25mm above the finished floor level, except in plant rooms and other areas where 'wet floors' are expected whereby the sleeves shall end 50mm above the finished floor level.
- b) All sleeves shall be of sufficient size to allow free movement of pipes. The gap between pipe and its sleeve shall be firmly packed with fiberglass blanket material. However, for pipes / sleeves passing through fire barriers, the gap between the pipes and sleeves shall be packed with approved type fire resistance material of at least equal fire rating to the fire barriers. The ends of the sleeves shall be caulked with non-hardening mastic the proposal for which shall be submitted to the Employer / Engineer for Notice of No Objection. The fibreglass, fire resistance materials or non hardening mastic shall be provided and installed by the Contractor.
- c) Contractor's attention is drawn to the vertical pipe ducts. At floor levels in the building, the pipe ducts shall have floor slab and where pipes pass through these slabs sleeves shall be provided.
- d) Brass or copper plates, chrome plated in public areas, shall be slipped over pipes before installation, to cover raw ends of pipe sleeves. Split cover plates will not be accepted. The 20mm projection of pipe sleeves may be reduced after all construction work has been finished such that the cover plates attached to the finished work in an acceptable manner.

4.7.8.12 Stainless Steel Bellow Expansion Joints

Stainless steel expansion joints shall be provided wherever expansion loops or changes in direction of pipe work (for allowing expansion and contraction of pipe work) is not feasible.

4.7.8.13 Pipe Anchors

- a) Anchors shall be positioned in association with pipe work changes in

direction and at expansion joints and loops so as to absorb stresses due to pipe work expansion and internal pressure by transmission of such forces to the ground or structure at appropriate points.

- b) Anchors shall be constructed to withstand the hanger thrust during piping hydraulic pressure testing.
- c) All details and sizes of anchors shall be submitted to the Employer / Engineer for Notice of No Objection, prior to installation.

4.7.9 VALVES AND ACCESSORIES

4.7.9.1 General

- a) Valves and cocks shall be provided for the proper operation of the system.
- b) All valves, cocks etc. shall comply with the requirements and the relevant code of practices for fire protection system.
- c) Service isolating valves shall be fitted to all items of plant including tanks, pumps etc.
- d) All valves shall be suitable for the working and test pressure of the system concerned.
- e) Valves shall be fitted in accessible positions for operation and repair. The connection between each valve and the adjacent equipment shall be made either with a union or flange for ease of dismantling.
- f) The Contractor shall provide access openings for flow switches and valves installed above ceilings.
- g) Regulating valves shall be of globe type for fitting on branch pipes, by-passes etc. and where regulation of flow is required for balancing the systems.
- h) All valves shall be of heavy duty type suitable for the working hydraulic pressure stated and installed with the valve stems truly vertical or horizontal.
- i) All valves shall be arranged so that clockwise rotation of the spindle closes the valve. Hand wheels shall have cast-on direction arrows. Where installed at changes in direction of the pipe work, angle valves are preferred to straight through valves and bends.
- j) All valves except those for the hose-reel shall be secured in open/close position with leather strap and padlock after erection. The Contractor shall provide common keys for all padlocks. Open / close position indicators shall be provided for the valves as per the requirements of the relevant codes and standards.
- k) Isolating valves up to and including 50mm bore shall be of copper alloy construction full way split disc wedge pattern to BS EN 12288. Valves shall have inside screw gate, non-rising stem, high tensile bronze spindle and screwed bonnet. Valves shall have screwed female ends.
- l) Valves of 65mm bore and over shall be flanged cast-iron, fully sluice with inside screw solid wedge, non-rising stem and high tensile bronze spindle to BS 3464. Valves shall have bolted bonnets. Flanges of flanged valves shall be made to BS EN 1092-2 or other equivalent standards. However, valve for sprinkler system shall be of outside screw and yoke type in accordance with the requirement of NFPA.

- m) At the pressure gauge, stainless steel bleed valve shall be provided (which act as a stop cock and enable bleed off small amount of water to read zero pressure).

4.7.9.2 Valve Identification

All valves shall be identified by means of suitable tag or sign which shall clearly indicate the following :

- I. Section under control or served.
- II. Valve number.

4.7.9.3 Non-Return Valves

On the discharge end of each pump, a non-return valve shall be fitted. Valves shall be non-slamming hinged swing type to BS EN 12334 , having cast iron body with bronze trim and be suitable for the working pressure of the system. Valves shall be suitable for installation in horizontal or vertical pipe work. The valves shall be selected in relation to the velocity of the water in the pipes. In all cases, the valves are required to operate silently on reversal of water flow.

4.7.9.4 Drain Valves / Cocks

Drain cocks of gland pattern shall be provided in such locations that all sections of piping systems can be drained, and shall be of 15mm size for pipes up to 50mm diameter, and 20mm size for larger pipes. Drain cocks shall be complete with stainless steel hose union.

4.7.9.5 Air Release Valves

Automatic air eliminators, air bottles or air cocks of manufacturer as per the Notice of No Objection by the Employer / Engineer shall be provided at all high points where venting may be required.

4.7.9.6 Strainers

Strainers shall be installed at the outlet of each water tank, water pump inlets, water gong inlets and other areas where necessary. Strainers shall be of "Y-type", flanged end, with stainless steel mesh of not less than 2mm x 2mm mesh. The bodies shall be of cast iron, with drain plug and end flange for draining and cleaning out purposes.

4.7.9.7 Orifice Plates

Orifice plates shall be fitted as necessary in order to assist in hydraulically balancing the system and to provide the specified pressure/flow condition at the sprinkler. The orifice plates shall be approved type and installed in accordance with approved standards. The Contractor shall submit calculation to the Employer / Engineer to determine the size of the orifice to achieve the desired pressure drop across the orifice plate.

4.7.9.8 Cleaning Procedure

- a) Every precaution shall be exercised to avoid introducing foreign matter such as welding beads and slag or dirt into piping system. Completed welds shall be hammered to loosen debris. All piping, valves and fittings shall be internally cleaned of oil, grease or dirt, prior to assembly into system, by use of wire brush and swab.

- b) Following fabrication and erection, all piping 150mm and smaller shall be cleaned by flushing with clean water and ran to waste until thoroughly free of all dirt, oil and cuttings, etc. Each size of pipe shall be flushed separately before being joined with larger size piping.
- c) Pipe of 20mm in diameter and larger shall be cleaned by pulling through a steel brush the entire length of each pipe size, followed by fibre brush or swab. Brushes and swabs shall be slightly larger than the inside diameter of the pipe being cleaned.
- d) All cleaning operations shall be continuous throughout the piping system, except at joints required for final jointing of various sections of cleaned piping. After cleaning and when the final joints have been made, the end of sections of piping shall be adequately and tightly sealed off to prevent any dirt, water or other foreign matter from entering through the ends of the pipe.
- e) All strainers shall be inspected and thoroughly cleaned. Before submitting piping systems for acceptance, the Contractor shall provide temporary strainers where required for cleaning and flushing operation.
- f) The Contractor shall allow for the draining down of the entire system before commencing any alteration and modification works.

4.7.10 Automatic Clean Gas Total Flooding System & Panel Flooding System

4.7.10.1 General

A total flood system shall be employed within the following areas; S&T UPS and battery System, Signalling and communications equipment rooms.

The Works for automatic analogue addressable clean gas total flooding central bank system shall comply with BS EN 15004 and UL and FM listed.

The type of clean gas selected shall have the following characteristics :

- a) Zero ozone depletion potential.
- b) Minimum global warming potential.
- c) Suitable for use in human occupied rooms i.e. the gas at its designed fired concentration shall be safe to human in the fired room.
- d) The clean gas total flooding system shall be a centralized cylinder bank system. Clean gas cylinder rooms shall be appropriately located within the station to house these cylinder banks. The total number of connected duty cylinders for each bank shall be determined with the assumption that at any instant only one of the clean gas protected rooms will catch fire. At each cylinder bank, the cylinders shall be grouped to serve various sizes of clean gas protected rooms. Upon detection of fire, the respective group shall discharge clean gas into that sole clean gas protected room with the design gas concentration. Pressure monitoring device shall be provided to monitor leakage at all the cylinders and send status signals to the nearest CGP / SAPs / MAP.

All components of the clean gas system shall be specifically listed or approved by recognized institutions and shall be interchangeable.

4.7.10.2 Review Enclosure Integrity

All total flooding systems shall have the enclosure examined and tested to locate and then effectively seal any significant air leaks that could result in a failure of the enclosure to hold the concentration level for the specified holding period.

4.7.10.3 Storage Containers

- a) The clean gas supply shall be stored in containers designed to hold clean gas at 15000 kPa and at ambient temperatures. The containers shall be suitable for both automatic and manual control.
- b) Containers shall be super pressurized and tested to test pressure of 25000 kPa.
- c) The containers shall be designed, constructed, tested and marked in accordance with the latest EU Norms or similar design. Clean gas agent containers shall not be recharged without retesting if more than 5 years have elapsed since the date of the last test and inspection, or others equivalent.
- d) Each cylinder shall have a permanent name plate specifying the agent, tare and gross weight in addition to the super-pressurization level. The date of charging shall also be indicated.
- e) The cylinders shall be floor mounted and suitably supported in a purpose made rack which provides for convenient individual servicing or weighing of contents. Cylinders shall be so installed as not to obstruct the swing of the clean gas room doors.
- f) A reliable graduated pressure indicator, which accounts for variation of cylinder pressure with temperature, shall be provided for each container. Markings shall be provided to indicate when the pressure in the cylinder has dropped below the normal acceptable working pressure. The pressure indicators shall be installed for easy and accurate reading and shall not be obstructed.
- g) Each cylinder shall be fitted with an automatic pressure release device based on the system design of the Contractor which provides relief at 20,700 kPa to 23,500 kPa, which shall be less than the test pressure defined in BS en 15004.
- h) Means shall be provided to prevent clean gas discharging into other cylinder containers on the same manifold which may have been previously discharged and to prevent loss if the clean gas is released when any of the cylinders are disconnected.
- i) A manual override strike button shall be provided at the clean gas storage cylinder
- j) The clean gas cylinders shall be painted signal red or as per the system requirements.

4.7.10.4 Cylinder Discharge Valve

Each cylinder shall be fitted with a quick action discharge valve.

4.7.10.5 Piping And Fitting

- a) The piping of the clean gas system shall be as per the relevant BS EN standards.

- b) All pipe work shall conform to the requirements of BS and / or BS EN standard on clean agent fire extinguishing system latest edition.
- c) Welded manifolds shall be hot dipped galvanized and shall be tested to a pressure of minimum 22,500 kPa. A pressure test certificate shall be issued by the manufacturer.
- d) Flexible piping, tubing or hose (including connections) used shall be of approved materials and the piping system shall have a minimum bursting pressure not less than that of the manifold pipe.
- e) Suitable provisions such as steel reinforced flexible hose shall be provided between the cylinder discharge valve and fixed pipe system to compensate for tolerance in container height and to allow easy removal and installation of container. Tools shall be supplied for the removal and dismantling of all special fittings.
- f) The piping system shall be securely supported with allowance made for agent thrust forces, thermal expansion and contraction. White arrows shall be painted on the pipe to indicate the direction of discharge from the cylinders.
- g) The piping system inside all the clean gas protected rooms shall be suitably earthed to the nearest equipment terminal.

4.7.10.6 Discharge Nozzles

- a) The discharge nozzles used shall comply with the requirements of BS and / or BS EN standards.
- b) The discharge nozzle shall be of corrosion resistant metal, and shall not be obstructed by other installations and/or equipment. The nozzles shall be installed in such a manner that the discharge of the clean gas shall not cause any damages to the installed equipment and fixtures, etc within the protected room.
- c) The nozzles shall be selected and located such that design concentration will be established in all parts of the clean gas protected area, and that the discharge will not unduly create dust clouds that might extend the fire, create an explosion, or otherwise adversely affect the contents of the protected area.
- d) Permanent markings shall be provided on the nozzles to facilitate the identification of the type, size and orifice diameter.
- e) 2 sets of tools per station shall be provided to facilitate the removal of nozzles.

4.7.10.7 Clean Gas Panel (CGP)

4.7.10.7.1 General

- a) The CGP shall be provided such that it is within sight from the doors of the rooms protected by it.
- b) The CGP shall have UL / FM listed or LPC approval.
- c) The CGP including the battery cabinet shall be wall mounted or recessed type and shall be of a dust-proof construction. The Contractor shall provide the necessary recesses and access doors. CGPs installed outside the building shall be of a weatherproof construction, and provided with a

stainless awning to protect it from the elements, and shall be at least rated to IP55.

- d) Paints used shall be durable and colour fast, compatible with use in external environments.
 - e) The CGP shall be fabricated from minimum 2mm thick electro galvanized steel sheet, epoxy powder coated (signal red in colour) to a minimum thickness of 60 microns. All angles and channels shall be hot-dipped galvanized. The cabinet shall be fitted with a lockable door. All alarm zone indicators and associated switches shall be visible behind the locked door without opening the door. The transparent door cover shall be of the hardened tempered glass type
 - f) The manufacturer's name, together with any other appropriate means of identification of the alarm system, shall be clearly and permanently marked on the control panel.
 - g) The CGP shall have at least 25% spare capacity on each detection/module devices loop for future expansion.
 - h) The Contractor shall ensure that the CGPs are installed such that they are not damaged as a result of the swing of the doors.
 - i) System and components
 - 1) All components of the control panel shall be solid state and compatible with the MAP, and circuits shall be in readily replaceable modules. The control circuitry for the complete system and all PCB designs shall be submitted for review by the Engineer prior to manufacture and/or fabrication.
 - 2) The design of the panel shall be for maximum reliability with minimum and easy maintenance
 - 3) The CGP shall monitor and display the status with LEDs but shall not limit the same to the batteries "main power supply", charger "ON / FAILURE", mode of operation "automatic/manual", first and second alarm fault, gas discharge, and valves "OPEN / CLOSED". It shall be provided with switches for but not limited to, "FAULT BUZZER ISOLATE", "TEST LAMP" and "SILENCE".
 - 4) The CGP shall monitor but shall not limit the same to the detectors, manual clean gas release break glasses and operate valves, alarm bells, beacon lights, evacuate and gas fired signs serving the respective gas protected rooms
 - 5) A voltage free fire signal from the CGP via SAP shall send a signal to LSC(fan control panel) to initiate the ventilation/exhaust mode operation of the particular clean gas protected room.
- The addressable signals from CGP shall include the following:
- i. Fire alarm,
 - ii. Common fault,
 - iii. Low pressure in clean gas cylinders.
- 6) The respective CGP shall transmit a signal to open the respective valves

to release the clean gas from the required number of cylinders to the gas protected room.

4.7.10.7.2 Indicator and Control Function

- a) All indicators shall be long-life LEDs.
- b) The control panel shall provide the control functions complying with the requirements of BS and / or BS EN standards.

4.7.10.7.3 Power Supply

- a) The clean gas system shall operate on 24V DC supply. The supply shall be drawn from the sealed, maintenance free dry type batteries which are kept fully charged by a suitable automatic charger operating on mains supply. The supply shall be capable of operating the system under maximum normal load for 24 hours and then continue to operate the system for the full design discharge period envisaged.
- b) The capacity of the battery shall be such that in the event of mains failure or disconnection of charging power , the battery shall be capable of maintaining the standing load condition for not less than 24 consecutive hours and, after the 24 hour period, shall have sufficient capacity to transmit a full alarm including all bells, sirens and illuminated warning signs for a period of 10 minutes. The battery shall be housed in a well ventilated, dust and vermin proof and weatherproof enclosure and shall be at least rated to IP55. The Contractor shall submit detailed calculations to justify the capacity of the battery, charger and their compatibility.
- c) The Contractor shall provide power supply through fuse connection units outside the CGPs.

4.7.10.7.4 Battery Charger

- a) The battery charger shall be of constant potential with current limiting and automatic boost charging features and must be capable of fully recharging the battery within 12 hours after a full discharge. Visual indicators for battery charging and charger fault shall be provided. The criteria on charger design with respect to battery selection shall be submitted for Notice of No Objection by the Employer / Engineer. All power transistors, rectifiers and associated components shall be integral parts of the charger unit, with adequately sized heat sinks for all heat dissipating components.
- b) The control panel shall be capable of operating continuously at 110% of the rated voltage in supervisory condition without damage, and operate successfully during alarm conditions at 110% or 85% of rated voltage
- c) Isolating switches shall be provided within the control panel for cutting off the mains and battery power supplies during maintenance and repair.
- d) Battery charger shall be kept in a separate cool, dry, well ventilated compartment. They shall be kept in a locked cabinet or a container that can be opened only by the use of a key which shall be similar to that used for the main panel door. Such cabinet or container shall be readily accessible for inspection and shall not be above the control cabinet. The interior of the cabinet or container shall be protected against corrosion. The compartment shall be appropriately earthed. Cable entry to the

compartment shall be rimmed and bushed.

4.7.10.7.5 Electrical Works

- a) All electrical works shall comply with relevant standards as stated in the electrical requirements.
- b) All wiring shall be of minimum size of 1.5mm^2 copper conductors for control cables and of a minimum size of 2.5mm^2 cables for power circuit. All cables shall be installed concealed in galvanized threaded metal conduits.

4.7.10.7.6 Clean Gas Live Discharge Test

- a) The Employer / Engineer will at his sole discretion nominate any 3 clean gas protected rooms of the Contract package for a full live discharge test to be performed by the Contractor. The system shall be re-armed upon successful completion of tests. The Contractor shall repeat the live discharge test if the original test is found to be unsatisfactory
- b) The Contractor shall carry out live discharge tests to demonstrate that they function in accordance with the Specification
- c) Should the live discharge tests prove that the equipment/interfaces do not comply with the Specification, the Contractor shall be responsible for the rectification, modification or replacement of the equipment and / or system as required by the Employer / Engineer .
- d) The Contractor shall provide all measures and equipment to protect the equipment/fixtures during the live discharge test. Any damage incurred shall be borne by him including the costs towards replacements.

4.7.10.8 Automatic Operation of System

- (a) When one detector in the protected room has been activated, the following functions shall be executed simultaneously.
 - (1) The alarm bells within the protected area shall sound.
 - (2) The alarm buzzer at the CGP shall be activated and sound continuously. The first 'alarm' indicator light shall be lighted up.
 - (3) The 'EVACUATE AREA IMMEDIATELY' sign(s) at all exits within the protected area and warning beacon light(s) provided to the protected area shall illuminate and flash.
 - (4) The CGP via SAP shall transmit a voltage free fire signal to the LSC to shut down the fan, packaged evaporator unit and open damper for pressure relief of that particular gas protected room. The signal shall keep the motorized fire dampers of all gas protected rooms closed, served by the same common mechanical ventilation duct.
 - (5) Fire dampers shall be pneumatically operated due to snapping action resulting in faster closure and thereby cutting of air supply. For 2-way

/ 3-way control valve UL listed may be acceptable. For electrical control valves, then the power supply need to be backed up with Generator supply.

- (b) When another detector of the same zone within the same protected room is activated, the following functions shall be executed simultaneously.
 - (1) The second 'Alarm' indicator light of the CGP shall illuminate.
 - (2) The siren inside the protected room shall sound.
 - (3) The respective CGP shall transmit a signal to release the clean gas from the required number of cylinders to the respective gas protected room.
 - (4) After the second detector is activated the clean gas shall be discharged after a 30-second delay. The discharge time of the clean gas from the nozzles shall not exceed 60 seconds to achieve the minimum design concentration as recommended by the manufacturer(s) of the gas and NFPA 2001.
 - (5) The 'GAS FIRED' sign(s) of the clean gas protected area shall flash upon receipt of signal from the CGP. The LED on the control panel shall light up to give a positive indication of clean gas discharged when the pressure switch is activated.

4.7.10.9 Manual Operation

- (a) The clean gas system shall be capable of being manually activated by a manual gas release station (break glass unit), provided adjacent to the exit of the clean gas protected area. The break glass shall have a seal or cover to prevent vandalism. A suitable notice in English in Traffolyte to indicate the purpose and use of the unit shall be provided.
- (b) An approved independent means for manual operation shall be provided for the clean gas release for each of the protected room.
- (c) The manual releases shall cause the complete system to operate in its normal fashion. The manual releases shall perform shutdown and alarm functions at the same time, as described in other Clauses.

4.7.10.10 Shut Down Signals For Air-conditioning Units, Fans, Automatic Closures To Openings

- (a) The Contractor shall provide signals for de-energizing the fans, air-conditioning units and activating the motorized dampers serving the clean gas protected rooms. The interface point between the automatic clean gas total flooding system and the ECS shall be provided at an ITB located inside

the LSC rooms. The necessary wiring, relays, contactors and ITB between the CGP/SAP and the ITB shall be provided. The wiring from the ITB to the ECS fans and fire dampers control shall be done.

- (b) The extraction fan can only run when the fire alarm signal at the CGP and MAP are reset and transmitted via the ITB to the LSC.
- (c) After the extraction, an clean gas clear reset signal shall be sent to the LSC via ITB to allow the restart of the ECS equipment.
- (d) Should any of the alarm signal lines be isolated, an indication light together with buzzer shall be registered at the CGP, SAPs and MAP.

4.8 Cables / Wiring

4.8.1 General

The Contractor shall be responsible for bringing in the supply cable or wiring to the Contractor's distribution/control panels (or junction boxes or enclosed circuit breakers or safety switches) at the locations as required. The Contractor shall connect the cable from the designated location to the isolator or circuit breaker in the panels or to the equipment. The connections and installation thereof shall form part of the Contract.

The equipment rating shall be based on the following electrical system :

- (1) Rated Voltage : 415 V / 240V
- (2) Rated Frequency : 50 Hz.

All electrical conductors such as bus-bars, cables, wires, terminals, etc. shall be colour- coded as follows :

- (1) Phase R : Red
- (2) Phase Y : Yellow
- (3) Phase B : Blue
- (4) Neutral : Black
- (5) Ground : Green or Yellow Strip Green

- (4) Large wires and cables shall be colour coded with tapes as specific colour.

- (5) Low Voltage Cable :

The technical requirements shall be as specified in Electrical Section.

Fire Resistant Cable (FR) :

The technical requirements shall be as specified in Electrical Section.

Conduits and accessories :

The technical requirements shall be as specified in Electrical Section

Boxes and Accessories :

The technical requirements shall be as specified in Electrical Section

Equipment grounding :

The technical requirements shall be as specified in Electrical Section

4.8.2 Installation

The Works shall be executed to completion and in conformity with these Specifications/Contract stipulations.

Low Voltage Cables :

e) The technical requirements shall be as specified in Electrical Section.

Conduits :

The technical requirements shall be as specified in Electrical Section.

- a) All cables shall be in conduits, trunkings and trays as appropriate. All cable runs shall be continuous and without joints. They shall also be run neatly and vertically, horizontally or match the features of the building.
- b) All control and power cables shall be of the 1100V grades respectively.

4.8.3 Interface Terminal Board (ITB)

Interface terminal board shall be of the Insulation Displacement Connection (IDC) type, which complies with the IEC 947-7-1 standard. The IDC interface terminal board shall use a C-shaped jaw working in an elastic warping zone to pierce through the insulation of a cable to form an electrical connection capable of absorbing shocks and vibrations (exceeding VDE 0611 standard's requirement).

The elastic nature of this C-shaped jaw shall ensure also that electrical connections with copper core(s) remain secure and maintenance-free even after many years of use in varying temperature cycles. The C-shaped jaw shall be of iron-free copper alloy material thereby giving minimal bimetallic or galvanic effects when connected to copper core(s).

Cable connections to an IDC interface terminal board shall be vapour-tight; with the only exposed copper surfaces from the cable in contact with the C-shaped jaw, which is tightly wrapped round by the insulating material of the cable. Insertion of cables into IDC interface terminal boards shall be done with a semi-automatic full cycle tool which guarantees consistent quality electrical connections.

The interface terminal board shall also be provided with switch connection, disconnect link bar and heavy duty switch blade. At least 3 sets of tools necessary for connection and extraction of the wire shall be provided in a lockable toolbox.

4.8.4 Electrical Requirement In The Control Panel

- a) All wiring inside the control panel shall be colour coded, neatly bundled and tagged for easy identification.

- b) All terminal blocks/connectors shall be of the type suitable for mounting on rail.
- c) A circuit diagram shall be laminated and mounted on the internal side of the door panel indicating clearly the schematics and function of each outgoing terminal.

4.9 Interface Requirements

4.9.1 General

The Contractor shall be responsible to ensure that the various E&M systems supplied are properly interfaced and integrated with that of others throughout the Contract Period.

The Contractor shall liaise and coordinating with other SWCs to mutually agree the protocols to be used for all necessary data exchange.

4.9.2 Interface with Fire Detection & Alarm System

The Contractor shall provide hardware, software, data, etc. to interface with M & E SCADA via the ITBs for the monitoring of the fire protection system.

- a) MAP shall be interfaced via serial link data interface.
- b) Standard RS485 shall be used with baud rates of up to 19.2kbps. C955 shall provide data cable terminated with male connector plug.
- c) Standard ISO 3309 / 4335 high-level data link control (HDLC) protocol format shall be adopted unless otherwise accepted by the Employer / Engineer . Such acceptance would not be given unless the Contractor can demonstrate that the proposed protocol is fully compatible and meets the performance requirements of the interface. Open and widely used non-proprietary industrial communication protocols shall be preferred.
- d) Any change in the field data shall be updated within 0.5 second of occurrence.
- e) Apart from the system initialization, the communication shall generally be event driven with information that has changed being transmitted. However the interface shall maintain regular checks of the integrity of the link with any failure detection indicated with alarms.
- f) Information to be provided

The Contractor shall provide information which includes but not limited to the following :

- 1) Exact number of points and its addresses,
 - 2) Equipment identifiers/labels and locations,
 - 3) Fire Zone schematic drawings (in hard copy and soft copy) and Man Machine Interface (MMI) design,
 - 4) Functional description of protection scheme,
 - 5) Communication protocol.
- g) This information shall be provided in a format within a time frame to be

coordinated well in advance. This shall be subject to the Notice of No Objection by the Employer / Engineer.

h) Work demarcation

The Contractor shall be responsible to supply and terminate the cable from the MAP to the ITB. The ITB shall be located adjacent to the MAP but its exact location shall be coordinated by the Contractor.

4.9.3 Interface with MMS

In case the Employer decides to implement a MMS, the Contractor shall be required to work to register all equipment and spares data with the format and methodology to be defined.

4.10 Surface Treatment

4.10.1 Corrosion Protection

All materials and equipment supplied under this Contract shall be suitable for being delivered, stored and operated under tropical conditions of high temperature, high humidity, heavy rainfall and mildew and fungus-conductive environment.

The process for tropicalising shall be in accordance with the best modern design and manufacturing practices.

4.10.2 Metals

- a) Iron and steel shall be painted or galvanised or metal sprayed as appropriate. Indoor parts may alternatively have chromium or other suitable protective finish. When it is necessary to use dissimilar metals in contact, these shall be selected such that the potential difference between them in the electro-mechanical series will not cause galvanic corrosion. If this is not possible, the contact surface of one or both of the metals shall be electroplated or otherwise finished in such a manner that the potential difference is reduced within the required limits or, alternatively, the two metals shall be insulated from each other by a suitable insulating material or a coating of varnish compound.

b) Bolts, screws, nuts

Threaded components like bolts, screws, washers and nuts, when used, shall be sherardised to BS 7371: Part 8, Class s1. Where plating is not possible owing to thickness tolerance limitations of corrosion resisting steel type shall be used.

Corrosion-resisting steel, copper-nickel alloy or bronze shall also be used for bolts and nuts throughout the Works, when they are subject to frequent adjustment or removal.

Connections shall be such that potential differences do not cause galvanic corrosion.

- c) Fabrics, cork, paper and similar materials, which are not subsequently protected by impregnation, shall be adequately treated with suitable fungicide. Sleeveings and fabrics treated with linseed oil varnish shall not

be used.

d) Adhesives

Adhesive shall be especially selected to ensure the use of tapes which are impervious to moisture, resistant to mould growth, and not subject to the ravages of insects.

e) Electrical material and equipment

Material and components which are inherently fungus resisting or are protected by hermetic sealing or oil immersion need not to be treated. Other elements shall be protected by additional varnish for high humidity and given an anti-fungus treatment.

4.10.3 Painting

- a) All steel surfaces, except stainless steel and the interiors of all compartments permanently sealed by welding shall be prepared and shall receive protective coating. In general, unless galvanized, all exposed piping, ductwork (including colour coding), metallic equipment cases, equipment cabinets, junction boxes and terminal cases shall be painted. Non-ferrous metals, stainless steel and protected metals will normally not be painted.
- b) Wherever possible, all painting shall be undertaken before delivery to site. The Contractor shall ensure that all surfaces have been properly prepared for application of paint including cleaning, priming and drying. The application of the paint shall be in accordance with the manufacturer's recommendations and undertaken in appropriate conditions.
- c) The dry film thickness of primed surfaces shall be generally 50 microns with an allowed ponding not greater than 60 microns in areas such as covers, welds and bolts. The total dry paint film thickness of the paint system on bare steel surfaces and on metal coated surfaces shall not be less than 130 microns .
- d) Painted surfaces which have been damaged shall be cleaned to bare metal, or metal coating where this has been applied, and the edges of the undamaged paint abrasively bevelled . Where a metal coating has been damaged, the affected area shall be rubbed down to remove excessive roughness, cleaned and an additional coat of zinc rich primer applied. Where there is a damaged galvanized surface, cold galvanized paint shall be applied first before the zinc rich primer. The paint shall be re-applied to the full specification to the affected area and overlapping the surrounding area.
- e) The Contractor shall ensure that the finished painted surfaces meet the thickness requirements without discontinuities or voids using appropriate equipment and undertake re-painting where necessary.
- f) Metalizing
 - 1) If the equipment is not be provided with finish paint, then the zinc coating shall have a minimum thickness of 500g/m² coated

surface.

- 2) Any electrical boxes or other housing enclosure used in outdoor condition shall be hot-dipped galvanized, unless stated otherwise.

4.10.4 Schedule of Colours for Identification

Sl. No	Service Description	Colour
1	Fire protection services	Signal Red, colour other than signal red subject to Engineer's acceptance
2	Drains and overflows	
2.a	Outside plant rooms	Black Lacquered
2.b	In plant room	Polished copper
3	Fire protection conduit	Signal Red
4	Pumps :-	Signal Red
4.a	Casing	Light Orange
4.b	Motor Belt guard	Signal Red
4.c	Base	Signal Red
5	Valves :-	
5.a	Bodies	Signal Red
5.b	Hand wheel	Black
6	Bases and Supports	Signal Red
7	Control panel including clean gas control panels, pump control panels	Signal Red
8	MAPs and SAPs :	Signal Red
9	Electrical including motors, conduits	Signal Red
10	Battery Charger Cabinets	
10.a	Exterior	Signal Red
10.b	Interior	Gloss white
11	Tool box	Signal Red

4.11 Testing, Commissioning & Validation

4.11.1 Testing, Commissioning and Validation Plan

The Contractor shall be required to submit the Testing and Commissioning Plan which shall include a schedule of tests with the identified standards to which the tests are to be carried out. The Contractor shall update the Plan as necessary. The Plan shall include the following :

- a) A detailed description of the testing and commissioning philosophy and the testing & commissioning process including the demonstration of a successful interfaces with other systems.
- b) Details of the testing & commissioning organisation to be set up by the Contractor, including staff responsible for testing & commissioning activities.

- c) Descriptions of methods and procedures for testing & commissioning, procedure for the set up of all test equipment with necessary supporting documentation.
- d) Details of the testing & commissioning schedule, management and coordination requirements.
- e) Details of how safety shall be addressed for all personnel and equipment during testing and commissioning.
- f) Details of all testing & commissioning standards and guidelines that the Contractor shall follow.

The Contractor shall submit test specifications for all tests including integrated tests to the Engineer for acceptance prior to the commencement of the tests.

The Contractor shall perform testing and commissioning of all the fire protection system.

The Contractor shall provide all necessary facilities, labours, instruments, materials, inert gas, fuel and power to carry out such testing and commissioning to verify and validate that the installation meets the requirements.

4.11.2 Hydrostatic Test

All hydrostatic tests shall be conducted for a period of not less than 6 hours to at least two (2) times the specified working pressure. The Contractor shall record all test figures together with schedules of pipe lengths and shall note that testing will be witnessed by the Employer / Engineer. A pressure drop of not more than 3% after 6 hours will be acceptable.

4.11.3 Tests of Acoustic and Vibration

- (a) Sound level readings and vibration tests shall be conducted in DG, fan and pump rooms during construction of the works and at any other time as desired by the Employer / Engineer.
- (b) Sound level readings shall be taken with correctly calibrated octave band sound level meter at designated spaces as desired by the Employer / Engineer

4.11.4 Electrical Test

The following tests shall be carried out to the satisfaction of Employer / Engineer :

1) Verification of polarity

To ensure that all fuses and single pole control devices are connected to the live conductor only.

2) Insulation resistance tests

Insulation resistance tests shall be carried out at 240V single phase and at 415V three phase circuits for:

- i. Line to line,
- ii. Line to earth,
- iii. Neutral to earth,
- iv. Line to neutral.

3) Earth continuity tests

The test shall be carried out by means of a line-earth loop test or neutral-earth loop test in accordance with IEE regulations.

4) Earthing tests

The earthing resistance of equipment shall be measured with loop impedance test in accordance with latest IEE regulations.

5) Battery capacity shall be tested by tripping the ac supply (normal and emergency) and by setting the entire system under alarm condition. Time period for which the battery can support the system shall be recorded.

4.11.5 Test at Manufacturer's Factory and On Site

The tests at Manufacturer's factory shall include all tests in accordance with the relevant standards and any tests called for by the Employer / Engineer to ensure that the Plant being supplied meets the requirements of the Specification. For material / equipment not covered by any standard or specifically mentioned in this Specification, the tests shall be done as agreed by the Employer / Engineer .

The Contractor shall supply and install all materials, supplies, labour and equipment/instrument required for testing. The Contractor shall make preliminary tests and prove the Works as satisfactory. The Contractor shall notify the Employer / Engineer well in advance to be present for final testing of all materials / equipment. The Contractor shall replace defective Works with new Works for defects identified/disclosed by tests or, if required by the Employer / Engineer . The Contractor shall conduct tests in stages if so directed by the Employer / Engineer to facilitate work of others.

For all pipe work, all necessary testing junctions and bends shall be supplied & installed and sealed off or removed as directed by the Employer / Engineer.

4.11.6 Site Tests during Construction

- a) The pressure tests shall be carried out on site in convenient sections during the construction of the Works.
- b) Before the tests are carried out, the Contractor shall remove connected equipment and components which are liable to be damaged under test, and shall provide and fix all necessary gauges, blanking flanges etc.

4.11.7 Preliminary Commissioning Checks

- a) The Contractor shall ensure that all equipment are thoroughly cleaned, lubricated and checked for serviceability immediately before setting to Works. The Contractor shall pay particular attention to the removal of building debris from the pipe work systems.
- b) The Contractor shall pay special attention to the need to thoroughly flush out all pipe work systems to ensure that all foreign matters are removed.
- c) The Contractor shall inspect and check all automatic controls and safety devices for serviceability before the working fluid or electricity is applied to the system.

4.11.8 Commissioning

When the various installations have been completed and the preliminary commissioning checks carried out, the Contractor shall set to work, regulate and calibrate all systems in the entire installation. Special attention shall be paid to the following items :

- a) That all valves, switches and controls etc. are regulated and capable of proper operation and in the case of isolation valves that they are capable of tight shut off.
- b) That all instruments are correctly calibrated and read accurately.
- c) That all services are tested in accordance with the details in the relevant clauses of the Contract Specification and relevant standards.
- d) Pumps, pressure reducing sets, etc. shall be operated to ensure that all control systems are functioning correctly and are properly set, sequenced or interlocked.

4.11.9 Performance Tests

- a) After the Works have been completed, the Contractor shall be required to carry out or assist in carrying out the performance tests.
- b) Performance tests for all installations shall be carried out to demonstrate that they function in accordance with the intent of the Contract Specification.
- c) Should the performance tests prove that the equipment do not comply with the requirements of the Contract Specification, the Contractor shall be responsible for the rectification, modification or replacement of the equipment and/or system as required by the Employer / Engineer .

4.11.10 Final Acceptance Tests

- a) Following commissioning of the entire installation , the Contractor shall carry out final acceptance tests in accordance with a programme to be submitted to the Employer / Engineer for Notice of No Objection.
- b) Should the results of the acceptance tests show that plant, systems and/or equipment fail to perform to the efficiencies or other performance figures as given in the Contract Specification, the Contractor shall adjust, modify and if necessary replace the equipment without any additional cost implications to the Employer in order that the required performance be obtained

Where acceptance tests are required by the relevant authorities having jurisdiction, these tests shall be carried out by the Contractor, the proposal for which shall be submitted to the Employer/Engineer for Notice of No Objection.

4.11.11 Integrated Testing and Commissioning (ITC)

- a) Before the commencement of integrated tests, the Contractor shall complete his own local tests. The Contractor shall submit test specifications for integrated tests to the Employer / Engineer for Notice of No Objection, prior to the commencement of the tests.

- b) The Contractor shall coordinate with the civil works and SWCs in preparing an integrated system test plan to test all the points/installations. All testing tools and manpower required for the tests, which will be witnessed by the Employer / Engineer shall be provided by the respective Contractors. The integrated system test plan shall at least include :
 - 1) The scope of the integrated testing,
 - 2) The objective of the tests and the associated design and operating criteria to be proved / demonstrated,
 - 3) The pass / fail criteria of the test,
 - 4) The inter-dependency and interaction with all systems supplied and those supplied by other interfacing contractors and their integrated testing programme.
 - 5) The systems / equipment required to be completed by other interfacing Contractors for each test,
 - 6) A schematic diagram of the integrated tests in the sequence they are to be carried out,
 - 7) A narrative explaining the integrated testing process and methodology, with cross-reference to the schematic diagram,
 - 8) The write-up format on a test-by-test basic,
 - 9) Estimated duration of the Contractor's involvement in each test.
- c) The Contractor shall generate or emulate data signals for the points/installations being tested. Emulation shall be used only if real time signal generation is not possible or impracticable.
- d) On completion of tests or test cases, both interfacing contractors shall endorse the test records for submission to the Employer / Engineer . Where a failure is recorded in any test cases, the interfacing contractors shall reschedule another test regardless of where the fault or defect lies.
- e) The Contractor shall be responsible for taking the lead in conducting the ITC of fire alarm system, clean gas system, pre-testing the activation and re-setting the associated fire alarm devices and panels of the clean gas room.
- f) Fire alarm tests

The objectives of the fire alarm test are to verify and validate the correct operations of interface between automatic fire alarm system and :

 - 1) Active voice communication system,
 - 2) AMS,
 - 3) AFC gates,
 - 4) M & E SCADA
 - 5) ECS,
 - 6) Fire roller shutters,
 - 7) Lifts and escalators.

- 8) TVS,
 - 9) Door Access Control System and Security System,
 - 10) Power Supply and traction,
 - 11) Signaling, Telecommunications and PSD.
- g) Clean gas test including the VESDA system

The objectives of the clean gas test are to verify and validate the correct sequences and operations of the ventilation system within a clean gas protected room in the event of a fire alarm within the protected area.

4.11.12 Integrated Factory Acceptance test

The Contractor shall undertake an Integrated Factory Acceptance Test (IFAT) which will be held in factory. Such IFAT shall be done in the presence of the Employer/Engineer.

A 100% input/output check simulated data may be used subject to the Notice of No Objection by the Employer / Engineer. The Contractor shall be responsible for planning, programming, coordinating, preparing, managing and executing the IFAT. This IFAT will be the final proving of the interface design prior to on site interface tests and commissioning. The Contractor is required to coordinate and agree on the schedule of IFAT and provide input on the preparation of IFAT plan and procedures.

The Contractor shall provide the Testing, Commissioning & Validation Certificate after the successful Installation, Testing, and Commissioning & Validation of the systems in accordance with the applicable standards and the Contract document.