

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 VII - OUTLINE DESIGN SPECIFICATIONS

June 2018



PUNE METRO UNDERGROUND SECTION

CONTRACT UGC-02

TENDER DOCUMENTS

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PUNE METRO UNDERGROUND SECTION
CONTRACT UGC-02
SECTION VII – OUTLINE DESIGN SPECIFICATIONS

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PART II – EMPLOYER’S REQUIREMENT

Section VII - Outline Design Specifications

S.01 Design Standard and Rail Geometry

June 2018

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1 DESIGN STANDARDS AND RAIL GEOMETRY

1.1 General

1.1.1 Purpose and Scope

- (1) These Outline Design Specifications (ODS) pertain to all the Works covered under Contract Package UGC-02 of the Pune Metro, Phase – I underground section from Budhwar Peth Station to Swargate Station.
- (2) These ODS provide the minimum standards to which the Works shall be designed.
- (3) These ODS shall be read in conjunction with the Section VIII - Outline Construction Specifications (OCS) where applicable. If any discrepancy is noted between ODS and OCS, the ODS shall take precedence and shall be adopted.
- (4) Wherever in this section and other sections of the Contract Documents, any term provides for notice of no-objection (hereafter referred to as notice) of the Employer or the Engineer, the same shall mean and denote Notice in writing even if not so expressly stated.

1.1.2 Codes and Standards

- (1) Subject to the requirements of this document and other Contract documents, all design work shall comply with the appropriate current standards issued by the Bureau of Indian Standards (BIS), or if such a standard does not exist, then the appropriate current standard issued by the British Standard Institute (BSI). If appropriate standard from BIS and BSI does not exist, then subject to Notice by the Engineer, an appropriate current standard from a reputable institution may be used.
- (2) All standards shall be that including Amendments and Addenda, current at the date of submission of tender.

Alternative or additional codes, standards and specifications proposed by the Contractor shall be internationally recognised codes including Indian Railway Standards (IRS) and Indian Road Congress (IRC) and shall be equivalent to or better than Indian Standards issued by the Bureau of Indian Standards or any other Indian professional bodies or organisations subject to being in the opinion and Notice of the Engineer suitable for incorporation into the Specifications.
- (3) A list of codes and Standards/Specifications is provided below for reference only.

Indian Railway Standards (IRS)	
IRS 2008	Bridge Rules
IRS 1997	Concrete Bridge Rules

IRS 1991	Bridge Structures and Foundation Codes
IRS 1997	Steel Bridge Code
IRS 1998	Indian Railway Bridge Manual
IRS 1985	Manual on Design and Construction of Well and Pile Foundations
Indian Roads Congress Standards (IRC)	
IRC 5: 1998	Standard Specifications and Code of Practice for Road Bridges, Section I – General Features of Design
IRC 6: 2000	Standard Specifications and Code of Practice for Road Bridges, Section II – Loads and Stresses
IRC 11: 1962	Recommended Practice for the Design of Layout of Cycle Tracks
IRC 18:2000	Design Criteria for Pre-stressed Concrete Road Bridges (Post-Tensioned Concrete)
IRC 19:1977	Standard Specifications and Code of Practice for Water Bound Macadam
IRC 21:2000	Standard Specifications and Code of Practice for Road Bridges Section III–Cement Concrete (Plain and Reinforced)
IRC 22:1986	Standard Specifications and Code of Practice for Road Bridges, Section VI – Composite Construction
IRC 24:1967	Standard Specifications and Code of Practice for Road Bridges, Section V – Steel Road Bridges
IRC26:1970	Recommended Practice for the Construction of Earth Embankments for Road Works
IRC 37:1984	Guidelines for the Design of Flexible Pavement
IRC 45 : 1972	Recommendations for Estimating the Resistance of Soil below the maximum Scour Level in the Design of Well Foundations of Bridges
IRC 48:1972	Tentative Specifications for Bituminous Surface Dressing Using Pre-coated Aggregates
IRC 75:1979	Guidelines for the Design of High Embankments
IRC 78:2000	Standard Specifications and Code of Practice for Road Bridges, Section VII Parts 1 and 2, Foundations and Substructure
IRC 83:1987	Standard Specifications and code of practice for Road Bridges, Section IX - Bearings Part I & II: Bearings (Metallic and Elastomeric)
IRC 87:1984	Guidelines for the Design and Erection of False Work for Road Bridges
IRC 89:1997	Guidelines for Design and Construction of River Training and

	Control Works for Road Bridges
IRC: SP 11	1988 Handbook of Quality Control for Construction of Roads and Runways
Bureau of Indian Standards Codes	
SP 7: 2005	National Building Code
IS 73: 1992	Paving Bitumen
IS 150: 1950	Ready mixed paint brushing, finishing stoving for enamel colour as required
IS 205: 1992	Non-ferrous metal Butt Hinges
IS 206: 1992	Tee and strap hinges
IS 207: 1964	Gate and shutter hooks and eyes
IS 208: 1987	Door handles
IS 210: 1993	Grey iron castings
IS 215: 1995	Road tar
IS 217: 1988	Cutback Bitumen
IS 269: 1989	33 grade Ordinary Portland Cement.
IS 278: 1978	Galvanised steel barbed wire for fencing
IS 280: 1978	Mild Steel wire for general engineering Purposes
IS 281: 1991	Mild Steel sliding door bolts for use with Padlocks
IS 362: 1991	Parliament hinges
IS 363: 1993	Hasps and staples
IS 383: 1970	Coarse and fine aggregates from natural Sources for concrete
IS 432: 1982	Mild steel and medium tensile steel bars and hard drawn steel wire for concrete reinforcement Part 1 Mild steel and medium tensile steel bars Part 2 Hard-drawn steel wire
IS 453: 1993	Double-acting spring hinges
IS 455: 1989	Portland slag cement
IS 456: 2000	Code of practice for plain and reinforced concrete
IS 457: 1957	Code of practice for general construction of plain and reinforced concrete for dams and other massive structures
IS 458: 1988	Precast concrete pipes (with and without reinforcement)
IS 459: 1992	Corrugated and semi-corrugated asbestos cement sheets
IS 460: 1985	Test sieves
IS 516: 1959	Method of test for strength of concrete
IS 650: 1991	Standard sand for testing cement
IS 733: 1983	Wrought aluminium and aluminium alloy bars, rods and

	sections for general engineering purposes
IS 737 1986	wrought aluminium and aluminium alloy sheet and strip for general engineering purposes
IS 771 1979	Glazed fire-clay sanitary appliances Part 1 General requirements Part 2 Specific requirements of Kitchen and laboratory sinks Part 3/Sec. 1 Specific requirements of Urinals - Slab Urinals Part 3/Sec. 2 Specific requirements of Urinals - Stall Urinals
IS 774: 1984	Flushing cistern for water closets and urinals
IS 775: 1970	Cast iron brackets and supports for wash basins and sinks
IS 777: 1988	Glazed earthenware wall tiles
IS 778: 1984	Copper Alloy gate, globe and check valves for water works purposes
IS 779: 1994	Water meters
IS 780: 1984	Sluice valves for water works purposes (50 to 300 mm size)
IS 781: 1984	Cast copper alloy screw down bib taps and stop valves for water services
IS 783: 1985	Code of practice for laying of concrete pipes
IS 800: 2007	Code of practice for general construction in steel
IS 814: 1991	Covered electrodes for manual metal arc welding of carbon and carbon manganese steel
IS 875: 1987	Code of practice for design loads (other than earthquake) for buildings and structures
IS 883: 1994	Code of practice for design of structural timber in building
IS 909: 1992	Under-ground fire hydrant, sluice valve type
IS 1003	Timber panelled and glazed shutters Part 1 1991 Door shutters Part 2 1994 Window and ventilator shutters
IS 1030:1989	Carbon steel castings for general engineering purposes
IS 1038:1983	Steel doors, windows and ventilators
IS 1077:1992	Common burnt, clay building bricks
IS 1080:1986	Design and construction of shallow foundation in soil(other than raft ring and shell)
IS 1161:1979	Steel tubes for structural purposes
IS 1195:1978	Bitumen mastic for flooring.
IS 1200 - Part 1	Methodology of measurement of Building and Civil Engineering Works
IS 1230:1979	Cast iron rainwater pipes and fittings

IS 1237:1980	Cement concrete flooring tiles
IS 1239:1990	Mild steel tubes, tubular and other wrought steel fittings Part 1 Mild steel tubes Part 2 Mild steel tubular and other wrought steel pipe fittings
IS 1322:1993	Bitumen felts for water proofing and damp-proofing
IS 1341:1992	Steel butt hinges
IS 1343:1980	Code of practice for Pre-stressed Concrete
IS 1346:1991	Code of practice Waterproofing of roofs with bitumen felts
IS 1458:1965	Railway bronze ingots and casting
IS 1489:1991	Portland Pozzolana Cement.
IS 1536:1989	Centrifugally cast (spun) iron pressure pipes for water, gas and sewage
IS 1537:1976	Vertically cast iron pressure pipes for water, gas and sewage
IS 1538:1993	Cast iron fittings for pressure pipes for water, gas and sewage
IS 1566:1982	Hard-drawn steel wire fabric for concrete reinforcement
IS 1592:1989	Asbestos cement pressure pipes
IS 1703:1989	Copper alloy float valves (horizontal plunger type) for water supply fittings
IS 1726:1991	Cast iron manhole covers and frames
IS 1729:1979	Sand cast iron spigot and socket soil waste and ventilating pipes, fitting and accessories
IS 1732:1989	Dimensions for round and square steel bars for structural and general engineering purposes
IS 1785:1983	Plain hard-drawn steel wire for prestressed concrete Part 1 Cold-drawn stress – relieved wire Part 2 As drawn wire
IS 1786:1985	High strength deformed steel bars and wires for concrete reinforcement.
IS 1791:1985	Batch type concrete mixers
IS 1795:1982	Specifications for pillar taps for water supply purposes
IS 1834:1984	Hot applied sealing compounds for joint in concrete
IS 1838:1983	Pre-formed fillers for expansion joint in concrete pavements and structures (non extruding and resilient type) Part 1 Bitumen impregnated fibre
IS 1888:1982	Method of load tests on soils
IS 1892:1979	Code of practice for sub surface investigations for foundations

IS 1893:1984	Criteria for earthquake resistant design of structures
IS 1893:2002	Criteria for earthquake resistant design of structures, Part 1 General Provisions and Buildings
IS 1904:1986	Design and construction of foundations in soils General Requirements
IS 1948:1961	Aluminium doors, windows and ventilators
IS 1949:1961	Aluminium windows for industrial buildings
IS 1977:1976	Low Tensile Structural steel
IS 2004:1991	Carbon steel forgings for general engineering purposes
IS 2062:2006	Steel for general structural purposes
IS 2074:1992	Ready mixed paint, air-drying, red oxide-zinc chrome, priming
IS 2090:1983	High tensile steel bars used in prestressed concrete
IS 2114:1984	Code of practice for laying in-situ terrazzo floor finish
IS 2116:1980	Sand for masonry mortars
IS 2119:1980	Code of practice for construction of brick-cum-concrete composite
IS 2202:1991	Wooden flush door shutters
IS 2326:1987	Automatic flushing cisterns for urinals
IS 2386:1963	Methods of test for aggregates for concrete Part 1 Particle size and shape Part 2 Estimation of deleterious materials and organic impurities Part 3 Specific gravity, density, voids, absorption and bulking Part 4 Mechanical properties Part 5 Soundness Part 6 Measuring mortar making properties of fine aggregates Part 7 Alkali – aggregate reactivity Part 8 Petrographic examination
IS 2430:1986	Methods of sampling of aggregate for concrete
IS 2548:1996	Plastic seats and covers for water closets
IS 2681:1993	Non-ferrous metal sliding door bolts (aldrops) for use with padlocks
IS 2690:1993	Burnt - clay for flat terracing Tiles
IS 2692:1989	Ferrules for water services
IS 2720 1972 - 2002	Methods of Tests for Soils (all Parts)
IS 2751:1979	Recommended practice for welding of mild steel plain and

	deformed bars used for reinforced construction
IS 2906:1984	Specification for sluice valves for water works purposes (350 to 1200 mm size)
IS 2911:2010	Code of practice for design and construction of pile foundations Part 1 Concrete piles <ul style="list-style-type: none"> • Section 1 Driven cast –in-situ concrete piles • Section 2 Bored cast-in-situ concrete piles • Section 3 Driven precast concrete piles • Section 4 Bored precast concrete piles Part 3 Under-reamed piles Part 4 Load test on piles
IS 2950:1981	Code of practice for design and construction of raft foundations.
IS 3067 1988:	Code of Practice for General Design Details and Preparatory Work for Damp-Proofing and Water-Proofing of Buildings.
IS 3370:2009	Code of practice for concrete structures for the storage of liquids
IS 3564:1995	Hydraulically regulated door closers
IS 3812:1981	Fly ash for use as pozzolan and admixture
IS 3847:1992	Mortice night latches
IS 3955:1967	Code of practice for design and construction of well foundations
IS 3989:1984	Centrifugally cast (spun) iron spigot and socket soil, waste and ventilating pipes, fittings and accessories
IS 4082:1996	Recommendations on stacking and storage of construction materials and components at site
IS 4138:1977	Safety code for working in compressed air
IS 4326:1993	Earthquake resistant design and construction of buildings – code of practice
IS 4656:1968	Form vibrators for concrete
IS 4736:1986	Hot-dip zinc coatings on mild steel tubes
IS 4826:1979	Hot-dipped galvanised coatings on round steel wires
IS 4925:1968	Concrete batching and mixing plant
IS 4926:1976	Ready mixed concrete
IS 4968:1976	Method for sub surface sounding for soils
IS 5525:1969	Recommendations for detailing of reinforcement in reinforced concrete works

IS 5529:1985	Code of practice for in-situ permeability tests
IS 5640:1970	Method of test for determining aggregate impact value of soft coarse aggregate
IS 5816:1970	Method of test for splitting tensile strength of concrete cylinders
IS 5889:1994	Vibratory plate compactor
IS 5892:1970	Concrete transit mixers and agitators
IS 6003:1983	Specification for indented wire for pre-stressed concrete
IS 6006:1983	Specification for uncoated stress relieved strands for prestressed concrete
IS 6051:1970	Code for designation of aluminium and its alloys
IS 6248:1979	Specification for metal rolling shutters and rolling grills
IS 6403:1981	Code of practice for determination of bearing capacity of shallow foundations
IS 6603:1972	Stainless steel bars and flats
IS 6760:1972	Slotted countersunk head wood screws
IS 6911:1992	Stainless steel plate, sheet and strip
IS 7181:1986	Horizontally cast iron double flanged pipes for water, gas and sewage
IS 7196:1974	Hold fast
IS 7205:1974	Safety code for erection of structural steel work
IS 7231:1984	Specifications for plastic flushing cisterns for water closets and urinals
IS 7273:1974	Method of testing fusion-welded joints in aluminium and aluminium alloys
IS 7293:1974	Safety code for working with construction machinery
IS 7320:1974	Concrete slump test apparatus
IS 7534:1985	Sliding locking bolts for use with padlocks
IS 7861:1975	Code of practice for extreme weather concreting Part 1 For Hot Weather concreting Part 2 For Cold Weather concreting
IS 7969:1975	Safety code for handling and storage of building materials
IS 8009:1976	Calculation of settlement of foundations
IS 8041:1990	Rapid – hardening Portland cement
IS 8112:1989	43 grade ordinary Portland cement
IS 8142:1994	Method of test for determining setting time of concrete by penetration resistance
IS 8500:1991	Structural steel-micro alloyed (medium and high strength

	qualities)
IS 9013:1978	Method of making, curing and determining compressive strength of accelerated cured concrete test specimens
IS 9103:1979	Admixtures for concrete
IS 9284:1979	Method of test for abrasion resistance of concrete
IS 9417:1989	Recommendations for welding cold worked bars for reinforced concrete construction
IS 9595:1996	Recommendations for metal arc welding of carbon and carbon manganese steels
IS 9762:1994	Polyethylene floats (spherical) for float valves
IS10262: 2009	Recommended guidelines for concrete mix design
IS 10379: 1982	Code of practice for field control of moisture and compaction of soils for embankment and subgrade
IS 10500: 1991	Drinking water specification
IS 12269: 1987	53 grade ordinary Portland cement
IS 12894: 1990	Fly ash lime bricks
IS 13630: 1994	Ceramic tiles – methods of tests
IS 13920: 1993	Ductile detailing of reinforced concrete structures subjected to seismic forces
IS 15388: 2003	Specifications for Silica Fume
SP 36 (Part 1):	Compendium of Indian Standards on Soil Engineering (Laboratory Testing)
SP 36 (Part 2):	Compendium of Indian Standards on Soil Engineering (Field Testing) Indian Standard Hand Book on Steel Sections Part-I
	CRRI and IOC, New Delhi Bituminous Road Construction Hand Book
ASTM Standards	
ASTM C-1202	Test methods for Electrical indication of concrete's ability to resist chloride ion penetration.
ASTM C-1240	Micro Silica/Silica fume in concrete
ASTM D-297	Methods for Rubber Products-Chemical Analysis
ASTM D-395	Compression set of vulcanized rubber
ASTM D-412	Tension testing of vulcanized rubber
ASTM D-429	Adhesion of vulcanized rubber to metal
ASTM D-573	Accelerated aging of vulcanized rubber by the oven method
ASTM D-624	Tear resistance of vulcanized rubber
ASTM D-797	Young's modulus in flexure of elastomer at normal and subnormal temperature

ASTM D-1075	Effect of water on cohesion of compacted bituminous mixtures
ASTM D-1143	Test method for piles under static axial comp. test
ASTM D-1149	Accelerated ozone cracking of vulcanized rubber
ASTM D-1556	In-situ density by sand replacement
ASTM D-1559	Test for resistance to plastic flow of bituminous mixtures using Marshall apparatus
ASTM D-2172	Extraction, quantitative, of bitumen from bituminous paving mixtures
ASTM D-2240	Indentation hardness of rubber and plastic by means of a Durometer
ASTM D-3689	Testing method of testing individual piles under static axial tensile load
ASTM D-4945	Test method for high strain dynamic testing of piles
ASTM E-11	Specification for wire cloth sieve for testing purpose
ASTM :Section 4:	Construction, Volume 04.08: Soil and Rock I, and Volume 04.09: Soil and Rock II,
AASHTO Standards	
AASHTO M6-81	Fine aggregate for portland cement concrete
AASHTO M31-82	Deformed and plain billet-steel bars for concrete reinforcement
AASHTO M42-81	Rail-steel deformed and plain bars for concrete reinforcement
AASHTO M54-81	Fabricated steel bar or rod mats for concrete reinforcement
AASHTO M 81-75	Cut-back asphalt (rapid-curing type)
AASHTO M 82-75	Cut-back asphalt (medium-curing type)
AASHTO M85-80	Portland cement
AASHTO M 140-80	Emulsified asphalt
AASHTO M 147-67	Materials for aggregate and soil–aggregate sub-base, base and surface courses
AASHTO M148-82	Liquid membrane-forming compounds for curing concrete
AASHTO M154-79	Air-Entraining admixtures for concrete
AASHTO M173-60	Concrete joint-sealer, hot-poured elastic type
AASHTO M194-82	Chemical admixtures for concrete
AASHTO M213-81	Preformed expansion joint fillers for concrete paving and structural construction
AASHTO M 282-80	Joints sealants, hot poured, elastomeric-type, for port-land cement concrete pavements

AASHTO M 294-70	Fine aggregate for bituminous paving mixtures
AASHTO T22-82	Compressive strength of cylindrical concrete specimens
AASHTO T23-80	Making and curing concrete compressive and flexural strength test specimens in the field
AASHTO T26-79	Quality of water to be used in concrete
AASHTO T96-77	Resistance to abrasion of small size coarse aggregate by use of the Los Angeles machine
AASHTO T99-81	The moisture-density relations of soils using a 5.5-lb (2.5kg) rammer and a 12-in (305mm) Drop
ASHTO 104-77	Soundness of aggregate by use of sodium sulphate or magnesium sulphate
AASHTO T176-73	Plastic fines in graded aggregates and soil by use of the sand equivalent test
AASHTO T180-74	The moisture density relations of soils using a 10-lb (4.54kg) rammer and an 18-in (457mm) Drop
AASHTO T182-82	Coating and stripping of bitumen-aggregate mixtures
AASHTO T191-61	Density of soil In-place by the sand-cone method
British Standards	
BS 812	Testing Aggregates - Parts 117 to 119.
BS 1377	Methods of Test for Civil Engineering Purposes - Parts 1 thru 9.
BS 4395 Part 2	High strength friction grip bolts and associated nuts and washers for Structural Engineering Higher Grade
BS 4447	The performance of pre-stressing anchorages for post-tensioned construction
BS 4449	Specification for Carbon Steel Bars for the Reinforcement of Concrete
BS 4486	Hot rolled and hot rolled & processed high tensile alloy steel bars for pre-tensioning of concrete
BS 4550	Methods of testing cement
BS 4592	Industrial Type Metal Flooring, walkways and stair treads
BS 4604 Part 2	the use of high strength friction grip bolts in structural steel work. Higher grade (parallel shank)
BS 4870	Approval testing of welding procedures
BS 4871	Approval testing of welders working to approved welding procedures
BS 4872	Approval testing of welders when welding procedure approval is not required

BS 5075	Concrete admixtures
BS 5135	Process of arc welding of carbon and carbon manganese steels
BS 5212 Part 2	Cold poured joint sealants for concrete pavements
BS 5328	Methods for specifying concrete, including ready mixed concrete
BS 5400	Steel, concrete and composite bridges
BS 5400 Part 4	Code of practice for design of concrete bridges
BS 5400 Part 6	Specification for materials and workmanship, steel
BS 5606	Accuracy in building
BS 5896	High tensile steel wire and stand for the pre-stressing of concrete.
BS 5930:	Code of Practice for Site Investigations.
BS 5950 Part 2	Specification for materials, fabrication and erection: hot rolled sections
BS 6031	Code of Practice for Earthworks.
BS 6105	Corrosion-resistant stainless steel fasteners
BS 6164	Safety in tunnelling in the construction industry.
BS 6349	Code of Practice for Dredging and Land Reclamation.
BS 6443	Penetrant flaw detection
BS 6681	Specification for malleable cast iron
BS 7079	Preparation of Steel substrates before application of paints and related products
BS 7385 Part 2	Evaluation and measurement for Vibrations in Buildings – E to Damage levels from Ground-Borne Vibrations
BS 7542	method of test for curing compound for concreter
BS 8000 Part 4	Code of Practice for Waterproofing.
BS 8000 Part 5	Code of Practice for Below Ground Drainage.
BS 8002	Code of Practice for Earth Retaining Structures.
BS 8004	Code of Practice for Foundations.
BS 8007	Design of Concrete Structures for Retaining Aqueous Liquids
BS 8081	Code of Practice for Ground Anchorages
BS 8110	Structural use of concrete
BS 8301 Section 5	Code of practice for building drainage
BS 8550	Concrete – Specification of Materials
BS EN 1997	Eurocode 7: Geotechnical design
BS EN 1998	Eurocode 8: Design of structure for earthquake resistance

CIRIA Report 44	Medical Code of Practice for working in compressed air
CIRIA Report 80	A review of instruments for gas and dust monitoring Underground
CIRIA Report 81	Tunnel water proofing
CIRIA Report C515	Groundwater Control – Design and Practice
CIRIA Report C580	Embedded Retaining Walls – Guidance for Economic Design
CIRIA Report C660	Early Age Thermal Crack Control in Concrete
Other Publications	
<ul style="list-style-type: none"> • Standard Method of Measurement for Civil Engineering Works, Edition 1, 4/92 • American Petroleum Industry (API) Standard 1104 • UIC/772-R The International Union of Railways Publication • SS 460 48 66 1991 Swedish Standard Vibration and Shock Guidance Levels for Blast-Induced Vibrations • NS8141 1993 Vibration and Shock in Structures, Guidance Limits for Blasting –induced Vibrations • National Fire Protection Association, NFPA 130-2010: Standard for Fixed Guideway Transit and Passenger Rail Systems • International Society for Rock Mechanics (ISRM), Suggested Test Methods, (various dates). • British Tunnelling Society Specification for Tunnelling • Austrian Society for Rock Mechanics: Geotechnical Underground Structures Design • International Tunnel Association: Guidelines for the Design of Tunnels • ITA/AITES Accredited Material: Seismic Design and Analysis of Underground Structures • Muir Wood, A.M. (1975) The Circular Tunnel in Elastic Ground • D.J. Curtis et al (1976) Discussion Paper - Circular Tunnel in Elastic Ground • CG Lai et al (2000) Probabilistic Seismic Hazard Assessment and Stochastic Sire Response Analysis at the Archaeological Site of Kancheepuram in Southern India. IUSS Press 	

1.2 Geometric Design Criteria

1.2.1 General

	CRITERIA	DIMENSION
1	Gauge	1435mm
2	Max. operating speed	80Km/h
3	Design Speed	90 Km/h
4	Max. Axle load, loaded condition	16 tonne
5	Max. Gradient running track Max. Gradient depot connecting track	4% 4%
6	Minimum vertical curve radius Minimum horizontal curve radius	1500m 200 m (main line track)
7	Traction power collection	Overhead catenary system (OCS) at 25kV (AC) Rails shall be used for traction return

1.2.2 TRACK ALIGNMENT STANDARDS

A. Chainage

The chainage shall refer to the horizontal projection of the track centre line.

B. Gauge

The gauge is the distance between the inner faces of the head of the rails, measured 14 mm below the top of the rails. Standard gauge of 1435 mm shall be used.

C. Horizontal Alignment and Cant

- 1) The data for the horizontal alignment refers to the track centre line.
- 2) The general limits for horizontal radius are as follows:
 - Minimum limit on main line (other than turnouts and their connecting curves) shall be 200m.
 - Minimum limit on main line for turnouts and their connecting curves shall be 190m.
- 3) Minimum limit for horizontal radius along platform = 1000 meter.
Note: Straight platform tracks are preferred.
- 4) Equilibrium cant (in mm) is calculated as $11.8V^2/R$.
Where, V is speed in KMPH and R is radius of curve in meter.
- 5) Cant shall be applied by raising the higher rail above the level of the track profile. The lower rail shall follow the track profile.
- 6) Cant is positive when outer rail is higher than inner rail.
- 7) The Maximum limit for applied cant is 125 mm.
- 8) The applied cant along platform = 0.
- 9) Cant deficiency is calculated as equilibrium cant minus applied cant.
- 10) The Maximum limit for cant deficiency is 100mm.

- 11) Cant transitions shall be linear.
- 12) The Minimum limit for cant gradient is 1:440
Note: This criterion can be expressed as $L_t \geq 0.44 \cdot \Delta D$, where transition length L_t is given in meter and ΔD is the change of cant over the length of the cant transition.
- 13) The Maximum limit for rate of change of cant is 55 mm/s.
Note: This criterion can be expressed as $L_t \geq 0.005 \cdot V \cdot \Delta D$, where transition length L_t is given in meter, V is permissible speed in km/h and ΔD is the change of cant over the length of the cant transition.
- 14) The Maximum limit for rate of change of cant deficiency is 55 mm/s.
Note: This criterion can be expressed as $L_t \geq 0.005 \cdot V \cdot v$, where transition length L_t is given in meter, V is permissible speed in km/h and v is the change of cant deficiency over the length of the cant transition.
- 15) Transition curves shall normally be used between circular curve and straight track, and between circular curves with different radii.
Note: Exceptions are permitted for curves in turnouts and their connecting curves, crossovers, depot tracks, sidings etc.
- 16) The transition curve shall be of the mathematical shape of a clothoid, where curvature changes linearly as a function of chainage.
- 17) Limit for the length of a clothoid is determined from requirements in sub clauses C.12, C.13 and C.14 above. The Minimum transition curve length shall be 15m.
- 18) The Minimum limit for the length of an element (straight or circular curve) located between two transition curves is 20 m.
- 19) Two transition curves shall not be directly connected to each other, unless the common tangent point is an inflexion point within a reverse transition.
- 20) If two transition curves are directly connected to each other according to sub clause 1.2.2, item 19 above and one transition curve has a cant transition, the other transition curve shall have either a cant transition with the same cant gradient or no cant gradient at all.

D. Vertical Alignment

- 1) The data for the vertical alignment shall refer to the top of the rail. For canted track, the vertical alignment shall refer to the low rail.
- 2) The Maximum limit for gradient is 4%.
- 3) On horizontal curves, the general limit for gradient shall be reduced with an equivalent gradient due to curve resistance. The reduction is defined as 0.04% per degree of curvature.
Note: The equivalent gradient, expressed in percent, can be approximated to $70/R$, where R is the horizontal radius in metres.
- 4) Along platforms, the limits for gradients are defined as follows: Normal limit 0.1%

Exceptional limit 0.25%

Note: Horizontal platform tracks are preferred.

- 5) The Minimum Limit for the vertical radius is 1500 meter
- 6) The Minimum Limit for the length of a vertical curve is 20 meter.
- 7) Vertical curves shall not coincide with cant transition.
- 8) Vertical curves shall not coincide with turnouts and diamond crossings.

E. Turnouts and Crossovers

Turnouts on main line shall be of following types as shown in Employer's tender alignment drawings:

- R300 1:9 turnout
- R190 1:9 turnout
- R190 1:7 turnout

1.3 Railway Design Requirements

1.3.1 Railway Alignments

- (1) The horizontal and vertical alignments of the railway are given in the Drawings as listed in Appendix 1 Employer's Requirements. These drawings are included in Tender Drawings.
- (2) The Contractor shall design the civil engineering works to the given alignments. Subject to the provisions of the Contract, changes to the given alignments may be permitted to suit the specific characteristics of the design as per paragraph 3.0 of Employer's Requirements - Functional at no extra cost to the Employer and subject to prior Notice of the Employer/Engineer of these intended changes.
- (3) While proposing changes to the design alignment, the Contractor shall make due allowance for track cants on curves and shall comply with the Contract kinematic envelope and structural gauge.
- (4) While designing the centre of tunnels (determining the design coordinates of tunnel centre) on horizontal curves with Cant, the rotation of tunnel about the mid- point of the top of inner Rail shall be taken into account as shown in the Schedule of Dimensions (SOD). The design cant will be based on the maximum attainable speed on each curve in all-out run mode of the Rolling Stock. The Contractor shall interface with the designated Rolling Stock Contractor for determining the design cant on each curve. In any case the design cant to be taken into account for determining the design tunnel centre coordinates on each curve shall be noticed from the Engineer.

1.3.2 Minor Deviations in Alignment

Minor deviations from the horizontal and/or vertical alignments may be permitted with prior Notice of the Engineer or as suggested by the Engineer subject to conditions stipulated in Contract Employer's Requirements – Functional.

1.3.3 Railway Design Requirements

The Contractor shall be responsible for the design and placement of a lower first stage or 'primary' concrete layer within the cut and cover structures, bored and NATM tunnels. The Trackwork Contractor will undertake the design of a higher second stage or 'secondary' concrete layer, trackslabs and trackwork to conform to the final design alignments. The design of all railway operating equipment, including signals and signalling cables, the traction power electrification equipment, telecommunication links, and the like, that are required for the railway will be undertaken by others under separate contracts with the Employer.

1.3.4 Setting out

The Contractor shall provide permanent survey monuments and shall provide full details of co-ordinates and levels to the Trackwork Contractor and other Interfacing Contractors.

1.3.5 Second stage concreting

- (1) The Trackwork Contractor shall carry out the second stage concreting for laying the trackwork and equipment to the final lines and levels. In this regard, the Contractor shall provide the required interfacing starter bars (shear connectors), stirrups and roughened surfaces in the primary concrete pour to facilitate anchorage of the second pour, duly interfacing the requirement with the designated Track Work Contractor.
- (2) The Contractor shall design the complete drainage system of the Works. The Contractor shall provide drainage pipes, channels and basins/sumps as part of the structural provisions within the first stage concrete pour. The connection and detailing of the Trackwork drainage with the overall drainage scheme/system as designed by the Contractor shall be interfaced with the designated Track Work Contractor.

1.3.6 Railway Cross-sections and Structure Gauges

- (1) The Kinematic Envelopes and Structure Gauges for rolling stock on both straight and curved tracks shall be as per the Appendix for Schedule of Dimensions in Employers Requirement.
- (2) The tunnel design shall ensure that the proposed intrados is sized to adequately allow installation, containment and maintenance of all equipment required and which is placed outside the Structure Gauge (Swept Envelope).
- (3) The tunnel design must also allow proper placement and distribution for signalling equipment/other systems utilities and services, safety niches, cross-passages, vent shafts access ways and entry or exit points that complement the items in the above clauses.

1.2.1 Clearances

Structures shall not infringe the clearances specified in the Contract Schedule of Dimensions. See also section 1.3.6(2) above.

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 VII - Outline Design Specifications

S.02 Cut & Cover Structure

June 2018

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2. CUT & COVER STRUCTURES

2.1 General Principles

1. Cut-and-Cover structures include all stations, station entrances/exits, vent shafts, pedestrian subways, utilities, services, ducts, Cut & Cover ramp structure (where applicable) and the like, other than bored & NATM tunnels. However, the provisions/stipulations in these specifications shall also be applied to all other works under the Contract, wherever considered applicable and relevant.
2. The Cut-and-Cover structure is proposed to be a rigid box section with permanent walls as external wall support system and flat slab with column forming the internal structural framing. The roof slab shall support the soil and vehicular surcharge while the passenger and plant/services/structural loads are carried by the concourse slab/intermediate slabs. The track and platform loads (including passenger and plant/services/structural loads) shall be supported by the base slab. The permanent walls shall resist the lateral earth and hydrostatic pressures in addition to the surcharge and services/structural loads.
3. The completed stations, station entrances, vent shafts and pedestrian subways shall comply with Contract water-tightness criteria.
4. Where temporary walls are intended as part of the Permanent Works, the Contractor shall justify the feasibility and suitability of such to the Engineer.
5. The Contractor shall take into account, but not be limited to, the following in the design of the cut-and-cover structures.
 - (i) Method of construction, including temporary works and construction sequence.
 - (ii) Ground/structure interaction, including the effects of temporary works.
 - (iii) Ground pressure, shear force and bending moment distribution during construction and in the long-term.
 - (iv) Short- and long-term ground and groundwater response.
 - (v) Other static loads changes such as; excavation, surcharge, traffic loadings and the like.
 - (vi) Long-term surface water level changes
 - (vii) Dynamic (such as seismic or vibratory plant) loads and displacements.
6. For the purposes of assessing ground and groundwater pressures, the cut-and-cover structures shall be considered to be effectively impermeable rigid box structures subject to “at rest” (K_0) earth pressure.
7. The Contractor shall design to minimise the effects (such as movement, distortion of the ground and the like) on all EBS that may be affected by the Works and shall comply with all the requirements/provisions of the Contract in this respect. Where necessary the Contractor shall provide additional support for these EBS.

8. Temporary ground support shall be designed in accordance with the requirements of the Contract.

2.2 Design Principles

- (1) The design of all cut-and-cover structures shall take into account, but not be limited to the following.
 - a) The variation in ground conditions along the alignment;
 - b) The geological/hydro geological features and their variations including rock joint orientation and spacing etc.;
 - c) The variation in engineering properties of soil or rock within the influence of the Proposed Works.
 - d) All dewatering and groundwater cut-off systems required to maintain dry and stable conditions within all excavations required for these Works.
 - e) Any ground treatment before, during or after construction of the Works (eg, groundwater recharge etc.) which is required to stabilize the ground and EBS in order to minimise adjacent ground and EBS movement and distortion.
 - f) Methods by which the completed structure shall be secured against flotation. Any temporary dewatering system shall not be turned off unless and until provisions have been made to satisfy that, the structure will not be subject to leakage or flotation when the groundwater returns to the design levels.
 - g) Differential groundwater pressures
 - h) Methods of waterproofing the completed structure.
 - i) The magnitude of ground and EBS movements and distortions, and changes in loading conditions on these EBS that might be expected as a result of the Works and how these will be mitigated so as to comply with any imposed constraints or so as to minimise disturbance/adverse effects to these EBS.
 - j) Any difficulties that the Contractor's intended plant might meet with in respect of access, clearances, working space and obstruction to excavation.
 - k) Maintenance of traffic flows along/on roads including access to adjoining properties and roads.
 - l) Noise/vibration levels produced during construction, and subsequent operation of the railway.
 - m) Control of heave, swell, piping and instability of the excavations.
 - n) The effects of earthquake, vibration and vibration induced movements
- (2) The following methods of construction shall be used in soft ground either individually or in combination depending upon the particular requirements of

the location, size and type of structure.

a) Diaphragm Walls

Particular attention shall be paid to the wall and panel alignment, the stability of excavation, the mix and condition of the slurry, placement of the reinforcement cage, methods for forming and locating box-outs, waterproofing of the vertical panel joints, placement of concrete, and the overall integrity and water-tightness of the formed wall.

b) Secant Piles Wall, Sheet Piles/Soldier Piles and Horizontal Lagging

Particular attention shall be paid to the construction/installation of the piles and ground support systems to ensure their integrity and water-tightness and to provide adequate support to the ground during excavation

Diaphragm/Secant piles walling is the preferred support method for the proposed deep stations, vent shaft/TBM Shafts/other shafts and other deep excavations. Other methods of support may be used for the other relatively shallow excavations such as station entrances/exits, pedestrian subways, utilities and services ducts etc, where site conditions/constraints so permit.

- (3) Only diaphragm wall and secant piles wall can be allowed to form part of the permanent works.
- (4) Where the excavation involves soft ground in upper portion and hard ground (rock) in lower portion. The diaphragm/secant piles wall may be permitted to be terminated into hard ground at a level that provides adequate rock socketing and the required water-tightness, depending upon the geological and hydrological conditions. In such situations, particular attention shall be paid for design and detailing of the required shear-pin connection between the diaphragm/secant piles wall and the supporting hard ground below and to the ground treatment (e.g. grouting etc.) to seal the junction between the walls, the ground, and its surroundings to ensure their integrity and water-tightness. In the hard ground portion, an adequately designed Reinforced concrete (RCC) permanent lining wall shall be provided. Particular attention shall be paid for design and detailing of the connection of this RCC lining wall to the various slabs (including base slab) as applicable and to the diaphragm/secant piles wall, depending upon the location/shape/size/available space etc., to ensure integrity and water-tightness of the so formed structural configuration.

2.3 Excavation Support

(1) General

- a) The Contractor shall prepare and submit to the Engineer for Notice of No Objection a detailed Design Report including calculations schedules and drawings for each proposed excavation support wall construction, prior to the commencement of any such works. This Design Report shall take into

account but not be limited to the following.

- i) Earth pressure.
- ii) Hydrostatic pressure.
- iii) Deck load.(traffic and construction equipment load)
- iv) Surcharge loads.
- v) Seismic and/or vibratory loads
- vi) Support types and arrangement.
- vii) Any other incidental load.
- viii) Construction/deconstruction sequence.
- ix) Calculated ground and adjacent EBS movements and distortions.
- x) Calculated fluctuations in groundwater levels both within and outside of the excavation and support walls.
- xi) Calculated changes in EBS loading conditions

(2) Method Statement

- a) The Contractor shall prepare a Method Statement giving the full details of materials, plant and operations involved in the construction of excavation support walls. This Method Statement shall be incorporated into the Design Report submission for the Engineer's Notice of No Objection and shall include but not be limited to the following details.
 - i) Formation of the joints between panels and installation of water stops.
 - ii) Method of producing the durable concrete.
 - iii) Methods of handling within the excavations and disposing of groundwater outside of the excavations
 - iv) Sequence of excavation and concreting of panels.
 - v) Methods of instrumentation, monitoring and reporting of the performance of all adjacent EBS that may be affected by the Works.
 - vi) Methods of instrumenting, monitoring and reporting on the performance of the excavation support walls and their lateral support systems.
 - vii) Type and construction of permanent lining wall.
 - viii) Contingency and Emergency procedures to be implemented in the event that monitoring indicates tolerances associated with the excavation support wall may be exceeded.
- b) Where temporary ground support is to be provided using bentonite slurry, the following additional information shall be provided in the Method Statement for these Works.
 - i) Mixing, transporting and placing equipment for the bentonite slurry.

- ii) Method of treatment and disposal of contaminated bentonite slurry.
 - iii) Type, source, chemical and physical properties of the bentonite to be used.
 - iv) Stability, dimensions and details of guide walls.
 - v) Cleaning and re-use of the bentonite slurry.
 - vi) Calculations to show that the density of the bentonite and lowest head of slurry are sufficient to maintain the stability of the trench excavated for the support wall, in the ground conditions envisaged, to its full depth.
- c) Where the excavation in hard ground, i.e. rock, is involved the Method Statement shall be prepared in accordance with Outline Construction Specification – Civil and Structural Works, if blasting is permitted. There may be certain locations along the alignment, where blasting shall not be permitted. The Contractor shall propose alternative methods (other than blasting) for excavating hard ground at such locations and include the methodology for the same in the Method Statement for the Notice of No Objection from Employer/Engineer.

2.4 Design Life and Serviceability

2.4.1 General

The 'design life' of a structure or component is that period for which the item is required to fulfil its intended function when maintained in accordance with agreed procedures to meet a required level of performance. The definition of a 'design life' for a structure or component does not necessarily mean that the structure will no longer be fit for its intended purpose at the end of that period. Neither will it be expected to necessarily continue to be serviceable for that length of time without adequate maintenance to mitigate the demands of degradation.

2.4.2 Civil Engineering Structures

- (1) The design life of all civil engineering structures shall be a minimum of 120 years unless otherwise specified or agreed upon.
- (2) Adequate measures shall be taken to ensure a minimum of 120 years serviceability of civil structures by producing durable concrete structures. For achieving this suitable property enhancers/ blending materials conforming to relevant BIS codes (or more stringent International Standards/Codes wherever required) may be used as deemed appropriate and subject to Notice of No Objection from the Engineer.
- (3) A Durability Approach and Assessment Report (DAAR) shall be prepared by the Contractor for all the Permanent Works under the Contract to demonstrate his approach in design, construction and selection of materials so as to achieve 120 years design life, and submitted to the Engineer for obtaining a Notice of No Objection. It is brought to the notice of the Contractor that the Specifications, Requirements and Conditions as stipulated in the Contract are

the minimum standards/parameters to be adopted for the Works under the Contract. However, as part of Contractor's DAAR, the Contractor shall be required to review all these Contract stipulations and justify their adoption or otherwise propose more stringent standards/parameters for the Works to achieve the stipulated design life and the durability requirements of the Works under the Contract. The DAAR shall include, but not be limited to:

- a) The appraisal of the deterioration mechanisms that will affect various materials during the service life;
 - b) The appreciation of the failure criteria for the elements and components;
 - c) The philosophy as to how the selected design will achieve the durability objective;
 - d) The identification of the critical elements and issues and their treatment with respect to the durability;
 - e) The specific provisions of the relevant International Codes/Standards (first preference being given to BS Codes/Standards, where applicable) that will be followed to explicitly meet the durability objective (including BS EN 206:2013, BS 8500-1:2006 etc.); and
 - f) The requirements for the post construction maintenance.
- (4) The concrete shall be tested for impermeability according to DIN 1048 and ability to resist chloride ion penetration according to ASTM C-1202. Water permeability shall not be more than 10 millimetres (at the concrete age of 28 days). RCPT value shall not exceed 1000 coulombs at the concrete tested at the age of 28 days.
- (5) The design life of the above ground building structures including ancillary buildings, utility support, structures and ventilation shafts etc. shall also be 120 years.
- (6) The design life of non-structural elements shall be 50 years

2.4.3 Road Pavements

The design life of all pavements shall conform to the requirements of relevant Codes.

2.4.4 Serviceability of Civil and Building Works

- (1) Paint systems for steelwork, wherever permitted by the Engineer, shall ensure a minimum life of 5 years before full maintenance painting is required.
- (2) The corrosion protection of non-structural steel items shall be appropriate to the accessibility of the item for inspection and maintenance.

2.5 Materials

2.5.1 Cement

- (1) Ordinary Portland cement (OPC) of 43 grade and 53 grade conforming to IS 8112-1989 and IS 12269-1987, respectively, shall be used.
- (2) Portland Pozzolana Cement (PPC) conforming to IS 1489 may also be used.

- (3) The Engineer may give Notice for the usage of sulphate-resistant Portland cement conforming to IS 12330 for structural elements exposed to soil/ground.
- (4) In all cases the cement shall meet the 28 day strength requirement of IS 8112- 1989 or IS 12269-1987.

2.5.2 Concrete

- (1) The material properties shall be as follows

Concrete Grade	Specified Characteristic Compressive Strength of 150 mm ³ at 28 days in MPa (IS 456- 2000);	Coefficient of Thermal Expansion per °Celsius	Poisson's Ratio
M35	35	1.17x10 ⁻⁵	0.15
M40	40		
M45	45		
M50	50		
M60	60		

- (2) Short term modulus of elasticity (Ec) shall be as per clause. 6.2.3.1 of IS 456-2000.
- (3) The modular ratio shall be as per clause B-1.3, Annex B of IS 456:2000.
- (4) Density of concrete shall be 25 kN/m³ for reinforced concrete and 24 kN/m³ for plain cement concrete.

2.5.3 Reinforcement

- (1) Only thermo-mechanically treated reinforcement bars of grade Fe415/Fe500D with minimum total elongation of 14.5% conforming to IS 1786 shall be adopted
- (2) The Permanent Structures shall use thermo-mechanically treated reinforcement bars of grade Fe500D only.
- (3) The material properties shall be as follows.

Young's Modulus MPa	Yield Stress MPa	Diameters mm	Density kN/m ³	Poisson's Ratio	Thermal coefficient per °C
200,000	415 for Fe 415 500 for Fe 500D	8, 10, 12, 16, 20, 25, 28, 32, 36,40	78.5	0.3	12X 10 ⁻⁶

2.5.4 Structural Steel

- (1) Design of Structural steelwork shall comply with IS 800.
- (2) Two types of structural steel to be used and shall comply with the following standards:
 - a) IS: 4923-1997 “Hollow steel sections for structural use with Yst 310”
 - b) IS: 2062-2006 “Steel for General Structural Purposes (Grade B- Designation 410-B)”
- (3) Hollow steel sections shall be square (SHS) or rectangular (RHS). Other traditional rolled sections like plates, angles, channels, joists can also be used where required.
- (4) The connection with concrete shall be effected by internally threaded bolt sleeves (hot dipped galvanized @ 300 grams per square metres) manufactured from IS: 2062 Grade B mild steel. The sleeve shall receive hexagon-head bolt M20 Class 8.8 as per IS: 1364 (Part 1) with galvanized spring washer.
- (5) The connections within the steel structure shall be designed as direct welded members with or without gusset plates. The minimum thickness of metal for SHS/RHS sections for main chord members as well bracings shall be 4 mm as applicable for steel tubes in cl. 6.3 of IS: 806.
- (6) Material Properties shall be as follows.

Steel Type	Young's Modulus	Tensile Strength	Yield Strength	Density	Poisson's Ratio	Thermal Expansion Coefficient
For Hollow steel sections (conforming to IS: 4923)	200,000 MPa	450 MPa	310MPa	78.5 kN/m ³	0.30	1.2x10 ⁻⁵ per °C
Structural Steel (Conforming to IS: 2062)		410 MPa	250MPa (for t<20mm), 240MPa (for 20mm < t < 40mm) 230MPa (for t > 40mm)			

2.6 Durability Criteria

- (1) In carrying out structural designs, the Contractor shall ensure that both the serviceability and ultimate limit states have been checked in accordance with the applicable Standards and Codes as included in the Contractor's DAAR.
- (2) In designing to achieve durability, the Contractor shall take full account of the prevailing ground and groundwater conditions and those predicted to occur

at the site within the design life of the Works.

- (3) The DAAR shall cover all structures, finishes and their components to identify the significant durability issues pertaining to their environmental exposure and functionality. Based on the durability objective and performance criteria for the components' materials, the following shall be taken into consideration, but not be limited to:
 - a) the environmental exposure conditions and the micro-environment;
 - b) Method of construction and its likely effect on the components & their materials.
 - c) the potential deterioration mechanism with such exposure conditions;
 - d) the likely material life;
 - e) the likely failure mechanisms;
 - f) the significance of failure;
 - g) the need for in-situ monitoring;
 - h) the accessibility for maintenance;
 - i) the maintenance and replacement options; and
 - j) the necessity of providing additional protection.
- (4) The DAAR shall address and set out the proposed approach to resolving the following issues, but not be limited to:
 - a) The corrosion protection of structural steel, reinforcement and exposed metals;
 - b) The concrete, its grades, its constituents (minimum contents and their characteristics and properties), its characteristics & properties, minimum cover, various tests to be done & test results to be obtained/complied, protective measures and crack width control etc.;
 - c) The waterproofing;
 - d) The jointing and sealing;
 - e) The fixings on/into structures;
 - f) The durability of envelope components (including finishes and cladding elements);
 - g) The method of rectification for the failure of critical elements; and

2.6.1 Concrete Grade

- (1) The minimum grade of concrete for underground structures shall be M35. However, for structural elements that might come in contact with Nallah Water the minimum concrete grade shall be M45. The properties of concrete shall be as specified in section 2.5.2 above.
- (2) Where concrete is to be placed under the slurry or water, such as diaphragm wall/secant pile wall and barrettes, the design compressive strength and shear strength of structural concrete shall be reduced in comparison to the adopted concrete grade. The characteristic strength of the compressive and shear stress shall be taken to be 80% of the characteristic strength of the adopted concrete grade.

2.6.2 Fire Resistance Period

- (3) All structures shall be designed for fire protection as specified by the applicable standards and codes. Materials specified for the Works shall be non-combustible and nor emit toxic fumes when subject to heat or fire, except where permitted under the Contract. In all cases where there is significant fire risk, materials shall be self-extinguishing, low flammability, low smoke and low toxicity
- (4) All the elements of the station structures (except non-load bearing separation walls) and all other underground structures shall be designed for a minimum fire resistance period of 4 hours. The Fire Resistance of non-load bearing separation walls shall be determined by their fire-compartmentation requirements.
- (5) The minimum element thicknesses for this fire resistance shall be as given in Table 2.1 below.
- (6) The minimum values for the covers to reinforcement for this resistance period are specified in Table 2.2

Table 2.1 Minimum Element Sizes for 4-hour Fire Protection

Element	Minimum Sizes for 4-hour FRP (mm)
RC Slab Thickness	170
RC Beam Width	280
RC Column Sizes	450
RC Wall Thickness: <1% reinforcement	240
RC Wall Thickness: >1% reinforcement	180
Blockwork Wall Thickness	150
Staircase (waists)	170

2.6.3 Crack Width

- (1) All structural concrete elements shall be designed to prevent excessive cracking due to flexure, early age thermal and shrinkage. The maximum crack widths shall be as specified in Table 2.2.
- (2) Flexural Cracking
Flexural crack width shall be checked in accordance with Appendix F of IS 456:2000. The limits specified in Table 2.2 shall apply irrespective of whether any additional protection, such as waterproofing membrane, is provided to the members at the exposed face of the structure.
- (3) Early age Thermal and Shrinkage Cracking
 - a) Suitable reinforcement shall be designed to prevent early age thermal and shrinkage cracking for walls and slabs more than 250 millimetres thick and subjected to internal and external restraints during construction. The thermal and shrinkage strains due to early age temperature differences and shrinkage shall be accounted for in the

design of reinforcement for cracking.

- b) It is preferred that smaller diameter bars in any direction are placed at closer intervals to prevent early age thermal and shrinkage cracks. The limits specified in Table 2.2 shall be imposed. Guidance can be sought from CIRIA C660 on Early Age Thermal Control of Concrete

Table 2.2 Cover and Crack Width Criteria

Element	Durability Exposure Condition	Max Crack Width (mm)	Minimum required Cover (mm)	Nominal Cover to be considered for Crack width check (mm)
Diaphragm Wall/Secant piles wall	Severe Moderate	0.2 (for ground face) 0.3 (for non-ground face)	80	45 40
Pile cap (side and bottom faces) resting on layer of blinding concrete not less than 50mm thick	Severe	0.2	80	45
Base Slab–Top Surface	Moderate	0.3	45	40
Base Slab–Bottom Surface(cast against ground/blinding)	Severe	0.2	70	45
Basement Walls				
a) Face in contact with ground	Severe	0.2	50	45
b) Other face	Moderate	0.3	40	40
Columns (Internal):	Moderate	0.3	40	40
Load bearing Walls (Internal)	Moderate	0.3	40	40
Non–load bearing Walls (Internal)	Moderate	0.3	30 [#]	–
Stairs	Moderate	0.3	55	40
Water Tank	Severe	0.2	45	45
Beams				
Top surface (contact with ground)	Severe	0.2	50	45
Top surface (No contact with ground)	Moderate	0.3	50	40
Bottom and sides	Moderate	0.3	50	40
– continuous		0.3	70	40
– simply supported				
Slabs				
Top surface (contact with ground)	Severe	0.2	70	45
Top surface (No contact with ground)	Moderate	0.3	45	40
Bottom surface	Moderate	0.3	45	40
– continuous	Moderate	0.3	55	40
– simply supported				

Notes

- or bar diameter, whichever is greater.

- Nominal cover is measured to the outermost reinforcement.
- Nominal cover does not include any allowance for construction tolerance.

3. External surfaces are fully protected by Architectural rendering and cladding and hence shall be considered having moderate exposure condition.

2.6.4 Above ground Ancillary Structures

- (1) Clauses 2.6.1 to 2.6.3 above stipulate durability requirements for underground structures. For aboveground ancillary structures, the following contents shall be adopted.
- (2) The minimum grade of concrete shall be M30
- (3) Fire Resistance Period: All the structural elements shall be designed for a minimum fire resistance period of 2 hours. The minimum element thicknesses for this fire resistance shall be as follows.

Sl. No.	Element	Minimum Dimension (mm)
1	RC Slab	125
2	RC Beams	200
3	RC Columns	300
4	RC Walls	160
5	Block Work Wall	100

- (4) Crack Width Check

Crack width in concrete shall be checked in accordance with Appendix F of IS 456-2000. The maximum allowable crack width shall be as given in Table 2.2 above.

2.6.5 Cracking of Concrete

Anti-crack reinforcement shall be provided in all walls and slabs more than 250mm thick to distribute cracking arising from shrinkage, early thermal and temperature effects.

Recommendations given in Clause 3.9.4.19 of Part 1 of BS 8110 shall be followed with the modification that reinforcement on each face in each direction should be at least:

- For grades 415 and above: 0.125% of the concrete cross-sectional area.
- For grade 250: 0.15% of the concrete cross sectional area.

In addition, spacing between the bars should not be greater than 150 mm.

Generally, bundling of bars and more than one layer of bars is not preferred. It is preferred that smaller diameter bars in any direction are placed at closer intervals to prevent early thermal and shrinkage cracks.

2.7 Loads and Requirements

2.7.1 General

Unless specified otherwise, the principles of structural design for concrete and steel

elements shall comply with IS 456 and IS 800, respectively. For design life and durability considerations, the Sections 2.4 and 2.6 above shall be referred to.

2.7.2 Nominal Loads

For the purpose of computing stresses and deformations, the following minimum loads and consequential effects shall be taken into account as applicable.

• Dead loads	DL
• Super Imposed Dead Load	SIDL
• Imposed (Live) loads	LL
• Railway Loads	RL
• Fatigue	FG
• Dynamic Effects	DI
• Derailment	DR
• Temperature Effects	TE
• Wind Load	WL
• Seismic Loads	EQ
• Construction/Erection	ER
• Shrinkage	SH
• Creep	CP
• Earth Pressure	ER
• Surcharge	SR
• Hydrostatic	WP
• Movement/Distortion	DS
• Earth Pressure	EP
• Surcharge	SR
• Hydrostatic	WP
• Accidental	AC
• Buoyancy/ Uplift	BU
• Differential settlement	DS

2.7.3 Design Loads

Design Loads shall include all the following loads:

(1) Dead Load

Self-weight of the material shall be calculated in accordance with IS 875: 1987,

Part I

(2) Superimposed Dead Loads and Imposed (Live) Loads

The minimum distributed and concentrated loads shall be in accordance with Table 2.3

Table 2.3: Superimposed Dead Loads (SIDL) & Imposed (Live) Load

Description	Superimposed Dead Load		Imposed Load		
	Finishes (kPa)	Partitions (kPa)	Ceiling & Services (kPa)	U.D.L. (kPa)	Concentrated Load ^(Note 2 & 3) (kN)
Station					
Concourse Area	2.4 ^(Note 5)	1.0 ^(Note 6)	1.0 ^(Note 6)	6.0 ^(Note 1)	15.0
Platform Area	2.4 ^(Note 5)	1.0 ^(Note 6)	-	6.0 ^(Note 1)	15.0
Track	(Note 11)		Refer Section 2.7.4		
Stairs and Landings	1.2 ^(Note 4)	-	1.0 ^(Note 6)	6.0 ^(Note 1)	15.0
General Plant Rooms, Pump Room	2.4 ^(Note 5)	-	1.0 ^(Note 6)	10.0 ^(Note 7)	22.5
General Office	2.4 ^(Note 5)	1.0 ^(Note 6)	1.0 ^(Note 6)	6.0	7.5
Staff Rooms	2.4 ^(Note 5)	-	1.0 ^(Note 6)	6.0	7.5
Toilets, Changing Room	2.4 ^(Note 5)	1.0 ^(Note 6)	1.0 ^(Note 6)	6.0	7.5
Store	2.4 ^(Note 5)	-	1.0 ^(Note 6)	10.0	15.0
Water Tank, Fire Tank	2.4 ^(Note 5)	-	-	20.0/(Water Height + 0.3m)	-
Chiller Rooms	2.4 ^(Note 5)	-	1.0 ^(Note 6)	10.0 ^(Note 7)	15.0 ^(Note 7)
Transformer Rooms, Substation	2.4 ^(Note 5)	-	1.0 ^(Note 6)	20.0 ^(Note 7)	20.0 ^(Note 7)
Switch Gear Plant Room	2.4 ^(Note 5)	-	1.0 ^(Note 6)	7.5 ^(Note 7)	10.0
Roof Slab	2.4 ^(Note 5)	-	1.0 ^(Note 6)	Soil Load ^(Note 8) + 20.0 ^(Note 9)	-

Notes:

1. Stairs and landings to be designed for the same load as the floors to which they give access with a minimum of 2.5 kPa and a maximum of 10 kPa
2. Concentrated loads act on a square of 300 mm each side.
3. As specified or wall loads in accordance with layout in architectural plan, whichever is greater.
4. All loads are unfactored.
5. Minimum of 100 mm thick screed on top, unit weight of 24 kN/m³
6. As specified above or the imposed load from services fixed to the underside of floor whichever is greater.
7. The design loads shall be actual plant/equipment loads or the ones specified above, whichever is maximum. For seismic design plant/machinery loading shall be considered as Super Imposed Dead Load.
8. Backfill / Earth Load Shall be calculated for the available soil depth for a unit weight of soil of 20 kN/m³. This shall be considered as Ground Load for the purpose of load combinations.
9. Allowance for vehicular (Live Load) surcharge.

10. The construction load on concourse level shall be minimum 10 kPa.
11. The Track loads due to:
 - a) Track work - Load due to 60 Kg (UIC) rails and guard rail and fittings
 - b) Track bed - RCC blocks or concrete pour or precast slabs in RCC with inserts and fittings in case of unballasted track (450 to 600 mm thick) or PSC sleepers over 250/300 mm of ballast for ballasted track.
 - c) Other loads - : as per Indian Railway Standards (IRS) and Bureau of Indian Standards (BIS)

2.7.4 Railway Loads

Each component of the structure shall be designed/ checked for all possible combinations of these loads and forces. They shall resist the effect of the worst combination:

(1) Vertical Train Live Load

The Train Live Load will have the following axle configuration



All axle loads = 16 tons

Maximum number of successive cars: 6

Configuration

a = 2.45 m

b = 2.20m

c = 12.50m (2a+2b+c=21.8m)

Maximum number of axles shall be loaded on the structure to arrive at maximum longitudinal force, maximum shear and maximum bending moments. The structure shall be checked for one-track load condition as well as (both) 2-tracks load condition.

(2) Lurching

Lurching forces are caused by the temporary transfer of part of live loading from one rail to another. In accordance with BS5400: Part 2 – Specification for Loads – Clause 8.2.7, 56% of track load shall be considered acting on one rail concurrently with 44% of the track load on the other rail. (See Figure below) This redistribution of load need only be taken into account on one track where members support two tracks. Lurching may be ignored in the case of elements that support load from more than two tracks.

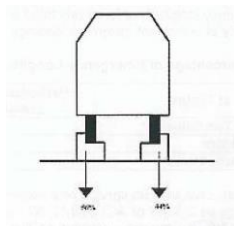


Figure 2.1: Track Load Arrangement for Lurching Effect

(3) Fatigue Loading:

The nominal loading for the design of members in accordance with fatigue requirements (BS 5400: Part 10) shall comprise trains with six individual cars each having four axles, the axle loads and vehicle lengths will be provided by the Rolling Stock Supplier (As specified in 2.7.4 (1)).

Fatigue load history shall be evaluated to provide valid and representative design spectra, with stress histories analysed by the rainflow or equivalent method, both in conjunction with annual tonnage's of rail traffic per track. The provision of BS 5400 Part 10 Clause 9.3.3 or other relevant method may be used as a rigorous method of evaluation or compliance with fatigue criteria.

(4) Dynamic Loading:

Impact factor for longitudinal analysis shall be 1.2 while for transverse analysis CDA shall be calculated as per IRS Bridge Rules. Dynamic loading shall not be applied to piles, pile caps, centrifugal loads or braking/traction loads.

(5) Longitudinal Loads (Horizontal Train Live Load):

a) Braking and Traction

- Longitudinal loads from braking and traction shall be 18% and 20% of the un-factored vertical live load per track respectively.
- Where a structure carries two tracks, both tracks shall be considered to be occupied simultaneously. Traction forces shall be considered as acting on one track and braking forces acting on the other, with both acting in the same direction simultaneously to produce the worst loading condition in the rails and supporting elements.
- Longitudinal forces acting on the track shall be considered to be dispersed through the track before being transmitted to the substructure. This shall be calculated based on IRS Bridge Rules, IS Codes and relevant BS Codes.
- Provision shall be made in supporting element for effect of horizontal and longitudinal forces transferred to rail, especially in the girders with ballast less deck.
- Additional permissible stresses while considering this contingency will be proposed by the Contractor for notice by the Engineer. Forces shall be calculated for continuous welded rail with a concrete structure interaction resulting from temperature differential of rail and concrete base.
- Longitudinal forces shall consider the effects on stability and safety of the

applied axle-loading arising from a broken rail on a ballast less track.

- As per IRS Bridge Rules, correction slip no.22 dated 17/1/1994, in transverse/longitudinal seismic condition, only 50% of gross tractive effort/braking force shall be considered.

b) Centrifugal Forces

Centrifugal Forces: Check for Centrifugal forces shall be made as per IRS Bridge Rules.

(6) Derailment and Collision Loads

Derailment loading:

As per latest Design Code ACI 358, 1R-92, for derailment check, derailment load correspond to the application of 50% of one coach weight, applied horizontally as a 5m long uniform impact load. This “DR” load corresponds to an ULS load. For SLS Combinations (Group V), a 1/1.75 coefficient will be applied to the DR load.

Collision Load (CL):

Collision Load is considered as per IS875 (Part 5) – 1987 Clause 6.1.2. A concentrated load of 70kN at 1.20m above the road level will be considered in the design of parapet wall of ramp.

2.7.5 Wind Loading

Wind loading may affect the surface elements of underground structures such as vent-shafts, entranceways, cooling towers and ancillary structures etc. It is also a factor on temporary structures during construction. IS 875: Part 3 shall be applied to determine the appropriate design wind loads in combination. Wind effects from venting in below-ground areas shall be designed appropriately.

2.7.6 Temperature Loading

Forces may arise from a thermal gradient within a structural element; this may be from external sources or, in the case of fresh concrete, from the internal heat of hydration during curing.

These forces shall be considered in combination with those from other types of loads to determine the worst loading condition. ‘Locked-in’ forces from temperature effects (eg, from curing of concrete) shall be considered as a permanent load and due allowance made in the design for such.

Temporary works with structural steel bracing elements or similar may also suffer adverse effects from thermal strains. These thermal strains shall be suitably accounted for and suitable measures shall be taken to avoid losses in preloading and subsequent excessive deformations in structural members.

2.7.7 Seismic Loading

(1) General

Seismic effects shall be considered on all structures, including underground structures.

Evaluation of seismic loads shall conform to the relevant Indian Standards or to other relevant seismic standards or references where the Indian Standards are either not applicable or do not provide sufficient guidance

The zonal demarcations for levels of seismicity shall be evaluated as per IS 1893-2002. Where two or more zones are deemed to act on a structure, the more onerous level of compliance shall be used in the design when a static lateral force analysis approach is used. Alternatively, the structural loads can be directly evaluated using a dynamic lateral force (response-spectra) approach.

The structure is required to be evaluated as an 'important service and community building' for the purpose of 'functional use' as stated in IS1893.

Seismic design using a response-spectra approach requires adopting the more onerous loading from strong-motion data from recent seismic events in the region or from earthquake events that have occurred in the similar ground conditions and suitably factored accounting for intensity in the region.

The effects of load changes and deformation as a result of soil behavior (e.g., liquefaction) shall be allowed for in the assessment and design.

(2) Seismic Design For Above-Ground Structures (Ancillary Structures)

Earthquake design shall follow the seismic requirements of IS 1893 and the ductile detailing of reinforced concrete structure shall comply with IS 13920 & IS 4326.

The design base shear shall be calculated based on recommendation given in IS: 1893. The total design lateral force or design seismic base shear (VB) along any principal direction shall be determined by the following expression:

$$VB = AhW$$

Where,

Ah = Design horizontal acceleration spectrum value, using the fundamental natural period Ta calculated according to clause 7.6 of IS 1893-2002 (Part 1) in the considered direction of vibration, and;

W = Seismic weight of the building calculated according to cl. 7.4.2 of IS1893-2002 Part 1

The design horizontal seismic coefficient Ah for a structure shall be determined by the following expression:

$$Ah = \frac{Z I S_a}{2 R g}$$

Where,

- Z = Zone factor. The project site falls within Zone III. Zone factor (Z) of 0.16 shall be taken as per IS 1893-2002 (Part 1).
- I = Importance factor shall be taken as 1.5.
- R = Response reduction factor shall be as per Table 7 of IS 1893/ RDSO approved guidelines (whichever is more onerous for design consideration shall follow)
- Sa/g = Average response acceleration coefficient for rock or soil sites as given by Fig. 2 and Table 3 of IS 1893 based on appropriate natural periods (T_a) and damping of the structure. These curves represent free field ground motion.

Damping for the concrete structure shall be assumed as 5%.

Based on type of foundations provided for the structure and soil strata type, the appropriate spectral coefficient shall be selected from Fig. 2 of IS 1893-2002 Part 1.

The vertical seismic coefficient will be taken as two thirds of the design horizontal acceleration as per clause 6.4.5 of IS 1893-2002 Part 1.

(3) Seismic Design For Underground Structures

- A. Earthquake effects on underground structures can be grouped into two categories:
- Ground shaking; and
 - Ground failure
- B. Ground Shaking Effects
- The underground structures' seismic design shall be based on the free-field deformation of the surrounding ground and its interaction with the structure. Two types of deformations which characterize the seismic response of structures shall be evaluated:
 - Longitudinal axial and curvature deformations
 - Transverse ovaling or racking deformations
 - The evaluation procedures for seismic response of underground structures shall be based on either simplified analytical method, or more complex numerical modelling approach, depending on the degree of complexity of the ground-structure system, subsurface conditions, the seismic hazard level, and the importance of the structures. The numerical modelling approach shall be considered in cases where simplified analysis methods are less applicable, more uncertain, or inconclusive.
 - The "Technical Manual for Design and Construction of Road Tunnels — Civil Elements", Publication No. FHWA-NHI-10-034 U.S. Department of Transportation, Federal Highway Administration (FHWA), December 2009, shall be adopted as the primary reference for seismic design

with regard to deformation and strain demands stated in relevant Indian Codes. Other references listed below might also be used for seismic design.

- Hashash, Y.M.A., Hood, J.A., Schmidt, B. and Yao, J, “Seismic Design and Analysis of Underground Structures”
 - Wang, J, “Seismic Design of Tunnels”
 - Kuesel, R.K., "Earthquake design criteria for subways"
 - Macormick
- iv. The dynamic pressure acting on the underground structures shall be evaluated based on Wood’s approach published in 1973 (Report No. EE73-05, “Earthquake Induced Soil Pressure on Structures”, J.H. Wood) and “Earth Retaining Structures” in the Bulletin of New Zealand National Society for Earthquake Engineering (Vol. 13, No.3).

C. Ground failure

- i. Ground failure broadly includes various types of ground instability arising in situations such as :
- Underground structure crossing a known seismic fault.
 - Underground structures located in an area subject to ground failure (i.e., liquefaction or slope instability).
- ii. In general, analytical procedures that are used for evaluating buried pipelines subjected to fault displacements can be followed for evaluating the underground structures. Three methods that could be utilized in the evaluation and design of linear buried structures (ASCE Committee on Gas and Liquid Fuel Lifelines, 1984) are:
- Newmark-Hall procedure,
 - Kennedy et al. procedure, and
 - Finite element approach.

2.7.8 Construction/Erection Forces and Effects

The weight of all permanent and temporary materials together with all other forces and effects which can operate on any part of structure during construction/erection shall be taken into account. Allowance shall be made in the design for “locked-in” stresses caused in any member during construction/erection.

2.7.9 Shrinkage and Creep

Provision shall be made for the effects of shrinkage and creep within concrete structure. This includes interface shear transfer mechanisms as a result of differential creep and residual shrinkage effects from staged casting of concrete elements. The shrinkage and creep strains shall be included in calculation of long term deflection of all structural elements in accordance with Annexure C of IS 456-2000 and the limits specified in Section 2.8 shall be applied.

2.7.10 Movement and Distortion

Consideration of the forces resulting from differential movement (distortion) of foundation elements shall be checked as appropriate. All movements and distortions must not be greater than the least of the following limits:

- Adhered to in relevant codes.
- As acceptable to the Relevant Authority.
- As specified in the contract.

These may be architectural, structural, rail performance or other types of limitations currently in force.

2.7.11 Earth Pressure

Underground vertical elements that are in direct contact with the ground shall be designed as permanent retaining walls to resist the lateral earth pressure at rest. The Contractor shall deduce the earth pressure coefficients based on his geotechnical investigations. For rock masses the coefficient of earth pressure should be based on in-situ stress condition. The available ground investigation records are provided in Tender Drawings and Reference Document of the Contract for reference purposes only.

2.7.12 Surcharge

- (1) For existing buildings and other existing structure occupying areas around the excavation, detailed assessments based on building and foundation type, and loading are to be carried out to determine the applied loads and other impacts of such building loads on the proposed underground structure. For future buildings or planned infrastructure, the appropriate Authorities and Engineer shall be consulted for obtaining the details for taking into account the surcharge to be considered for the design of underground structures.
- (2) Swargate station shall be designed for minimum G + 5 commercial building load.
- (3) Where provision for a specific future structure is not made, a minimum uniformly distributed surcharge of 50kPa at the design finished ground level shall be assumed. In case, the actual building load surcharge exceeds 50kPa, the actual value shall be considered.
- (4) Footpath live load shall be adopted as 5kPa.
- (5) A vehicular live load surcharge of 24 kPa shall be adopted for the design of all underground structures. .
- (6) A general loading due to construction plants and equipment (during construction stage) shall be taken to be a minimum of 10kPa. For heavy plants and equipment, the actual loading shall be determined individually and considered in the design.

2.7.13 Groundwater

- (1) Loads due to water pressure shall be calculated using a unit weight of 10 kN/m³

- (2) Should liquefaction of soils be a potential risk then the design water table level for permanent structures shall include layers affected by liquefaction if this is above the design groundwater levels.
- (3) The effects of temporary drawdown, seepage and base heave effects shall be considered in design of the temporary works, and catered for in the permanent works if there is a 'locked-in' effect from carry-over forces. The extent of the temporary walls shall be sufficient to mitigate the effects of such loads during construction.
- (4) The effects of flotation loads shall be allowed for in the design both in the temporary and permanent design stages.
- (5) The proposed structures (primarily the stations) may act as obstructions to groundwater movement. The Contractor shall design and subsequently construct for unobstructed movement of the groundwater through and around these structures so that these structures do not result in changes to the phreatic surface that exceed normal expected diurnal fluctuations.

2.7.14 Accidental

The design shall allow for a minimum impact loading of 50 kN acting at any position and at any direction on temporary works or on partially completed permanent works.

2.7.15 Redundancy loads

- 2.7.16** The temporary structure shall allow for the effects of a 'one-strut failure' condition. A single strut/anchor failing at any position and at any stage shall be evaluated Ultimate Limit State (ULS) condition with a FOS of not less than 1.05.

2.7.16 Differential Movement Between In-Line Structures

Differential movement between adjacent in-line structures arising from static and/or dynamic loading shall be evaluated. Due allowance for such shall be incorporated into the size of the structures and detailing of joints to ensure that the total and differential movements, including distortion and relative rotation, between in-line structures shall not exceed the serviceability limits of the structures for the design life of the structures.

2.7.17 Air Pressure

A minimum Air Pressure of +/- 2.5KPa shall be considered for Cut & Cover tunnel /NATM tunnel design

2.7.18 Loading Combinations

Each component of the structure shall be designed and checked for all possible combinations of applied loads and forces. The load factors and load combinations for ultimate limit states are specified in the Tables 2.4 below and for serviceability IS 456 to be adopted, whereas each component of the structure shall be designed / checked for all possible combinations

Load Combination	Dead Load (DL)		Imposed Load (IL)		Ground and Water Loads		Wind Load ⁷ (WL)	Seismic Load ⁴ (EQ)
	Adverse	Beneficial	Adverse	Beneficial	Adverse	Beneficial		
1. DL + IL	1.5	-	1.5	-	1.5	-	-	-
2. DL + EQ	1.5	0.9	-	-	1.5	-	1.5	1.5
3. DL + IL + EQ	1.2	-	1.2	-	1.2	-	1.2	1.2
4. Construction Stage(**)	1.3	-	1.3	-	1.3	-	-	-
5. Collision/Accidental	1.5	1.0	1.5	-	1.5	1.0	-	-

Table 2.4 Ultimate Limit State Load Combinations

Notes :

- 1 Load combination 4 will be used in checking temporary works proposals and checking the structure during temporary construction stages. The imposed load is the construction imposed load.
- 2 For checking structures at the Extreme water levels, the reduced partial factors of safety for water loads are to be 1.05.
- 3 Structural steel design load combinations and partial factors of safety for the design of structural steelwork are to be in accordance with IS 800 - Code of Practice for the Structural Use of Steel Work
- 4 Earthquake loads are reversible.
- 5 50% imposed load is to be used in line with the building mass calculated for seismic loads in load case 2 & 3.
- 6 Creep, shrinkage, temperature and differential settlement are not considered in combination with the lateral loads at ultimate limit state. Creep and shrinkage effects will usually be minor for building type structures, no specific calculation will be necessary for Ultimate limit state.
- 7 Wind load combinations are applicable for above-ground structures and shall be considered in addition to the other combinations.
- 8 Wind and earthquake load will not be considered to be acting simultaneously.
- 9 (**) For those structural members which are load bearing during the construction stage and subsequently form part of the Permanent Works , the Serviceability Limit State(SLS) checks shall be carried out both for "Construction" and "Service/Operation" stages.
- 10 For serviceability load combinations, IS 456 to be followed.

2.7.19 Design Conditions

- (1) The Contractor shall define the partial load factors and overall design factors of safety in accordance with the relevant Standards and Codes for the following four main conditions.
 - a) “Construction” - during and immediately after construction of the Works.
 - b) “Service/Operation” - during general operation of the completed facility.
 - c) “Accidental” - during “Construction and/or “Service/Operation” when unusual incidents, such as collision/derailment etc occur, which may alter loading conditions.
 - d) “Extreme” - during “Construction and/or “Service/Operation” when groundwater may rise to unusually high level.
- (2) The assumed partial load factors and overall design factors of safety for the four main conditions shall be included with the calculations to determine and design for the most critical cases as provided in his design submissions.
- (3) For ground loads on cut-and-cover structures, the worst combination (minimum and maximum) of lateral loading shall be considered for the Construction and Service/Operation condition.

2.8 Deflection Criteria

The deflection limitations imposed in IS 456 and IS 800 shall be followed for Concrete and Structural Steel elements respectively.

2.8.1 Vertical Deflection Limits

The deflection of a structure or part thereof shall not adversely affect the appearance or efficiency of the structure or finishes or partitions. The deflection shall be limited to the following.

- (1) Concrete structures
 - a) The final deflection due to all loads including the effects of temperature, creep and shrinkage and measured from the as-cast level of the, supports of floors, roofs and all other horizontal members, should not exceed span/250.
 - b) The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 millimetres whichever is less.

- (2) Steel structures

Designs shall comply with the limits defined in IS 800.

2.9 Design Groundwater Levels

2.9.1 General

The groundwater levels to be assumed in design for various stages or conditions shall be as follows:.

“Construction” – groundwater level at measured maximum elevation plus 1.5m.

“Service/Operation” – Maximum flooding level at 1 in 50 years plus 1.0 m .

“Accidental” – groundwater level at ground level

“Extreme” – Maximum flooding level at 1 in 50 years plus 2.0m

2.9.2 Flotation

- (1) The minimum depth of cover to underground structures shall be 2.0m or depth to the underside of major utilities (eg, sewer mains, storm water mains and the like) whichever is the greater.
- (2) For protection against flotation in the fully dry internal condition, the following shall apply.
 - a) A load factor of 0.9 shall be applied to the self-weight of the structure, including the first stage only of the track concrete.
 - b) A load factor of 1.0 shall be applied to the weight of backfill material over the structure.
 - c) The overall factor of safety against flotation shall not be less than 1.1 and 1.05 for any of the permanent and temporary stages respectively.
- (3) The Contractor shall check all proposed underground structures for the possibility of flotation due to differential water pressure and shall design each and every underground structure such that the factors of safety against flotation are achieved for all load cases.
- (4) The Contractor shall ensure that his method and sequence of construction is such that an adequate resistance to uplift is maintained at all times, and shall put forward his proposal to this effect.
- (5) Suitable measures such as those listed below to counteract flotation forces for the Permanent Works shall be incorporated in the Contractor's design. The measure(s) chosen shall suit the particular conditions and the method of construction;
 - a) Toeing-in of the base slab into the surrounding ground.
 - b) Provision of tension piles or provision of concrete shear keys between the RCC lining wall and surrounding Rock.
 - c) Increasing the dead weight of the structure by:
 - thickening of structural members; providing an extra thickness of concrete beneath the base slab tied into the structural base slab;
 - extending the excavation support walls;
 - providing counterweights in parts of the structure with high density material.
- (6) Where the base slab is toed-in to the surrounding ground, the following shall apply for flotation check:

- a) For cohesionless ground, such as sandy soils, a factor of safety of 2.0 or load factor of 0.5 shall be applied to the frictional resistance of the cohesionless ground strata above the toe. The cohesion factor shall not be considered.
 - b) For cohesive ground, such as clayey soils, a factor of safety of 2.5 or load factor of 0.4 shall be applied to the cohesion factor of the cohesive ground strata above the toe. The frictional resistance shall not be considered.
 - c) For hard ground (rocky strata) a factor of safety of 2.0 or load factor of 0.5 shall be applied to the shear resistance of the hard ground strata above the toe.
 - d) The value of the weight of ground (soil or rock) above the toe shall be calculated as for backfill material with a load factor of 0.9.
- (7) The value of the weight of any additional thickness of concrete shall take account of the increased volume of water displaced.

2.10 Civil Design Works

2.10.1 Excavation Base Stability

- (1) The Contractor's design shall include adequate precautions against base heave, piping and failure of his excavations during construction. The stability of the excavation bases shall be checked in accordance with an acceptable method of analysis which shall allow for all reasonable loads within and outside of the excavation.
- (2) The Contractor shall show in his calculations the contribution made to the base stability of the excavation by his proposed method of construction and shall state the factor(s) of safety used in the design. The factor(s) of safety shall relate to the method of construction and to the particular location of the Works, and shall be subject to the Notice of No Objection from the Engineer.

2.10.2 Excavation Toe Stability

- (1) The Contractor's design shall ensure adequate toe stability of retaining structure during construction. The toe stability shall be checked in accordance with an acceptable method of analysis which shall allow for all reasonable loads within and outside of the excavation.
- (2) The conventional approach based on active and passive pressures shall be preferred with a suitable factor of safety in consultation with Engineer.

2.10.3 Waterproofing

- (1) All the underground structures shall be designed as un-drained structures i.e. the groundwater shall not be allowed to drain into the structures. Groundwater leakage rates into the completed Permanent structures shall be limited to damp patches only and shall not under any circumstances exceed a overall value of 0.1 litres/m²/ day, over a given area of structure and a value of 0.2 litres/day on any separate square metre area of the structure.

- (2) The quality and grade of the concrete, treatment of construction joints, areas of slab pours and external waterproofing membranes shall be chosen such that the required standard of waterproofing can be achieved and maintained. Waterproofing membrane shall be provided to base slabs of all cut-and-cover structures and to walls where the structure is built in an open excavation or by bottom-up method.
- (3) An external waterproofing membrane shall be provided over the roof of the structure so that the roof of the permanent underground structure is completely watertight.
- (4) Detailing of structure shall include provision of splays, chamfers and fillets as appropriate to facilitate the laying and performance of waterproofing membranes.
- (5) Materials for expansion joints, caulking, grouting and the like shall have acceptable fire performance for use on an underground metro system.
- (6) Exposed diaphragm walls (or permanent walls) in cut-and-cover structures shall be rendered or shotcrete and troweled, as necessary, to provide a uniform finish without distinct changes in colour or line. All rendered or shotcrete walls shall be provided with a controlled drainage system to direct any seepage permitted under the Contract to the floor drainage system.

2.10.4 Water Control in Excavations

- (1) During construction in water-bearing ground, seepage water shall be controlled by suitable means and the design shall provide for the same. The Contractor shall obtain the Engineer's prior Notice of No Objection to the process he intends to adopt to control groundwater inflow, and the treatment and disposal of any groundwater collected.
- (2) The piezometric pressure outside of the excavations shall at all times remain within the normal expected groundwater variation and permissible safe limits of groundwater drawdown as brought out by the Contractor in his EBS investigation and study report to limit the ground movement and distortions to protect the EBS and restrict the EBS damage to be within the permissible limits as per the provisions/stipulations of the Contract. In any case the Groundwater table shall not be allowed to get lowered by more than two (2) metre below the lowest recorded groundwater table (the lowest recorded groundwater table shall be considered as the lowest level of groundwater table as recorded by the Contractor prior to the construction). The Contractor shall be responsible for all local authority approvals required for his groundwater control methods.
- (3) Notwithstanding the limits on groundwater leakage rates, the design shall aim to ensure that no loss of ground or groundwater occurs through any part of the structure.

2.10.5 Underpinning of Existing Building Structures (EBS)

- (1) Where the construction of bored tunnels or other underground works necessitates the removal of existing support or foundations to existing buildings, structures, utilities, services, wells, pavements, road furniture and the like (collectively termed EBS) the Contractor shall carry out investigations on the extent of the existing works, their design and loading conditions.
- (2) The Contractor shall design and carry out such works as are necessary to maintain the integrity of the EBS at all times including their entire design life, at no extra cost (no extra payment to the Contractor) to the Employer. No work shall commence prior to the Notice of No Objection of the Engineer being given. Cost of design and provision of any support/strengthening of such structures will be deemed as included in the Contractor's Contract Price.
- (3) For EBS protection, refer to Section 3, Geotechnical and Bored Tunnel of this Outline design specification.

2.10.6 Drainage and Flood Protection

All openings into the Metro Rail Structures shall be located above the 1 in 50 year flood level plus an allowance for a 0.5m rise in sea level as applicable. In general structures located on flat land shall have a minimum flood protection of 1.2 metres above the surrounding ground level. This may be achieved with a combination of steps up into entrances and removable flood boards. The Contractor shall be responsible for design and provision of flood boards, as may be required.

2.10.7 Seepage Barriers

- (1) The Contractor shall provide seepage walls or barriers to all external underground walls that lie within public areas, staffrooms and plant-rooms, except for Pump, Environmental Control System and Tunnel Ventilation rooms, shafts and plenums. In the public area, the seepage barrier may be provided by either a finished wall with air gap behind or by architectural finishes mounted on framing attached to the external wall. In non-public areas a block or brickwork wall shall be provided. In all cases the Contractor shall design the seepage gap with a seepage drainage channel such that discolouration or water damage to the seepage walls cannot occur. Access panels to inspect and maintain the drains shall be included. All such finishes, panels and fixings and the like shall be non-corrodible and comply with the Contract design life requirements.
- (2) At platform level in the stations, the visual aspect of the platform walls must be aesthetically pleasing and exposed diaphragm walls/secant pile walls (if any) must be provided with a surface which will give a uniform finish without distinct changes in colour or alignment. All external trackside diaphragm walls/secant pile walls (if any) must be either rendered or shotcreted or provided with another finish which has Notice of No Objection by the Employer/E.

2.11 Temporary Works

2.11.1 General Principles

- (1) In general Temporary Works shall be designed in accordance with the same design standards as the Permanent Works. However, Temporary Works design may take into account the limited duration over which such temporary works are expected to function. The calculations and drawings shall make clear where provision for limited duration has been allowed for, particularly where this may have a substantial influence on the stability of the Temporary Works.
- (2) The design of Temporary Works shall take account of all the applied external forces and imposed structural deformations and, where applicable, the effects of removal of load from the ground.

2.11.2 Design of Temporary Excavation Support

- (1) Excavations for cut-and-cover structures in soft ground shall be supported by diaphragm walls or secant piles walls which may be incorporated into the Permanent Works. Design of these elements shall include full step-by-step analyses of the progressive change in the loading (including deflections of these elements and the resultant settlements/distortions of the ground surface) and required temporary support conditions as the excavation proceeds and subsequently as these temporary elements are integrated into the Permanent Works.
- (2) Braced/anchored excavations shall be analysed by finite element or similar methods in which the changes in ground stresses are properly related to the deflections which occur in the structural elements, by the use of appropriate stiffness and other parameters. Relevant empirical evidence from similar excavations must be referred to in support of the conclusions of the analyses. Simplified analytical models and methods shall be employed to calibrate and support finite element analyses of the various permutations of structure geometry and loading.
- (3) Temporary works shall be designed as far as possible to be removed when no longer required, and shall not be left in the ground. Temporary works which are viewed as being impossible to remove on completion of the Permanent Works shall be dismantled to a minimum depth of 2 metres below the finished ground surface and designed so that there will be no risk of ground settlement or other deleterious effects as a consequence of decay and/or collapse of these Temporary Works.

2.11.3 Ground Movements

- (1) In accordance with Section 3, Clause 3.5 of this Outline Design Specification of this Contract, the Temporary and Permanent Works designs shall limit ground movement and distortions around the site and to avoid damage to adjacent EBS.
- (2) The Contractor shall carry out a risk assessment for all EBS within the

influence zone of the Works in accordance with section 3 of Outline Design Specification. The analyses for the Temporary Works shall be properly related to the conclusions of this risk assessment.

2.11.4 Construction Dewatering

- (1) Temporary dewatering of construction excavations will be required to provide an undisturbed, stable and dry subgrade to permit construction and backfilling of the Permanent Works under dry conditions.
- (2) In general, the groundwater within the excavations shall be maintained at a level that permits achievement of the above and avoids heave, piping or base failure of the excavation.
- (3) Temporary dewatering methods (including recharging methods, if required) and system operations, along with other required temporary works, shall not lower the groundwater outside the walls supporting the excavations, nor result in undue settlement, distortion or loss of ground at adjacent EBS. In this respect, all the provisions/stipulations of the Contract pertaining to the permissible limits of groundwater table drawdown and protection of EBS (limits of EBS damage) shall be fully complied with.
- (4) The Contractor shall prepare and submit his design of his construction dewatering system (including recharging system, if required) to the Employer/ Engineer for his Notice of No Objection. The construction dewatering design shall include determination of subsurface conditions and geotechnical design parameters, analyses to establish feasible methods, and system definition in sufficient detail to demonstrate that the general objectives can be achieved without adverse effect on adjacent EBS. The selected system shall generally provide for continuous (24-hour-per-day) operation, adequate reserve equipment, and standby power.

2.11.5 Ground Improvement

- (1) Ground-improvement may be required along certain alignment segments of the Contract to control ground and EBS movement and distortion that may be induced by excavation and tunnelling and at tunnel break-in/break-out locations, in advance of bored tunnel excavation.
- (2) The Contractor shall prepare and submit his designs and method statements supported by analysis for all ground improvement to the Engineer for his Notice of No Objection. These designs shall define performance objectives for the ground improvement
- (3) Instrumentation, monitoring and reporting details for verifying achievement of ground improvement performance objectives in accordance with Outline Design Specification, section 3, Clause 3.4 shall be included in the ground improvement design submission.
- (4) The information and assumptions on which the ground improvement is based shall be shown on the design drawings.

2.12 Connection Details

2.12.1 Corners

The Contractor shall pay particular attention to corner joints of large structural members. External wall/slab junctions shall be provided with crack control steel and transverse ties. Radius of bend of main tension bars shall be increased to cater for the high bearing stresses within the bend.

2.12.2 Construction Joints

The design and detailing of construction joints shall be sufficient for the proposed works and the construction joints shall be minimised to reduce the risk of leakage.

2.12.3 Slab to Wall Connections

For top-down construction in particular, attention shall be paid to the practicalities of the design and detailing of the slab to wall connections and the means by which the integrity of the construction joints at these connections will be assured.

2.12.4 Connections between Bored and Cut-and-Cover Structures

- (1) Where bored tunnels connect to cut-and-cover structures, this joint shall be designed and completed by the Contractor for the cut-and-cover structure. The design of this connection joint shall consider the possibility of differential movement during both construction and in-service.
- (2) The differential movement between the bored tunnel and cut-and-cover structure shall be sufficiently small so as not to cause overstressing of this joint which shall be designed to permit an appropriate degree of movement in all directions. Particular attention shall be paid to the waterproofing detail, to ensure that the water-tightness of this joint is not inferior to the standard joint between precast tunnel segments.

2.13 Instrumentation

For instrumentation of cut & cover structures refer to Outline Design Specification, Clause 3.4, Section 3.

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 VII - Outline Design Specifications

S.03 Geotechnical, Bored and NATM Tunnels

June 2018

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3 GEOTECHNICAL, BORED AND NATM TUNNELS

3.1 General

3.1.1 Purpose and Scope

- (1) This section of these Outline Design Specifications covers the design of the geotechnical, bored tunnel and NATM Tunnel works in this Contract.
- (2) The purpose is to establish the minimum requirements for the investigations, design, instrumentation and monitoring for the geotechnical, bored tunnel and NATM Tunnel works in this Contract.

(3) Definitions

"Geotechnical works" shall mean ground investigations, foundations, earthworks, deep excavations, slopes, embankments and earth-retaining structures, instrumentation and monitoring and reporting for the Works and protection to EBS
"EBS" shall mean all existing buildings, structures, services, utilities, railways, wells, pavements, slopes, street furniture and the like.

"Bored tunnel works" shall mean all underground works that are constructed by TBM/Shield Machines beneath and enclosed by the ground surface.

"NATM works" shall mean all underground works that are designed & constructed with the principles of New Austrian Tunnelling Method using cyclic sequence of excavation with installation of supports [pre-support/temporary support/ primary support/ permanent (final) support] and are beneath & enclosed by the ground surface.

3.1.2 Standards and Regulations

- (1) The requirements of the standards, codes and regulations listed in Section – Standards and Rail Geometry of this Outline Design Specifications shall apply, unless amended by these Outline Design Specifications.
- (2) The version of the standards, codes, and regulations shall be the latest version and with latest amendments issued up to the date of submission of the tender.

3.1.3 EBS Protection

- (1) The Contractor shall minimise the induced loads, and total and differential deflections (angular distortion) of the ground surface and EBS above or below the ground surface that may result from the Works. The impacts of construction shall be so limited as to not affect the operation of the EBS, road and pavement.
- (2) "green-field" condition shall be considered in determining the total and differential deflections of the ground and EBS.

3.2 Ground Assessment

3.2.1 General Ground Conditions

- (1) The Contractor shall be responsible for determining the geology, ground conditions, hydrogeology and geotechnical design parameters for his proposed construction area.
- (2) The regional geology for the area are generally documented by the Geological Survey of India.
- (3) The Employer will make available to the Contractor, for information only, geotechnical information he has collated – Reference Document. The Contractor

shall supplement this information to the extent necessary to ensure that all his construction will satisfy the Employer's requirements, specifications and conditions as set out in the Contract.

- (4) The soil investigation undertaken by the Employer shall not be relied upon to provide adequate information concerning the nature of the ground to enable the Contractor to fully develop comprehensive method statements for geotechnical, bored tunnelling, NATM tunnelling and cut and cover works, and related activities. In preparing his designs and method statements, the Contractor shall carry out his own assessment on the adequacy of the available geotechnical information, and shall indicate where he considers such information to be deficient having regard to the particular works or activities to which the design or method statement relates.
- (5) The Contractor shall at his own expense conduct further soil investigations/ site investigations/ geotechnical investigations/ ground investigations / geological investigations/ hydro-geological investigations, where his designs or method statements identify that it is necessary or prudent to do so. This is to enable the Contractor to identify all reasonably foreseeable circumstances which may affect the execution of the Works and to ensure that there is no likelihood of meeting unexpected conditions of a critical nature.
- (6) The Contractor shall compile a list of risks expected in his Risk Register and submit this to the Engineer together with his proposed designs along with the proposed mitigation measures to eliminate such risks.
- (7) If the Contractor intends to carry out additional ground investigations from the surface, beyond the limits of the Works areas, he shall make his own arrangements with landowners and occupiers for the necessary access. He shall not assume that such access will necessarily be granted. The Engineer will provide assistance where such additional investigation is deemed to be to the benefit of the Works. If surface access for ground investigations is not available, or if for any other reason there is a significant likelihood of encountering geological hazards whose location is unknown, the Contractor shall identify in his method statements the means by which such hazards will be identified as the construction proceeds. The Contractor shall also identify how his geotechnical, bored tunnel, NATM tunnel and cut-and-cover structure design and construction activities will be modified to recognise any deficiency in the ground information prior to construction.
- (8) Detailed seismic loading and ground-acceleration criteria are discussed under Loads and Requirements of these Outline Design Specifications. Consideration of design-level seismic forces in the design of temporary structures is generally not required, except at locations, to be agreed by the Engineer, where public safety and loss/ damage to adjacent properties/Structures might be involved. At such locations, the effects of the design seismic event on the stability of excavations, the performance of the proposed structures and on the potential for liquefaction of soils shall be taken into account in the design.

3.2.2 Site Investigation Requirements

- (1) The intent and objectives of the additional site investigations shall be to collect all pertinent and reliable data and information required to produce a safe and durable design and also to meet all the Contract requirements.

- (2) For the purpose of these Outline Design Specifications, site investigation shall be considered to include, but not be limited to, the following.
 - a) Compiling and reviewing pertinent existing geological data.
 - b) Compiling and reviewing pertinent existing geotechnical data supplied and from the vicinity projects.
 - c) Compiling and reviewing pertinent existing foundation, structure, substructure, utilities and other related data from the vicinity projects.
 - d) Performing a detailed field reconnaissance.
 - e) Performing geophysical surveys/investigations.
 - f) Performing ground investigations that include, but are not limited to drilling, soil sampling, rock coring, groundwater sampling, in-situ field installations and testing, trial pits, soil stripping, rock mapping and cored holes in EBS, where appropriate.
 - g) Performing laboratory testing on soil, rock, and groundwater samples collected from the ground investigations, including chemical testing to identify potentially corrosive conditions and/or contamination that may be a threat to public and durability of works.
- (3) As a minimum, the site investigation programme shall consider the locations and lateral and vertical extent of the following.
 - a) Major existing structures such as viaducts, bridges, flyovers, underpasses/subways and crossing structures, underground water and sewage treatment plants, water tunnels, bored tunnels, NATM tunnels, cut-and-cover tunnels, portal structures, retaining structures, commercial developments, ancillary structures and the like.
 - b) Earthworks such as soil and rock excavations, embankment fills, land reclamations, areas requiring ground improvement, borrow pits and areas, disposal areas and the like.
 - c) Existing adjacent structures that may be influenced by proposed construction works. That is, structures adjacent to, above, or below excavations or tunnels that may be affected by construction works such as dewatering or blasting; structures deemed to have poor structural integrity; structures containing sensitive equipment or materials, structures with heritage/historic/cultural significance and the like.
 - d) Significant engineering geological features that may influence the proposed construction works. That is, major/principal faults, shear zones, persistent jointing; mass wasting, old landslips and the like.
 - e) Electrical Earthing.
- (4) All EBS, including private water supply wells/tube wells.
- (5) Ground investigations (GI) as part of a comprehensive site investigation programme, shall be conducted in accordance with IS1892 and BS 5930. The extent of such GI shall be consistent with the form, type and extent of the proposed construction works unless otherwise agreed with the Engineer.
- (6) All aspects of the Work shall be conducted under the direction of qualified geotechnical personnel. Detailed plans, technical specifications, and standard

forms, outlining the proposed staffing and reporting formats, and indicating the types, locations, and proposed depths of ground investigations relative to the proposed Works shall be prepared and submitted to the Engineer for seeking his Notice of No Objection prior to undertaking any such work. Any and all revisions to the site investigations and GI programmes shall be submitted to the Engineer for seeking and obtaining his Notice of No Objection.

- (7) All GI data shall be prepared in accordance with IS/BIS and internationally accepted standards using Association of Geotechnical and Geo-environmental Specialists (AGS) format or equivalent and Geotechnical Integrator (GINT) software, latest versions. All data shall be provided in both printed and electronic file formats.
- (8) Prior to any investigation in any area the Contractor shall obtain all approvals from the Relevant Agencies/Authorities and determine the locations of any services or utilities that may be damaged by the proposed GI. The Contractor shall comply with the requirements of all Agencies/Authorities and protect any and all utilities and services from damage that may result from his GI.
- (9) Additional drill-holes, tests and the like shall extend a minimum depth of 6 metres below the underside of the proposed structures (tunnel – 6m below invert level and Cut & Cover Structure – 6m below base slab bottom) and preferably not directly on the line of the tunnels. The additional GI should result in investigation spacing no greater than 50 metre centres for the whole of the route, and not less than twelve per station and in addition to borelogs drilled for tunnel two per cross-passage. Additional GI should also be carried out where unusual features have been identified such as deep weathering of the rock, high piezometric pressures, loss of drilling fluid or very weak ground, and the like.
- (10) Drill holes of dia 300mm and less made for any purpose along the alignment shall be filled (plugged in) with grout of M25 grade, whereas the concrete grout can be allowed for hole dia more than 300mm to the satisfaction of Engineer.

3.2.3 Investigation Methods

- (1) Geological studies
 - a) Geological studies shall include, but not be limited to, a review of pertinent and existing literature, aerial photographs, and remote-sensing data; a detailed field reconnaissance of the site; and preparation of project-specific maps and cross-sections.
 - b) Project-specific geological plans and cross-sections shall be prepared to 1:2000 scale, for both horizontal and vertical directions. The geological plans shall be overlain on suitable base plans which show relevant features such as survey grid, roads, selected EBS and the like.
- (2) Geophysical surveys/Investigations
 - a) Geophysical surveys/investigations shall be carried out where appropriate to provide additional site-specific information on depths and characteristics of overburden soils and bedrock.
 - b) Geophysical (e.g., seismic refraction, reflection, Side acting shear wave, resistivity, magnetometer, gravity, and the like) surveys/investigations may be used to obtain subsurface information for planning other detailed GI studies, and for extending information between other investigation positions. All such

geophysical surveys/investigations shall be calibrated by appropriate absolute GI methods such as drilling, Cone Penetration Tests (CPT), test pits and the like.

(3) Exploratory drill-holes

Exploratory drilling in soil and rock, disturbed and undisturbed soil sampling, and rock coring shall be performed according to procedures outlined in IS 1892 and BS 5930. Full-time monitoring by qualified geotechnical personnel is required to direct the drilling, sampling, and coring, and also to prepare field records for these drill-holes.

(4) Other ground investigation methods

Other GI methods to be employed shall include, but are not limited to, the following.

- a) Field testing: Standard Penetration Tests (SPT), Cone Penetration Tests (CPT) with pore pressure measurement (CPTu) or with seismic cone (CPTz), in-situ vane shear, pressuremeter, permeability tests, water absorption tests, impression packer or/and discontinuity surveys, acoustic borehole imaging, in-situ density, plate load testing, point load tests, "cover-meter" and the like.
- b) Field instrumentation: standpipes, piezometers, inclinometers, extensometers and the like.
- c) Test pits with and without the recovery of "disturbed" and "undisturbed" samples.
- d) Inspection pits.
- e) Hand-auger bores.
- f) Coring through rock, earth retaining structures or other manmade features.
- g) Vibrocoring.
- h) In-situ (constant or falling head) permeability tests.
- i) Packer tests for rock permeability and/or rock jointing.
- j) Pumping tests.
- k) Groundwater sampling for chemical testing.

(5) Groundwater

- a) Standpipes and piezometers shall be installed during ground investigations to measure current and seasonal fluctuations in groundwater levels. The GI programme shall incorporate the details of a groundwater observation plan, including locations and details of standpipe/piezometer installations and frequency and duration of observations. The GI programme shall also include chemical analysis of groundwater.
- b) Where necessary, full-scale groundwater pumping tests deemed shall be conducted to develop design parameters for construction dewatering schemes.
- c) Groundwater information shall be interpreted, and recommendations for design groundwater levels, including variation of levels that may develop across structures during Construction and subsequent Rail Operations shall be provided by the Contractor.

(6) Environmental Testing for Soil and Groundwater Contamination

- a) Areas with potential land contamination concerns or suspected historical contamination, once identified in the assessment, shall be investigated for contamination.
- b) Soil/rock samples shall be collected at different depths using ground investigation methods such as trial pits, auger bores or other soil/rock boring methods. Groundwater monitoring wells shall be set up for the collection of groundwater samples.
- c) Care shall be taken to avoid cross-contamination and degradation of samples. All samples shall be, sealed in properly labelled air-tight containers and stored in a shaded, air- and moisture-tight store, the storage area of which shall be maintained at constant temperature and humidity in accordance with the standards.
- d) Unless otherwise permitted all such samples shall be tested within one week of having been obtained.

3.2.4 Laboratory Testing Methods

(1) General

The Contractor shall develop a laboratory testing programme which allows for the particular site conditions, project/Contract requirements and the applicable design standards, codes, regulations, and related publications as identified in these documents.

(2) Preparation and submission of information

All laboratory test data shall be prepared using the latest version of AGS format. All data shall be provided in both printed and electronic file formats. All testing shall be conducted by laboratories holding current accreditation under International Standards Organisation/Bureau of Indian Standards

(3) Soil testing

- a) Index/classification soil tests shall comprise; natural moisture content, specific gravity, particle size distribution (with and without hydrometer grading), Atterberg limits, bulk and dry density, dry density and moisture content relationships, and shrink-swell limits, where applicable.
- b) Strength testing shall include: single- and/or multi-stage, consolidated-drained and consolidated-undrained (with pore pressure measurement) triaxial tests; unconsolidated undrained triaxial tests; on “undisturbed” samples of diameter not less than 70 millimetres: vane shear tests on retrieved undisturbed samples.
- c) Consolidation testing shall include one-dimensional, consolidation or Rowe cell tests on undisturbed 60 to 100 millimetre diameter specimens.
- d) Soil permeability tests shall include constant-head and variable-head permeability tests performed using either a permeameter or triaxial cell.
- e) Chemical tests for soil and groundwater shall include determinations of resistivity, redox potential, acidity (pH), chloride ion content, sulphate ion content, total sulphate content, total sulphide content, organic content, and carbonate content and identification of other potentially corrosive conditions.

(4) Rock testing

Rock testing shall include water content, porosity, density, water absorption uniaxial compressive strength testing of intact rock core, triaxial strength testing of discontinuities (using Hoek cell or appropriate shear box), Brazilian tensile test, abrasiveness (Cherchar tests) and description of the rock (especially bound and unbound quartz content) based on evaluation of petrographic thin sections prepared for representative rock specimens.

(5) Environmental testing

Environmental testing of soil and groundwater samples shall test for potential contaminants such as; heavy metals, volatile organics, semi-volatile organics, pesticides, petroleum hydrocarbons, polychlorinated biphenyls, cyanide and other chemicals of concern.

3.3 Instrumentation, Monitoring & Reporting

3.3.1 General

- (1) The Contractor shall instrument, monitor and report on ground and EBS movements and distortions, groundwater levels, stresses and displacements in the excavation and lateral support systems, structural movements during construction to validate and check his predictions.
- (2) Monitoring shall be carried out on a case-by-case day-to-day or more frequent basis depending upon the importance of the EBS and/or the risk of damage to that EBS. Special attention shall be paid to the heritage/historical buildings, sensitive structures and wells located along the alignment.
- (3) Monitoring shall begin prior to commencement of the Works to enable instrument base-line values to be determined accurately, and shall continue until all movements and distortions to the ground and EBS, and changes to the groundwater table that might be attributed to the Works, as shown by the monitoring, have effectively ceased for a period of three months.
- (4) The Contractor shall submit a complete comprehensive instrumentation, monitoring and reporting scheme with his Design and prior to any construction which is designed to achieve the following.
 - a) To establish typical background movement, distortion, groundwater fluctuation, and noise and vibration limits for the ground, groundwater and EBS prior to commencement of the Works.
 - b) Protection to all parties during and after the construction by providing early warning of any excessive and undue movement and distortion of the adjacent ground and EBS.
 - c) To provide movement and deformation information for design verification of the Temporary and Permanent Works.
 - d) To ensure that the maximum allowable tolerances associated with various structures/elements within the zone of influence of the Works are not exceeded.
 - e) To confirm that groundwater drawdown outside of the excavations does not exceed the expected fluctuation limits
- (5) 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 Relevant Fire/Life Safety/any other Agencies/Authorities, 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.

3.3.2 Additional Requirements for NATM Works

- (1) General : The Contractor shall submit a complete comprehensive instrumentation, monitoring and reporting scheme with his Design and prior to any construction which is designed to achieve the following
 - a) Safety during and after the construction by providing early warning of any excessive and undue ground movement inside the tunnel.
 - b) To provide deformations and loading data for the verification of initial design of the initial and final support of the tunnel.
 - c) To provide information about tunnel behaviour in order to optimize excavation and support activities during construction
- (2) Special requirements
 - a) The instruments shall be installed at locations and in accordance with a time schedule as per approved scheme or at vulnerable locations encountered during excavation.
 - b) The geotechnical instrumentation and the monitoring program may be subject to alterations and modifications if required by the actual geological or geotechnical conditions.
 - c) All instrumentation shall be installed in accordance with the manufacturer's recommendations and with the additional requirements specified in this document.
 - d) The installed measuring equipment as well as the required space for measuring must be kept free and accessible for all the duration of construction.
 - e) All instruments shall be protected against damage by blasting and tunnel traffic. Where required protective covers or housings may be used to prevent damage of the instruments.
 - f) Readout units as dial gauges or tape extensometers shall be available at any time during tunnel construction. Spare parts and spare units shall be maintained on site.
 - g) All instruments and equipment used and required for the geotechnical measurements shall be made available for the inspection/verification of The Engineer throughout the construction period.
- (3) Reading and plotting data
 - a) Reading of the instruments, data processing and plotting of the measurement results shall be carried out by qualified personnel of the Contractor as approved by the Engineer.
 - b) For the optical displacement monitoring a software package shall be used which allows a direct data flow. This software shall include features as follows:

- Free stationing of the theodolite and calculation of standard deviation in all three coordinate directions.
 - Automatic target identification and recognition of new zero readings.
 - Calculation of 3D-coordinates and displacements of any desired point and its radial distance to the theoretical profile.
 - Correction of errors based on physical effects.
 - Transformation of coordinates after control measurements.
 - Measurement results shall be tabulated and presented in graphs.
- c) The software processing the data shall include following features:
- Development of displacements with time, directly associated with tunnel driving activities.
 - Plot of displacement vectors within the cross section.
 - 3D Displacement vector orientations
 - Excavation program related evaluation and presentation of displacements (Influence lines showing the influence of daily excavation on displacements of measuring points).
 - Assessment of displacements prior to zero measurement.
 - Development of differences in displacement with time e.g. roof settlement minus settlement of top heading footing.
 - Calculation of stresses and safety factors or degree of utilisation for the shotcrete lining based on optical displacement monitoring, and time dependent shotcrete strength.
 - Other evaluations as required by the Engineer and the Designer.
- d) For the monitoring of geotechnical instruments a software package shall be used which allows a direct data flow. This software shall include features as follows.
- Presentation of data related to the time and excavation progress within one plot.
 - Cross-sectional visualisation of measuring anchor and extensometer data.
 - Multiple plot capabilities (Forces/Radial strains in rock mass/ displacements).
 - Shotcrete stress calculation based on strain measurements and material law for young shotcrete as tested in situ.
- e) The first measurements (zero-readings), for each measuring instrument, shall be made immediately after installation or as soon as the particular instrument may allow.
- f) The frequency of the further measurements or readings can be envisaged for each measuring section as follows:
- 1st week: daily
 - 2nd week: twice a week
 - 3rd & 4th week: once per week

- Later: monthly and bi-monthly
 - When the bench is approaching the instrumentation section installed during top heading, reading frequencies shall be increased again.
 - The actual frequency of readings will however be influenced by the construction stages i.e. top heading/bench heading in the tunnel and shall be proposed by the Designer through Contractor.
- g) Data of the optical displacement monitoring shall be processed on the same day and plots shall be available at late afternoon or as requested by the Engineer. Other data from measurements must be processed within 24 hours after the readings have been taken and must be plotted. All processed data and visualised diagrams must be available for the Engineer scrutiny at any time. A copy of all records shall be permanently kept on site and made available to the Engineer. If required the Engineer may instruct shorter data processing and visualisation time.
- h) The Contractor has to immediately inform the Engineer in case he observes obvious unusual and unexpected readings or makes other unusual observations in the tunnel.
- (4) Methods of data evaluation and interpretation
According to their geo-mechanical relevance, the main monitoring parameters for tunnelling shall be as follows:
- a) Time – Displacement Diagrams, Magnitude of Displacements
Time-Displacement diagrams shall show the development of the displacement of one point versus time. Time-displacement diagrams shall be generated for all three components of the displacement vector (vertical, horizontal and longitudinal displacement). Construction phases (top heading, bench, and invert) shall be shown on the same diagram to allow for an easy correlation between displacement behaviour and construction activities.
 - b) Distribution of Displacement Vectors in Cross-section
Displacement Vector plots shall allow the representation of the cross sectional displacements and their development with time. Displacement vector plots shall allow the detection of weak zones and / or faults outside the excavation area. They shall provide additional information about the rock mass structure and deformation phenomena close to the tunnel.
 - c) Lines of Influence
Lines of Influence shall be produced by connecting displacement values of a number of monitoring points along the tunnel axis at the same time, similar to a “deflection curve”. Normally, a number of lines for a specified time span shall be shown on one plot. In addition, construction phases (top heading, bench and invert) shall be shown to allow for an immediate correlation between measured displacements and construction activities
 - d) Trend Lines
Trend lines shall be generated by connecting settlement values of individual lines of influence at a predefined distance behind the face.
 - e) Development of Longitudinal Displacements close to the excavation face:
This shall indicate changes in ground stiffness ahead of the face.

- f) Trend of advancing displacements due to bench excavation:
This shall reflect the influence of individual bench excavation steps on the already excavated tunnel sections.
- g) Development of Differential settlements :
This displacement option shall be used to show the difference in displacements between two monitoring points belonging to the same monitoring section.
- Usually the difference in settlements shall be displayed between:
Crown & side wall ($S_{\text{crown}} - S_{\text{sidewall}} = \Delta S$)
 ΔS for both side walls shall be observed.
 - And for horizontal displacements between:
Left and right side wall ($H_{\text{left}} - H_{\text{right}} = \Delta H$)
- (5) Control limits for Trigger (Alert, Action & Alarm) levels shall be defined by the Contractor for the monitored parameters (including the control parameters) based on the design and anticipated ground behaviour and support performance.
The examples of control parameters are:
- Displacement velocities derived from 3D absolute displacement monitoring
 - Differential Settlements
 - Trend Lines (increase in displacements corresponding to face advancement)
 - Shotcrete strains derived from strain measurements with shotcrete strain meters in the shotcrete lining.

3.3.3 Limiting Construction-Induced Vibrations at adjacent EBS

In the design, the effects of construction-related vibrations shall be considered. Unless otherwise accepted by the applicable government agencies and the Engineer, peak particle velocities at adjacent EBS shall not exceed the values in the Table below:

Peak Particle Velocities in mm/sec (Max. Allowable) at Adjacent EBS

Structures	Velocity Mm/sec
Most structures in "good" condition	25
Most structures in "poor" condition	5
Most structures in "fair" condition	12
Water-supply structures	5
Heritage structures/bridge structures	5

Above limits are maximum permissible, however this may have to be restricted further if required to avoid damage to the adjacent EBS or causing discomfort to the occupants. Along the proposed alignment, other limitations may be imposed at adjacent EBS, such as hospitals, school buildings, telephone-exchange structures, special water- supply structures and Heritage structures etc.. In addition working hours for such equipment causing vibrations may have to be restricted, keeping the convenience and comfort of the occupants in mind.

3.3.4 Submissions

- (1) The Contractor shall submit his designed instrumentation, monitoring and reporting scheme to the Engineer for seeking his Notice of No Objection. This scheme shall be designed to achieve the objectives stated in this document.
- (2) In order to complete the above scheme the Contractor shall refer to the information provided with the Contract documents and supplement this with his own GI as required by the Contract. This scheme should give due emphasis to the information provided with the Contract documents and shall include following, as a minimum.
 - a) Ground conditions including the geotechnical properties of the different soil and rock layers.
 - b) Adjacent EBS within the zone of influence including their existing condition and foundations as available.
 - c) Proposed method of construction, and the type of equipment proposed.
 - d) Assumptions and calculations for the basic design including the installation of appropriate instrumentation for monitoring and recording ground and groundwater movements, settlements & displacements, deflections, tilts , rotations, distortions, cracks, Performance of tunnel ground support(both in bored and NATM tunnelling works), pressures, loads/stresses & strains (including that in structural elements for the support of excavations and tunnel supports) and the like.
 - e) Proposed types of instrumentation, locations (including that of monitoring sections along with their types and details in NATM works) of and programs for establishing the base readings and continuous observations.
 - f) Proposed methodology for installation (including proposed installation programme & procedures, Quality Assurance Plan along with proposed tests for quality control, Site organization plan for deployment of Contractor's personnel), calibration (including function testing and acceptance tests), maintenance and operation/running (including Data Collection/ Data transfer systems; type and presentation of output to be produced by the Contractor) of the instrumentation system, including location of gauge houses, proposals for de-airing of piezometers and any other special requirements.
 - g) Frequency of the monitoring/data recording
 - h) Trigger (Alert, Action & Alarm) levels for each and every instrument and each and every parameter to be monitored.
 - i) Frequency of reporting monitoring records to Contractor's construction site staff and to the Engineer.

- j) Possible preventive and remedial measures to be adopted to ensure that the trigger levels are maintained within acceptable limits.

3.3.5 Types of Instrumentation

- (1) The types and quantities of geotechnical instrumentation shall be proposed by the Contractor, for the acceptance of the Engineer. Instruments of robust nature shall be used which are capable of giving reliable data to within the manufacture's tolerances over long periods of measurement.
- (2) The Contractor shall establish suitable temporary bench marks for the purposes of monitoring vertical movements. Such bench marks shall be outside the zone of influence of construction.
- (3) Precise levelling points shall be provided on monuments at ground level to extend throughout the area where predicted settlement is expected to exceed 5 millimetres.
- (4) Precise levelling studs (road nails) shall be installed on highway (on Roads) and pavement areas in array at 90 degrees to the tunnel alignment. These arrays shall extend to the outer edges of the 5 millimetres predicted settlement contour lines. Suitable monitoring points which cannot be readily disturbed shall be installed over open/park areas.
- (5) Precise levelling shall be carried out of survey monuments and of settlement monitoring points on EBS sufficient to determine the imposed strain. Where the structures are subjected to protective works, electro-level beam systems shall be employed, with a back-up system relying on the use of precise levelling pins also installed.
- (6) Precise levelling points/ devices are to be provided for levelling of the tunnel crown and other specific points (side walls etc.) during tunnel excavation to monitor settlements and bottom heaves.
- (7) Piezometers (vibrating wire, pneumatic, Casagrande and standpipe) are to be provided in the ground for measuring changes in piezometric pressure at different depths. The type of piezometer required will be determined by the anticipated response times.
- (8) Inclinerometers, strain gauges and extensometers in the ground and within diaphragm walls/secant piling wall (or retaining structures) are to be provided for measuring lateral displacements. The depth of the instrumentation in the ground shall extend beyond the influence zone of the Works with respect to ground movement and excavations and shall be fixed at least 1 metre below the bottom of the diaphragm wall/secant piling wall (or retaining structure). In case diaphragm wall/secant pile wall (or retaining structure) which has terminated above the final excavation level then the inclinometer shall extend at least 1m below final excavation level and/or into a hard stratum where there is no ground movement. Inclinerometer for slope stability shall be provided. The depth of the instrument for slope stability shall extend at least 1m below the final excavation level and/or into a hard stratum where there is no ground movement.
- (9) Extensometers and convergence bolts are to be provided to measures convergence at tunnel openings or at any other critical sections. Borehole extensometers shall be provided in soft grounds to monitor heave and vertical

deformations with depth.

- (10) Load cells shall be installed at selected struts and anchors in excavations to enable design predictions to be verified and to monitor performance.
- (11) Targets (Reflectors) shall be provided for determining 3D-coordinates and monitoring 3D-absolute displacements to track the target movements in space which shall allow a realistic assessment of deformation behaviour of the tunnel.
- (12) Strain meters shall be used for determining the stress development in the shotcrete lining by measuring strains. They shall be installed pair wise to allow determination of sectional forces such as normal thrust and bending moments. Strain meters shall be temperature compensated to compensate for temperature increase of the shotcrete during the hardening process.
- (13) Shotcrete Creep Test Equipment: An in-situ shotcrete creep test stand shall be installed in the vicinity of the excavation. It shall consist of a hydraulic piston with precise automatic load control, strain measurement installation on one specimen (200x200x400mm), temperature measurement installation within the specimen as well as shrinkage monitoring on two, non stressed specimens. The specimen shall be produced by means of the shotcreting equipment and shotcrete used for regular support. Time dependent stress levels shall be applied to the specimen and by means of the resulting stress-strain-time relation necessary parameters for the shotcrete material law shall be generated.
- (14) Radial pressure cells shall be used for measuring the development of ground pressure acting on the tunnel lining. They shall be of size 300 x 300 mm and regrettable. Readings shall be taken in a remote controlled manner with electrical transducers.
- (15) Tangential Pressure cells shall be used for determination of shotcrete lining stress. They shall be installed in areas of special interest such as intersections etc.. They shall have a dimension of 100 × 200 mm. Readings shall be taken in a remote controlled manner with electrical transducers.
- (16) Rock bolt axial force meter shall be used to determine the load development along the anchor. This will provide information on increase in load from the anchor tip to the anchor plate. Measuring anchors shall be installed together with rock bolt load cell and extensometers.
- (17) Rock bolt load cell shall be installed at the anchor plate to get information on the maximum anchor load and the degree of utilization of the anchor.
- (18) Tilt meters shall be provided on walls of adjacent EBS where tilt has been identified as being critical.
- (19) Crack meters shall be installed to monitor existing and new cracks on applicable EBS.

3.3.6 Monitoring and Reporting

- (1) The Contractor shall propose details of the performance monitoring of the Works and shall define appropriate trigger (Alert, Alarm and Action) levels for each EBS, each of the proposed instrument, each parameter to be monitored for Geotechnical and Bored tunnel works and each parameter/control parameter to be monitored for NATM works (to monitor ground behaviour and performance of the support). These trigger levels shall be defined by the Contractor and submitted

for the acceptance of the Engineer. Any changes to these trigger levels during the Works shall be subject to the Notice of No Objection from the Engineer.

- (2) The general definitions for the trigger (Alert, Action & Alarm) levels are given below.

"Alert Level" shall initially be set as 0.5 times the serviceability limit value defined for the monitored EBS/Instrument/parameter for Geotechnical and Bored tunnel works/ parameter and control parameter for NATM works.

"Action Level" shall be set at 0.8 times the serviceability limit value defined for the monitored EBS/Instrument/parameter for Geotechnical and Bored tunnel works/ parameter and control parameter for NATM works.

"Alarm Level" shall initially be set at the serviceability limit value defined for the monitored EBS/Instrument/parameter for Geotechnical and Bored tunnel works/ parameter and control parameter for NATM works.
- (3) The serviceability limit value for a monitored element/parameter shall be the lesser of:
 - a) calculated design value for the serviceability limit, including stresses and displacement/movement of geotechnical, bored tunnel and NATM tunnel works ;
 - b) monitored element movement/distortion which would theoretically cause service disruption.
 - c) For utilities, the values of settlement/rotation those are acceptable to the Relevant Agencies/Authorities and/or the Engineer.
 - d) allowable structure or ground limits corresponding to "Slight" Damage Classification – refer Table 3.1 below.
 - e) Groundwater drawdown (a drop of water table during construction) by one metre below the lowest recorded groundwater table (the lowest recorded groundwater table shall be considered as the lowest level of groundwater table as recorded by the Contractor prior to the construction).
- (4) If any of the trigger levels is reached, the Contractor's Response shall comprise of emergency actions which could include the following and other necessary measures.
 - a) On reaching an "Alert Level" at any location, the Contractor shall immediately submit a written report to the Engineer, reviewing all total and differential movements/distortions (or the relevant parameters) to date, assessing the effects of the movements/distortions (or of the relevant parameters) on the monitored elements and predicting further movement (or further deterioration of the parameter) and their effect on monitored elements based on the trend to date. Where it is considered and agreed by the Engineer that movement (or the relevant parameter) trends indicate that "Action Level" may be reached during the course of the Works, the Contractor shall be required to submit proposals for remedial measures to limit further movement (or further deterioration of the parameter) for seeking the Notice of No Objection from the Engineer. The remedial proposals shall include the details of the remedial measures and their likely efficiency. Notwithstanding the above, a change between consecutive readings greater than 5 millimetres

(movement) shall necessitate the imposition of “Alert Level” status regardless of the global movements.

- b) On reaching an “Action Level” at any location, the Contractor shall submit an updated report reviewing the movements including differential movements and distortion (or the relevant parameters). The report shall assess the effects on monitored elements and predict further movement (or further deterioration of the parameter) and their subsequent effect on monitored elements. The report shall allow for remedial works that have been implemented and shown to be effective. Where it is considered and agreed by the Engineer that movement (or relevant parameter) trends indicate that “Alarm Level” may be reached or exceeded during the course of the Works, the Contractor shall reassess the design and propose remedial measures (including design modifications) for seeking the Notice of No Objection from the Engineer. The Contractor shall propose a Contingency Plan that shall be implemented in the event “Alarm Level” is reached or exceeded and obtain Notice of No Objection from the Engineer. The Contractor shall also develop an Emergency Plan that shall be implemented in the event the applied contingency measures cannot control the situation and obtain Notice of No Objection from the Engineer. In addition, a new set of “Alert Level” and “Action Level” values which take into account the implementation of the proposed remedial works shall be proposed by the Contractor for seeking the Notice of No Objection from the Engineer before work may be allowed to continue. The Contractor shall also provide a report after the remedial measures (including the design modifications) have been implemented, detailing the full history of movements (or other relevant parameters) and effects of implemented remedial measures in relation to the actual construction work. The report shall also contain the review and interpretation of events along with a justification to proceed with the Work for seeking the Notice of No Objection from the Engineer. Work shall only be resumed after a Notice of No Objection has been received from the Engineer.
- c) In case an “Alarm Level” is reached or likely to be reached, all work shall be suspended within 30 metres (or as required) of the instrument/or affected portion of the Works. The Contractor shall immediately implement the measures as defined in the Contingency/Emergency plans to make the related part of the Works safe and control the situation. The Contractor shall provide a report detailing the full history of movements (or other relevant parameters) and an interpretation of events to the Engineer. To resume the suspended work, the Contractor shall demonstrate to the satisfaction of the Engineer that it is safe to do so. The Suspended Work shall only be resumed by the Contractor after a Notice of No Objection has been obtained from the Engineer.
- (5) Throughout the construction period, all adjacent EBS shall be subject to regular inspections by the Contractor’s Engineers. Signs of distress in any structures shall be recorded and steps taken to immediately alleviate such distress.

3.3.7 Frequency of Monitoring

- (1) Sufficient time shall be allowed between installation of instruments and

commencement of relevant site activities to enable a reliable set of base readings to be established for all installed instrumentation. These time scales shall be agreed with the Engineer when the Contractor submits his proposed instrumentation scheme.

- (2) All instruments shall be connected to data logging equipment where possible so that measurements can be taken on a continuous 24 hour basis. Data shall be accessible via computers in the Engineer's site offices. An alarm system shall be incorporated into the computer network, with the alarm being activated if gauge readings exceed any of the agreed Alert, Action and Alarm levels.
- (3) Reports of monitoring results shall be submitted to the Engineer within 24 hours. A detailed graphical presentation of historical values of monitoring shall be submitted on a weekly basis in a format agreed with the Engineer. All results/information shall be submitted to the Engineer weekly on virus-free digital storage devices. The information on the storage devices must be retrievable using Microsoft Excel software running on IBM PC or compatible systems. Where a greater frequency of monitoring is required than on a 24-hour cycle, the Contractor shall submit the reading taken directly at the site to the Engineer on the same day.
- (4) All instruments shall be suitably protected against accidental damage, vandalism and adverse climatic conditions. Any damaged instrument shall be replaced immediately, with a set of base readings being taken as soon after installation as practicable.
- (5) The Contractor shall permanently record in both hard and soft (electronic) form for future reference as required all readings and observations from each installed instrument. On the Monday of each week the Contractor shall provide to the Engineer the updated records (in both hard and soft copy) for all instruments. These records shall show all previous readings in both numerical and graphical form and include the location, type and trigger levels for each instrument, noting any exceedances and any changes to the instrumentation location, type or records.
- (6) The Contractor shall permit access to the Works for personnel from academic/research institutions as approved by the Employer so that they can collect relevant data for making studies on performance of various underground construction elements. The Contractor shall make all such instrumentation data freely available to these academic/research institutions for academic/research purposes only.

3.3.8 Protection, Maintenance and Repair

- (1) The Contractor shall protect and maintain in good working condition all monitoring instruments and devices throughout the Contract period. Any instrument or device deemed critical to the Works that is not functioning properly or accurately shall be replaced immediately at the Contractor's own cost.
- (2) The Contractor shall ensure that all instruments and devices accessible to public shall be protected with sturdy lockable boxes.

3.3.9 Removal

- (1) No instrument or device shall be demolished, abandoned, removed, disposed of,

or rendered inaccessible without the agreement of the Engineer.

- (2) All instruments and devices shall be removed on final acceptance of the Works. All terminal boxes and covers shall be removed and disposed of. All boreholes and excavations shall be completely filled and all instruments and devices attached to EBS removed to the satisfaction of the Engineer.
- (3) All costs incurred in the satisfactory removal of the instruments and devices are deemed to be included in the Contract rates and prices.

3.4 EBS Protection

3.4.1 General

- (1) The Contractor shall be responsible for the control of all ground movements and distortions and for any resulting damage to EBS. During the Preliminary Design phase, the Contractor shall investigate all EBS that may be influenced by the Works and establish allowable movement and distortion criteria for each individual or group of EBS. The Contractor's EBS study shall extend to a certain distance beyond the potential influence zone (Refer Employers Requirement – Construction, Section D(9)) on each side of the tunnel alignment centreline and also to a certain distance beyond the potential influence zone on each side of the station alignment centreline. The respective influence zones and the distances beyond these influence zones, where EBS study shall have to be conducted by the Contractor, shall be proposed by the Contractor with the required backup details during the Preliminary Design Phase for the acceptance of the Engineer.
- (2) For operating rail tracks, maximum permissible total movement shall not be greater than 15 millimetres or as agreed by the Concerned Rail Authorities. Angular distortion to rail tracks shall be limited to an absolute maximum of 5 millimetres in 10 metres (1:2000) longitudinally, and 1 in 2500 transversely as measured across any one single track set. These requirements are in addition to any other requirements imposed by applicable government/other agencies, utility companies/authorities and the Employer.
- (3) The Contractor shall design both his Temporary and Permanent Works to ensure that ground and EBS movements and distortions are maintained within tolerable limits and that operation of EBS, Roads and pavements are not affected by the movements and distortions. The Contractor shall also design these Works such that groundwater regime is not affected post-construction stage and the changes to the groundwater level do not exceed normal seasonal variations during Operations Phase of the Project.
- (4) The Contractor shall obtain a Notice of No Objection from the Engineer and relevant Agencies/Authorities and/or utilities companies prior to carrying out any dewatering of the ground. Dewatering may only be carried out within contained excavations once the walls or water cut-offs/barriers which provide that containment are all in place and proven to be effective to the satisfaction of all interested parties and the Engineer.
- (5) The Groundwater drawdown (a drop of water table during dewatering/construction) outside the excavation/adjacent to works, shall be controlled such that the water table doesn't get lowered by more than one metre below the lowest recorded groundwater table (the lowest recorded

- groundwater table shall be considered as the lowest level of groundwater table as recorded by the Contractor prior to the construction). For ensuring this the Contractor shall provide recharging well system, if required.
- (6) The Contractor's attention is drawn to the Conditions of Contract and Employer's Requirements relating to repair of damage should any arise as a result of the Contractor's construction activities.
 - (7) The Contractor shall take due regard of the presence of all utilities and services within and adjacent to the Works.
 - (8) The Contractor shall instrument and regularly monitor the ground and EBS adjacent to all excavations to determine the rate and magnitude of any movements and distortions.
 - (9) Movement and distortion shall be limited such that any individual EBS shall not suffer damage greater than "Slight" as defined in the "Damage Classification" in **Table 3.1.**
 - (10) Movement and distortion to critical/sensitive structures such as hospitals, bridges, flyovers, underpasses/sub-ways, viaducts, heritage structures and "protected" structures etc. shall be limited to "Negligible" as defined in the "Damage Classification" **Table 3.1.**

3.4.2 Minimising Ground Movements

- (1) All tunnel(bored and NATM) and stations(cut-and-cover and NATM) works shall be constructed in such a way as to minimise ground and EBS movements and distortions by immediate installation of support/pre-support to the ground and by cutting off of any inflow of water into the Works. Care should be exercised to ensure that there is no over- excavation.
- (2) Construction from the surface shall be undertaken with due regard to the settlement associated with the particular method chosen.
- (3) The following support methods shall not be permitted.
 - a) Use of ground anchors beneath adjacent buildings without the prior approval of the Employer
 - b) Non-recoverable timber ground support.

3.4.3 Condition Survey

- (1) The Employer will make available to the Contractor, for information only, the Building Condition Survey information available with him – refer Part 4. The Contractor shall supplement this information, by way of carrying out his own Building condition Survey, to the extent necessary to ensure compliance with the the Employer's Requirements, Specifications and Conditions as set out in the Contract.

The Contractor shall determine the potential influence zones for his Works and undertake condition surveys and EBS study as per **clause 3.4.1** for ensuring compliance with all the provisions of the Contract.

3.4.4 Prediction of Ground Movements

The Contractor shall provide predictive assessments of the anticipated ground and EBS movements and distortions within the potential influence zones and a certain distance beyond these influence zones [please refer clause 3.4.1(1)], and submit these predictions to the Engineer when making submittal of his proposed method of

construction, and tunnel/station support methods (Excavation & lateral supports for stations and initial & final supports for tunnels).

3.4.5 Assessment of Impact on Structures

- (1) The Contractor shall provide an assessment of the effect of the predicted movement on all structures within the zones of influence and a certain distance beyond these influence zones [please refer clause 3.4.1(1)].
- (2) The Contractor shall assign to each and every EBS that may be affected by the Works one of the risk categories, in accordance with criteria defined in “Damage Classification” in Table 3.1.
- (3) Movements and distortions shall be limited as defined in clause 3.4.1 above.
- (4) Depending upon the level of risk, the Contractor shall propose precautionary and protective measures and submit these to the Engineer for seeking his Notice of No Objection. Once agreed by the Engineer these measures shall be implemented by the Contractor prior to any works within the areas and at no extra cost to the Employer.

3.4.6 Staged Assessment

- (1) The Contractor shall assess the effects of movements and distortions on EBS in one, two or three stages, depending upon the findings at each stage, as described below:-
- (2) Stage 1 Assessment
The effect of movement and distortion on EBS foundations is assessed but the pattern of settlement is ignored. Any structure where the predicted settlement is less than 10 millimetres and the predicted ground slope is less than 1/500 need not be subject to further assessment. For critical/sensitive structures, a more stringent slope and settlement criteria shall be adopted to comply with the provisions of clause 3.4.1(10). All other structures within the zone of influence and a certain distance beyond [please refer Clause 3.4.1(1)] shall be subjected to a Stage 2 assessment.
- (3) Stage 2 Assessment
The EBS identified to be having a potential risk as a result of Stage 1 assessment shall be individually assessed using a limiting tensile strain approach. This method of assessment takes into account the tensile strains in the ground and uses a simple idealised model of the building. Tried and tested references from the literature may be utilised as an alternative.
In case of all Cut & Cover excavations, all NATM tunnelling works and for those EBS that cannot be satisfactorily represented by a simple idealised model of a building, Numerical simulation of ground movement due to construction activities shall be done to assess the settlement/distortion subject to the acceptance by the Engineer. The geological features, such as joints orientation and spacing etc., shall also be taken into account for such analyses, where appropriate.
For critical/sensitive structures and based on their structural condition a more stringent damage classification shall be adopted to comply with the provisions of clause 3.4.1(10).
- (4) Stage 3 Assessment
All EBS which are placed in Category 3 or above in the “Damage Classification” in

Table 3.1, during the second stage assessment, and also all critical/sensitive structures for which a more stringent damage classification is required to be adopted to comply with the provisions of clause 3.4.1(10), shall be subjected to a further settlement/distortion assessment. A detailed structural survey shall be undertaken by the Contractor to determine the structural form and condition of all such buildings/structures, followed by an analysis of how individual elements of the building/structure would be affected by the predicted settlement/distortion. The method, extent and detail of the analysis will be determined on a case-by- case basis and may include, inter alia, an analysis of the soil/structure interaction, structural behaviour, and the possible effects of differential stiffness of the foundations.

As a result of the Stage 3 analysis, the requirement for any protective works shall be established and the details of any protective works including designs and method of working determined. Details of such works shall be submitted to the Engineer for seeking his Notice of No Objection. All such protective works shall be carried out by the Contractor at no extra cost to the Employer.

Table 3.1: Building Damage Classification

Building Damage Classification 1 (after Burland et al. 1977 and Boscardin and Cording, 1989)				
1	2	3	4	5
Risk Category	Description of Degree of Damage	Description of Typical Damage and Likely Form of Repair for Typical Masonry Building	Approx Crack Width	Max Tensile Strain %
0	Negligible	Hairline cracks		Less than 0.05
1	Very Slight	Fine cracks easily treated during redecorations. Perhaps isolated slight fracture in building. Cracks in normal exterior brickwork visible upon close inspection	0.1 to 1	0.05 to 0.075
2	Slight	Cracks easily filled. Redecoration probably required. Several slight fractures inside building. Exterior cracks visible: some repointing may be required for weather tightness. Doors and windows may stick slightly.	1 to 5	0.075 to 0.15

Building Damage Classification 1 (after Burland et al. 1977 and Boscardin and Cording. 1989)				
1	2	3	4	5
Risk Category	Description of Degree of Damage	Description of Typical Damage and Likely Form of Repair for Typical Masonry Building	Approx Crack Width	Max Tensile Strain %
3	Moderate	Cracks may require cutting out and patching. Recurrent cracks can be masked by suitable linings. Tack-pointing and possibly replacement of a small amount of exterior brickwork may be required. Doors and windows sticking. Utility services may be interrupted. Water tightness often impaired.	5 to 15 a number of cracks greater than 3	0.15 to 0.3
4	Severe	Extensive repair involving removal and replacement of sections of walls, especially over doors and windows required. Windows and door frames distorted. Floor slopes noticeably. Walls lean or bulge noticeably, some loss of bearing in beams.	15 to 25 but also depends on number of cracks	Greater than 0.3
5	Very Severe	Major repair required involving partial or complete reconstruction. Beams, load bearing, walls lean badly and require shoring. Windows broken by distortion or Danger of instability.	Usually greater than 25 but depends on number of cracks	

Notes :

1. The table is based on the work of Burland et al (1977) and includes typical maximum tensile strains for the various damage categories (column 5) used in the stage 2 settlement analyses
2. Crack width is only one aspect of damage & should not be used on its own as its direct measure.

3.5 Bored Tunnel

Unless otherwise advised by the Engineer the bored tunnel alignment shall follow the alignment shown on the Tender Drawings. Any changes to the alignment, proposed by the Contractor or otherwise required, for whatever reasons, shall require Notice of No Objection from the Engineer and shall not entitle the Contractor for any Claim.

3.5.1 Design Submissions and Method Statement

- (1) The Contractor shall prepare and submit to the Engineer for seeking his Notice of No Objection, a Design Report which includes; calculations, schedules, construction methodology, specifications on material and drawings for the bored tunnel construction, prior to the commencement of such works. Additional information shall be supplied upon request of the Engineer.
- (2) The Design Report shall explain the design philosophy, design assumptions, and design parameters of all Civil, and structural works to be undertaken. Reference shall be made to Part 2, Employer's Requirements: Sub-division C – Design: for the requirements for the Design Report submission.
- (3) The Contractor shall also prepare a Method Statement which presents full details of the design, the materials, equipment, plant and operations involved in the construction of bored tunnel. The Method Statement shall be consistent with the construction methodology presented in the Design Report. This Method Statement shall be submitted to the Engineer for seeking his Notice of No Objection in support of the Design Report.

3.5.2 Types and General Construction Methods

- (1) The running bored tunnels shall comprise twin single-track bored tunnels generally at a clear separation of at least a diameter of tunnel between the closest edges of two tunnels. This criterion may vary according to location and ground conditions.
- (2) The top of rail alignment is shown on the Employer's plan and profile drawings. Unless specified otherwise, the bored tunnels shall be circular in shape.
- (3) Bored tunnels are generally expected to be in rock (weak rock and hard rock) and at places in a mixture of soil and rock (weak rock and hard rock).
- (4) Initial ground support for the bored tunnels constructed by TBM method is expected to comprise ground pre-treatment (where necessary) and/or precast concrete segments,
- (5) The final ground support for the bored tunnels constructed by TBM is expected to be pre-cast concrete (plain or reinforced concrete) segmental lining. The pre-cast concrete segmental lining may serve both as initial as well as final ground support.
- (6) The Contractor shall be responsible for the safety and security of excavations at all times during the execution of the Contract.
- (7) The Contractor shall present to the Engineer for seeking his Notice of No Objection, the details of his proposed methods for excavation, spoil removal, ground treatment, installation of initial support and the permanent lining (final support) construction.
- (8) Excavation shall be carried out in a uniform and controlled manner, over-

cutting or over-excavation shall be kept to a minimum. No excavation shall take place until the Engineer's Notice of No Objection has been obtained.

- (9) The Contractor shall adopt such appropriate methods and take such steps as are necessary to control water inflows and movement into the tunnel being bored and to maintain the stability of the excavation.
- (10) Where the Contractor's site and EBS investigations indicate that there are already limits in imposition for movements, distortions and/or protection in respect of existing adjacent EBS, the Contractor shall provide calculations to demonstrate that the method of excavation will result into compliance of all those limits/requirements. The Contractor shall also comply with the requirements of the Relevant Authorities with regard to movements or distortions of these EBS. Where such limits/requirements are not specified by the Relevant Agencies/Authorities, the Contractor shall assess each EBS that may be affected by the Works and submit his proposed limits of movements and distortions that are needed to be imposed for those EBS, to ensure compliance to all the provisions of the Contract, for seeking Notice of No Objection from the Engineer.
- (11) The Contractor shall submit to the Engineer details of his proposed instrumentation and monitoring arrangements for ground and EBS movement and distortion and changes to the groundwater table(s) and the trigger (Alert, Action & Alarm) levels for each and every identified EBS and/or monitoring instrument in accordance with the Contract.

3.5.3 Bored Tunnel Support Design Requirements

- (1) The principal method of construction of the bored tunnels is expected to be a Shield driven tunnel (TBM method) with a permanent precast concrete lining. Exceptions to these permanent linings may be at cross-passages (links between tunnels), enlargements of the bored tunnel and at the junction between cut-and-cover and bored tunnel sections. In such locations permanent cast-in-place concrete linings shall be used, or alternative types of permanent lining may be proposed subject to the Notice of No Objection from the Engineer.
- (2) The design of the bored tunnel lining shall be fully compatible with the construction methodology as proposed by the Contractor.
- (3) The design shall also take into account all expected loads, the requirements of the overall schedule, the need for further investigations as necessary, and contract limitations with regard to ground movements and dewatering (groundwater drawdown) .
- (4) The Contractor shall ensure that ground movements and distortions, and changes to the loads and piezometric pressures which may affect adjacent EBS either at surface or underground, are within the allowable tolerances for each of those EBS.
- (5) All analysis shall clearly show that the designs achieve the design factors of safety.
- (6) The design method shall take into account the interaction between the lining and the ground, the deflection of the lining and the redistribution of the loading dependent upon the relative flexibility of the lining, the variability

and compressibility of the ground.

- (7) The design shall consider and minimise the short- and long-term influence of the bored tunnels on the groundwater regime, and similarly the influence of the groundwater on the bored tunnels.
- (8) The design shall consider and conform to all durability aspects of the permanent bored tunnel lining including permeability/transmissivity, electrical resistivity, Alkali Silica Reactivity resistance and chloride/sulphate resistance as per the latest and relevant International Standards. In this respect Contract provisions pertaining to DAAR in Section 2 of these specifications shall be referred to and fully complied with by the Contractor.
- (9) The design shall take into account the proximity of the lining to the tunnel face at the time of installation and the potential for additional ground loads as the face advances.
- (10) The design shall allow for the expected variation in ground conditions and the size, proximity, timing and method of construction of adjacent excavations/ tunnelling. The lining flexibility shall make due allowance for likely deflection of the lining during construction and operation.
- (11) During tunneling, ground conditions shall be constantly reviewed based on what was expected and what conditions were actually encountered to allow excavation to be carried out in the safest and most efficient manner. This review shall be fully integrated into the construction risk control and management systems and should typically include:
 - a) Probing ahead of and around the bored tunnel face In rock conditions.
 - b) Interpretation of fresh data and correlation with previous information.
 - c) Prediction of ground conditions likely to be encountered.
 - d) Investigation on the surface for the presence of water wells / bore wells for domestic use in residential areas that intersect the alignment.
- (12) Ground information from all construction activities shall be collated and interpreted.
- (13) The geotechnical design parameters adopted and the design of the bored permanent tunnel lining shall be subject to the Notice of No Objection from the Engineer prior to commencement of design.
- (14) The Contractor shall design all necessary linings for bored tunnels and shafts including temporary linings.
- (15) If any proprietary methods, materials or components are proposed to be used, the Contractor shall be responsible for their fitness for purpose in accordance with the Contract.
- (16) The Contractor shall determine the configuration of rings, segmentation, and details of joints, fixings and the like to suit ground conditions, loadings, methods of construction and all functions in the completed Works as described herein. The design shall address aspects including the following, as appropriate.
 - a) Ring configurations,
 - b) Segment size and form,

- c) Fixing details including for:
 - ring to ring fixings;
 - segment to segment fixings;
 - fixings for all equipment to be installed under this Contract;
 - fixings for all equipment required by Designated/Interfacing Contractors to suit segment position;
 - handling, stacking and installation of segments;
 - holes, recesses and fixtures for other system components.
 - d) Designs shall allow for tolerances in production and installation of segments.
 - e) Other components, such as:
 - grout hole valves;
 - gaskets;
 - bedding and packing materials.
 - f) Cavity grout, between lining and ground.
 - g) Instrumentation and monitoring to demonstrate performance of the installed linings.
- (17) The Contractor shall submit for the Notice of No Objection from The Engineer a comprehensive schedule of tests to establish the quality and performance of all elements of the segmental lining, including:
- segment materials;
 - permeability;
 - production tolerances;
 - capacity of segment with holes, recesses and other inserts;
 - joint performance and load capacity including effect of joint misalignment and birds mouthing with aligned and misaligned joints;
 - performance of joint bedding/packing materials;
 - lateral bending tests to demonstrate resistance to jacking forces;
 - gasket performance with aligned/misaligned joints;
 - self-sealing grout hole;
 - capacity of all fixings;
 - cavity grout.

3.5.4 Design Loads

- (1) The design method shall consider in-situ ground stresses and shall provide evidence and/or measurements in support of the parameters adopted in the design as part of the calculations. The ground load on the tunnel shall be based on the actual height of overburden above the tunnel lining. The coefficient of earth pressure at rest of the soil strata surrounding the tunnel and the rock loading shall be as worked out from the geotechnical/rock-mechanics engineering principles. The effect of over-consolidation of ground shall not be considered in the design of final ground support of tunnel. Distortional loading due to out of balance verticle and horizontal earth pressure shall be based on a lower bound horizontal earth pressure coefficient.

- (2) No ground relaxation shall be considered in the design of initial and final ground support for bored tunnel constructed by TBM method.
- (3) For segmental lining, the lining stiffness shall take account of the rotation at the radial joints. Secondary moments due to joint eccentricities shall be added. To assess the effect of radial distortion, the moment of inertia of the complete ring shall be reduced to account for the increased flexibility due to the presence of the segment joints. The resulting moment, together with the minimum axial load, will be checked against the structural capacity of the lining section
- (4) The design shall take into account all additional loads, stresses and strains imposed by or on adjacent EBS and assumed distortions and loads by or on the proposed bored tunnels.
- (5) Where bored tunnels are adjacent to or beneath EBS, the design shall demonstrate that these EBS shall not be subjected to unacceptable movement, distortion or loss of support which endangers the stability of the EBS and that any resulting movements and distortions will be within prescribed limits determined by the authority for that EBS, the Engineer, or by the Contractor as agreed with the Engineer. Please also refer provisions of clause 3.4 in this respect, which shall be fully complied with by the Contractor.
- (6) Linings shall be designed to withstand all environmental loadings, distortions and other effects without detriment. In general, bored tunnel support shall be designed to fulfil the following requirements and to resist the following loads.
 - a) Superimposed surface loads from traffic, existing structures over and adjacent to the bored tunnel, and any specified future loads.
 - b) Appropriate ground loads (including soil load, rock load and rock wedge load), water pressure, and seismic loads.
 - c) Railway loads.
 - d) Superimposed dead and live loads from utilities, services, systems' provisions, pathways & walkways etc.
 - e) Structural requirements for resisting buckling.
 - f) Long- and short-term ground yield or squeeze.
 - g) Unequal grouting pressures.
 - h) Adjacent bored tunnelling or excavation.
 - i) Openings in, or extensions to, the lining.
 - j) Long- or short-term loads induced by construction.
 - k) Temperature and shrinkage.
 - l) Handling loads, including impact especially on segments.
 - m) Jacking forces, where appropriate.
 - n) Accidental loading such as fire and derailment.
 - o) Any other loads as considered appropriate and necessary
- (7) The design shall also consider the relative rates of loading / unloading in both the lateral and vertical directions, and the resultant induced tunnel deformations whether temporary or permanent.

- (8) The design of the bored tunnel linings shall take into account the proximity of the bored tunnels one to another, the sequence and timing of construction and the proximity of adjacent EBS.
- (9) All components of underground structures shall be proportioned to withstand the following applied loads and forces.
 - a) Dead load comprises the self-weight of the basic structure and secondary elements supported and the ground load. The depth of cover shall be the actual depth or a minimum of 3 metres. The depth of cover shall be measured from the ground surface to the tunnel crown.
 - b) Traffic surcharge shall be equivalent to Class AA loading of IRC-6. Latest revision.
 - c) Loads from existing or known future adjacent structures above or within the area of influence, which will remain in place above the bored tunnels, or any specified future loading. The applicable foundation load and its influence shall be computed based on the type and use, and the foundation type which supports that structure.
 - d) Additional support and/or ground treatment shall be provided unless it can be shown that adequate provision already exists. Non-PMRL structures shall not be supported directly by the bored tunnel lining.
 - e) Where provision for a specific future structure is not made a minimum uniformly distributed surcharge of 50kPa at the design finished ground level shall be assumed.
 - f) Hydrostatic pressure, ignoring pore pressure relief arising from any seepage into the tunnel. For derivation of hydrostatic pressure, the maximum groundwater level shall be taken as the 1 in 50 year return period water level or actual water level at the time of construction whichever is the higher, plus a 1.0m allowance for contingencies. The minimum groundwater level shall be taken as the lowest recorded value minus 3m or the level to which the groundwater table may be drawn down during construction, whichever is lower.
 - g) Loads and load changes due to known construction activity in the vicinity of the bored tunnel, such as the excavation and the formation of underpasses, basements, pile groups, bridges, diaphragm walls and cable ground anchors etc.
- (10) The permanent bored tunnel support shall be designed and checked for all possible combinations of applied loads and forces.

3.5.5 Bored Tunnel Support – General

- (1) The minimum internal finished diameter of as-built single track bored tunnel, constructed by TBM method, shall be 5600mm exclusive of all as –built tolerances (that means with tolerances the overall diameter of bored tunnel shall be 5800mm) with respect to the designed axis of the tunnel. This means that at no point on circumference of the as-built tunnel, the distance between designed axis (theoretical/design centre of the tunnel) of the tunnel and internal surface (intrados) of tunnel shall be less than 2800mm.
- (2) The Contractor shall submit to the Engineer for seeking his Notice of No

Objection, full details of his proposed method of construction including specification of the proposed permanent support including supporting arrangements, formwork details and surface finish

3.5.6 Bored Tunnel Support – Permanent Support

- (1) The permanent bored tunnel support or lining, constructed by TBM method, shall be bolted segmental precast concrete (plain or reinforced) rings that are held securely in place and will remain so for all known possible future conditions.
- (2) Exceptions to these permanent linings may be at cross-passages (links between tunnels), enlargements of the bored tunnel and at the junction between cut-and-cover and bored tunnel sections. In such locations permanent cast-in-place Concrete linings shall be used, or alternative types of permanent lining may be proposed subject to the Notice of No Objection from the Engineer.
- (3) The Contractor shall take into account all of the following when considering the design of the permanent lining.
 - a) The internal diameter required to accommodate the Kinematic Envelope, Structure Gauge, and track-bed arrangement as provided by the Trackwork Contractor and also the OHE(Overhead contact system) arrangement as provided by the Traction Contractor
 - b) Due allowance for relative movement between bored tunnels and cut-and-cover structures as described in the Contract.
 - c) The stiffness of the permanent lining shall be sufficient to limit the allowable deflection on radius under the expected loadings to a maximum of 10 millimetres with a maximum longitudinal distortion of 10 millimetres in 10 metres (1 in 1000) and a transverse distortion (ovalisation) of 4 millimetres in 6.0 metres (1 in 1500).
 - d) Short-term (during construction) intermediate (immediately after construction) and long-term (full design life) loading conditions.
 - e) Stresses induced by grouting.
 - f) Ground pre-treatment, where applicable
 - g) The reinforcement for segmental concrete lining shall be detailed such that there is no electrical continuity across the circle joints. To prevent the stray current effects and to inhibit the corrosion, suitable property enhancers shall be added in to concrete. Such concrete shall be tested in accordance with ASTM C 1202 and DIN 1048. RCPT value shall not exceed 1000 coulombs(at the concrete age of 28 days) and Water permeability shall not be more than 10 millimetres (at the concrete age of 28 days).Reinforcement of in-situ concrete lining shall be bonded to mitigate stray currents. The bonding shall be part of the corrosion control system designed and installed by the Contractor to the Notice of No Objection by the Engineer. The corrosion control system shall be tested and proven to the satisfaction of the Engineer that the corrosion control system functions as designed in all locations.
 - h) For Bonding and Earthing of Tunnel Lining (Stray Current Protection), the Contractor shall provide stray current protection for the tunnel linings in accordance with the Contract and as required by the Interfacing/Designated

Contractors.

- i) The formation of blind holes and all other fixings for brackets and equipment shall be detailed such that they have no adverse effect on the integrity, water-tightness and design life of the linings.

3.5.7 Segmental Lining Design

- (1) The design life of segmental lining shall be 120 years and that of non-structural components shall be 50 years.
- (2) The design Fire Resistance Period shall be 4 hours.
- (3) A segment shall be evaluated as a short column subjected to axial load and moments. The minimum diameter of main reinforcement and confinement reinforcement shall be provided following requirements of column.
- (4) The design of the segments shall be adequate for all stresses induced during stacking, lifting, transport, erection jacking and impact, including in-service impact.
- (5) The width of segments shall suit the method of construction and shall not be so large that part shoving of the shield becomes a general necessity.
- (6) The width of the segments shall be consistent with the capacity of the circle bolting arrangements to withstand the shear forces induced in linings built with staggered joints.
- (7) The thickness of the segments shall be adequate for the planned reinforcement and the required concrete cover. The minimum thickness of segmental lining shall be 275mm.
- (8) The maximum design crack width at ground face (extrados) of the lining shall not exceed 0.2 mm. However at the non-ground face (intrados) of the lining, the maximum design crack width shall not exceed 0.3mm.
- (9) Two sealing gaskets shall be incorporated in the segment design. Materials for sealing gaskets shall be one gasket of hydrophilic material and one gasket of elastomeric type. The elastomeric gasket shall be suited to the conditions under which it is required to operate for the 120 year design life and have an acceptable fire performance for use on an underground railway. The gasket grooves shall allow for accurate mating of the gaskets of adjacent segments
- (10) A groove for post-construction grouting/caulking as necessary shall be provided on the intrados for each segment joint.
- (11) Where steel bar reinforcement is incorporated into the concrete segments the minimum cover to all reinforcement, including link steel, shall not be less than 40 millimetres to the intrados and 50 millimetres to the extrados, except only at bolt holes where reduced cover of 25mm is acceptable provided a plastic sheath is cast in. However, the nominal cover to be considered for crack width check shall be 40mm for the intrados face and 45mm for extrados face. The minimum Grade of concrete for segmental lining Shall be M45 (with a compressive characteristic strength of 45MPa).
- (12) Blind grout holes with removable plastic covers shall be provided in the centre of each segment excluding the key, and shall be of a nominal 50 millimetres diameter. All grout holes shall be fitted with non-return valves with double-seal

rings.

- (13) The lengths of segments shall be chosen with regard to bending stresses during handling, storage and erection and the long term stresses due to ground loading and the resultant deflections. In the design for handling, storage and erection a safety factor of 5.0 shall be applied to the self-weight of the segment combined with zero axial load.
- (14) Opening of longitudinal joints. In the design of segmental lining a 1% of the tunnel diameter or 50mm poor build (whichever is more) shall be taken into account.
- (15) The design of linings shall include tapered rings in order to negotiate the alignment curvature and to correct for line and level during construction with the minimum use of circumferential joint packers consistent with attaining the required degree of water-tightness of the bored tunnels in accordance with the Contract.
- (16) Drilling for fixings at pre-determined points on the lining may be permitted provided such drilling does not fully penetrate the lining or structurally damage the segment or result in denigration of the water-tightness of the tunnel.

3.5.8 Cast-In-Place Concrete lining (Cross-passages and NATM tunnel)

- (1) Construction of a cast-in-place lining for initial or permanent support whether of reinforced or unreinforced (plain) concrete shall comply with the requirements of the Construction Materials Section of Outline Construction Specification.
- (2) The minimum Grade of concrete used for permanent support shall be M35 and the minimum thickness shall be 300mm. Where steel bar reinforcement is incorporated into the concrete lining, the minimum cover to all reinforcement, including link steel, shall not be less than 40 millimetres to the intrados and 50 millimetres to the extrados. However, the nominal cover to be considered for crack width check shall be 40mm for the intrados face and 45mm for extrados face.

3.5.9 Sprayed concrete (Cross-passages and NATM tunnels)

- (1) Materials for sprayed concrete shall comply with Concrete Materials Section, of Outline Construction Specification.
- (2) Sprayed concrete shall be used only in initial support (primary support).

3.6 Waterproofing (Cross-passages and NATM tunnels)

Suitable waterproofing materials and methods shall be used to meet the water tightness requirements stated in Clause 2.10.3, Section 2 of this Outline Design Specifications. The waterproofing membrane and methods used shall comply with the relevant BS/ASTM codes and the Contract.

3.6.1 Cavity grouting

All cavities shall be completely filled with non-shrink cement-based grout of the appropriate design mix.

3.6.2 Tunnel Boring Machine – General

- (1) The Contractor shall deploy sufficient number of TBMs complete with all backup equipment and spares to complete the Works within the Contract key dates and programme.
- (2) The Contractor shall be fully responsible for the selection, design and supply of

the TBM, shields and backup equipment.

- (3) The TBM shall be robust with adequate safety margins for the anticipated duty, designed and manufactured to comply with all safety standards.
- (4) The TBM procured for this project must be capable of efficient excavation and installation of support within the expected site and ground conditions. This includes soil, rock, soil/rock mixture and existing EBS (notably wells/tube-wells) all mainly below the groundwater table.
- (5) The Contractor shall submit to the Engineer for his Notice, a programme for the provision, factory inspection, testing, transport, erection and commissioning of each TBM. The Engineer's Notice shall not absolve the Contractor of his responsibility to use appropriate equipment and complete the Work as scheduled.
- (6) TBM shall be assembled at the manufacturer's works on completion of fabrication or modification and tested to demonstrate that all components operate correctly before the Employer or his authorised representative. Trial running will also be required at site following assembly, prior to commencement of bored tunnel driving.
- (7) The Contractor shall ensure that all key personnel who are responsible for the driving, maintenance and control of the machine have received the necessary training in the duties that they are required to perform. Such training shall include emergency procedures.
- (8) The Contractor shall provide and maintain a complete list of the names of persons and their duties, responsibility for the operation of the machine, who have completed the appropriate training to an accepted standard. A Certificate of Competence shall be provided by the Contractor.

3.6.3 Tunnel Boring Machine – Machine Requirements

The TBM shall have, as a minimum, the following facilities.

- (1) All TBM machines shall be capable of being operated in closed-face mode (wherever ground and groundwater conditions so demand and to comply with all the Contract requirements/provisions), the cutter-head of which shall be capable of clockwise and anticlockwise rotation and shall only be able to excavate the ground whilst the hydraulic rams are being actuated.
- (2) TBM design shall ensure that the cutter-head can be retracted back from the unexcavated ground to minimise the risk of the TBM jamming and to facilitate maintenance.
- (3) TBM shields shall be truly circular, strong enough to avoid distortion during driving, and suitable for building the tunnel linings.
- (4) The Contractor shall supply, erect, drive, maintain, dismantle and remove the TBM shields and all back-up equipment and materials upon completion, all of which shall remain the property of the Contractor.
- (5) TBM design shall make adequate provision for the safety of the workmen and the application of safe methods of tunnelling.
- (6) TBM shall be shop-manufactured in units of convenient size, suitable for field erection, dismantling and reassembling under the Contract site conditions.

- (7) TBM shall be equipped with shove-rams of sufficient capacity to move the TBM through all materials/Ground conditions encountered, to the lines and grades (horizontal and vertical alignments) as applicable for the Contract works. The shove-rams shall be capable of simultaneous and individual actuation, controllable individual pressure and variable extension.
- (8) Shove-rams shall be fitted with shoes so placed that the reaction of the shove-rams will be safely and evenly distributed against the ground and/or the tunnel lining so as not to cause undue damage or deflection of the ground or tunnel lining.
- (9) TBM shall be equipped with a tunnel lining erector system capable of lifting, moving and placing each lining segment safely into its final position within the periphery of the lining ring being formed.
- (10) During the tunnelling operation, the Contractor shall provide and maintain a closed-circuit television (CCTV) system with a minimum of two (2) cameras placed strategically within the tunnel. The CCTV system shall be linked to the office of the Engineer and the two (2) cameras shall move in tandem with the TBM shield.
- (11) A data logging system shall be located in the TBM control room for monitoring and recording all activities and shall be linked to Engineer's office at the ground surface.
- (12) Hand-held extinguishers of the appropriate type shall be sited at suitable locations within the TBM shield and the TBM backup.
- (13) A gas detection system shall be installed on the TBM for monitoring and recording the levels of toxic gases that may emanate from the ground and the tunnel construction equipment.
- (14) The Contractor shall use hydraulic oil in his plant which minimises the risk of an oil-initiated or oil-based fire.
- (15) The Contractor shall provide adequate forced ventilation, which complies with the Contract minimum air-flow requirements within the tunnel and at the tunnel face.
- (16) The Contractor shall provide back-up power supply and emergency hydraulic pressure control systems for all critical tunnelling equipment including; excavation, segment erecting systems, grouting equipment and the like.
- (17) Where slurry system TBMs are proposed, the slurry treatment plant shall produce soil/spoil that is suitable for filling and compaction in accordance with this Contract.
- (18) TBM shall be designed for and equipped with a supplemental ground stabilisation system. This system shall comprise regularly spaced grout ports built into the shield for drilling into and grouting the ground ahead of the tunnel face. The location and number of ports shall be adequate for implementation of face stabilisation measures needed for access to the face in all ground conditions. All ports shall be readily accessible and fitted with valves.
- (19) TBM shall be designed to enable the void between the segment lining and the ground (tunnel extrados) to be grouted continuously from the shield as the shield is propelled forward by synchronised operation. TBM design shall allow control of the grouting volume, pressure and pipes to be cleaned in the event of a

blockage. Grout pipes shall be integral within the thickness of the TBM tailskin. A minimum of four (4) separate grout pipes shall be provided. External grout pipes shall not be permitted.

- (20) Provisions shall be made throughout the length of the machine and back-up facilities for the detection and automatic suppression of fires. The system shall be maintained in an efficient operating condition at all times.
- (21) The TBM tailskin shall be fitted with a tail wire brush and grease seal system that prevents ingress of water, excavated material and/or grout into the TBM operational areas. Facilities shall be provided for replacing the tail wire brush and grease seals from within the excavation/tunnel. The Contractor is advised to provide grout check "plates" located at the rear of the tailskin to limit grout migration (from backgrouting of the installed segments) along the shield towards the cutter-head.
- (22) The TBM shall be designed to maintain a pressure on the excavated ground at all times. This pressure shall at least balance the in-place earth and hydraulic pressures making up the total overburden pressure and shall be capable of varying the face pressure as the overburden pressure changes. The design shall also take into account the soil/rock type, density, gradation, strength and abrasion.
- (23) The TBM shall incorporate a two-compartment air lock for man access to the cutter-head and face. A complete compressed air installation, including compressor, chiller and medical lock shall also be provided and commissioned prior to the commencement of tunnelling in soft/mixed ground. Work carried out under compressed air condition shall comply with international standards and local safety regulations.
- (24) The Employer/Engineer may inspect and witness the fabrication and factory testing of TBM at the offshore location. The cost of these visits will be borne by the Employer. The Contractor shall provide all necessary assistance to facilitate the Employer/Engineer's inspection and witnessing of the TBM fabrication and testing.
- (25) The cutter-head discs/picks shall be able to be renewed from the rear of the cutter-head (back-loaded) and shall be interchangeable.
- (26) Specific Requirements
 - a) Where boulders could be expected to be encountered an Earth Pressure Balance Machine (EPBM) cutter-head shall permit a maximum 300 millimetre boulder to pass through the cutter-head. The EPBM shall have the capability to handle, break up as required and remove such size boulders through the screw conveyor.
 - b) For an EPBM a minimum of six (6) pressure sensors shall be provided at the bulkhead and three (3) at the screw conveyor.
 - c) For all EPBM a spoil conditioning system shall be provided so that all the spoil within the plenum chamber (and screw conveyor) remains fluid/plastic, and this fluidised spoil fills the entire plenum chamber which then; allows the pressure cells on the bulkhead to operate correctly, creates a plug at the screw conveyor, and reduces wear to the cutter-head and screw conveyor.

- d) For an EPBM in case of hydraulic failure an independent back-up system for closing the gate to the screw conveyor shall be provided.
 - e) For a Slurry TBM (STBM) a stone crusher shall be provided in front of the slurry discharge aperture for breaking down boulders into sizes that can be handled by the STBM mucking system.
 - f) For all STBM the slurry properties shall be checked during each shift to ensure compliance with the criteria for face-support filtrates, viscosity and density.
- (27) The TBM operation panel shall monitor and where appropriate control the following.
- a) Forward thrust, cutter-head torque, penetration and speed
 - b) Volume of soil/spoil removed correlated with forward advance of the shield.
 - c) Ram pressure and location used.
 - d) Main bearing grease and oil lubrication pressure flow and temperature.
 - e) Alignment and attitude of shield and segment
 - f) Electrical load characteristic and supply source
 - g) Depending on the type of TBM chosen, the following items shall be monitored:
 - h) For EPBM; face pressure
 - i) For STBM; slurry pressure, level, and flow rates.
 - j) For EPBM; torque and speed for the screw conveyor and opening ratio of gate.
 - k) For STBM; compressed air pressure in air chamber.

3.7 NATM Tunnels

The design and construction of NATM Tunnels shall comply with all the provisions/stipulations of the Contract.

3.7.1 Design Submissions and Method Statement

- (1) In his design the Contractor shall take adequate measures to minimize the amount of deformations inside the tunnels, thus minimizing the ground relaxation, so as to minimise the ground surface settlements/distortions with a view to comply with all the requirements/provisions of the Contract in respect of EBS protection.
- (2) The Contractor shall prepare and submit to the Engineer for Notice, a Design Report which includes; calculations, schedules, construction methodology, monitoring proposal, specifications on material and drawings for the NATM tunnel construction, prior to the commencement of such works. Additional information shall be supplied upon request of the Engineer.
- (3) The Design Report shall explain the design philosophy, design assumptions, and design parameters of all Civil and structural works to be undertaken. Reference shall be made to Employer's Requirement, Section C– Design: for the requirements for the Design Report submission. In addition, the following items shall be accounted for in the Design Report:
 - a) Expected performance of the proposed support system for NATM tunnel
 - b) Support system requirements for various geological conditions likely to be

encountered

- c) Sequence of initial support and final support for the tunnel
- (4) The Contractor shall also prepare a Method Statement which presents full details of the design, the materials, equipment, plant and operations involved in the construction of NATM tunnel. The Method Statement shall be consistent with the construction methodology presented in the Design Report. This Method Statement shall be submitted to the Engineer for Notice in support of the Design Report.

3.7.2 Types and General Construction Methods

- (1) The configurations and profiles of NATM tunnels as shown in the tender drawings are only for information and the same shall be detailed/ finalized by the Contractor duly complying all the Contract provisions/requirements. The proposed profiles of the NATM tunnels including that of tunnel invert shall be suitable for the applicable ground conditions
- (2) The top of rail alignment is shown on the Employer's plan and profile drawings. Unless specified otherwise, the NATM tunnels shall generally be in horseshoe shape with appropriate invert profile suitable for the applicable ground conditions.
- (3) NATM tunnels are in general expected to be in weak rock, hard rock and mixed ground conditions.
- (4) Initial ground support (primary support) for the NATM tunnels is expected to comprise, rock dowels, rock anchors, lattice girders, steel ribs, spiles, pipe-roof, plain or reinforced shotcrete and a combination of the aforesaid supports.
- (5) The final ground support (permanent support) for the NATM tunnels is expected to be plain or reinforced cast in-situ concrete lining. The design of final ground support shall ignore the presence/contribution of initial ground support.
- (6) The Contractor shall be responsible for the safety and security of excavations at all times during the execution of the Contract.
- (7) The Contractor shall present to the Engineer for Notice, details of his proposed methods for excavation, spoil removal, ground treatment, installation of initial support and final support construction.
- (8) Excavation shall be carried out in a uniform and controlled manner, over-cutting or over-excavation shall be kept to a minimum. No excavation shall take place until the Engineer's Notice has been obtained.
- (9) The Contractor shall adopt such appropriate methods and take such steps as are necessary to control water in-flows and movement into the tunnel being excavated and to maintain the stability of the excavation.
- (10) Where the Contractor's site and EBS investigations indicate that there are already limits in imposition for movements, distortions and/or protection in respect of existing adjacent EBS, the Contractor shall provide calculations to demonstrate that the method of excavation will result into compliance of all those limits/requirements. The Contractor shall also comply with the requirements of the Relevant Authorities with regard to movements or distortions of these EBS. Where such limits/requirements are not specified by the Relevant

Agencies/Authorities, the Contractor shall assess each EBS that may be affected by the Works and submit his proposed limits of movements and distortions that are needed to be imposed for those EBS, to ensure compliance to all the provisions of the Contract, for seeking Notice of No Objection from the Engineer.

- (11) The Contractor shall submit to the Engineer details of his proposed instrumentation and monitoring arrangements for ground and EBS movement and distortion and changes to the groundwater table(s) and the trigger (Alert, Action & Alarm) levels for each and every identified EBS and/or monitoring instrument in accordance with the Contract.

3.7.3 Tunnel Design Requirements

- (1) The design life of final support shall be 120 years and that of non-structural components as 50 years.
- (2) The design Fire Resistance Period for the final support of the tunnel shall be 4 hours.
- (3) Minimum grades of shotcrete and concrete shall be M30 and M35 respectively.
- (4) The excavation sequences for heading, benching and invert shall be designed in such a manner that the deformations inside the tunnel shall be limited to the design deformations as considered in fixing the excavation profile. The design calculations for the support system shall be carried out with standard software available in the market, e.g. UDEC, 3DEC, FLAC, PLAXIS, etc. However, the Software proposed to be used by the Contractor shall have been validated on similar applications and if found necessary, the Contractor shall submit the required documents/details in support of such validation. The design submitted for the same shall also indicate the adjustment for support system requirement with respect to the instrumented data gathered during execution.
- (5) During the tunnel excavation, the water-inflow shall be controlled to meet all the obligations and responsibilities of the Contractor as stated in the Contract. For this purpose the required ground treatment/ dewatering, as may be necessary, shall be undertaken by the Contractor.

3.7.4 Design Loads

- (1) The design method shall consider in-situ ground stresses and shall provide evidence and/or measurements in support of the parameters adopted in the design as part of the calculations. The ground load on the tunnel shall be based on the actual height of overburden above the tunnel lining and the coefficient of earth pressure at rest of the soil strata surrounding the tunnel and the rock loading as worked out from the rock-mechanics engineering principles. The effect of over-consolidation of ground shall not be considered in the design of final ground support of tunnel. .
- (2) The design shall take into account all additional loads, stresses and strains imposed by or on adjacent EBS and assumed distortions and loads by or on the proposed NATM tunnels.
- (3) Where NATM tunnels are adjacent to or beneath EBS, the design shall demonstrate that these EBS shall not be subjected to unacceptable movement, distortion or loss of support which endangers the stability of the EBS and that any resulting movements and distortions will be within prescribed limits determined

by the authority for that EBS, the Engineer, or by the Contractor as agreed with the Engineer. Please also refer provisions of clause 3.4 in this respect, which shall be fully complied with by the Contractor.

- (4) Linings shall be designed to withstand all environmental loadings, distortions and other effects without detriment. In general, NATM tunnel support shall be designed to fulfil the following requirements and to resist the following loads.
 - a) Superimposed surface loads from traffic, existing structures over and adjacent to the NATM tunnel, and any specified future loads.
 - b) Appropriate ground loads (including soil load, rock load and rock wedge load), water pressure, and seismic loads.
 - c) Railway loads.
 - d) Superimposed dead and live loads from utilities, services, systems' provisions, pathways & walkways and structural elements within the tunnel etc.
 - e) Structural requirements for resisting buckling.
 - f) Long- and short-term ground yield or squeeze.
 - g) Unequal grouting pressures.
 - h) Adjacent bored/NATM tunnelling or excavation.
 - i) Openings in, or extensions to, the lining.
 - j) Long- or short-term loads induced by construction.
 - k) Temperature and shrinkage.
 - l) Accidental loading such as fire and derailment.
 - m) Any other loads as considered appropriate and necessary
- (5) The design shall also consider the relative rates of loading / unloading in both the lateral and vertical directions, and the resultant induced tunnel deformations whether temporary or permanent.
- (6) The design of the NATM tunnel linings shall take into account the proximity of other tunnels one to another, the sequence and timing of construction and the proximity of adjacent EBS.
- (7) All components of underground structures shall be proportioned to withstand the following applied loads and forces.
 - a) Dead load comprises the self-weight of the basic structure and secondary elements supported and the ground load. The depth of cover shall be the actual depth or a minimum of 3 metres. The depth of cover shall be measured from the ground surface to the tunnel crown.
 - b) Traffic surcharge shall be equivalent to Class AA loading of IRC-6. Latest revision.
 - c) Loads from existing or known future adjacent structures above or within the area of influence, which will remain in place above the NATM tunnels, or any specified future loading. The applicable foundation load and its influence shall be computed based on the type and use, and the foundation type which supports that structure.
 - d) Additional support, ground treatment or additional lining thickening shall be provided unless it can be shown that adequate provision already exists. Non-

Maha Metro structures shall not be supported directly by the NATM tunnel lining.

- e) Where provision for a specific future structure is not made a minimum uniformly distributed surcharge of 50kPa at the design finished ground level shall be assumed.
 - f) Hydrostatic pressure, ignoring pore pressure relief arising from any seepage into the tunnel. For derivation of hydrostatic pressure, the maximum groundwater level shall be taken as the 1 in 50 year return period water level or actual water level at the time of construction whichever is the higher, plus a 1.0m allowance for contingencies. The minimum groundwater level shall be taken as the lowest recorded value minus 3m or the level to which the groundwater table may be drawn down during construction, whichever is lower.
 - g) Loads and load changes due to known construction activity in the vicinity of the NATM tunnel, such as the excavation and the formation of underpasses, basements, pile groups, bridges, diaphragm walls and cable ground anchors and the like.
- (8) For members exposed to earth/ground and ground water (tunnel support), the maximum design crack width shall not exceed 0.2 mm irrespective of whether any additional protections, such as waterproofing membrane, are provided to the members at the exposed face (ground face) of the structure. However for the non-ground face (intrados of support) of the members, the maximum design crack width shall not exceed 0.3mm.
 - (9) The permanent NATM tunnel support shall be designed and checked for all possible combinations of applied loads and forces.

3.7.5 NATM Tunnel Support - Initial Support

- (1) Where tunnelling is carried out by NATM principle, temporary support is expected to be pipe piles, spiles, structural steel sets, lattice arch girders, base plates, ties and connections and lagging sprayed concrete (shotcrete) or cast-in-place concrete. All of them shall comply with the relevant standards and may be used together with appropriate ground pre-treatment as deemed necessary for the ground conditions likely to be encountered.
- (2) Steel sets and lattice arch girders shall be rolled to suit the dimensional requirements of the designed opening. The Contractor shall provide dimensional details of the steel sets or lattice arches girders and lagging which include all calculations regarding imposed loads before and after any ground pre-treatment.
- (3) Spiles shall be steel rods or tubes of outside diameter not less than 32 millimetres.
- (4) Pipe piles shall be steel tubes of outside diameter not less than 40 millimetres.
- (5) Rock dowels shall be untensioned steel bars threaded at one end and provided with a face plate, shim plates and a conical seated washer and nut, or split or deformed steel tubes, or glass fibre reinforced resin rods.
- (6) Rock bolts shall be tensioned bar manufactured out as one of the following types - solid steel bar, slit or deformed steel tube, glass fibre reinforced resin rods.
- (7) Alternative materials shall be subject to the Notice of the Engineer.

3.7.6 NATM Tunnel Support – Final Support

- (1) The tunnel final support constructed by NATM method shall be cast-in-place concrete (plain or reinforced) that are held securely in place and will remain so for all known possible future conditions.
- (2) The Contractor shall take into account all of the following when considering the design of the final support.
 - a) The internal dimensions required to accommodate the Kinematic Envelope, Structure Gauge, and track-bed arrangement as provided by the Trackwork Contractor and also the OHE (Overhead contact system) arrangement as provided by the Traction Contractor
 - b) Due allowance for relative movement between tunnels and cut-and-cover structures as described in the Contract.
 - c) The stiffness of the permanent lining shall be sufficient to limit the allowable deflection on radius under the expected loadings to a maximum of 10 millimetres with a maximum longitudinal distortion of 10 millimetres in 10 metres (1 in 1000) and a transverse distortion (ovalisation) of 4 millimetres in 6.0 metres (1 in 1500).
 - d) Short-term (during construction) intermediate (immediately after construction) and long-term (full design life) loading conditions.
 - e) Stresses induced by grouting.
 - f) Ground pre-treatment, where applicable
 - g) The reinforcement for final tunnel support shall be detailed such that there is no electrical continuity across the circle joints. To prevent the stray current effects and to inhibit the corrosion, suitable property enhancers shall be added in to concrete. Such concrete shall be tested in accordance with ASTM C 1202 and DIN 1048. RCPT value shall not exceed 1000 coulombs (at the concrete age of 28 days) and Water permeability shall not be more than 10 millimetres (at the concrete age of 28 days). Reinforcement of in- situ concrete lining shall be bonded to mitigate stray currents. The bonding shall be part of the corrosion control system designed and installed by the Contractor to the Notice of No Objection by the Engineer. The corrosion control system shall be tested and proven to the satisfaction of the Engineer that the corrosion control system functions as designed in all locations.
 - h) For Bonding and Earthing of Tunnel Support (Stray Current Protection), the Contractor shall provide stray current protection for the tunnel support in accordance with the Contract.
 - i) The formation of blind holes and all other fixings for brackets and equipment shall be detailed such that they have no adverse effect on the integrity, water-tightness and design life of the linings.

3.8 Cross-Passages

- (1) Passenger emergency evacuation design for cross-passages between running tunnels shall be in accordance with the requirements of NFPA-130-2010 standard for fixed guideway transit and passenger Rail system as follows.
- (2) In single-track tunnels the distance from a station (platform end) to a mid-tunnel

escape shaft (to the surface) or to the next station (platform end) shall not exceed 762 metres. Cross-passages shall be permitted to be used in lieu of emergency exit stairways to the surface where trainways are divided by a minimum 2 hours rated walls or where trainways are in twin bores.

- a) The distance between adjacent cross-passages in the tunnel shall be provided as per clause NFPA 130-2010, clause 6.2.2.3.2
- b) Track cross over shall not be considered as cross passages
- (3) The locations of cross-passages shall be chosen to avoid critical sections of the alignment where their construction could have an adverse effect on adjacent structures.
- (4) The openings into the running tunnels shall have a width of 1.2 metres and a height of 2.1 metres. Throughout the cross-passage a minimum headroom of 2.1 metres shall be maintained over a width of 1.2 metres.
- (5) The cross-passage floor screed shall be laid to fall and drain into the running tunnel drainage system. Floor level shall correspond with the level of the bored tunnel escape route.
- (6) A concrete bulkhead fitted with steel door and frame shall be constructed to isolate the cross-passage from each running tunnel. This door shall be self-latching, have a fire resistance of 2 hours minimum and shall be capable of withstanding the maximum differential pressures on either side created by the passage of trains. The maximum force to open the door shall be as per NFPA 130-2010, clause 6.2.2.4.2
- (7) The cross-passage permanent lining shall comprise concrete lining designed generally in accordance with the requirements of these documents with the following exception that the maximum allowable deflection on radius shall be as per IS : 456 clause 23.2 (b)
- (8) The junctions with the running bored tunnels shall be steel-framed and encased with concrete. The junctions shall be designed to fully support the running tunnel linings at the openings together with the ground and groundwater loads on the junction itself.
- (9) The cross-passages and junctions shall comply with same water-tightness criteria as the bored tunnels.
- (10) Where openings for cross-passages and the like are to be formed in running tunnels with segmental concrete linings, temporary internal supports to the running tunnel lining shall be provided. These supports shall adequately restrain the ground and lining such that on completion of the openings and removal of the temporary supports the total deflection of the linings in either the opening, junction or running tunnel and water ingress do not exceed the limits.

3.9 Temporary Shafts

- (1) The principal method of access for the erection, launching and retrieval of TBM and for the supply and removal of materials for the tunnelling works is expected to be within the ends of station box structures and preferably from the off road station site areas (wherever possible). If provision cannot be made in the structural design of the station works or in the construction programme, the Contractor shall propose alternatives and submit the same to the Engineer's Notice prior to commencement of the Works.

- (2) The Contractor shall be responsible for obtaining all appropriate approvals from the Relevant Authorities for all such alternative works. No additional payment shall be admissible on this account as the Contractor is deemed to have accounted for the same in his tender/bid documents.
- (3) Temporary access provisions within the station box or outside the permanent wall of the station shall be designed and constructed to ensure the integrity of the temporary works and permanent structure at all stages of the Works and the water-tightness of the completed station and bored/NATM tunnels.
- (4) The scope of work for additional temporary shafts shall include all of the following.
 - a) Any additional site investigation considered necessary by the Contractor to design and execute these works.
 - b) All topographic, utility and building condition surveys;
 - c) Analysis of potential ground movement effects and the design of measures to control such effects.
 - d) Structural design of the shaft to meet the Contract requirements for cut- and-cover design.
- (5) The Contractor shall ensure the compatibility of permanent and temporary Works designs and construction schedules and that construction interfaces are resolved.
- (6) Temporary access shafts shall be backfilled with suitable material in accordance with the Contract. Temporary works shall be removed to 2 metres below original ground surface level, unless otherwise instructed, prior to full ground reinstatement work. All affected roads, pavements and landscaped areas shall be fully reinstated.
- (7) Where temporary shafts are required within or adjacent to road alignments such that the works for and operation of the temporary shaft may interfere with traffic on that road, the temporary shaft design shall aim to minimise long term traffic disruption at this location. The size, layout and period of occupation of road space at this temporary shaft shall be included in the Contractor's submissions to the Engineer for notice. The design shall allow for all EBS as specified in these documents.

3.10 Tunnel Maintenance Walkways

- (1) The Contractor shall be responsible for the design, provision and installation of a tunnel maintenance walkway throughout. The maintenance walkways (to be provided for both the tracks) shall be provided between the end of platform to the beginning of next (adjacent) station's platform.
- (2) The location of the walkway shall be determined to provide a generally continuous walkway to permit maintenance access and staff at any point in the tunnel.
- (3) The fixed steps/ladders/stairs from track-bed level to walkway level, as required shall be provided by the Contractor as Noticed by the Engineer.
- (4) The walkway shall provide a durable non-slip surface set to a fall away from the track at a level as shown in approved SOD of the Project and as agreed by the Engineer. The walkway shall be minimum 600 mm wide and provide a 600 mm

wide X 2000mm high walkway space (walkway envelope) clear of fixed equipment. It is to be noted that the walkway width mentioned in this section is the minimum width required for walkway, whereas in case of side evacuation the suitable walkway with shall be provided. For same the space requirements given in Pune underground-approved SOD shall be followed.

- (5) The Contractor shall interface with the Designated/Interfacing Contractors to determine the setting out dimension from track centre line.
- (6) The design shall permit maintenance access to tunnel services mounted below the walkway and allow for ducts and/or pipes/cables to pass from below to above walkway level without impinging on the 600mm clear width.
- (7) The walkway shall be designed for a uniformly distributed load of 2.5kN/m^2 and shall be securely fixed to resist the effects of passing trains and movement of passengers and emergency services personnel. The design life shall not be less than 50 years.
- (8) Metal components such as bearers or handrails shall be provided with stray current corrosion protection as required. Particular attention shall be paid to step voltage from the Rolling Stock to earth for the protection of passengers.

3.11 Sumps in Running Tunnels

- (1) Sumps shall be located at every low point of the twin tunnels and located inside a cross-passage at the low-point. Where there is no cross-passage (between the twin tunnels) at the low-point, Sumps shall be located at these low points within each running tunnel. In case of siding/stabling/turn-back tunnels (single/twin tunnels) also the Sumps shall be located at suitable locations and as agreed by the Engineer. The Contractor shall coordinate with the adjacent station plumbing design before installation of pumps and drain-pipe connections.
- (2) Wherever practicable, the vertical alignment shall be chosen such that the locations of sumps avoid critical sections where their construction could have an adverse effect on adjacent structures.
- (3) The size of each sump shall take account of the anticipated rate of flow into the sump, the priority rating, the number and types of pumps to be installed and the reserve capacity required above alarm level.
- (4) The reserve capacity of a groundwater seepage sump shall be calculated on the basis of the area of bored tunnel/NATM tunnel/other underground structure's lining/wall, applicable to the sump in accordance with the following formula.

$$V_R = A * v * t * \text{F.O.S.} * 10^{-3}$$

Where,

V_R = Volume of reserve, m^3

A = lining/wall area, m^2

v = Maximum leakage rate, $\text{l/m}^2/\text{day}$

t = Maximum response time, (day)

F.O.S. = Factor of Safety

- (5) For running tunnel/underground structures', sumps the response time "t" shall be 24 hours and the factor of safety shall be 1.5.

- (6) The sump design shall include outlets for the longitudinal drain pipe and discharge mains, pumps of suitable capacity and power connection. Sumps shall be fitted with steel covers and provided with step irons or access ladder. Permanent discharge mains shall be installed as well as embedment of conduits for permanent electric power cables to the pumps.
- (7) The Contractor shall investigate the overall capital cost and running costs and feasibility of either installing the discharge mains to the station or a direct pumping main through a borehole to the surface and submit his proposal to the Engineer for Notice. The layout shall be such as to facilitate easy removal and replacement of pumps.
- (8) The linings of the sumps shall be designed for the appropriate ground and groundwater loads.
- (9) The design and construction of the junctions with the running tunnel linings shall be in accordance with the general requirements of these Outline Design Specifications.

3.12 Underpinning of Existing Structures (EBS), Ground Treatment and Temporary Support

The Contractor shall formulate all the required proposals, including their design, for underpinning of EBS, Ground Treatment and Temporary supports etc., as may be necessary to fulfil all his obligations and responsibilities under the Contract and submit them to Engineer for seeking his Notice of No Objection. Once agreed by the Engineer all such works shall be carried out by the Contractor at no extra cost to the Employer.

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 VII - Outline Design Specifications

S.04 STATION ARCHITECTURAL WORKS

June 2018

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4.1 GENERAL

4.1.1 Introduction

This section defines the principles for layout and arrangement decisions for all station buildings within the network of the Pune Metro Rail Project. This design criteria deals only with the Line 1 underground passenger stations including elevated station at Civil Court and concentrates on the spatial, environmental, and functional aspects of the station design.

The sizing of the station areas shall be sufficient to accommodate the forecast ridership figures, as approved by the Employer, and the corresponding emergency egress requirements.

All related research, survey and other information gathering organized and performed by the Contractor should support to carry out the same design along with the requirements described herein. The final product of all design including related structures and services performed by the Contractor shall conform to the best and appropriate quality and performance in all aspect of function and aesthetics.

4.1.2 Design Requirements

- a) Unless stated otherwise in the Contract Documents the whole of the architectural works shall be constructed to comply with the relevant Laws and Regulations of the Indian Government and of Pune as well as complying with the requirements of the Pune Public Utility Authorities, Fire Regulations, and such additional requirements as may be stated in the documents.
- b) The design requirements relating to station passenger capacity shall be based on the best information on passenger numbers and flow patterns available at the time of design, notwithstanding the passenger numbers, included for information purposes in the Attachment A of this section.
- c) Unless stated otherwise in the Contract Documents the design requirements related to fire safety and escape shall be generally in accordance with NFPA 130 Standard for Fixed Guideway Transit Systems, 2017 Edition and references therein.
- d) The stations shall be designed to the crush loaded capacity of a 6 car train, which shall be considered as shall be 1574 passengers/train for the purpose of station design.

4.1.3 Design Factors

The design of the stations will respond to and be determined by the following factors:

- Operational requirements in the use of Island Platforms, side platforms and Platform Screen Doors (PSD)
- Traffic, Road and Pedestrian Requirements
- Passenger Integration with the other modes of transport in the vicinity of stations
- Provision of Utilities
- Structural Requirements
- Passenger forecasts and the resulting entrance location requirements
- Interfaces with proposed and potential future development projects
- Environmental Considerations including flood control
- Buildability and disruption due to construction
- Flexibility in design to allow stations to respond to site specific requirements
- Future expansion
- Phasing of plant and machinery provisions, ; and
- Maintenance and accessibility of equipment

4.1.4 Design Objectives

The station designs will need to have regard to the following objectives;-

For the public in general:

- Provide an attractive welcoming image with clear, spacious 'column free' public areas maximising the use of structural voids and natural lighting.
- Provide a positive Urban Design Impact (including to adjoining properties)
- Provide a distinctive corporate image
- Provision of links to other transportation systems for passenger integration
- Provision of links to existing parking facilities;
- Provision of links to adjoining properties, subways, pedestrian ways and footbridges
- Smooth traffic circulation at the stations and their entrances particularly with regard to the passengers arriving/leaving the stations by personal, private, Para-transit and public-transport modes.
- Safeguards to pedestrians, residents and adjoining properties from noise, vibration and air pollution
- Provide and maintain traffic safety on the roads
- No decrease in pedestrian utility at footpath level

For the operator:

- Provision for ease of use in different conditions; (normal, peak, off peak, abnormal, congested and emergency)
- Provide a quality work place and atmosphere for manned area and service personnel.
- Provide facilities that are easy to operate manage and maintain.
- Minimize on manning levels and responsibilities
- Exploit/realise the full potential for commercial revenue earning opportunities (both from fare-box and non-fare-box source) and the capacity/capability to link into commercial developments
- Provision of a flexible concept of circulation to allow to allow for substitution of escalators for stairs, additional points of vertical access (including to street level) as well as links to adjoining properties, footbridges and extended elevated walkways or subway systems.
- Provide the capability of increasing the number of ticket gates or direction of access, as the future needs may dictate. The ability to change to a different type of ticketing system as technology changes/advances.
- Services provision to the best of international standards but capable of upgrading to allow for increased levels of comfort or amenity.
- Provide advertising spaces at concourse and platform levels and the capability of providing additional space for this purpose at road side, over roads, on walkways and any other prime visual locations to generate additional revenue.
- Ability to construct a part of the station for initial operation and easily extend facilities for future expansion.

For the passengers:

- The effects of the design on passenger perception and behaviour
- The attractiveness of the facilities as measured by the following criteria;
 - Safety Intrinsic safety of the proposals
 - Time Perception of time, information, access time, waits time, reliability, and certainty.

- **Materials** The look and feel of materials, the sensory qualities of sound, light, smell, air quality, cleanliness and lack of contaminants.
- **Security** The risk of assault, perceived personal threat
- **Weather** Protection from rain and direct sunlight
- **Comfort** Fresh air and coolness (including necessary environmental control systems)
- **Access** Access for disabled passengers from street level to platform.
- **Signage** A detailed display signage at platforms, concourse and street levels, and direction signage to destinations including emergency signage. As well Station name at Platform level and Street Level.

4.1.5 Design Criteria

This section sets out the design criteria to be adopted in the planning and design of Metro stations in order to ensure consistency in layout, form, operation, and maintenance and system-wide identity. It is also intended that there shall be a consistency in construction, passenger circulation, operation and maintenance procedures throughout the system.

Stations will vary in complexity along the route and have been located by an interactive process influenced by ridership forecasts, interchange requirements with other rail systems, public transport interchange requirements, station spacing, alignment, utilities, road and pedestrian requirements, interfaces with developments and environmental considerations.

Concourse level will be assessed on station-by-station basis and will be determined by site constraints and passenger access requirements.

4.1.6 Essential Design Requirement

The Contractor shall have the freedom of planning and designing the stations subject to the following:

- The Number of elevators, escalators, staircases and their sizes shall be based on the patronage figures. A minimum of Fruins Level of service E (LOS-E) shall be maintained during normal service scenarios
- The Number of AFC gates and their arrangements shall be interfaced with the designated/interfacing AFC Contractor and the same shall have the approval of the Employer/Engineer.
- Boundary of land shall generally remain the same as shown in Tender Drawings. However, the Employer may alter the land boundaries depending upon the land acquisition by the Employer.
- The platform widths shall remain the same as shown in Tender Drawings. However, the same need to be validated by the Contractor and any change/alteration shall require the approval of the Employer/Engineer.
- The number and location of the entrances into the stations shall remain as shown in the Tender Drawings. However the position of the entrances and ancillary buildings/facilities may be varied by the Employer depending upon the availability of land and land acquisition by the Employer

4.1.7 Basis for Criteria

The essential quality in a satisfactory station layout is the provision of adequate space for the movement of patrons between ground level entrances and onto trains in the most direct and logical way. Important criteria that shall be applied in the development of station designs are to include:

- Sizing of Station Passenger Handling Facilities
- Emergency Evacuation

- Electrical & Mechanical Plant and Equipment space requirements
- Operation Requirements and Operational Accommodation
- Fire Safety & Compartmentation.
- Stipulated Design Standards
- Passenger circulations, comfort, ease of use, safety & security.
- Directional signage, way-finding, advertising, information signage, clocks
- Weather protection
- Development of uniform approach to the design and material usage
- Constructability of the stations.
- Street space identity for entrances

4.1.8 Permanent Land

The above ground structures and support facility shall be located within the permanent land shown on the drawings. Permanent land thus shown is land acquired by the Employer for the purposes of locating all above ground structures and support structures. Underground station structures shall be confined to the limits of the Works Areas as shown on the drawings.**

Private and government property will be affected by the temporary and permanent structures required for the Tunnel & Station support facilities. The Drawings show permanent street level station entrances and other support facilities based on current assumptions. The Contractor shall ensure that the design developed will fit with the actual land take by the Employer.

**** Refer to Tender Drawings**

4.1.9 Functional Spaces

In addition to safe and convenient passenger circulation, the station buildings are required to accommodate station operations and system functional space to operate and maintain the stations, building services, plant space (MEP/FP/Com./Signal Systems/Ventilation etc.) and rail operations.

The layouts showing functional spaces as currently understood from various sources have been shown in the tender drawings only for information. The layout and program requirements (using spaces noted in the Attachment-B: Space matrix for Underground stations) need to be reviewed duly interfacing with the relevant Designated/Interfacing Contractors and a final layout & program list shall be provided by the Contractor for each station buildings.

4.2 STATION LAYOUT

4.2.1 General

1) Layout

The layout of the stations is influenced by the track geometry, operational requirements, predicted passenger circulation & there life safety and electrical and mechanical requirements. The station shall be divided into public & non-public areas (those areas where access is restricted). The public areas shall be further subdivided into paid and unpaid areas.

Stations shall be designed around island platform configurations taking into account particular constraints imposed by the various station sites. Side platforms shall be considered for elevated line at Court station.

2) Platform

The platform level shall have adequate assembly space for passengers during normal, emergency and delayed operating service conditions.

The platform level at each station is determined by the minimum structural and spatial requirements, which allows for a concourse area to be located between street and platform.

3) Concourse

The concourse may contain the automatic fare collection system in a manner that divides the concourse into two distinct areas paid and unpaid. The 'unpaid area' is where passengers gain access to the system, obtain travel information and purchase tickets. On passing through the automatic ticket gates the passenger enters the 'paid area' which provides access to the platforms.

The arrangement of concourse is assessed on station by station basis and is determined by site constraints and passenger access requirements. It shall be planned in such a way that maximum operational surveillance can be achieved by the ticket window operator/EFO operator over ticket machines, automatic ticket collection gate (ATG) /automatic fare collection (AFC) gates, stairs and escalators. Ticket machines and ATG/AFC gates, shall be positioned to minimize cross flows of passengers and provide adequate circulation space.

Sufficient space for queuing and passenger flow shall be allowed at the top and bottom of stairs and escalators, ticket machines, ATGs and AFCs, entrances and exit point of the elevators.

Depending on site situation unpaid area could be provided below, at or above ground in line with the available permanent land. All security arrangements as required by the employer should be provided.

4) Entrances

Station entrances shall be located with particular reference to passenger catchment points and physical site constraints within the right of way allocated to the Metro System. Integrated entrances and ticket offices will also be permitted. All entry points will be assessed and addressed to flood control requirements station-by-station basis. Station entrances shall have provisions for closing and securing the station during non-operational hours.

5) Station accommodation

Office accommodation, operational areas and plant room space is required in the non-public areas at each station. The functions, and minimum sizes (where applicable) are given in Attachment B (Space Matrix for Underground and Elevated Stations).

4.2.2 Queuing

Space shall be provided for queuing at all circulation and passenger service elements. The queuing area provides space for passengers to queue at various circulation elements, service areas and decision points without disrupting the movement of other passenger flow routes.

Queuing spaces shall be placed end to end; and shall not overlap. They shall be considered as part of the general space requirements for any given area, as indicated below:

Location	Min. queuing space
Card Readers, from face	2400mm
Add-Value Machines, from face	2400mm
Customer Service Centre, from counter edge	2400mm
Escalators, from working points	8000mm
Excess Fare Office, from counter edge	2400mm
Lifts, from threshold	2400mm
Stairs, from working points	4000mm
Ticket Gates and smart card gates, from face	6000mm
Ticket Sales Windows, from counter edge	2400mm
Ticket Vending Machines, from face	2400mm

A minimum of Fruin's LOS D (level of service) in queuing areas shall be provided during normal peak flow conditions. Queuing space in front of security/ frisking booths shall be maximized. At platform level queuing area provided for escalators & staircases shall be adequate to provide above mentioned level of service to alighting passengers from a trains running at designed headway during peak hours.

4.2.3 Railing and Fall Protection

Horizontal railing, functioning as guard rails, to the heads of stairs, escalators cut-out or other open wells through floors, shall be constructed to a minimum height of 1200 ± 5 mm above adjacent finished floor level. These should be designed in such a way as to withstand a crush load of 2.25KN per metre run.

In addition a handrail at 0.9m from finished floor level shall be provided. Materials shall be stable and robust. Any apertures within the railing shall preferably be enclosed with solid material but consideration may be given to the use of translucent or transparent materials as alternatives.

The design concept and materials of fall protection system for stair flights and the open wells shall be compatible with each other. Stairways will have handrails on each side of the stairs.

4.3 PASSENGER HANDLING

4.3.1 General

Passenger handling requirements greatly influence the station design and operation of the Metro Railway System. The design shall be based on a careful analysis of the requirements of the passengers and the operator.

It is essential that the system is designed to provide maximum attraction to passengers and the following criteria shall be observed:

- minimum distance of travel to and from the platform
- Provide adequate capacity for passenger movements
- Passenger convenience, including good signage relating to circulation and orientation.
- Provide safety and security, including a high level of protection against accidents.

4.3.2 Operator's Requirements

Following operational requirements should be incorporated:

- minimum capital cost is incurred consistent with maximising passenger attraction
- minimum costs are incurred consistent with maintaining operating efficiency and the safety of passengers
- flexibility of operation including the ability to adapt to different traffic conditions, changes/upgradation in fare collection methods and provision for the continuity of operation during any extended maintenance or repair period, etc.
- Provision of good visibility of platforms, fare collection zones and other areas, thus aiding the supervision of operations and monitoring of efficiency and safety.
- Provision of clear, logical and easy to understand display of passenger information and advertising.
- Maximising the comfort, safety and security of the passengers.

4.3.3 Provision of Escalators and Stairs

Escalator installations in the first instance may be less than the ultimate provisions made in the design. However structural provision shall be made in the entrance design and construction for future installation as required. All escalators from platform to concourse shall be installed on day one.

Stations shall be designed to accommodate passenger movement between two floor levels in paid area using escalators and staircases for up and down movement. The number of escalators and staircases shall be verified by checking the passenger flow capacity to be adequate for the Peak passenger flow rates, for both normal and emergency conditions.

Provision shall also be made in the electrical supply, together with consideration given to the inclusion of cables and conduit. Such stairs to be replaced by escalators in future shall be constructed so that they may be removed with minimal disruption to station operations. Stairs fed by escalators shall be sufficiently wide as to provide a capacity at least equal to that of the escalator.

For passenger convenience, the provisions of maximum number of escalators as permitted by NFPA shall be made.

4.3.4 Lifts (Elevators)

In principle, the provision of lifts shall be made from the street level sidewalk approach to the unpaid area of each station. Similarly paid area shall have Lift / Elevator to access the platform level. The lifts should be heavy duty transit lifts for 24-hours a day use in transportation terminals. The passenger lifts will have a rated net passenger capacity of minimum 13 persons, exclusive of the dead weight of an empty car.

4.3.5 Passenger Movement in Stations

In order to transfer passengers efficiently between street level and train and vice versa, station planning shall be based on established principles of pedestrian flow and arranged to minimise unnecessary walking distances and cross flows between incoming and outgoing passengers. A typical flow pattern for a passenger will be as follows.

- 1) Upon arrival at one of the entrances a passenger after passing through security screening will proceed to the concourse unpaid area to obtain travel information and buy a ticket. A passenger will then enter the paid area by passing with a valid ticket through an automatic ticket gate and proceed to the platform to board the first train traveling to his selected destination. A journey from the platform to the entrance will be in reverse with the exception that when a passenger's ticket is not valid, it will have to be exchanged for a valid ticket and an excess fare paid before leaving the paid area.
- 2) The detailed passenger flow forecast figures to be used for station design are provided in Attachment A. These figures provide peak hour flows for each direction of travel. The peak minute flow with surge shall be assumed as 2% of the peak hour passenger flow.
- 3) Except emergency exit capacity, all other aspects of station design shall also satisfy peak minute passenger flows corresponding to the ultimate passenger capacity of the line with operating headways of 3 minutes.
- 4) Each station shall be individually assessed and a view taken to ensure ultimate passenger handling capacity is available and that there is the ability to install the minimum and most economic facilities in the first instance.
- 5) Passenger handling components comprise stairs, escalators, elevators and automatic fare gates, that are required to process the peak traffic from street to platform and vice versa. These facilities shall also allow the emergency evacuation of the station to a place of safety within the specified time limit.

4.3.6 Pedestrian modelling shall be employed to verify adequacy of passenger facilities including ticketing, security, AFC gates, entry-exits and evacuation etc. Passenger Handling Capacities

In accordance with NFPA 130 except where specified below:

Moving escalator	as per Annex H of EN-115-1
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4.3.7 Passenger Flow and Level of Service

- a) Cross flows and changes in direction of passenger flow shall be minimised or eliminated. Obstructions, such as columns and barriers, shall be located away from the main passenger flow. Access points between concourse and platform shall be evenly distributed along the platform, and where possible minimise the walking distances for outgoing passengers and facilitate an even distribution of passengers waiting on the platform to board a train.
- b) To facilitate passenger flow, separation between incoming & outgoing passengers at entrances may be by a left hand rule and/or by escalator up and stairs down arrangements. This shall be further optimized as per operational requirements. The differing proportions of arriving and departing passengers in the morning and evening peaks shall be catered for by reversing the direction of ticket gates while catering to the security requirements. Public spaces shall be planned to provide open spaces allowing maximum surveillance by station staff. Narrow passageways, dead ends and visual obstructions shall be avoided.

- c) During design peak minute flow conditions the level of service for passenger flow in stairways, passageways, corridors, queuing area near automatic ticket gates, ticket offices, staircases and escalators, and passenger interchange areas shall be designed to provide an optimum level of services (minimum of Fruin's LOS D).
- d) Capacity Passenger Load Analysis: The public areas of station are required to accommodate peak capacity passenger loads for convenient passenger circulation. Preliminary assumptions have been made regarding widths of platforms, stairs/escalators, concourses, passageways and fare arrays. The following criteria need to be with the Employer/Engineer.
 - i. Minimum peak period level of service for passenger circulation
 - ii. Peak period train loads and frequency.
 - iii. Design peak passenger flows(both in and out) at stations
 - iv. Peak period passenger registrations and transfers.

4.3.8 Emergency Evacuation from Public Areas

Means of Egress shall be designed as provided in NFPA 130 (2017 Edition) and referenced documents. Following shall be the guiding principles in general for planning purposes:

- i) The ultimate design capacity of the corridor shall be considered as 31480 passengers in peak hour in peak direction with an operating headway of 3 minutes.
- ii) The crush loaded capacity of a 6 – Car Train shall be considered as 1574 passengers.
- iii) The station loads and section loads shall be factored up to correspond to the ultimate design capacity of the corridor (31480 phpd).
- iv) The worst case scenario giving rise to highest Platform Occupant Load (POL) shall be considered. For this purpose a traffic scenario with ultimate design capacity of the corridor, the crush loaded train capacity, design operating headway, appropriate service disruptions & system reaction time and surge factors shall be considered with the approval of the Employer/ Engineer.
- v) Peak hour passenger flows at station and peak hour link loads as provided in attachment A.
- vi) Trains on the non-incident line will not stop at a station affected by an emergency.
- vii) Egress Capacity Analysis
The stations' design shall satisfy the egress criteria as stipulated in NFPA-130 (2017 edition)
 - To provide sufficient egress capacity to evacuate the platform occupant load in 4 minutes or less.
 - To permit evacuation from the most remote point on the platform to a point of safety in 6 minutes or less.
- viii) The capacities of means of egress components and the travel speeds shall be considered as per NFPA-130 (2017 edition)
- ix) In stations, the concourse shall be deemed (designated point of safety) as a point of safety as per NFPA-130 (2017 edition) subject to the fulfilment of the requirements stipulated in the Standard.
- x) Escalators shall be permitted as a means of egress in stations as per the stipulations of NFPA-130 (2017 edition)
- xi) One escalator at each level shall be discounted while calculating egress capacity, as well discounted escalator shall be one having most adverse effect upon egress capacity as per NFPA-130 (2017 edition)
- xii) Elevators shall not be accounted as a means of egress even though their use for

the purpose is permitted as per NFPA-130 (2017 edition)

- xiii) In the event of fire, AFC gates shall remain in open position(designed to get released in the event of fire) to permit unimpeded travel in the direction of egress as per NFPA-130 (2017 edition)
- xiv) The Capacity of moving escalators shall be considered as per Annex H of EN 115-1.
- xv) Where the concourse is considered as a point of safety, the area of the concourse shall be large enough to accommodate the concourse occupant load (COL).
- xvi) The usable area at platform and concourse (point of safety) shall be sufficiently sized to hold the occupant load with Fruin's LOS E as per NFPA-130 (2017 edition), which can be taken as 0.2 square meter per person.

**** Above guiding principles will be refined further in design stages.**

4.3.9 Concourse Barrier Gates

Gates shall be provided in the barriers enclosing the paid area. At least one swinging gate shall be installed at the end of each major array of ticket gates. A minimum clear opening of 1200 mm is to be provided and the gate shall open in the outward direction from the paid area. These gates are to be opened in the event of an emergency and shall be included in the escape capacity calculations.

The total number of barrier gates required in the concourse will depend on the requirements for Emergency escape.

4.4 PLATFORM DESIGN STANDARDS

4.4.1 General

(i) Length

The platform length shall be 140 metres long measured between the controlled doorways or separation walls. This allows for the length of 6 car train and a stopping tolerance.

(ii) Width

All clearances from the platform edge shall be maintained as per the Schedule of Dimensions (SOD) for the project.

The platform edge shall have an adequate safety margin with a non-slip surface and a yellow warning strip of 100 mm wide of contrasting texture. The platform ends shall be provided with a 1000 mm wide security gate and be installed with a suitable alarm system.

(iii) Features

- a) A 1000 mm wide stair shall be provided at each end of the platform leading to the track bed.
- b) The platform nosing shall be level with the sill of the train doors of the rolling stock under normal conditions and for design purposes this shall be taken as 1090 mm above rail level. This may change once specific rolling stock has been chosen.
- c) Elevated Platforms shall be laid to a fall at 1:100 from the platform edge for a distance of 3000 mm away from the tracks. Underground Platforms should be laid flat.
- d) Markings on the platform to assist and control the flow of passengers shall be provided.
- e) Edge of platform shall be aligned as per the provisions of SOD with respect to the central line of as constructed track.

4.4.2 Platform Width Calculations

Space occupied by stairs, escalators, structure, seating, etc., shall not be included as part of the platform area.

Platform widths shall be determined to cater for the greater of the following scenarios:

1. Normal Service

Normal operating conditions require a reservoir of space for passengers waiting for a train. An average area of 0.5m² per passenger (Fruin's LOS D) is considered desirable under these circumstances. The required platform width for the design peak condition shall be calculated as follows:

$$\text{Required platform width} = \text{PSDW} + 0.6 + \frac{(F \times SI \times 0.5)}{PL}$$

Where,

F = peak one minute flow of boarding and alighting passengers entering a platform

SI = service interval (minutes)

PL = Platform Length

PSWD = width of PSD from platform edge

This formula is based upon the assumption that a 600 mm wide zone adjacent to the platform door will remain unoccupied when there is no train at the platform.

2. Delayed Service

The minimum platform width shall also be checked for against the following criteria for a delayed service scenario. For an island platform, the area between the boundaries of the two platform faces can be included in the calculation. An average area of 0.35m² per passenger (Fruin's LOS D) is considered desirable under these circumstances.

- Service disruption will be applicable to incident line, whereas non-incident line will function normally.
- A delay in service of 5 minutes is assumed in one direction in the peak hour.

$$\text{Thus Required Platform Width} = \text{PSDW} + \frac{[(5 \times F_i) + (SI \times F_{ni})] \times 0.35}{PL}$$

Where ,

SI = Service Interval (minutes)

F_i = Peak one minute flow of boarding and alighting passengers entering peak direction platform

F_{ni} = Peak one minute flow of boarding and alighting passengers entering non peak direction platform

PL = Platform Length

PSWD = width of PSD from platform edge

4.4.3 Other Features

- The track alignment through a station shall be straight and level. However, consideration may be given to using horizontal curvature where required with minimum radius of 1000 metre. Each location shall be judged individually.
- Manhole access shall be provided into any under-platform cable or duct compartment
- Drains shall be provided in all voids under platforms, where applicable.
- A Train Operator's toilet with a rest room shall be provided at terminal station platforms and at others as may be designated by MAHA METRO.
- Space for fire hydrants, fire hose reels, communications equipment's, paging equipment, signage track side advertising panels, and commercial communications facilities, shall be provided as required.
- Passenger access points shall be arranged to encourage the distribution and collection

of passengers evenly along the whole of the platform length. If required, access points may be offset from station to station to provide an even loading of passenger on train.

- g) All required emergency provisions for traction, signalling etc. should be provided post detailed interface with other disciplines.
- h) Interface with E&M: Station layouts with huge volumes in public spaces may be detailed without false ceilings. Such a layout would require unconventional routing of services. In absence of false ceiling in public areas; all services like lighting, camera, speakers, etc. shall be routed through overhead integrated service boom. Air conditioning of such volumes would be inefficient if routed through ceiling. HVAC ducts shall be routed below floor and provision for floor mounted units shall be accordingly interfaced and considered during detailing of such spaces.

4.4.4 Clearances

All track and platform clearances shall be maintained as required in the Schedule of Dimensions (SOD) for Pune Metro stations.

4.4.5 Seating

A minimum of four banks of three seats shall be provided along the length of each platform away from the main passenger flows. In the case of an island platform, consideration shall be given to the location of seats in the central area. The length of each bank of seats shall not exceed 2000 mm and the top shall be fixed at a height of 400 mm from the finished floor.

Where possible, the seats shall be cantilevered from a back wall to facilitate floor cleaning. The projection from the wall shall not exceed 500 mm.

4.5 CONCOURSE DESIGN STANDARDS

4.5.1 General

The concourse shall be divided into two distinct areas by AFC gate arrays and security barriers. The unpaid area is where passengers obtain travel information, and purchase tickets before proceeding through the automatic fare collection gate line into the adjacent paid area from which access is made to the platform level.

4.5.2 Concourse Size

The layout of the concourse is mainly determined by the location of station entrances, emergency evacuation requirements, and the siting of access points to the platform. General standards are:

- Where more than one concourse area is planned then the paid areas shall be connected to allow station staffs access to both areas and passengers an alternative means of exit.
- Public facilities in the concourse shall be located clear of the main passenger flow routes.

The size of the concourse which shall be needed to accommodate the design passenger flows shall vary with the number of ticket windows, and the way in which the primary concourse elements are arranged. This depends in turn on escalator and staircase requirements and the location of the entrances.

4.5.3 Access and Space

The unpaid area shall provide adequate space for passenger circulation and direct flow lines between ticket machines and Automatic ticket gates. Space shall be allowed for passengers' decision making and the provision of public facilities and ticket machines for boarding passengers.

The paid area shall give direct and clearly defined access to the platforms. Any public facilities in the paid area shall be located away from the direct route to the escalators and stairs.

Paid areas shall be separated from unpaid areas by a suitable balustrade barrier or glass partition. Where necessary this balustrade will contain emergency exit gates and make due allowance for both the initial and future installation of Automatic ticket gates.

A lift for passenger use, particularly the disabled and for first aid and minor casualties shall be provided between platform and concourse. A similar facility shall be provided between concourse and street level in association with at least one principal entrance.

All platforms shall have at least one passenger staircase extending to the concourse level. This staircase must be located within the paid area in order that it may be used when an escalator is out of service and during emergencies.

4.5.4 Clearances

In all public areas a minimum ceiling height of 3000 mm shall be adopted with a minimum height of 2500 mm to the underside of local obstructions such as signage. Electrical and Mechanical installations and service routes shall be contained above the ceiling height, and allowances for these services shall be taken into account.

A floor finishes zone 150mm deep or as required shall be provided to contain all necessary floor cable trunking for the provision of ticket machines and ticket gates associated with the Automatic Fare Collection system. The trunking shall not disrupt the finished floor surface.

5m clear height is required in back of house areas and operational areas.

4.5.5 Acoustics

Due consideration shall be given to the acoustic environment of all public areas with particular reference to the design and performance of the public address system. The acoustic design of stations must provide a good aural environment, in which people can communicate clearly and easily, and the build-up of excessive noise is suppressed. Public Address announcements must be easily heard and understood. A comfortable acoustic environment must also be provided for the employees in the non-public areas, such as in office and administration areas. The detailed design consultant of the Contractor must provide documentation that the final station designs achieve these goals.

Selection of appropriate finishes providing effective sound absorption can control the level of reverberation and provide a comfortable acoustic environment.

Note **: Platform level shall be designed in such a way so that any major structural sound disturbances could be avoided with regard to the selection of materials.

4.6 ENTRANCES

4.6.1 General

Station entrances provide the link between the station concourse and the surrounding streets, and their location must reflect the separate constraints of both. Where required they shall also cater for inter modal interchange which may include bus transfer, taxi, motorised rickshaws, motorcycle and bicycle transfer, kiss and ride and park and ride facilities etc. Covered integrated links with such facilities shall be considered if the predicted passengers warrant.

The design of entrances shall ensure they are easily identified as being part of the Metro system.

Entrances shall be located within the right of way under the control of the Maha Metro. The number location and width of entrances shall remain as shown in Tender Drawings, generally unless otherwise notified by the Employer/Engineer.

4.6.2 Requirements to Locate Entrances

a) At-grade entrances and facilities of an underground station, as small as they are

compared to their sub-surface building mass, must be designed to be visible, recognizable and to attract passengers. Entrances shall unite the various vertical circulation elements such as stairs, escalators and lifts, together under one roof to enforce intuitive way finding. The position of entrances shall be determined by the juxtaposition of buildings, location of roadways, footpath width, space availability and flow directions of passenger traffic.

- b) The widths of adits/accessways shall take into account predicted passenger flows and available space with minimum width of shall be 4500 mm. Entrances to stations shall have adequate capacity to satisfy predicted passenger flows and emergency evacuation requirements.
- c) Each entrance shall contain a closure device for securing the station during non-operational hours and as a means of crowd control. The preferred method shall be electrically operated roller shutters or collapsible gates.
- d) Entrances and emergency exits are to be adequately lit so as to help passenger orientation especially in cases of emergency evacuation. An emergency lighting system is to be in place as a backup with an uninterrupted power supply in case of power failure. Any external areas or features such as seating areas, drop offs, frisking etc. are also to be adequately lit to help prevent vandalism or crime, and to make the entrances clearly visible and attractive at night.
- e) Each station shall be accessible via at entrances from street level, wherever possible, at least one from either side of the street. Each entrance shall optimally have at least one escalator, lift and stair. Where planning constraints dictate, alternative solutions may be proposed for the consideration and decision of the Employer/Engineer.

Each entrance shall have the consideration of space at ground for covered frisking facilities where possible. In case of the integrated entrances the frisking space shall be considered in subways/walkways/sky-walk/unpaid concourse etc.

4.6.3 Flood Control

All entrances extending to street level shall be protected against flooding. This protection shall be by the provision of a minimum of 4 steps and/or ramp of equivalent height up to a landing a minimum 600 mm above adjacent flood levels. The design of such protection shall be achieved/ verified by Contractor according to the proper study of flood history record and topographical survey data.

Where required for flood protection the stairwell on pavement entrances shall be surrounded by a solid concrete balustrade 900 mm high. At sites not affected by flooding alternative entrance envelopes can be proposed.

4.6.4 Material Considerations

The selection of materials shall not radically depart from those used within stations and shall be robust, hard wearing and maintenance free.

Floor finishes are to be laid to adequate falls in order to allow for the occurrence of any seepage, rainwater (from foot traffic), washing water, etc. associated drainage provisions, including sumps and pumping facilities shall be provided.

4.6.5 Integrated Entrances

An integrated entrance is an entrance incorporated within a development and may not be under the direct control of the Metro. It shall not form part of a required exit route for either a station or the development and shall not be included in passenger capacity calculations.

1 Fire Precautions

All provisions with respect to the fire safety of the station and the development shall be agreed with the Fire Services who may require specific safety

requirements at particular locations.

2 Flood Control

Where the entrance is below ground level, or below the predicted flood level, full height flood-proof doors shall be provided at the point of entry to the railway or other approved locations. These are required to ensure that conditions outside the immediate control of the Metro do not endanger the railway.

3 Frisking

Frisking facilities shall be provided inside the integrated entrances (as required for all standard station entrances), before entering to the dedicated entrances for the Metro system.

4.6.6 Entrances in Developments

- Entrance structures within a development shall be designed in such a way that the use of the entrances is not adversely affected by any future redevelopment of the building structure.
- Entrances shall be separated from the development by four-hour FRP structure up to the discharge point of the entrance onto the footpath.
- Flood protection, as required for all standard station entrances shall be provided.
- Frisking facilities, as required for all standard station entrances shall be provided.

4.6.7 Development Entrances under the control of Maha Metro

Where a horizontal or vertical entrance to an Integrated Commercial Area is provided, and is under the direct control of the Maha Metro, it may be used as part of an escape route in the event of a fire. The Integrated Commercial Area will need to be designated as a Place of Safety and will therefore come under stringent Fire Precautions and the design will be agreed on an individual basis.

4.7 ESCALATOR, STAIR AND LIFT (ELEVATOR'S) DESIGN STANDARDS

4.7.1 Entrance and Concourse Requirements

These are preferred standards, where site conditions permit consideration shall be given to entrance configurations that provide access from concourse to ground level via a single stair or escalator rise.

- For greater rise heights, the entrances may be divided into two portions; both portions shall have equal number of escalators and staircases.

2 Other requirements

Entrances shall be arranged so that where possible the first riser of a flight of stairs shall be 1000 mm from any change of direction in the entrance.

Where the width of the staircase is 2400 mm or more a central handrail shall be provided on the stairs (but not at landings).

Where staircases are parallel to escalators, the first riser shall preferably be positioned one tread width from the lower Escalator Working Point (EWP) towards the upper EWP, but the total rise may dictate otherwise.

Where an entrance escalator allows passengers to ascend directly to street level the roof or rain canopy shall be enlarged to provide a greater waiting area.

4.7.2 Concourse and Platform Requirements

- Where possible, the escalators shall be evenly distributed along the whole length of the station so as to avoid a concentration of passengers at a particular area. An escalator working point (EWP) shall preferably be not less than 8000 mm from any obstruction across the direct path of passengers. Where escalators are arranged in

banks, the clear distance from the escalator working point shall be increased by at least 1000 mm for each additional escalator. Traffic flow across the path of passengers is deemed as an obstruction.

2 Safety

The combined capacity of stairs and escalators must be capable of satisfying the emergency evacuation requirements or normal passenger handling requirements, whichever are the greater.

A smoke containment bulkhead shall be provided at the foot of all stairs and escalators serving the platform level. It shall extend to the structural soffit from a height of 3000 mm above the platform finished floor level.

3 Other requirements

Where possible, passengers shall not have to travel from one passenger level to the next by more than one escalator. However all escalators and stair cases provided for interchange passenger flows from a level below ground to a level above ground shall preferably have a break at ground level for emergency evacuation facility.

Preferably no access shall be allowed from public stairways to plant-room areas.

4.7.3 Firemen's Staircase

An independent access staircase shall be provided for the sole use of firemen and station operational staff for each station. This staircase shall exit at ground level to open air and shall gain access to station control room of the station.

Firemen's staircase and other provisions shall be in accordance with firefighting requirements. The firemen's staircase shall not be included in the emergency evacuation calculations.

In absence of firemen's staircase a firemen's lift (arrangement of paid and unpaid lifts is acceptable) shall be provided. This lift shall exit at ground level to open air and shall gain access to each principal level of the station.

4.7.4 Escalators

All the escalators shall be designed as per Annex H of EN-115-1. The actual details/requirements shall be interfaced with appropriate system contractor/ employer.

4.7.5 Stairs

These standards refer to all stairways used by the public including auxiliary staircases. All staircases shall comply with local regulations

1) General Requirements

- All staircases are considered as egress elements and shall comply with the provision of NFPA 101
- All treads, nosing and intermediate landings shall have non slip (slip resistance) surfaces.
- All stairs shall be provided with handrails on both sides. Where the clear width exceeds 2400mm a central handrail shall be provided. A central handrail may also be considered elsewhere where crowd control and passenger flows dictate. The handrail shall extend a minimum of 600mm beyond the bottom riser and 300mm beyond the top riser.
- At both ends of stairs, a minimum run-off zone of 4000 mm in length and at least as wide as the stairs shall be provided. The run-off zone shall be clear of all obstacles or structural elements.
- The leading edge of stair treads shall be provided with a rounded nosing with a

radius of between 6mm and 12mm.

2) Design Parameters

Continuous flights of stairs for use by the public shall have the following design parameters:

Risers per flight	as per NFPA 101
Height of riser & Length of tread (subject to pitch)	as per NFPA 101
Stair width	Minimum 1500mm for normal movement of passengers. Minimum as per NFPA 101 for emergency use of passengers.
Length of intermediate landings	Lesser of 2000 mm or width of stairs.
Handrail	900 mm high, 50 mm diameter 1200 mm high, guard rail 45 mm clearance between handrail and inside balustrade or wall finish.
Falls at entrance stairs	Flood landings are to fall 1:100 towards the street with side channels.

- Staircases fed by an escalator shall be made sufficiently wide to provide capacity at least equal to that of the escalator.
- The width of a staircase shall be measured from the finished surfaces of the inside faces of the balustrades or staircase walls. The only permitted projection into this width shall be the handrail.
- No open risers shall be allowed.

3) Firemen's Staircase

The minimum width of the Firemen's Staircase shall be 1200 mm, with tread and riser heights and all other requirements relative to this staircase to be in accordance with firefighting regulations.

4.7.6 Lifts

These standards refer to all lifts used by the public on all levels:

1) General Requirements

- All lifts shall comply with the provision of NFPA 101 and EN-115.
- Lift of minimum 13 passenger capacity shall be provided.
- A minimum run-off zone of 2400 mm shall be provided at each landing. The run-off zone shall be clear of all obstacles or structural elements.

2) Other Related Works

- Station shall have two or more lifts as per passenger flows. In some areas structural provision shall be made in the design and construction for future installation of lifts. The Future lift space shall be completely closed with full safety and not reachable to passengers, at later date these lifts can be installed.
- The lifts serving the street level shall be weatherproof and flood protected with fire rated separation from any adjacent development areas. They shall be connected by a 2 m wide paved access to the nearest road or footpath.

- These lifts shall be available for use by the disabled and any other person if required with provision for stopping at all floor levels in the station.
- Ramps shall be provided where a change in level is not negotiable by lift. The differently abled commuters shall follow the same route as any other commuter.
- Depending on cash handling arrangements for each station, the lift shall also serve the street level where access for a security armored car is required. However, security and flood precaution requirements must be satisfied.

All the design parameters mentioned are for initial station planning and to facilitate civil provisions. The actual details/requirements shall be interfaced by the Contractor with the designated/ interfacing Lifts and Escalator Contractor and as approved by MAHA METRO.

4.8 DESIGN FOR THE DIFFERENTLY ABLED

4.8.1 General

Unless stated otherwise in the Contract Documents the design shall be in accordance with the standards specified in “The Persons with Disabled Act” and “Harmonised Guidelines and Space Standards for Barrier Free Built Environment for Persons with Disability and Elderly Persons”, published by Ministry of Urban Development in 2016.

4.9 CORRIDOR AND RAMP DESIGN STANDARDS

4.9.1 Corridors

The width of corridors or passageways in public areas shall be determined by capacity requirements subject to the minimum dimensions given below:

- minimum for unidirectional movement 1800mm
- minimum for bi-directional movement 2000mm
- minimum for staff only movement 1200mm
- minimum for a corridor more than 30m length 3000mm
- minimum for corridor where equipment is moved 2400mm

Minimum headroom in underground passageways & corridors shall be 3000 mm from finished floor to finished ceiling / false ceiling.

4.9.2 Ramps

Ramps shall only be used for small changes in level or for use by wheelchairs and the following gradients shall apply:

- preferred gradient 1:20
- maximum gradient 1:12

Ramps shall be a minimum width of 1200mm for unidirectional movement and 1500mm for bi-directional movement. Rest platforms should be considered for long ramps (exceeding 10m) provided for wheelchair users. Rest platforms should provide a level area 1800mm long at intervals of 10m.

4.10 PASSENGER AMENITIES

4.10.1 General

A number of amenities shall be provided for the use of passengers within the station. Where these involve stationary passengers then the facilities shall be located clear of the main passenger flows.

4.10.2 Advertising

Advertising will be an important source of revenue for the Metro but the extent of the demand for advertising will depend on market forces. Potential sites for advertising within a station shall be located so as not to conflict with the principal requirement of the provision of signage to direct passengers, especially in an emergency.

4.10.3 Signage

Passenger information signs located at stations will be many and varied ranging from station entrance signs to train indicator panels and information panels.

All signage shall be of as per a uniform system-wide signage strategy provided by MAHA metro. Signs are to be provided in three languages.

Location of clock and public information system to be clearly identified

4.10.4 First Aid

First Aid and the treatment of minor injuries will be initially catered for at the First Aid Room.

4.10.5 Refuse Bins

Refuse bins shall be located throughout the station and approaches for disposal of small items of rubbish. The size of the bins shall be restricted to minimize the fire risk. The bins shall be emptied periodically and rubbish transferred initially to the refuse store and then to a ground level refuse collection point for removal by the public authorities.

4.11 ACCESS FOR MAINTENANCE

4.11.1 General

- a) All areas of the station shall be accessible for inspection and maintenance.
- b) Door and access panel sizes shall be of sufficient width and height for the installation / removal of the equipment within the room or rooms served. Manhole access shall have a minimum clear opening of 750 x 750 mm.
- c) Room layouts shall make provision for withdrawal space and circulation space around equipment where appropriate.
- d) The design of provisions for accommodating services routes and the location of equipment shall take into account maintenance and replacement requirements. Where ever possible services and equipment shall not be located above open wells or similar positions that will require the use of special equipment to gain maintenance access.
- e) To facilitate the replacement of large items of plant and equipment a minimum of two access hatch from track to concourse shall be provided at each end of a station. Lifting beams of appropriate capacity shall be provided together with heavy duty fire rated hatch covers. For initial design purposes a clear opening size of 3.0m x 3.0m shall be used but this shall be reviewed as plant sizes are defined.

4.11.2 Vertical Access

Vertical access for maintenance staff shall utilize one of the following:

- 1.2m minimum width of standard stair
- 1.0m wide 60° maximum pitch metal staircase with handrails with a maximum rise of 3.0m

- 0.5m minimum width of ladder access with hoops provided from a height of 2.0m for all rises above 3.0m
- 0.5m width of step irons. Step irons shall only be used where the rise is less than 3.0m.

4.12 FIRE PROTECTION

4.12.1 General

The design of stations shall be in accordance with NFPA 130 2017 Edition.

The design of a station shall include the following:

- fire prevention measures
- fire control measures
- fire detection systems
- means of escape
- access for firemen
- means of firefighting

All aspects of fire prevention and control will be subject to the approval of the authority having jurisdiction.

4.12.2 Fire Prevention

Fire prevention measures shall be designed and implemented to minimize the risk of outbreak of fire by appropriate choice, location and installation of materials and equipment. In station planning terms, potential sources of fire shall be reduced by:

- the use of non-combustible or smoke retardant materials where possible
- provision of layouts which permit ease of maintenance for equipment and cleaning of the station
- Prohibition of gas based cooking facilities in the staff areas.
- prohibition of smoking
- provision of cigarette and litter bins
- general good housekeeping
- staff training and procedures

4.12.3 Fire Control

Control of the spread of fire and smoke shall be achieved by compartmentation of fire risk areas, smoke extraction and smoke containment.

Compartmentation is aimed at limiting the extent of a fire. A compartment consists of a portion of the station or other structure, which is separated from adjoining portions by walls, floors and/or doors. Any opening shall be capable of being sealed in the event of a fire, e.g. duct openings sealed with fire dampers. Fire resistance periods (FRPS) shall be selected for spaces according to their degree of fire load and the degree of protection required for life safety, security of the system and the preservation of adjoining areas. Openings, including ducts and passages between MAHA METRO property and any adjoining structure which allows free access into the MAHA METRO property shall be protected by fire doors, fire shutters, fire dampers, etc., as appropriate.

4.12.4 Means of Escape from Non-Public Areas

Non-public areas of stations are accessible only to MAHA METRO Staff and usually only in small numbers. These areas shall be compartmented and fully covered by the fire detection and alarm system.

Escape from all non-public areas shall be possible to a point of safety. Where only one direction of escape is available travel distances shall be less than 25m. Where escape is

possible in more than one direction the travel distance shall be less than 40m Escape routes from plant areas may include manhole or ladder access.

4.12.5 Firemen's Staircase

The staircase shall be pressurized, and shall be fitted with sprinkler system and a fire-fighting hydrant. The locations of these stairs will be determined on a case by case basis.

4.12.6 Fire-Resisting Construction

The main structural elements shall be designed to have a Fire Resistance Period (FRP) not less than that specified below:

Fire Resistance Period (hours)		
Structural Elements	Underground structures, and other structures incorporating development above	Surface and overhead structures, without development above
Roof Structure	4	0*
Stations	4	2
Substations	4	2
Cable tunnels	4	2
Running tunnel linings	4	-
ECS & Ventilation Buildings	4	2
Ancillary Buildings	4	2
Staircases	4	2

* Where it can be shown that the structural elements supporting the roof can survive the design fire without undue risk of collapse.

4.12.7 Compartmentation of Station Areas

1) Lifts

Lifts in public (paid) areas may consist of glass cars with glazed doors and glass lift shafts. Such shafts shall be protected by concealed smoke reservoir bulkheads in suspended ceilings. Where lifts pass through floors that are not protected by smoke extraction they shall be separated from that floor by a minimum of one-hour (60 minutes) FRP separation.

2) Offices and Plant Rooms

Station Control Room glazing shall be protected by two (120 minutes) hour FRP automatic fire shutters.

All offices and plant rooms shall be separated from the public circulation spaces by two (120 minutes) hour FRP separation. Each plant room shall be a separate compartment. In plant rooms, roller shutters may be used, in addition to fire-rated personnel pass doors. Such shutters shall normally be closed and shall be fire rated to the same FRP as the wall in which they are contained. The Fire Resistance Periods to be used for sub-compartmentation shall be not less than specified below. Offices and staff areas shall be separated from the public spaces, but shall not be subject to sub-compartmentation.

4.12.8 Separation from Property Developments

The structural elements supporting, and the compartment walls and floors separating a station from a Property Development Area shall have four-hour (240 minutes) Fire Resistance Period. Where necessary this separation may be achieved by fire shutters. If a shutter comes down over the front of a shop or otherwise blocks an Escape Route, an alternative means of escape shall be provided.

4.12.9 Fire Compartmentation Drawing Submittal

For each station and surface building the Contractor shall prepare and submit a comprehensive set of layout drawings over-marked to fully illustrate designated compartments and their fire-rated-period classifications.

4.12.10 Fire Resistant Period for Sub-Compartmentation

In the accompanying Table

Note:

1. The FRP requirements in the Table are for general application only. With Individual FRP requirements considered on a case by case basis.
2. * Fire separation where adjoining staircases shall be 4 hours (240 minutes)

Fire Resistance Period (hours)		
Compartments	Underground structures, and other structures incorporating development above	Surface and overhead structures, without development above
Substations	4*	2*
Station Substations (including transformer rooms)	4*	2*
Ventilation Plant rooms	2	1
Electrical Equipment Rooms (excluding transformer rooms)	2	1
Escalator machine Rooms	2	1
Lift machine Rooms	2	1
Signalling Equipment Rooms	2	1
UPS/ Battery Rooms	2*	2*
Rectifier Transformer Room	2*	2*
Rectifier transformer bay (Outdoor)	N/A	N/A
Control Rooms (including Computer rooms)	2	2
Telecommunication Rooms	4	2
Ventilation Shafts	2	-
Under-platform Cable ducts	2	1
Exhaust Ducts	1	1
Protected Staircases	4	2
Store Rooms	2	1
Refuse Rooms	2	1

Fire Resistance Period (hours)		
Compartments	Underground structures, and other structures incorporating development above	Surface and overhead structures, without development above
Station Facilities, Offices, and other Rooms in Staff Areas	1	1
Pump Rooms	4	2
Standby Diesel generator Rooms	4	2
Fuel Storage tank Rooms	4	2
All other Areas	1	1
Toilet	2	1

4.13 PROVISIONS FOR FARE COLLECTION

4.13.1 General

Automatic fare collection system shall comprise of a Central Computer, Ticket Sorter, Station Computer, Ticketing Machines, Automatic Ticket Gates and Ticket Readers. Ticket vending in concourse of a station will consist of ticket issuing machines of two types. One machine type will be a ticket vending machine (TVM) which shall be located in the unpaid area of station accessible to passenger entering in the station. The second machine type will be a booking office machine (TOM) to be located within ticket office and will be operated by authorised staff.

Ticket gates shall be provided for controlling entrance and exit from the unpaid and paid areas. The gates shall be operated automatically by flashing contactless smart card/tokens at the gate allowing entrance/exit upon validation of correct fare.

4.13.2 Ticket Vending

Ticket Vending Machines (TVM) and Ticket Office Machines (TOM) :

The quantity of TVM and TOM shall be as per AFC requirements and verified against the projected flow of passengers at each station, and as approved by Employer/Engineer. However ticketing space should be designed taking passenger flow for the ultimate System Capacity

For initial planning purposes the following assumption can be made to calculate quantities of referred machines:

- TOM machines will issue both single and multi-journey ticket.
- Sufficient automatic ticket issuing machines shall be provided to cater for peak one minute flow rate without waiting period for ultimate ridership;
- At system opening date it is assumed that ticket sales (both single and multi-journey) will be from TOM machines, with each counter capable of serving 10 passengers per minute;
- A minimum of two ticket issuing machines shall be provided at each station. For space allocation purpose, expansion capability two windows shall be provided;
- TVM machines number will depend on the difference of passenger flow demand in ultimate system capacity and demand. Space for installation of TVM machines in future shall be provided.

- Each TVM machine will maintain a throughput of 5 passengers per minute assuming normal passenger actions and reactions.
- TVM machines shall be incorporated in a secure suite. The secure suite is to facilitate maintenance of TVM, loading and unloading of cashbox from the rear side of a TVM in a secure environment.

4.13.3 Automatic Ticket Gates

1) Type of Gates:

Ticket gates shall be reversible gates proving entry/exit. For initial planning purposes the ticket gates shall be taken as 1900 mm long, 300 mm wide, 1100 mm high with a clear passage of 600 mm for normal gates. For wide gate for disabled passenger, the clear passage shall be 900 mm (min)

2) Design Criteria

The following design criteria shall be adopted for the requirements of ticket gates.

- All passengers will use ticket gates on entering and leaving the system.
- Each ticket gate shall cater for 28 passengers per minute.
- Space shall be provided for sufficient ticket gates to cater for the predicted passenger flow in the year ultimate system capacity passenger flow.
- The gate array shall be located to facilitate most efficient passenger flow both for boarding and alighting. In order to optimize the infrastructure, the gates quantity must be estimated considering that all gates are reversible type, which can be configured in entry and exit mode depending on the passenger flow.
- The minimum distance from either end of the ticket gate arrays to any obstruction shall be 6m for passenger queuing.

3) Future Provisions

If future layouts are expected to differ from the initial operating layout, provision shall be made for power and control cable connections in the initial design. This shall include cabling for installation of TVM machines in future.

4) Other Gates

Emergency exit gates shall be provided in the barriers enclosing the paid area. At least one gate should be installed at the end of each major array of Ticket Gates. Each gate shall provide a minimum clear opening of 1200 mm and shall open in the outward direction from the paid area. These gates shall be included in the escape capacity calculations.

The total number of barrier gates required in the concourse will depend on the requirements for emergency escape.

Fixed stainless steel barrier shall be provided at the empty space in the gate area to physically separate paid and unpaid area.

The barrier array must accommodate the Excess Fare Collection Office.

4.14 STATION SIZING CALCULATIONS

Following the completion of acceptance of each of the final station layout designs, the Contractor shall submit a complete set of station sizing calculations, as confirmation of the final passenger handling facilities, emergency escape capacities, station sizing, fare collection requirements etc. to the Employer/Engineer.

ATTACHMENT-A - PASSENGER FORECAST

Passenger forecast shall be as per Detailed Project Report Chapter 2- Traffic Study prepared by DMRC. The same is attached hereunder.

ATTACHMENT-B - MINIMUM STATION ACCOMODATION AND FINISHING- UNDERGROUND STATIONS AND ELEVATED STATION

Pune Metro-Station Room Accommodation and Finishes						
Sr. No.	Room name	Size (Sq.m)	Room Specifications			
			Floor	Wall	Ceiling	Railings
1	Ticket Office(per booth)	1 no. (1.7mx2.4m)	1. Anti-Static Raised Access floor total 450 mm with Anti Dust sealer coat on concrete floor 2. Granite Worktop with supports	1. 12 mm thick Clear Toughened laminated glass on concourse side and cement plaster finished with Acrylic 2. Emulsion paint on internal walls elsewhere.	1. Non Perforated 600x600 powder coated M.S. ceiling panels with clear height of 3000mm from the floor 2. Anti-dust sealer coat on surfaces above the false ceiling	
2	Audit & Cash Storage Room	10	600x600 vitrified tile flooring of approved colour over 20 mm cement mortar bed with screed under layer screed laid to slope total 150 mm	1. Cement plaster with plastic emulsion paint including levelling surface with cement putty 2. 300 mm Vitrified Skirting	1. Non Perforated 600x600 powder coated M.S. ceiling panels with clear height of 3000mm from the floor 2. Anti-dust sealer coat on surfaces above the false ceiling	
3	Excess Fare Office (free standing unit) at both ends.	5 (1 at each end)	1. Anti-Static Raised Access floor total 450 mm with Anti Dust sealer coat on concrete floor 2. Granite Worktop with supports	1. 12 mm thick Clear Toughened laminated glass on concourse side and 2. Cement plaster finished with Acrylic emulsion paint on internal walls elsewhere.	1. Non Perforated 600x600 powder coated M.S. ceiling panels with clear height of 3000mm from the floor 2. Anti-dust sealer coat on surfaces above the false ceiling	

Pune Metro-Station Room Accommodation and Finishes						
Sr. No.	Room name	Size (Sq.m)	Room Specifications			
			Floor	Wall	Ceiling	Railings
4	Station Control Room	40	Anti-Static Raised Access floor total 450 mm with Anti Dust sealer coat on concrete floor	12mm thick Clear Toughened laminated glass on concourse side and cement plaster finished with Acrylic Emulsion paint on internal walls elsewhere.	1. Non Perforated 600x600 powder coated M.S. ceiling panels with clear height of 3000mm from the floor 2. Anti-dust sealer coat on surfaces above the false ceiling	
5	Station Manager's Room (includes meeting area)	25	600x600 vitrified tile flooring of approved colour over 20 mm thick cement mortar and under layer of screed laid to slope total 150 mm	12mm thick Clear Toughened laminated glass on concourse side and cement plaster finished with Acrylic Emulsion paint on internal walls elsewhere.	1. Non Perforated 600x600 powder coated M.S. ceiling panels with clear height of 3000mm from the floor 2. Anti-dust sealer coat on surfaces above the false ceiling	
6	First Aid Room	15	600x600 vitrified tile flooring of approved colour over 20 mm thick cement mortar and under layer of screed laid to slope total 150 mm	1. Walls up to 2100 mm height finished with 300x600 vitrified tiles and area between tiles up-to false ceiling 2. Below False ceiling: Cement plaster with plastic emulsion paint including levelling surface with cement putty	1. 15 mm thick calcium silicate board false ceiling finished with plastic emulsion paint 2. Anti-dust sealer coat on surfaces above the false ceiling	

Pune Metro-Station Room Accommodation and Finishes						
Sr. No.	Room name	Size (Sq.m)	Room Specifications			
			Floor	Wall	Ceiling	Railings
7	Security Room	15	600x600 vitrified tile flooring of approved colour over 20 mm thick cement mortar and under layer of screed laid to slope total 150 mm	1. Walls up to 2100 mm height finished with 300x600 vitrified tiles and area between tiles up-to false ceiling 2. Below False ceiling: Cement plaster with plastic emulsion paint including levelling surface with cement putty	1. 15 mm thick calcium silicate board false ceiling finished with plastic emulsion paint 2. Anti-dust sealer coat on surfaces above the false ceiling	
8	Store Room	12		Below False ceiling: Cement plaster with plastic emulsion paint including levelling surface with cement putty	Anti-dust sealer coat on surfaces above the false ceiling	
9	Cleaners Room	10	600x600 Antiskid vitrified tile flooring of approved colour over 20 mm thick cement mortar with under layer of screed laid to slope total 150 mm	1. Walls up to 2100 mm height finished with 300x600 vitrified tiles 2. Area between tiles up-to false ceiling plastered and finished with plastic emulsion paint including levelling surface with cement putty	15 mm thick calcium silicate board false ceiling finished with plastic emulsion paint	

Pune Metro-Station Room Accommodation and Finishes						
Sr. No.	Room name	Size (Sq.m)	Room Specifications			
			Floor	Wall	Ceiling	Railings
10	Refuse Store	10	600x600 vitrified tile flooring of approved colour over 20 mm thick cement mortar and under layer of screed laid to slope total 150 mm	1. Walls up to 2100 mm height finished with 300x600 vitrified tiles and area between tiles up-to false ceiling 2. Below False ceiling: Cement plaster with plastic emulsion paint including levelling surface with cement putty	1. 15 mm thick calcium silicate board false ceiling finished with plastic emulsion paint 2. Anti-dust sealer coat on surfaces above the false ceiling	
11	Staff Lockers-Male	16	1. 600x600 Antiskid vitrified tile flooring of approved colour over 20 mm thick cement mortar with under layer of screed lay to slope total 150 mm 2. Granite Counter	1. Walls up to 2100 mm height finished with 300x600 vitrified tiles and area between tiles up-to false ceiling 2. Cubicle Partition 3. Below False ceiling: Cement plaster with plastic emulsion paint including levelling surface with cement putty	1. 15 mm thick calcium silicate board false ceiling finished with plastic emulsion paint 2. Anti-dust sealer coat on surfaces above the false ceiling	

Pune Metro-Station Room Accommodation and Finishes						
Sr. No.	Room name	Size (Sq.m)	Room Specifications			
			Floor	Wall	Ceiling	Railings
12	Staff Lockers-Female	16	1. 600x600 Antiskid vitrified tile flooring of approved colour over 20 mm thick cement mortar with under layer of screed lay to slope total 150 mm 2. Granite Counter	1. Walls up to 2100 mm height finished with 300x600 vitrified tiles and area between tiles up-to false ceiling 2. Cubicle Partition 3. Below False ceiling: Cement plaster with plastic emulsion paint including levelling surface with cement putty	1. 15 mm thick calcium silicate board false ceiling finished with plastic emulsion paint 2. Anti-dust sealer coat on surfaces above the false ceiling	
13	Staff Mess Room	25	600x600 vitrified tile flooring of approved colour over 20 mm thick cement mortar and under layer of screed laid to slope total 150 mm	Walls up to 1200 mm height finished with 300x600 vitrified tiles and area between tiles up-to false ceiling plastered and finished with plastic emulsion paint including levelling surface with cement putty	1. 15 mm thick calcium silicate board false ceiling finished with plastic emulsion paint 2. Anti-dust sealer coat on surfaces above the false ceiling (including walls)	
14	OTE Fan Room	As per fan room layout	52 mm thick Hardonite industrial floor with 40 mm cement concrete and 12 mm thick top layer of hardcrete cement hardener with 98 mm Cement concrete sub base	1. Cement Block wall finished with anti-dust sealer paint as per approved colour 2. 300 mm high Concrete skirting over 18 mm thick plaster	Concrete finished with anti-dust sealer paint as per approved colour	

Pune Metro-Station Room Accommodation and Finishes						
Sr. No.	Room name	Size (Sq.m)	Room Specifications			
			Floor	Wall	Ceiling	Railings
15	UPS Fan Room	As per fan room layout	52 mm thick Hardonite industrial floor with 40 mm cement concrete and 12 mm thick top layer of hardcrete cement hardener with 98 mm Cement concrete sub base	1. Cement Block wall finished with anti-dust sealer paint as per approved colour 2. 300 mm high Concrete skirting over 18 mm thick plaster	Concrete finished with anti-dust sealer paint as per approved colour	
16	Tunnel Ventilation Fan Room (including plenums)	As per fan room layout	52 mm thick Hardonite industrial floor with 40 mm cement concrete and 12 mm thick top layer of hardcrete cement hardener with 98 mm Cement concrete sub base	1. Cement Block wall finished with anti-dust sealer paint as per approved colour 2. 300 mm high Concrete skirting over 18 mm thick plaster	Concrete finished with anti-dust sealer paint as per approved colour	
17	TVS Panel Room	45 (1 at each end)	52 mm thick Hardonite industrial floor with 40 mm cement concrete and 12 mm thick top layer of hardcrete cement hardener with 98 mm Cement concrete sub base	1. Cement Block wall finished with anti-dust sealer paint as per approved colour 2. 300 mm high Concrete skirting over 18 mm thick plaster	Concrete finished with anti-dust sealer paint as per approved colour	
18	Compressor room	20 (1 at each end)	52 mm thick Hardonite industrial floor with 40 mm cement concrete and 12 mm thick top layer of hardcrete cement hardener with 98 mm	1. Cement Block wall finished with anti-dust sealer paint as per approved colour 2. 300 mm high Concrete skirting over 18 mm thick	Concrete finished with anti-dust sealer paint as per approved colour	

Pune Metro-Station Room Accommodation and Finishes						
Sr. No.	Room name	Size (Sq.m)	Room Specifications			
			Floor	Wall	Ceiling	Railings
			Cement concrete sub base	plaster		
19	AHU	150 (1 at each end or as per VAC design)	52 mm thick Hardonite industrial floor with 40 mm cement concrete and 12 mm thick top layer of hardcrete cement hardener with 98 mm Cement concrete sub base	1. Cement Block wall finished with anti-dust sealer paint as per approved colour 2. 300 mm high Concrete skirting over 18 mm thick plaster	Concrete finished with anti-dust sealer paint as per approved colour	
20	Maintenance Room	20	52 mm thick Hardonite industrial floor with 40 mm cement concrete and 12 mm thick top layer of hardcrete cement hardener with 98 mm Cement concrete sub base	1. Cement Block wall finished with anti-dust sealer paint as per approved colour 2. 300 mm high Concrete skirting over 18 mm thick plaster	Concrete finished with anti-dust sealer paint as per approved colour	

Pune Metro-Station Room Accommodation and Finishes						
Sr. No.	Room name	Size (Sq.m)	Room Specifications			
			Floor	Wall	Ceiling	Railings
21	Signalling Equipment Room	45	Anti-Static Raised Access floor total 450 mm with Anti Dust sealer coat on concrete floor	1. Cement Block wall finished cement plaster and Acrylic emulsion paint including levelling the surface with cement putty 2. 100 mm high vitrified tile skirting over 18 mm thick plaster above raised level	1. Non Perforated 600x600 powder coated M.S. ceiling panels with clear height of 3000mm from the floor 2. Anti-dust sealer coat on surfaces above the false ceiling	
22	Telecom Equipment Room	50	Anti-Static Raised Access floor total 450 mm with Anti Dust sealer coat on concrete floor	1. Cement Block wall finished cement plaster and Acrylic emulsion paint including levelling the surface with cement putty 2. 100 mm high vitrified tile skirting over 18 mm thick plaster above raised level	1. Non Perforated 600x600 powder coated M.S. ceiling panels with clear height of 3000mm from the floor 2. Anti-dust sealer coat on surfaces above the false ceiling	
23	S&T UPS/Battery	50	52 mm thick Hardonite industrial floor with 40 mm cement concrete and 12 mm thick top layer of hardcrete cement hardener with 98 mm Cement concrete sub base, with acid resistant coating	1. Cement Block wall finished cement plaster and Acrylic emulsion paint including levelling the surface with cement putty 2. Walls up to 2100 mm height finished with 300x 600 Glazed Ceramic and area between tiles up-to false ceiling is to be painted	1. Non Perforated 600x600 powder coated M.S. ceiling panels with clear height of 3000mm from the floor 2. Anti-dust sealer coat on surfaces above the false ceiling	

Pune Metro-Station Room Accommodation and Finishes						
Sr. No.	Room name	Size (Sq.m)	Room Specifications			
			Floor	Wall	Ceiling	Railings
24	Inert Gas System for S&T Rooms	15	52 mm thick Hardonite industrial floor with 40 mm cement concrete and 12 mm thick top layer of hardcrete cement hardener with 98 mm Cement concrete sub base	1. Cement Block wall finished with anti-dust sealer paint as per approved colour 2. 300 mm high Concrete skirting over 18 mm thick plaster	Concrete finished with anti-dust sealer paint as per approved colour	
25	CDMA Room	20	600x600 vitrified tile flooring of approved colour over 20 mm thick cement mortar with under layer of screed laid to slope total 150 mm	1. Walls up to 1200 mm height finished with 300x600 vitrified tiles 2. Below False ceiling: Cement plaster with plastic emulsion paint including levelling surface with cement putty	1. Non Perforated 600x600 powder coated M.S. ceiling panels with clear height of 3000mm from the floor 2. Anti-dust sealer coat on surfaces above the false ceiling	
26	Public Toilet Male	30	600x600 Antiskid vitrified tile flooring of approved colour over 20 mm thick cement mortar with under layer of screed laid to slope total 150 mm	1. Walls up to 2100 mm height finished with 300x600 vitrified tiles 2. Below False ceiling: Cement plaster with plastic emulsion paint including levelling surface with cement putty	1. 15 mm thick calcium silicate board false ceiling finished with plastic emulsion paint 2. Anti-dust sealer coat on surfaces above the false ceiling	

Pune Metro-Station Room Accommodation and Finishes						
Sr. No.	Room name	Size (Sq.m)	Room Specifications			
			Floor	Wall	Ceiling	Railings
27	Public Toilet Female	30	600x600 Antiskid vitrified tile flooring of approved colour over 20 mm thick cement mortar with under layer of screed laid to slope total 150 mm	1. Walls up to 2100 mm height finished with 300x600 vitrified tiles 2. Below False ceiling: Cement plaster with plastic emulsion paint including levelling surface with cement putty	1. 15 mm thick calcium silicate board false ceiling finished with plastic emulsion paint 2. Anti-dust sealer coat on surfaces above the false ceiling	
28	Handicap Toilet	4	600x600 Antiskid vitrified tile flooring of approved colour over 20 mm thick cement mortar with under layer of screed laid to slope total 150 mm	1. Walls up to 2100 mm height finished with 300x600 vitrified tiles 2. Below False ceiling: Cement plaster with plastic emulsion paint including levelling surface with cement putty	1. 15 mm thick calcium silicate board false ceiling finished with plastic emulsion paint 2. Anti-dust sealer coat on surfaces above the false ceiling	
29	Sewage Ejector Room	20	52 mm thick Hardonite industrial floor with 40 mm cement concrete and 12 mm thick top layer of hardcrete cement hardener with 98 mm Cement concrete sub base	1. Cement Block wall finished with anti-dust sealer paint as per approved colour 2. 300 mm high vitrified tile skirting over 18 mm thick plaster	Concrete finished with anti-dust sealer paint as per approved colour	

Pune Metro-Station Room Accommodation and Finishes						
Sr. No.	Room name	Size (Sq.m)	Room Specifications			
			Floor	Wall	Ceiling	Railings
30	Fire Command Centre	25	600x600 vitrified tile flooring of approved colour over 20 mm thick cement mortar and under layer of screed laid to slope total 150 mm	12mm thick Clear Toughened laminated Fire Rated glass on concourse side and cement plaster finished with Acrylic Emulsion paint on internal walls elsewhere.	1. Non Perforated 600x600 powder coated M.S. ceiling panels with clear height of 3000mm from the floor 2. Anti-dust sealer coat on surfaces above the false ceiling	
31	Auxiliary Substation(ASS)	180 (1 ASS on each side)	52 mm thick Hardonite industrial floor with 40 mm cement concrete and 12 mm thick top layer of hardcrete cement hardener with 98 mm Cement concrete sub base	1. Cement Block wall finished with anti-dust sealer paint as per approved colour 2. 300 mm high Concrete skirting over 18 mm thick plaster	Concrete finished with anti-dust sealer paint as per approved colour	
32	Inert Gas Room for ASS	15 (1 at each end)	52 mm thick Hardonite industrial floor with 40 mm cement concrete and 12 mm thick top layer of hardcrete cement hardener with 98 mm Cement concrete sub base	1. Cement Block wall finished with anti-dust sealer paint as per approved colour 2. 300 mm high Concrete skirting over 18 mm thick plaster	Concrete finished with anti-dust sealer paint as per approved colour	

Pune Metro-Station Room Accommodation and Finishes						
Sr. No.	Room name	Size (Sq.m)	Room Specifications			
			Floor	Wall	Ceiling	Railings
33	E&M UPS Battery Room	40 (1 at each end)	52 mm thick Hardonite industrial floor with 40 mm cement concrete and 12 mm thick top layer of hardcrete cement hardener with 98 mm Cement concrete sub base, with acid resistant coating	1. Cement Block wall finished cement plaster and Acrylic emulsion paint including levelling the surface with cement putty 2. Walls up to 2100 mm height finished with 300x 600 Glazed Ceramic and area between tiles up-to false ceiling is to be painted	1. Non Perforated 600x600 powder coated M.S. ceiling panels with clear height of 3000mm from the floor 2. Anti-dust sealer coat on surfaces above the false ceiling	
34	Electrical Panel Room	20	52 mm thick Hardonite industrial floor with 40 mm cement concrete and 12 mm thick top layer of hardcrete cement hardener with 98 mm Cement concrete sub base	1. Cement Block wall finished with anti-dust sealer paint as per approved colour 2. 300 mm high Concrete skirting over 18 mm thick plaster	Concrete finished with anti-dust sealer paint as per approved colour	
35	PSD panel room	15	Anti-Static Raised Access floor total 450 mm with Anti Dust sealer coat on concrete floor	1. Below False ceiling: Cement plaster with plastic emulsion paint including levelling surface with cement putty 2. 100 mm high vitrified tile skirting over 18 mm thick plaster above raised level	1. Non Perforated 600x600 powder coated M.S. ceiling panels with clear height of 3000mm from the floor 2. Anti-dust sealer coat on surfaces above the false ceiling	

Pune Metro-Station Room Accommodation and Finishes						
Sr. No.	Room name	Size (Sq.m)	Room Specifications			
			Floor	Wall	Ceiling	Railings
36	Maintenance & Equipment Room	15	52 mm thick Hardonite industrial floor with 40 mm cement concrete and 12 mm thick top layer of hardcrete cement hardener with 98 mm Cement concrete sub base	1. Cement Block wall finished with anti-dust sealer paint as per approved colour 2. 300 mm high Concrete skirting over 18 mm thick plaster	Concrete finished with anti-dust sealer paint as per approved colour	
37	Emergency Equipment Room	15	52 mm thick Hardonite industrial floor with 40 mm cement concrete and 12 mm thick top layer of hardcrete cement hardener with 98 mm Cement concrete sub base	1. Cement Block wall finished with anti-dust sealer paint as per approved colour 2. 300 mm high Concrete skirting over 18 mm thick plaster	Concrete finished with anti-dust sealer paint as per approved colour	
38	Sump Pump Room	10 (1 at each end)	52 mm thick Hardonite industrial floor with 40 mm cement concrete and 12 mm thick top layer of hardcrete cement hardener with 98 mm Cement concrete sub base	1. Cement Block wall finished with anti-dust sealer paint as per approved colour 2. 300 mm high Concrete skirting over 18 mm thick plaster	Concrete finished with anti-dust sealer paint as per approved colour	
39	ECS Plant Room	240	52 mm thick Hardonite industrial floor with 40 mm cement concrete and 12 mm thick top layer of hardcrete cement hardener with 98 mm	1. Cement Block wall finished with anti-dust sealer paint as per approved colour 2. 300 mm high vitrified tile skirting over 18 mm thick	Concrete finished with anti-dust sealer paint as per approved colour	

Pune Metro-Station Room Accommodation and Finishes						
Sr. No.	Room name	Size (Sq.m)	Room Specifications			
			Floor	Wall	Ceiling	Railings
			Cement concrete sub base	plaster		
40	Water Tank and Pump (inclusive of Fire Pump & Sprinkler Room)	200	52 mm thick Hardonite industrial floor with 40 mm cement concrete and 12 mm thick top layer of hardcrete cement hardener with 98 mm Cement concrete sub base	1. Cement Block wall finished with anti-dust sealer paint 2. Glazed Ceramic Tiles inside surface of Water tanks	Concrete ceiling finished with anti-dust sealer coat	
41	Generator Room(DG set)	120	52 mm thick Hardonite industrial floor with 40 mm cement concrete and 12 mm thick top layer of hardcrete cement hardener with 98 mm Cement concrete sub base	1. Cement Block wall finished with anti-dust sealer paint 2. Glazed Cermic Tiles inside surface of Water tanks	Concrete ceiling finished with anti-dust sealer coat	
42	Cooling Tower	180	If this is on terrace then Only terracing and water proofing will be there.			

Pune Metro-Station Room Accommodation and Finishes						
Sr. No.	Room name	Size (Sq.m)	Room Specifications			
			Floor	Wall	Ceiling	Railings
43	Solar Panel Control Room	30	52 mm thick Hardonite industrial floor with 40 mm cement concrete and 12 mm thick top layer of hardcrete cement hardener with 98 mm Cement concrete sub base	1. Cement Block wall finished with anti-dust sealer paint as per approved colour 2. 300 mm high Concrete skirting over 18 mm thick plaster	Concrete finished with anti-dust sealer paint as per approved colour	
44	Spare Room /BOH		600x600 vitrified tile flooring of approved colour over 20 mm thick cement mortar with under layer of screed laid to slope total 150 mm	1. Walls up to 1200 mm height finished with 300x600 vitrified tiles 2. Below False ceiling: Cement plaster with plastic emulsion paint including levelling surface with cement putty	1. Non Perforated 600x600 powder coated M.S. ceiling panels with clear height of 3000mm from the floor 2. Anti-dust sealer coat on surfaces above the false ceiling	
45	Staircase		Flamed Granite Tread	Polished Granite Riser	Non Perforated 600x600 powder coated M.S. ceiling panels	SS Wall/Floor mounted railing with infilled Glass Panels
46	Emergency Staircase		Honed Granite Tread & polished granite Riser	Plastic Emulsion Paint	Concrete finished with anti-dust sealer paint as per approved colour	S.S. HANDRAIL
47	Fireman Staircase		Kota Stone Tread & Riser	Concrete finished with anti-dust sealer paint as per approved colour	Concrete finished with anti-dust sealer paint as per approved colour	M.S. HANDRAIL
48	Platform Edge		600 Mm Wide Flamed Granite			

Pune Metro-Station Room Accommodation and Finishes							
Sr. No.	Room name	Size (Sq.m)	Room Specifications				
			Floor	Wall	Ceiling	Railings	
49	Public areas- Internal		1. Honed Granite 2. Vitrified Tiles 3. Basalt Stone 4. Tactile Flooring 5. Warning Strip @ Platform	1. Polished Granite 2. Vitrified Tiles 3. Basalt Stone Cladding 4. Aluminium Cladding- various colours powder coating including Copper shade 5. Stainless Steel Cladding 6. Zinc Cladding 7. Laminated Glass Cladding	1. Non Perforated 600x600 powder coated M.S. ceiling panels 2. Anti-dust sealer coat on surfaces above the false ceiling	Wall mounted SS Railing with infilled Glass Panels	
50	Station entrance- including access passageway and including subways into station		1. Honed granite 2. Vitrified tiles 3. Basalt stone 4. Tactile flooring	1. Polished Granite 2. Vitrified Tiles 3. Basalt Stone 4. Cladding 5. Texture Paint 6. Zinc Cladding 7. Aluminium Cladding - Various colours powder coating including Copper Shade 8. Glazing	1. Non Perforated 600x600 powder coated M.S. ceiling panels 2. Anti-dust sealer coat on surfaces above the false ceiling	Wall mounted SS Railing with infilled Glass Panels	
51	Entry Structure Roof at Street Level				1. Galvalume Sheet & Polycarbonate Sheet 2. Zinc Sheet Roofing		
52	Skylight				1. Double Glazed Glass 2. Poly Carbonate Sheet		

Pune Metro-Station Room Accommodation and Finishes						
Sr. No.	Room name	Size (Sq.m)	Room Specifications			
			Floor	Wall	Ceiling	Railings
SHAFTS						
1	TVS (tunnel)	9 (at each end)	Concrete finished with anti-dust sealer paint as per approved colour	Concrete finished with anti-dust sealer paint as per approved colour	Concrete finished with anti-dust sealer paint as per approved colour	
2	TVS (to street)	15 (at each end)	Concrete finished with anti-dust sealer paint as per approved colour	Concrete finished with anti-dust sealer paint as per approved colour	Concrete finished with anti-dust sealer paint as per approved colour	
3	OTE (tunnel)	6.5 (at each end)	Concrete finished with anti-dust sealer paint as per approved colour	Concrete finished with anti-dust sealer paint as per approved colour	Concrete finished with anti-dust sealer paint as per approved colour	
4	OTE (to street)	8 (at each end)	Concrete finished with anti-dust sealer paint as per approved colour	Concrete finished with anti-dust sealer paint as per approved colour	Concrete finished with anti-dust sealer paint as per approved colour	
5	UPS (tunnel)	5.5 (at each end)	Concrete finished with anti-dust sealer paint as per approved colour	Concrete finished with anti-dust sealer paint as per approved colour	Concrete finished with anti-dust sealer paint as per approved colour	
6	UPS (to street)	6.5 (at each end)	Concrete finished with anti-dust sealer paint as per approved colour	Concrete finished with anti-dust sealer paint as per approved colour	Concrete finished with anti-dust sealer paint as per approved colour	
7	Lift Shaft		Concrete finished with anti-dust sealer paint as per approved colour	Concrete finished with anti-dust sealer paint as per approved colour	Concrete finished with anti-dust sealer paint as per approved colour	

Notes:

- Final finishing items shall be selected from the provided palate at employer's discretion. Quantity of items shown is indicative and final quantities shall be arrived at by the contactor.
- Area and the requirement mentioned above is only indicative and room/space proportions, their locations, sizes etc. shall be finalized duly interfacing with the respective Designated/Interfacing systems and other Contractors and as approved by the Employer/Engineer, to cater to all the requirements, as may be necessary.
- ** Tunnel Ventilation Fan Room - Not preferred adjacent to public areas or offices unless architectural measures to reduce noise break-out to acceptable levels are taken

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 VII - Outline Design Specifications

S.05 E&M WORKS – STATION UTILITIES

June 2018

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5 E&M WORKS – STATION UTILITIES

5.1 General Requirement

The Technical Specifications (Outline Design Specification and Outline Construction Specification) and the Employer's Drawings 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 and associated tunnels which is compliant with the relevant standards and complete in all aspects to the satisfaction of Employer / Engineer.

The Technical Specifications describe 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.

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

5.2 Standards, Codes and Regulations

The entire system and its basic components shall comply in all respect 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.

All equipment, supply, erection, testing and commissioning shall comply with the requirements of Indian Standards and codes of practices given below as amended at the time of design. All equipment and material being supplied by the contractor shall meet the requirements of the Codes / Publications as given below: Also latest version must be indicated/adopted.

AMCA	Air Moving and Conditioning Association (USA)
ANSI	American National Standard Institute
ANSI B16.21	Standard for non-metallic 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
IS/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 + A2	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	Fixed fire fighting systems. Automatic sprinkler systems. Design, installation and maintenance
BS EN 15004-1	Fixed fire fighting 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,	Electrical insulation. Thermal evaluation and designation
Class F and Class H	
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 fire fighting 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
CIE	International Lighting Commission
	International Telegraph and Telephone Consultative Committee

CCITT	(Comité Consultatif Internationale de Télégraphique et Téléphonique)
CENELEC	European Committee for Electro technical Standardization(Comité European de Normalization Electro technique)
CISPR	The International Special Committee on Radio Interference (Comite International Special des Perturbations Radioelectriques)
EA	The Electricity Act, 2008
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 of the signaling and Telecommunication Apparatus
EN 50121-5	Railway applications. Electromagnetic compatibility.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 Control gear

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: 2010	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 control gear 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.

5.3 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
FRLSZH	Flame Retardant Low Smoke <u>Zero Halogen</u>
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

ACRONYM	DESCRIPTION
Ph	Phase
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
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
ACRONYM	DESCRIPTION
PCB	Pollution Control Board
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	Systems Wide Contractor
TCF	Technical Construction File
V DC	Volt Direct Current
VDE	Verband der Elektrotechnik (German Association for Electrical, Electronic and Information Technologies)
VESDA	Very Early Smoke Detection and Alarm
WLAN	Wireless Local Area Network

5.4 Electrical

5.4.1 General Requirement

5.4.1.1 Scope of Work

The scope of work in this sub-section will include the guidelines and methodology for design of electrical works for Under Ground Stations, Tunnels including cross passages, ventilation shafts/other shafts and Plenums wherever applicable and other buildings. The boundary line and control philosophy for E & M works inside the tunnel is shown in the tender drawings. Following services under the scope of the design report are described below.

1. Low voltage power distribution system:, cable, conduit, raceway, Brackets, trunking etc;
2. Low Voltage switchboards: Distribution boards, load centre, etc. Main Normal power Switchboards, Main Emergency power switchboards and Capacitor panels inside the Auxiliary Substation (ASS) are excluded from the scope of this contract;
3. Station/tunnel Lighting system including lighting control system: Interior, exterior, sign illumination, exit & fire exit, Emergency Lighting, Tunnel lighting, Intermediate Ventilation shafts (where applicable) and Cross Passage Lighting, road lighting;
4. Illuminated Tunnel Evacuation Signage System (ITESS) and Illuminated cross

passage Evacuation System (XPES).

5. Small power system for Station , Tunnels and Associated Buildings: Socket outlet, RCD, safety switches, power supply for mechanical equipment;
6. Earthing and bonding system;
7. Lightning protection system;
8. Diesel Generator (DG) Sets with associated panels and Diesel Storage Tanks
9. Uninterruptible power supply (UPS);
10. (M & E) SCADA interfacing system.
11. Enclosures and supporting brackets for housing and fixing equipment;
12. Electrical Fittings and Accessories
13. All equipment associated with any interfaces required to ensure operation within the performance requirements;
14. The power factor correction equipment (APFC), including capacitor bank is not a part of this contract.

5.4.1.2 Responsibilities

The responsibilities of the Contractor shall be as follows but not limited to:

- a) Detailed Design of the systems / packages listed in the scope of works including the requirements that are not specified here in but are required for the successful operation of the system / package.
- b) Supply & Installation of the Systems / Equipments / Devices & Components and all other accessories required for the complete functioning of the system.
- c) Testing, Commissioning, Verification & Validation of the Systems.
- d) Selection of equipments to meet performance criteria and specification with supporting calculations.
- e) Arrangements to handle expansion / contraction.
- f) Acoustic treatment and vibration isolation for MEP Equipment
- g) Co-ordination with all the other services and all designated/interfacing contractors for the interface requirements.
- h) Liaison with the Local Authorities/Relevant Authorities/Agencies & getting their approval.
- i) All legal fees & statutory requirements.

5.4.2 Design Services

The Contractor shall perform all design functions necessary for the development, manufacture/procurement, installation and site testing of systems, sub-systems and components to provide complete and operable electrical installations as described in this Specification. These design functions shall include, but not

limited to, the following:

- a) The contractor shall prepare drawings which clearly illustrate plant locations and configurations. Drawings shall contain plan view, elevations, sections, schedules, schematics and diagrams as required to fully cover the works.
- b) The contractor shall prepare specifications which provide a clear description of the functional requirements of each of the systems, sub- systems and components. This specification shall indicate the minimum acceptable levels of performance for the works with due consideration given to the service and environment in which the electrical equipment will be operating. The contractor shall identify by manufacturer and model or part number of each system component which he plans to install.
- c) The contractor shall prepare documents which explain the rationale for his designs. These documents shall be furnished along with the tender and at any other times required by the Engineer. The contractor shall perform engineering studies and comparative evaluations to ensure that his designs incorporate features to achieve optimum performance.
- d) The Contractor shall submit to the Engineer , criteria and calculations to determine feeder sizes, loads, voltage drop, prospective short circuit current, protection coordination, starting current characteristics, distribution board sizes and any other parameters of the design.
- e) The Contractor shall submit to the Engineer , lux level calculation for all lighting modes based on the light fittings proposed by the Contractor and agreed by the Engineer and in accordance with the Engineer's Requirements.
- f) All submissions, including design drawings and calculations, shall be endorsed by the Contractor's Professional / Chartered Engineer.
- g) The Contractor shall prepare floor and reflected ceiling plans, wall elevations in public areas, equipment layout plans, cable routings, and other documents necessary to facilitate the design interface co-ordination with designated/interfaces contractors. These plans shall be prepared at appropriate times and in sufficient details to permit successful co- ordination.
- h) The Contractor shall carry out in-depth co-ordination to ensure that the design is compatible in all aspects with their requirements. In the public areas and designated staff areas the Contractor also shall co-ordinate the location, depth and interfaces for routes, outlets and equipment mounted on and/or behind/through architectural finishes.
- i) The Contractor shall ensure that equipment selection and design of all Plant are such that harmonics in the power distribution system are kept to minimum and shall coordinate with the Signaling and telecommunication Contractor to match their requirement. The design shall comply with the latest edition of "G5/4 - Limits for harmonics in the UK electricity supply system" as published by Electricity Association of UK. The Contractor shall carry out a harmonics study for the whole electrical power distribution network. When the overall harmonics at the point of common coupling with Pune Electricity Supply

Authority exceeds the limits required by G5/4 due to the Contractors Plant, the Contractor shall be responsible for reducing the harmonics with the appropriate means subject to the Notice of No objection of the Engineer, to the allowable limits as determined by the Power Supply System and Over Head Equipment Contractor based on the percentage of system capacity used by the Contractor. All cost associated with measures taken to ensure compliance to the harmonics limits shall be deemed included in the contract.

- j) The Contractor shall take measurements of the harmonics spectrums at all points of common coupling. All measurements shall be taken with properly calibrated instruments provided by the Contractor. The Contractor shall prepare a report, tabulating the results of the measurements, for co-ordination with the Power Supply System and Over Head Equipment Contractor to carry out the harmonics study for the whole electrical power distribution network. The format of the report shall be as per the Power Supply System and Over Head Equipment Contractor requirements subject to Engineer's acceptance.

5.4.3 System Description

5.4.3.1 General

A) Design Criteria

- 1) System voltage: 415V 3 Phase 4 wires /240V 1 Phase 2 wires, 50Hz
- 2) Ambient temperature: As per ISHRAE recommendations
- 3) Demand Factor: 80%
- 4) Load power factor: 0.95
- 5) Voltage Drop (Final Circuit): 5%
- 6) Earthing system: TN-S System
- 7) Spare capacity (Distribution Panel): 20%
- 8) Spare capacity (Cable raceway): 40%

B) Colour Code

Cable and Busbar shall be phasing identified with colour codes as;

Phase A: Red

Phase B: Yellow Phase C: Blue Neutral: Black

Ground: Green or Yellow Strip Green

Emergency Lighting Cable: Orange

5.4.3.2 Low voltage power distribution system

The Low voltage power distribution system starts from the Auxiliary transformer's secondary side and feed power, 415V 3 Phase 4 wires /240V 1 Phase 2 wires, 50Hz to the whole loads via the two (2) Main Distribution Panels (LT).

Two (2) Auxiliary transformers are provided in Auxiliary Substations at either end of the station for each Underground station to supply power to all auxiliary loads. In case one transformer fails, the other transformer shall supply power to the all auxiliary loads and in case of mains failure/Two Transformers fail, standby (2) diesel generator will supply power to the essential and very essential loads.

Load categories shall be:

1. Normal load shall receive power from two (2) transformers for all stations and 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, waste water pumps, 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;
 - Fire detection and Alarm system;
 - Signalling system;
 - AFC 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 lightings;
 - Tunnel and Cross passage lighting ;
 - Tunnel and cross passage emergency evacuation signage lighting
 - Exit and emergency sign ;
 - Platform Screen Door Control system
 - Blue light stations provided by Power Supply and Traction Contractor

The power distribution system shall be designed by using of low voltage power cable run on the cable tray, Brackets, ladders, hangers, raceway/trunking and

conduit as suitable to supply power to various loads within stations, buildings, tunnels and cross passages. Maximum voltage drop for all circuits from main low voltage switchboards to the equipments, final circuits, shall be limited at 5% and the voltage at the terminal of motors shall not be less than 90% of the normal supply voltage during the motor starting.

The low voltage power distribution cables up to 35 sq. mm shall be made of copper, above 35 sq. mm shall be made of aluminium/ copper and comply with IEC 60502 or other international standards as specified and approved by the Employer/Engineer. The cables shall be designed for a maximum continuous conductor operating temperature of 90°C and for maximum short circuit temperature of 250°C. Full size neutral cables shall be provided for the power cables connecting to sub-main low voltage switchboards. Fire resistant cables shall be used for life safety purpose which shall be of Fire Retardant Low Smoke Zero Halogen type and comply with the performance requirements of IEC60331 and BS 6387 Category "CWZ". Raceway for all feeder cables shall be cable tray, cable ladder, wireway, trunking and conduit in accordance with IS Standards. The location of the raceway shall not be in the general public area and passage way. A 40% spare space shall be provided for all cable trays, cable ladder, wireway for future extension, while 20% spare space shall be provided for all DB.

5.4.3.3 Low voltage switchboards

Standards

IEC 60255/EN 60255: Electrical protection relays.

BS 381C/BS 4800: Specification for colours for identification, coding and special purposes.

IS 15652: Rubber mats for electrical purposes.

BS 1432: Specification for copper for electrical purposes: high conductivity copper rectangular conductors with drawn or rolled edges.

BS 13601: Copper and copper alloys. Copper rod, bar and wire for general electrical purposes

BS 1650: Specification for capacitors for connection to power- frequency systems.

BS 2757: Method for determining the thermal classification of electrical insulation.

BS 60085: Electrical insulation. Thermal evaluation and designation.

BS 5685: Electricity meters.

IEC-1036, 687, 1286 direct reading single / three phases meter (Digital Type).

IEC 60228/BS 6360: Specification for conductors in insulated cables and cords.

BS 60228: Conductors of insulated cables

BS 7211: Specification for thermosetting insulated cables (non - armoured) for electric power and lighting with low emission of smoke and corrosive gases when

affected by fire.

IEC 60185/BS 3938: Specification for current transformers.

BS 60044-1: Instrument transformers. Current transformers.

EN 60051: Direct acting indicating analogue electrical measuring instruments and their accessories.

IEC 61439/ EN 61439 Part 1: Low-voltage switchgear and control gear assemblies:Part-1 General Rules

IEC 60529/ EN 60529: Specification for degrees of protection provided by enclosures (IP code).

IEC 60947/ EN 60947: Part 2: Specification for low-voltage switchgear and controlgear. Circuit-breakers.

IEC 60947/ EN 60947: Part 3: Specification for low-voltage switchgear and controlgear. Switches, disconnectors, switch-disconnectors and fuse-combination units.

IEC 60947/ EN 60947-4-1: Specification for low-voltage switchgear and controlgear. Contactors and motor-starters. Electromechanical contactors and motor-starters.

IEC 60044-1: Instrument transformers.

IEC 60211: Maximum demand indicators, Class 1.0.

IEC 60076/EN 60076: Power Transformers.

EN 60742/BS 3535/ BS 61558: Isolating Transformers.

IEC 60521: Class 0.5, 1 and 2 alternating-current watt-hour meters.

IEC 60529/EN 60529: Degrees of protection provided by enclosures (IP Code).

IEC 60831: Shunt power capacitors of the self-healing type for AC systems having a rated voltage up to and including 1000 V.

IEC 60871-1: Shunt capacitors for AC power systems having a rated voltage about 1000 V.

Transformers shall be provided by the Power Supply & OHE contractor and the Contractor shall have to design the stations and provide for the space needed for this purpose duly taking into account the Structural loads matching the loads/capacity of the transformer. All the civil works necessary for Diesel Generator and fuel tank shall be done by the Civil Contractor (the Contractor).

There shall be two (2) main distribution panels connected that shall receive power from the two (2) Auxiliary transformers. The 2 main breakers and the TIE breaker of the main LV distribution board will be interlocked in such a manner that only maximum 2 of the 3 breakers could be switched on at any operation. Upon failure of one transformer, the other transformer shall respond and feed the power to all Auxiliary loads.

Total discrimination up to design fault level must be available between the various elements of switch gear selected.

The sub-main distribution panels shall be floor standing, meta-clad in minimum of Form 4b Type 5 in accordance with BS EN 60947-1 & BS 61439-2. These switchboards shall be designed and manufactured in accordance with IEC61439 standard with IP42 for Indoor and IP54 for outdoor protection. All switchboards shall have 20% spare space for providing circuit breakers for future loads installation.

The LV main switchboards shall also pass the arc fault containment tests in accordance with IEC 61641. The LV Main Switchboard shall be identical in mechanical construction to the LV Switchboard which had been type-tested by an acceptable, accredited and independent testing laboratory for the fault conditions, temperature rise limits and arc fault containment. Any manufacturer not having the above will not be considered for supply.

The following critical status and alarms for each LVSB shall be sent to BMS for remote monitoring via volt-free contacts or serial interface over standard protocol communication as approved :

- i) Individual ACB/MCCB open/close status,
- ii) Common alarm for ACBs/MCCBs trip on fault/lock out,
- iii) Common alarm for any local/remote or local/auto selector switch in local mode,
- iv) Control supply failure,
- v) ACB ready to close indication.
- vi) Emergency push button (EPB) operated, and
- vii) Busbar voltage ,current , frequency and energy parameters etc.
- viii) LVSB under voltage alarm and cause of tripping.

Bus-bars and Supports

Busbars and busbar connections shall be constructed in accordance with the requirements of IEC 61439-1 or EN 61439-1. The short-time withstand current rating shall be at least 70/65 kA for 1 second at 415 V.

- 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 50oC 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.

Air Circuit Breakers (ACB)

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 unauthorised 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 (I_n) 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 (I_n).
 - 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.

Molded Case Circuit Breaker (MCCB)

a) All Moulded 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.

MCCBs shall meet the following requirements:

- a) Number of poles: double-pole, triple-pole or four poles as specified on the Drawings,
 - b) Rated operational voltage: 240 / 415 V AC,
 - c) Rated insulation voltage: 660 V AC,
 - d) Rated uninterrupted current (In): as shown on the Drawings, but after taking into account the installation conditions and temperature deration.
 - e) Rated frequency: 50 Hz,
 - f) Rated short-circuit making capacity (Icm): shall be atleast 2.1 times of ultimate short ckt breaking capacity at 0.25 power factor,
 - g) Rated ultimate short-circuit breaking capacity (Icu): 65/50/35 kA (min),
 - h) Rated service short-circuit breaking capacity (Ics): 65/50/35 kA Further, Ics must be equal to 100% Icu for the selected breaker,
 - i) Utilization category: A or B as appropriate,
 - j) Degree of protection: IP 3X to IEC 60529 or EN 60529, and
 - k) Rated ambient temperature: 50 °C.
 - l) MCCB shall be suitable for isolation as per Annexure 7.1.2 of IEC 60947 – 2
- 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.
- m) All MCCB's should have front adjustable microprocessor based releases with adjustment in the range of 40 – 100% for nominal overloads and 2 – 10 times of rated current for short circuit faults

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.

BMS / SCADA / RS485/ Mod BUS connectivity of communicable ACB / MCCB

Junction box suitable for four no ACB connection shall be provided as per requirement.

Connecting cable with connector between ACB communication unit and junction box shall be provided.

24V DC source unit or as required (Incoming supply shall be tapped from the control supply available in the panel) for communication of ACB/MCCB with SCADA/BMS system.

Auxiliary Switches and Contacts

Auxiliary switches provided for indication, protection, metering, control, interlocking and supervisory purposes shall be readily accessible at the front of the LVSBs. Adequate secondary contacts shall be included to enable the auxiliary switch to be wired to the fixed portion of the equipment.

For each control compartment, spare auxiliary contacts with a minimum of two NO and two NC contacts shall be provided, and wired to suitably identified spare terminals.

Auxiliary contacts for all applications shall be rated at 240 V AC or 110 V DC with contact rating of at least 6 A AC or DC and operating life of at least one million on-load operations at 0.4 power factor inductive load.

Control Supply

240V control supply will be available from the station UPS. DP MCB protection shall be provided at incoming. Separate control bus of suitable rating made of copper shall be provided throughout the panel length, and the control bus should be accessible from the front of the panel. Control voltage tapping for different feeder shall be done with proper clamp. 240V voltage sensing relay with volt free contacts shall be provided for sensing the control supply for local and remote indication to BMS/SCADA. The control circuit shall be separated from other auxiliary circuits, i.e. indicating circuit, heater and lighting circuits, with dedicated circuit protective devices.

Equipment for BMS Interface

Volt-free contacts provided for BMS Remote monitoring interface shall comprise a pair of terminals operated directly by the equipment but electrically separated such that no potential derived from the equipment appears at the terminals. The terminals shall be wired from contaminates or required isolation shall be achieved by equipment panel manufacture to provide the interface terminals for BMS interface. All terminals shall be marked as per metro standard for proper identification. Panel manufactures shall provide necessary signal monitoring interface provision for BMS as per BMS tender specification. No such pseudo signals or change in contacts shall be allowed for BMS interface.

For the equipment to be controlled by the BMS, the panel manufacture shall provide remote control interface terminal with proper marking and with due isolation from VFC interface terminal. BMS PLC interface for control command shall be pulse type close contacts for single command output / double command output or a variable voltage/current (i.e 0v – 10V or 4mA – 20 mA) for analogue

output command. It is the responsible of panel manufactures to provide necessary interface detail during BMS commissioning or supervise as appropriate during installation and testing of BMS system. There shall be one interface for control open and one for control close operations. The Contractor shall provide appropriate equipment to sense and latch the remote control signal for performing the open/close control function. The BMS digital output (DO) & analogue output (AO) signal shall be as stipulated.

Contacts shall be rated to adequately make and break and carry continuously not less than 5 A at 250 V AC or 2 A at 110 V DC.

Volt-free contacts for sequence of event (SOE) alarms shall firmly close and seat in position once activated. The contacts shall not bounce or vibrate due to internal or external causes.

All communicable equipment shall be provided with interface provision for BMS using 2 wire RS485 communication port over standard protocol communication (Preferable MODBUS – RTU) interface. Required data point as per BMS requirement shall be configured in respective controller or equipment by panel manufactures as required with necessary hardware and software for above said serial link communication. It is the responsible of panel manufactures to provide necessary interface detail such as data point register address during BMS commissioning or supervise as appropriate during installation and testing of BMS system.

Marshaling Unit: Single location interface for different LV components of distribution panel shall be provided through marshaling chamber for BMS interface. All interface terminal and ports for BMS shall be wired upto the marshaling chamber. Necessary Marking and ferruling shall be provided for individual termination. Control command interface and other terminals having potential should have due separation from VFC interface terminals. Control and signal cable wiring from different relays, sensors, transducer, controller and contactor releases shall be through separate wiring contaminate to avoid fault current or external magnetic/ electric interface. All communicable breaker, controller or meters with provision of standard protocol (MODBUS -RTU over serial RS485, 2 wire) communication shall be individually wired upto the marshalling box interface terminal. Necessary multi dropping and single point interface provision shall be done through suitable short link. Minimum 25 communicable devices using standard protocol communication shall be looped for

single point interface to meet performance requirement. Marshaling chamber should have provided with necessary mounting arrangement or space provision for BMS remote IO module/ PLC equipment along with it's associated interface equipment and power supply unit. Panel manufactures shall provide the required termination and interface detail for BMS work. In case of requirement of supervision and guidance during BMS commissioning same shall be inclusive to the panel manufacture's scope of work. Marshaling box shall compile with EMC (Electro Magnetic Compliance) and protected from any electrical or magnetic interface. Required protection against of any BMS or Panel components has to be inclusive to respective contractor's scope of work. Any specific interface requirement not specified here with shall be wired upto the marshaling chamber interface terminal. BMS/SCADA interface point should only confine to marshaling box.

5.4.3.4 Spare Protective devices

Busbar Breaker Rating (A)	Minimum Capacity of Spare feeders (three phase & neutral)
600 – 1000	1 x 100 A, 1 x 200 A
1000 – 1600	1 x 100 A, 2 x 200 A
Above 1600	1 x 100 A, 2 x 200 A, 1 x 400 A

The sub-switchboards shall have a rated short time withstand current of 65 kA with copper earth bar sized 500 sq.mm or above and 50kA for 1 second with copper earth bar sized 300 sq mm or above respectively. For busbar of maximum current rating upto 1250A, short time withstand rating of 35KA and Earth bar sized at 200mm². The Contractor shall provide the higher KA rating if the 1 second short current of one switchboard is higher than above rating based on the fault current calculation. The incoming part of each LV Switchboard shall be completed with the following components;

1. Over-current protection;
2. Earth fault protection;
3. Under voltage and over voltage protection;
4. Voltmeter and selector switch;
5. Ammeter and selector switch;
6. Indicating lamps;
7. Digital meter for kW, kVA, kVAR and power factor meter (multi-function meter);
8. Power factor control;
9. ACB shunt trip;
10. Auxiliary contacts for remote monitoring via M & E SCADA system.

Devices with local and remote displays for measuring the percentage of total harmonic distortion (THD) in voltage and current shall be provided at each incomer ACB. All distribution panel boards and/or load centres shall be mounted at suitable height, above the finished floor level.

5.4.3.5 Distribution boards

General

- 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.
- 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.
- 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.

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 |

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.) |

5.4.3.6 Not used

5.4.3.7 Not used

5.4.3.8 Load Centre (distribution boards) and Circuit Breaker

General

The Contractor shall Design, supply and install load centres, safety switches and circuit breaker as specified herein.

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 |

Material Description

All equipment shall have the electrical characteristics as follows:

- | | | |
|-------------------|---|--|
| (6) System Wiring | : | 3-phases, 4-wires with ground or 1-phase, 2 wires with ground. |
| (7) Rated Voltage | : | 415V/240V |

- (8) Rated Frequency : 50 Hz.
 (9) Rated Continuous Current : As required
 (10) Rated Short Circuit Current : as specified/required (at 415 or 240 V.)

5.4.3.9 Not used

5.4.3.10 Low Voltage Cables

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.

All cables serving/related to the emergency related equipment/lighting etc. shall be of Fire Resistant as defined further in the specifications.

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 under fire

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.

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%.

Component

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.

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.

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.

5.4.3.11 Conduit, Cable Tray and Wireway

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 .

Cable ladders shall be used for supporting cables of bigger size and primarily in ASS area. Cable trays shall be used for cables of smaller sizes, control cables and wires.

Standard and Reference

The conduits, cable trays and wire ways shall comply with the following codes and standards:

- (3) ANSI C80.1 : Rigid Steel Conduit (RSC)
- (4) ANSI C80.6 : Intermediate Metal Conduit (IMC)
- (5) ANSI C80.4 : Conduit fitting
- (6) ASTM A123 : Hot-dipped galvanized for Steel Cable Tray
- (7) IS 694 : 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

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.

5.4.3.12 ELECTRICAL FITTING AND ACCESSORIES

Galvanised 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 galvanised 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 energisation.

5.4.3.13 Lighting System

Lighting fixtures shall be so designed so as to be installed easily with false ceiling and in-line with architectural plan & in close coordination with architect. False ceiling may not be provided in some public areas and lighting booms might be proposed with integrated cable trays.

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.

Unless specified otherwise, the minimum IP rating of various Luminaries used in various areas shall be as follows:

- Tunnels, Exterior areas IP 65
- Platforms, near Entry / exits, IP 54
- Other Areas and Plant rooms(Non-Sprinkler) IP 20

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.

Generally, all lighting fixtures shall be applied with 240V 1-phase 50Hz power

supply. The major lighting source will be LED lights, energy saving, high efficiency (≥ 100 lumen/watt), low loss, high life ($> 50,000$ hrs), THD $< 10\%$ and high power factor (≥ 0.95). The colour temperature of the LED light shall be $5700 \pm 300^\circ\text{K}$ and the colour rendering index (CRI) shall be 80 minimum. Lighting fixtures in finished areas (rooms with ceiling such as office, toilet, etc.) shall be recessed type, equipped with anodized aluminium mirror reflector. Lighting fixtures in unfinished areas such as machine/equipment rooms shall be surface mounted type. All Emergency Exit signs (including ITESS and XPESS) and 50% of the Emergency lighting fixtures in Stations and Tunnels (including cross-passages) shall be of self-contained battery powered (by 2 hours battery power packs) type. Uniformity factor of lighting level for all areas shall be not less than 0.7 and Emergency Lighting level in case of Emergency shall not be less than 25-50 Lux (Please also refer the table below under the heading illumination lighting level) when operated through UPS/DG sets and not less than 10 lux level when the emergency lights are operational only on their own two hours self-contained battery power packs.

The emergency lighting installation shall fully comply with NFPA 101 and NFPA 130, BS 5266 and emergency luminaires shall comply with BS 4533 Part 101 and Part 102.22/BS 60598 Part 1 and Part 2, CIBSE and other international standards.

Where large numbers of lighting fittings are installed, lighting fittings shall be switched in multiple circuits in order to allow management control of lighting levels [nominally 25 -50 Lux (also backed up by UPS and diesel generator), 33% after revenue hours, 66% during non-peak hours, and 100% of output during peak hours], and lighting fittings shall be supplied from separate power circuits in order to avoid the loss of whole illumination while one power circuit is gone. At PSD the illumination level shall be minimum of 250 lux and shall be provided all along the Platform gap/edge as a passenger safety requirement.

All large areas in stations shall be sub-divided so that alternate luminaires are fed and switched on from the circuits of alternate phases to enhance reliability and cater for local system failure. In Tunnel areas including cross passages area alternate luminaires shall be fed from the circuits of alternate phases.

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. Emergency Luminaires inside the Launch box (including mid-ventilation shaft, where applicable) shall be automatically controlled by Door Contactor Switch.

The lighting system shall be On/Off to suit the Emergency level (25-50 lux; Please also refer the table below under the heading illumination lighting level), 33%, 66% and 100% as far as practicable by centralized control PC workstation, via lighting control system, in SCR (in Station) combined with timer and photo cell.

Self-contained battery power pack unit with 2 hours operation time shall be provided for all emergency exit signs (including ITESS and XPESS) , emergency lighting for tunnels, cross-passages, public corridors, escape routes, exit ways, staff and plant rooms. The control of normal and emergency lighting in the various areas of the station shall be as follows:

Area	Scheme	Control	Monitoring	By
Public	Peak Traffic Hours (100% Task)	ON/OFF	ON/OFF	Controller in Station Control Room – Pass through 2 –wire Remote Control Station in SCR. Auto Switch on in case of Power failure conditions
	Non-Peak Traffic Hours (66% Task)	ON/OFF	ON/OFF	
	After Metro Revenue Hours (33% Task)	ON/OFF	ON/OFF	
	Emergency	ON/OFF	ON/OFF	
Outdoor	Task	ON/OFF	ON/OFF	Photocell/Timer switch via 2-wire Remote Control Station in SCR.
Plant Rooms, Functional Rooms	Task	ON/OFF	ON/OFF	Local Switch.
	Emergency	ON/OFF	ON/OFF	Auto Switch on in case of Power failure conditions
Ventilation Shaft, Under Platform Void Service, Service Duct, Culvert	Task	ON/OFF	ON/OFF	Local Switch
	Emergency	ON/OFF	ON/OFF	Local Switch Auto Switch on in case of Power failure conditions

All lighting switches shall be indicated on the drawings and mounted at 1,350mm above finished floor level unless otherwise specified. In the rooms with ceiling shall be flushed mounted.

Illumination Lighting Level

Illumination lighting level for all spaces shall conform to the codes and standards such as IS, IES, etc. The uniformity factor shall be not less than 0.7 for long corridors, passenger ways. Emergency lighting level shall be not less than 25- 50 lux for public areas, non-public areas , plant rooms, and escape routes . The following illumination criteria shall be followed at various locations:

Areas	Average Normal (Lux)	Minimum Emergency (Lux)
Lift Maintenance Room (if provided)	150-200	25-50
Inert Gas Room	200-250	25-50
Auxiliary Substation(ASS) Room	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
Transformer 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
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
Retail/Commercial	200-300	25-50
Parking (where applicable)	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

Areas	Average Normal (Lux)	Minimum Emergency (Lux)
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

Emergency Lighting

The emergency lighting installation shall fully comply with NFPA 101 and NFPA 130, BS 5266 and emergency luminaires shall comply with BS 4533 Part 101 and Part 102.22/BS 60598 Part 1 and Part 2, CIBSE and other international standards.

All emergency lighting luminaires and exit signs shall be fed from an Emergency Power Supply System (EPSS) capable to meet Type 10, Class 1.5, Level 1 in accordance with NFPA 110- Standard for Emergency and Standby Power Systems. For the switchover time to EPSS, the emergency lighting shall be fed by UPS source. The location of the same shall be according to architectural drawings.

Emergency Luminaires

- The luminaires shall be clearly marked with a label visible to persons standing on the floor beneath them.
- Emergency lighting luminaires shall, wherever possible, be fluorescent type for superior lamp life and lumen output. This includes linear lamps in conventional fluorescent luminaires and TCD lamps in down lights.

Illuminated Emergency Exit Signs

- Exit signs shall be manufactured to meet the appropriate requirements of BS4533 /BS 60598, BS 2560 and BS 5266, or other international standards.
- Each sign shall be internally illuminated by two lamps. 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.

Installation

- Install surface mounted emergency lights and exit signs plumb and adjust to align with building lines and with each other. Secure to prevent movement.

- b) Install suspended exit signs and emergency lights using pendant supported from swivel hangers. Install pendant length required to suspend sign at indicated height. Install accessories furnished with each emergency light and exit sign.
- c) Connect emergency lights and exit sign to branch circuit outlets. Make wiring connections to branch circuit using fire survival building wire in flexible conduits. Install specified lamps in each emergency light and exit sign.

The dimension of exit lights for the public areas shall be complete with fire retardant perspex panels and casing matching to the powder coated galvanized steel support to RAL 7012 30% gloss. The exit lights shall be single sided or double sided with or without directional arrows to suit the fire escape requirements of architectural layouts. The Contractor shall submit mock-up of the EXIT light installation for the Engineer's acceptance prior to actual site installation.

The Contractor shall supply and install all exit lights, conduits, mounting rods and brackets, powder coated galvanised steel support and all necessary cabling. Cables for suspended and cantilevered shall be run in flexible conduits encased in powder coated mild steel pipe.

The Contractor shall submit the Certificate of Conformity of Declaration of conformity of illumination under emergency condition for both station and tunnel.

5.4.3.5.1 Illuminated Tunnel Evacuation Signage System (ITESS) / Cross –Passage Evacuation Signage System (XPESS)

- (i) The ITESS shall 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.
- (ii) The XPESS shall provide clear and unambiguous illuminated signs, which shall indicate the location of the cross passage entrances to the passengers'.
- (iii) The integrity, including the operation of the ITESS and XPESS shall be capable of being maintained under fire conditions.
- (iv) A mock-up for the ITESS and XPESS shall be provided for the Engineer's approval.
- (v) Signage – Visibility
 - The illumination level and design of the ITESS and XPESS shall be such that when activated, these signs shall capture the attention of the passengers and staff within the tunnel and also of those being evacuated from the train.
 - ITESS shall be mounted up to 12m from the Head Wall / Tail Wall (HW/TW) unit and shall be installed at the opposite side of the platform (tunnel lighting/walkway)
 - The design of the ITESS shall ensure that each activated directional

arrow is uniformly lit and clearly visible from the track at a minimum distance of 48 meters, taking into consideration the ambient light level within the tunnel.

- No spill over of lighting to the adjacent inactivated directional arrow within the same housing shall occur.
- When in the “OFF” condition, the ITESS signs shall not show any illumination, and shall be a 'secret sign', not visible due to any ambient or tunnel lighting, including that caused by passing trains.

(vi) Housing and Assembly

The housing and assembly of the two direction sign shall be suitable for tropical tunnel environment and shall be designed to IP65 rating, fire resistant, LSOH, corrosion resistant and able to operate under fire conditions. The housing shall be stainless steel type.

(vii) Configuration

- The ITESS signs shall be installed at 24 meter intervals (centre to centre).
- The signs shall be installed at each cross passage entrance.
- The luminaries shall be, as far as practicable, “off-the-shelf” type readily available.

(viii) Power Supply , Cabling and Accessories

- The power for the ITESS & XPESS shall be supplied from the Station UPS system and in addition to this, these shall be backed- up by self-contained 2 hours battery power packs.
- The ITESS and XPES shall be from dedicated circuits.
- The cables for the ITESS and XPESS shall be fire resistant, LSOH, armoured, sheathed and rated at 1100V grade.
- All accessories used shall be selected or designed to ensure that the integrity of the ITESS/XPESS system and circuits are maintained under fire conditions and are suitable for tunnel environment with IP65 rating, fire resistant, LSOH.
- Failure of any ITESS /XPESS fitting shall not affect the rest of the fitting in the circuit.

(ix) Control

- The ITESS and XPESS shall be capable of being either remotely activated through M& E SCADA or from a manual control panel located within the Station Control Room SCR. SCR located at each station shall have control over tunnels (both north bound and sound bound tunnels) on both sides of the station .
- A typical drawing indicating the provision of control circuit grouping is included in the tender drawings. Crossovers and tunnel escape shafts
- i.e. mid ventilation shaft, wherever applicable, shall be included under

separate circuit group.

- The manual control panel in the SCR shall include a key lockable selector switch between “NORMAL” and “TESTING”
 - When set to “NORMAL” – ITESS and XPESS system shall be interlocked and the key can only be removed in this position.
 - When set to “TESTING” – ITESS and XPESS system interlocking shall get disabled and all the ITESS and XPESS shall be lit up.
- There shall be another set of selector switch on the manual control panel utilizing the same set of key used for the “NORMAL” & “TESTING” switching. The switch shall enable switching between “REMOTE” and “LOCAL” control.
 - When set to “REMOTE” - the system shall allow full control from the OCC via the M & E SCADA.
 - When set to ‘LOCAL’ - the system shall only be capable of being manually controlled from the SCR. The key can only be removed in this position.
- When the ITESS is activated, whether locally or remotely, the system shall be hardwire interlocked such that only one directional arrow shall be illuminated per sign.
- When XPESS is activated, whether locally or remotely, the system shall be hard wire interlocked such that ITESS will also be switched on. The XPESS on the North Bound and the South Bound tunnels shall also be interlocked.
- Provision shall be made for bypassing the interlocks on both ITESS and XPESS.
- Lamp Test button shall be designed for checking of indicating lamps on the ITESS/XPESS Control Panel.
- Remote M & E SCADA Control
 - (a) The interface for remote control of ITESS/XPESS at OCC shall be via voltage free contacts to the interface termination board (ITB).
 - (b) The control circuit grouping shall be co-ordinated with other emergency systems and linked to the ITB such that separate circuit grouping can be individually controlled.
- Local Station Control
 - (a) The ITESS /XPESS local control switches in the SCR shall be hardwire interlocked for the respective switch positions “Left / Off / Right” of the respective tunnel section concerned such that only one of the three switch positions of a particular bound tunnel can be activated.
 - (b) There shall be 3 number of illuminated Push Buttons for XPESS along the cross passage on the mimic panel, located in SCR namely XPESS (North bound tunnel), XPESS (South bound tunnel) and Off.
 - (c) For evacuating from Tunnel to adjoining Station A or B via the XPESS to the South bound tunnel , the XPESS North bound tunnel illuminated push button shall be depressed from the control panel.

5.4.3.5.2 Tunnel Lighting

- (i) 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.
- (ii) Tunnel lighting shall be spaced at not more than 15 m to provide with a minimum illumination level of 25-50 lux
- (iii) 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.
- (iv) The tunnel lighting shall be controlled by the following means:
 - (a) HW/TW (Head Wall/Tail Wall) – 2- position key override switch comprising with pad lockable cover.
 - (b) Tunnel lighting control panel (TLCP) at SCR
 - (c) OCC via M & E SCADA
- (v) The 2-position key override switch shall have the following selection option:
 - (a) LOCAL - It will effectively switch "ON" the tunnel lighting
 - (b) REMOTE - It will switch "OFF" the tunnel lights, which could then be switched "ON" either by SCR or OCC control.
- (vi) Control of the tunnel lighting via OCC shall only be possible when TLCP at SCR is set to its "OFF" position.
- (vii) The tunnel lighting can only be switched off when all the three means of control are in the off position.
 - (a) Control at HW/TW
 - (b) Control at SCR
 - (c) Control at OCC
- (viii) Tunnel lighting connection shall be of plug and socket type.
- (ix) By default tunnel lighting shall be in "OFF" mode.
- (x) Upon traction power failure, tunnel lighting between the two- (2) stations shall be switched on automatically. .
- (xi) All control and monitoring cables shall be provided from Tunnel Lighting DB and terminated into ITB. All contactors and accessories necessary for control and operation of the tunnel lighting system shall be deemed included in this Contract.
- (xii) Tunnel lighting control panel (TLCP) shall be provided in the SCR for local control of the tunnel lighting at SCR.
- (xiii) A PLC tunnel lighting controller shall be provided in the platform DB rooms (or as required) for local control of the tunnel lighting or interface with the M&E SCADA for remote controlling at SCR/OCC
- (xiv)

5.4.3.14 SWITCH AND SOCKET OUTLET

General

The Contractor shall Design, supply and install the switch and socket outlet as described and specified herein.

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 (IP Code) |
| (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 |

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.

Socket outlet shall be installed in all areas with wiring in radial circuit. Socket outlet for plant rooms shall be 2P+G, 240V, 16A & 3P, 415V, 32A universal pin switched type complying with IEC60884-1, installed with robust box, and exposed conduit. Socket outlet for Control Rooms and offices, that need to be good looking, shall be concealed conduit with boxes types. The Socket outlet shall be installed at 30cm height above finished floor level.

The power socket outlets in Tunnel Area including cross passages for maintenance purpose shall be supplied at 32A/63A, 415 volt, 3-phase, 16A, 240 volt, 1-phase 50 Hz. The socket outlets shall be industrial type 3/5 poles with neutral and earth (TP&N) rated IP65.

Weather proof type Socket Outlet, IP54, shall be provided on public corridor and outdoor area at 15m interval. Socket outlet for public corridors, small appliances shall be equipped with Residual Current Device (RCD) or Earth Leakage Circuit Breaker (ELCB) for human protection from electric shock. In public areas, plant rooms and switch rooms they shall be mounted at 350mm above finished floor levels. In control rooms, offices, staff rooms and mess room they shall be mounted 300mm above finished floor level or above furniture height to suit furniture and

equipment layouts. Industrial type power receptacle will be provided along with convenient receptacle to be as a typical group in all plant rooms and workshop area, wherever applicable, for maintenance purpose.

5.4.3.15 Emergency Power Supply

Emergency power supply for stations and Tunnels shall be comprised of standby diesel generator and uninterruptible power supply (UPS). Emergency Power Supply System (EPSS) shall be capable to meet Type 10, Class 1.5, Level 1 in accordance with NFPA 110- Standard for Emergency and Standby Power Systems.

Standby generator with suitable capacity will be provided at the stations to provide emergency low voltage power supply to the essential loads that can maintain the operation in a safe environment in the event of the failure of the normal station power supply. The non-essential loads will be shed before the generator takes up the loads.

The emergency power will be generated by standby generator to supply the power through the designated LV power distribution system via the automatic transfer switch. The power will be supplied for the following systems or facilities in each area.

- 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, waste water pumps, Ejector pumps in stations and tunnels;
- Uninterruptible Power Supply (UPS);
- Emergency small power outlet;
- PSD system

Uninterruptible power supply will be provided at the stations to supply continuous electrical power to the following critical systems:

- Telecommunication system;
- Fire detection and Alarm system;
- Signalling system;
- AFC 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 lightings;
 - Tunnel and Cross passage lighting ;
 - Tunnel and cross passage emergency evacuation signage lighting
 - Exit and emergency sign;
 - Platform Screen Door Control system
 - Blue light stations provided by Power Supply and Traction Contractor

The UPS will be provided with batteries that have sufficient capacity to back- up the above systems in the event of the failure of normal station power supply until the standby generator can take over.

5.4.3.16 Lightning protection system

Stations and all other building structures shall be protected with lightning protection system conforming to IS, IEC 62305, IEC1024 as appropriate.

A lightning protection system is required to;

1. Protect an above-ground structure from a direct lightning strike.
2. Protect the equipment housed within the structure and the zone of protection.
3. Protect personnel working within the structure and the zone of protection.

The system is designed with conventional faraday cage, comprising of 3 main components as:

- Air terminal, made of copper or aluminium shall be installed on the roof top and other parts of building above ground level.
- Down conductor may be designed as copper conductor run in conduit or insulated copper tape or use of building steel structure.
- Earth electrode, in general, shall be of copper clad with 5/8" diameter and 3m long underground direct burial complete with test box. The number of earth rods shall be depending on the earth resistance e . The lightning protection system shall be designed to consider the side flashing. Step voltage and touch voltage shall not exceed the design limit values that are not dangerous to human within area. The earthing electrode of lightning protection system can be used in combination with electrode of earthing system.
- The lightning protection system connects to the earthing system at zero potential level to protect incoming lightning current flow to the equipment inside stations and building structures. Lightning surge arrestor shall be

provided at low voltage side.

5.4.3.17 Earthing and bonding system

General

- a) The earthing system shall be designed complying with IEEE80, NEC, BS7430 and IS. Earthing system shall be provided for the purpose of safety from electric shock for personnel, Equipment, operation safety and to prevent stray current.
- b) The contractor shall carry out soil/ground resistivity tests at a time to be coordinated with his programme for construction of base slabs. It shall be early enough to allow at least 2 months' time for the redesign of earthing conductor, if necessary.
- c) The soil/ground Resistivity shall use the Werner 4 pin method and the results submitted to the engineer shall be endorsed by a registered Licensed Electrical worker. The contractor shall select a minimum of 2 test locations for each station, subject to the acceptance of the Engineer. Five sets of tests shall be conducted at each location; each set at pin spacing of 2 m, 4 m, 6 m, 8 m and 10 m respectively. The Contractor shall install the final earthing in accordance with the final approved design. The Installation and testing of the earthing system shall be in accordance with the Contract documents.
- d) The Contractor shall prepare the necessary detailed working drawings and test procedure and submit to the Engineer for acceptance.

Earth mat Design Requirement

- a) The Earth mat design shall ensure that the potential rise is to be limited to 4.0V above water earth. Disturbances from HV, LV, traction supplies when supporting the most adverse traffic pattern and power generating sources should be considered.
- b) The Earth mat should be designed to limit the coupling from any lightning system earth mat to 110V when a discharge of 100KA lightning strike occurs.
- c) The main power earth mat and clean earth system shall have a resistance not more than 1 ohm and 0.5 ohm respectively.

Installation and Execution

- a) The Ringed earth mat shall comprise of earth rods inclusive of electrode pits and heavy duty cover and 95 sq.mm bare stranded copper wires laid 300mm below base slab/ground level. The earth rod is made up of 3 meter long, 20mm diameter copper rod as per Tender Drawing (Please refer part 2, Section IX).
- b) One earth riser cable 185 sq mm XLPE shall be brought from the earth mat up through the basement floor or wall to each of the substation rooms, communication Equipment room, SCS rooms and relay room and other equipment rooms to the Engineer's acceptance.
- c) At each earth riser cable entry through the base slab, a tinned copper waterstop sleeve shall be provided to prevent the ingress of water. The sleeve shall be coated with epoxy resin.

- d) The Contractor shall co-ordinate with the relevant system wide contractors for termination of the earth riser cables on to the earthing busbar .
- e) The earth riser cables oversheath shall be green in colour. At each connection to the busbar, the cable shall be labelled “MAIN EARTHING CABLE” plus the value of earthing resistance and the testing data shall be engraved on a template and fixed permanently above the earthing busbar.
- f) The copper electrode at the earth inspection chamber at ground level shall have a label “Electrical DO not Remove”.
- g) Earth bars shall be 50mm x 6mm cross-section, hard drawn high conductivity tinned copper. The length of earth bar shall suit the number of outgoing ways required.
- h) No drilling of the earth bar shall be permitted except in terminations.
- i) Earth bars shall be complete with twin disconnecting links.

5.4.3.18 M & E SCADA Interface System

General

The Contractor shall Design the M & E SCADA Interfacing system as indicated in the drawings and the Specifications herein. The Contractor shall fully coordinate with Engineer and/or Designated/Interfacing Contractors in collecting all necessary technical interface details and information to produce the necessary interface document between Underground station contractor and Signalling and Telecommunication contractor.

The Contractor shall cross reference the requirement of SCADA remote control and monitoring interface as required for electrical equipment and shall provide the necessary VFC , remote control interface for SCADA. All BMS interface signals shall be wired from respective contacts or terminal to the SCADA interface terminals or port. Serial interface as applicable for ACB/MCCB and digital meter or MFMs shall be strictly on standard protocol communication (preferable with MODBUS-RTU, RS485, 2 wire communication). Necessary interface detail and drawing shall be provided to SCADA contractor during commissioning. All terminals and SCADA interface terminal and ports shall be wired to a separate chamber with adequate number of ITBs and with proper marking as per interface document. No such change in contact or pseudo signal shall be provided for critical alarms and control interface. In main distribution LVSB panel separate marshalling chamber shall be provided for SCADA interface terminals.

Material Description

The M & E SCADA interfacing system for E & M service shall consist of the following equipment:

- (i) Microprocessor based distributed controllers interface directly with sensors, actuators and environmental delivery systems, i.e. electrical system, Plumbing, Fire alarm system, Fire Fighting system and Tunnel Ventilation

and Underground Air conditioning works.

- (ii) Remote Processor units required for interface with different stations.
- (iii) 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, Platform Screen Doors system, Tunnel Ventilation and Underground Air conditioning works, Plumbing and Drainage System, Lighting System, Low Voltage Power Supply System, Diesel Generator (DG), Uninterruptible Power Supply (UPS), etc.
- (iv) Marshalling Cabinets (MS) shall be provided for termination of all M & E SCADA interface monitor and control signal wiring.
- (v) Associated Power & Control Cables.

Technical Requirement

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 Station Control room or as specified/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
<p>Analog 4 – 20 mA</p> <p>Dry contact (NO or NC)</p> <p>Pulse accumulator</p> <p>Override switch</p> <p>Photocell contact</p> <p>Transducer sensors</p> <p>Etc.</p>	<p>Analog 4 – 20 mA</p> <p>Dry contact (NO or NC), 20A, 250V</p> <p>Momentary-pulsed and Mechanically latched</p>

- (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.

5.4.3.19 Uninterruptible Power Supply (UPS)

General:

Underground stations shall have two nos. Uninterruptible power supplies (UPS) (of approx. capacity 80 kVA each, subjected to change and Validation by contractor through detail design) with individual battery banks of 30 minutes battery autonomy with battery manager to have interoperability of the battery bank for UPS are designed to provide back-up power for systems essential for railway operations.

The following systems are to be backed-up by UPS source:

- Telecommunication system;
- Fire detection and Alarm system;
- Signalling system;
- AFC System
- Master clock system;
- Public address system;
- Closed circuit television (CCTV);
- PC work stations in SCR;
- M & E SCADA; Power Supply SCADA, TVS SCADA ;
- Emergency lightings ;
- 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

Standards

Relevant Codes and Standards

The UPS and their constituent parts shall comply with the relevant latest version of British Standards, European Standard (EN), International Electromechanical Commission (IEC) standards, International Organization for Specification (ISO) Standards as specified below:

The following standards shall apply where appropriate:

Specification for Uninterruptible power systems (UPS)	IEC 62040 - 3, EN 50091 EN 62040
Safety of information technology equipment, including electrical business equipment	EN 60950
Power Transformers	IEC 60076, EN 60076
Isolating Transformers	BS 3535, EN 60742 BS 61558
Semi-conductor Converters	IEC 60146, EN 60146, EN 50329
Degree of Protection provided by Enclosures	IEC 60529, EN 60529
Surge Protective Devices	IEC 61643-1
EMC - Immunity	IEC 60801, EN 60801, EN 61000-4-3
EMC - Emission	VDE 0875, IEC 60555, EN 60555 IEC 61000-3-2/ 61000-3-3, EN 61000-3-2/ 61000-3-3
Electromagnetic compatibility Testing and Measurement Techniques	IEC 61000-4, EN 61000-4
Level measuring systems utilizing ionizing radiation with continuous or switching output	IEC 60982
Sound Level of Noise Source	ISO 3746, BS 4196-6
Flammability Tests	IEC 60707
Valve Regulated Sealed Lead Acid Rechargeable Single Cells	BS 6290 BS 60896
Low-voltage switchgear and control gear assemblies:Part-1 General Rules	IEC61439 – 1, EN 61439-1
Low-voltage Switchgear and Control gear	IEC 60947, EN 60947.
Specification for contactors	IEC60947 – 4, EN 60947-4
IEE Wiring Regulations	BS 7671
Code of practice for Earthing	BS 7430

Electromagnetic Compatibility

All equipment shall comply with IEC 62040 - 3 and EN 50091 – 2/ **EN 62040 - 2** and the following standards for the requirements of electromagnetic compatibility

Electromagnetic Compatibility - Immunity:

- IEC 60801-3, Level 3/ **IEC 61000-4-3**
- IEC 60801-4, Level 4
- IEC 60801-5

Electromagnetic Compatibility – Emission:

- IEC 60555 /IEC 61000-3-2/ 61000-3-3
- VDE 0875.

All equipment shall conform to the objective of the European Directives on EMC (89 / 336 / EEC) and where appropriate shall be fixed with the CE mark.

The radio frequency interference (RFI) levels generated by the UPS equipment shall also be in accordance with the requirements of BS 800/BS 55014-1, or other relevant international standards.

Material Description

- 1) The equipment and/or components shall be fully tropicalized 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 maintenance-free regulated lead acid batteries and other equipment necessary for completion of the system. The UPS shall be a dual unit parallel-redundant type with configuration, 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

- 2) The contractor shall ensure in design that the harmonics generated by each UPS unit shall not affect the performance of other UPS units and the entire electrical distribution system.
- 3) Environmental Conditions

The Contractor shall ensure in design that 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

- 4) 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 loads within specified parameters.

(2) Emergency Mode

- (a) Upon failure or loss of the main AC supply line, the critical 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 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.

5) 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.
- 6) 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
 - (5) 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 : > 0.95 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%

Inverter Unit

- (1) The unit shall be a transistorized solid state type, IGBT, which is designed for Pulse Width Modulation technology interconnected with 3 phase 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 | : | < 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° |

(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 (THDU)

- | | | | |
|------|----------------------|---|------|
| (i) | 100% linear load | : | < 1% |
| (ii) | 100% non-linear load | : | < 5% |

Static Bypass Switch

- (1) The static bypass switch shall be designed to bypass the critical load from the inverter to the main power source in the event of UPS malfunctions without interrupting the critical 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.

Maintenance Bypass Transfer Switch

- (1) A manually operated maintenance bypass switch shall allow the critical 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 loads to the normal power mains during the electrical disconnection of the UPS module for maintenance purpose.

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.

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.

Control and Annunciation System

- (1) The UPS shall incorporate the necessary control, instruments and annunciation to perform the completed 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:

(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:

(d) Rectifier	: Off, Over Temperature, Failure
(e) Inverter	: Off, Over Temperature, Failure
(f) Battery	: On Load, Over Temperature
(g) Load on Bypass	
(h) Overload	

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.

5.4.3.20 Diesel Generator

General

The Contractor shall supply, install, connect, test and commission a complete system of Prime duty type diesel generator sets (configuration 2 x 1000 kVA, Capacity subject to validation by contractor during detail design)to meet the load requirements for all essential loads as mentioned in these Specifications/Contract. Emergency Power Supply System (EPSS) capable to meet Type 10, Class 1.5, Level 1 in accordance with NFPA 110- Standard for Emergency and Standby Power Systems.

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 |
| (7) NFPA 110 Systems | : | Standard for Emergency and Standby Power |

In addition to above all relevant Central Pollution Control Board (CPCB) and State Pollution Control Board (SPCB) notifications shall be complied & certificate of approval shall be produced by the Contractor.

DG Set system as a whole should satisfy the requirements of Level 1, NFPA 110, Emergency and Standby Power Systems.

Material Description

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

All the cables (power and control) shall be Flame Retardant Low Smoke Zero Halogen FRLS 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.

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.

All other works, not specifically mentioned but required for satisfactory completion of work shall be done by the Contractor.

Automatic Gas flooding of AMF panel, using linear heat sensing tubes, Fire trace or equivalent shall be provided by the Contractor.

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.

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.

Component

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.
 - 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, and 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 or 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 600 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 with 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 fulfil 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 equipment, 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).

Alternator

12) 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.

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.

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.

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		
b) Indication and Alarm annunciation			
Engine side			
Additional	Indication	Alarm	
Charger on	Yes	-	
Failed to start	Yes	Yes	
Low oil press	Yes	Yes	
Gen. on	Yes	-	
Mains on	Yes	-	
c) Auto-Manual change over switch			
Start-Stop Reset	Buttons	Start-Stop	
Reset Alarm Reset	Buttons	Alarm Reset	
Lamp testing	Buttons	Lamp testing	

Battery System

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.

Control System

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 centre & station control centre. 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

Above or equivalent system shall be designed & provided as industrial standards

The annunciation alarm shall be repeated to the station control room through Station/Building Management System (BMS).

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.

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.

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	±	1%	
b) Voltage regulation	±	1%	
c) Frequency regulation	±	1%	
d) Maximum water temperature	±	5%	Of guaranteed performance
e) Minimum lube oil pressure	±	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 equipment fully comply with the conditions as set out in these Specifications.

5.5 Plumbing

5.5.1 General Requirement

5.5.1.1 Scope of Work

The Scope of works included in the Plumbing systems shall be as listed below:

- a) Sanitary Fixtures & Accessories
- b) Water Supply
- c) Drainage (Soil / Waste & vent)
- d) Rain Water Drainage (Surface water)
- e) Seepage Water Drainage (Underground Stations & Tunnels)

The Contractor shall be responsible for the design coordination of the Plumbing system with all the other Systems. The Plumbing system design shall be verified, tested and commissioned to the requirements of the Indian standards, NBC, Pune Water Supply Authority and other Municipality regulations in which the works are executed. The Contractor shall be responsible for checking and ensuring that the type of Plumbing system proposed complies with the codes of practice, standards, regulations and requirements of the statutory authorities. The Plumbing system schematic diagrams and Typical Details provided are indicative only and it is the Contractor's responsibility to ensure that the installation satisfy fully the Contract Provisions/Stipulations and complies with the relevant codes of practice and sanctioning authority requirements.

5.5.1.2 Responsibilities

The responsibilities of the Contractor shall be as follows but not limited to:

- A. Detailed Design of the systems / packages listed in the scope of works including the requirements that are not specified here in but are required for the successful operation of the system / package.
- B. Supply & Installation of the System / Equipment / Devices & Components and all other accessories required for the complete functioning of the system to the Notice of No Objection by the Employer / Engineer.
- C. Testing, Commissioning, Verification & Validation of the Systems and getting the Notice of no Objection by the Employer / Engineer.
- D. Selection of Plant to meet performance criteria and specification with supporting calculations
- E. Capacity of Seepage Water Sump and Sewage Sump.
- F. Due consideration shall be given when designing the storm water system especially for the stations where the Existing Subways are linked by a Proposed Subway to the Concourse levels of the Metro Stations.
- G. Necessary Bye Pass arrangements in the Pumped main in order to facilitate the disposal of seepage / storm water in case of Pump Failure. Emergency Tanker Connections shall be provided complete with a network of piping,

valves and quick connection couplings.

- H. Capacity of Seepage Water Pump Sets and Sewage Water Pump sets
- I. Sizing of Seepage Water Pipes & Sewage Pipes both Gravity and Pumped mains running in the Underground Stations and Tunnels.
- J. Pipe sizes, hydro pneumatic pumping system capacities and hydraulic pressure drop calculations in accordance with the actual characteristics of the pipe work and equipment installed
- K. Arrangements to handle expansion / contraction
- L. Acoustic and vibration isolation
- M. Co-ordination with all the other services for the interface requirements
- N. Liaison with the Local Authority & getting approval
- O. All legal fees & statutory requirements

5.5.1.3 Additional Standards, Codes and Regulations for Plumbing

In addition to the standards listed in Section 5.2 “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. All equipment and material 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 multi-storeyed 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 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 gage, 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: Part2 Multi door pattern
IS: 5312 (Part 2)	Specification for swing check type reflux (non-return) valves: Part2 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 basin
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
IS2002:	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.

5.5.1.4 Occupant Load

The Contractor shall refer the NBC and station space design carried out by him to arrive at the Occupant load in the station. Due consideration shall be given to the Cleaning staff, Maintenance Staff and all the other staff and requirements in the station to arrive at the water demand. The number of shifts to be considered shall be 2 shifts per day. The water demand shall be based on the NBC requirements of 45L/Person/Day for the Staff in the station. The water demand shall be based on

the NBC requirements of 15L/Person/Day for the Visitors in the Commercial / Retail areas as applicable. A calculation sheet based on the contractor's design shall be submitted for the Notice of No Objection by the Employer / Engineer.

5.5.2 Water Supply

5.5.2.1 General

The design of water supply to stations shall comply with the NBC and local authority requirements. The water demand shall be based on the NBC requirements of 45L/Person/Day for staff and 15L/Person/ Day for visitors in Commercial/Retail Areas. For station cleaning water requirement shall be taken as 1Litre/sq.m./day for platform, Mezzanine (Intermediate) & concourse areas. Additionally drinking water coolers for the Station staff shall be provided. The locations of such drinking water coolers are subject to co- ordination with the architectural and other services and the Notice of No Objection of Employer / Engineer. The storage capacity of the Water Tank shall be based on 2 days storage of daily water demand. The Water Supply system shall be designed to cater to the daily water demand of the Station Occupants and the operational requirements as listed but not limited to

- A. Water Supply for the Plumbing Systems (Water For Toilets in Station & Commercial Areas + Drinking water Fountains/coolers [Station Staff] + Taps provided in Plant Rooms & other areas including water requirement for cleaning)
- B. Water Supply for Fire Fighting Systems
- C. Water Supply for Cooling Tower Make-Up etc. (for ECS system)
- D. Water Supply for Landscaping (Roof Gardens / Small Planting Areas within the Station Limit, wherever applicable)

5.5.2.2 Water Quality

This Section specifies the furnishing and installation to complete and operable Reverse Osmosis/Water Softening Plant for cold water for reducing the TDS to below 100 mg/lit so as to generate water fit for drinking purpose and for make-up requirements for Cooling Towers of HVAC system.

The Plant should be designed to treat borewell/municipal supply water (TDS upto 3,000 mg./lit) to yield permeate with TDS less than 100 mg / lit.

The raw water analysis report is likely to be:

TDS	900 mg/lit
Total Hardness (as Ca Co3)	638 mg/lit
pH	6.5 to 8.5
Chlorides as Cl.	105 mg/lit
Alkalinity (as Ca Co3)	421 mg/lit
Sulphates as SO4	233 mg/lit

Coliform	Nil
E-Coli	Not mentioned
Total iron as Fe	0.6 mg/lit
Fluorides	7.0 mg/lit
Turbidity	7.0 NTU

Silt Density Index may be assumed to be less than 3.

(It is to be noted that the analysis report of tubewell bored at the station may vary within wide limits. For this reason it is specified that the R.O/ water softening plant be designed for a TDS upto 3000 mg/lit.

5.5.2.3 Water Supply for Plumbing Systems

The water requirement for the stations shall be proposed based on the provisions of IS 1172 and the prevalent practices. The water requirement for the stations & Tunnels shall be through the municipal mains supply (wherever feasible).

The Contractor shall design the water supply system in liaison with the local authorities for the following requirements:

- Availability of Municipal water source and getting connection from the municipal main
- Alternative water source if Municipal water supply is not available and necessary approval from the Authority ,
- Emergency Water supply requirements
- Treatment required for the municipal water supply (Treatment Plant or Point of Use units)

Depending upon storage capacity required and accessibility of tank location, domestic cold water tank storage tank shall be constructed of suitable type and capacity preferably of reinforced cement concrete. Water proofing shall be done as per the local authority requirements and to meet the Contract stipulations. In the event that the municipal mains cannot be connected to the station, the Contractor shall design and provide all equipment/provisions necessary to bring water to the water storage tank of required storage capacity and all plumbing accessories to supply water to the daily water demands of the station.

Emergency Water Supply requirements, in the event of a loss of regular water supply for upto 24 hrs, shall be such as to cater to the following operational needs;

- The air conditioning systems (ECS system) to all rooms containing equipment essential to the operation of the metro system and to the operational control room /SCR can remain operational at normal load;
- Water related facilities (e.g., toilets) for the key operational personnel and their managers in the SCR/Station Control Centre and relevant Offices can remain operational;

- C. Any other facilities essential to the operation of the station can remain operational.
- D. The necessary provisions shall be made in the design of water supply system to cater to the dedicated emergency water supply needs for the above mentioned items by regulating non-essential facilities..

The Contractor shall provide the water supply main connection complete with water meter / valves & controls to the storage tanks at each station. The Contractor shall consider the Employer's land-take (permanent) drawings while locating the water tanks and plant rooms. In stations where the Tanks & Plant area are to be located (as agreed by the Engineer) inside the stations/ underground, the doors & access of suitable size shall be provided for the removal of the biggest pump / equipment / accessories. The design for the elevated tanks as per the requirements of local authorities / fire brigade, if any shall be designed, co-ordinated and installed by the Contractor.

Drinking water tank/pump room shall not be located next to an ejector room / waste water sump room / sewage sump room or toilet or any potentially polluted area. The material for the water mains shall be as per the Notice of no Objection of the Engineer.

The water main shall be suitable to withstand the water main's pressure / system pressure. The tanks shall be with remote level monitoring and control system interfaced with the M&E SCADA. The level monitoring and control shall be suitable for the automatic operation of hydro pneumatic water supply pump sets and various control valves. The low level & high level of the water in the tanks shall be relayed to activate the alarm and the same can be displayed / monitored at the Station Control Room. No Glass reinforced Plastic (GRP) tanks / plates shall be used. The tanks shall be constructed with two compartments of equal capacity to facilitate the maintenance of the tanks without shutting down the system. All necessary provisions shall be made to achieve this. Each compartment of the tank shall be provided with sufficient access space for maintenance of tank. The tanks both fire water & Domestic/Municipal water storage tanks shall be provided with all necessary puddle flanges to make all the piping connections including but not limited to

- A. Inlet Connection
- B. Outlet connection
- C. Overflow connection
- D. Drain connection
- E. Provision for the float switches
- F. Internal overflow from one compartment to another (either in the structure or through piping)

- G. Provision for emergency tanker connection
- H. Provision for emergency Fire Brigade Draw off
- I. Fire brigade Inlet Connection (Fire Tank Only)

Access Ladders and Platforms as applicable shall be provided in the Plant room. The access ladders shall be provided in the following instances

- A. Access to the inside of both fire water and Domestic/Municipal water tanks (material of ladder shall be as per the Notice of No Objection by the Employer / Engineer)
- B. Access to equipment where regular maintenance works is required.
- C. Escape or emergency exit purposes.
- D. Any other situations where it is essential to provide one. (e.g., under platform voids in stations, air shafts etc.)

Extendable type handrails shall be provided where it is not practical to extend side strings above the landing level to form handrails (for example sump pits in cross passages where pedestrian access is required over the sump pit). They shall be provided at each string and shall be capable of being temporarily extended to provide temporary handrails. The water from the Plant room is distributed to all point of usage (toilet / Mechanical rooms / Lunch rooms etc.) through a hydro pneumatic system. The hydro pneumatic system shall be provided with emergency power supply. Water hammer arrestors shall be provided wherever required to prevent damage to the piping network.

Underground piping shall be laid at such a depth that it is unlikely to be damaged by traffic loads and vibration, where unavoidable special consideration shall be given to protect the piping by means of covering the pipe with concrete. Where piping has to be laid in any ground liable to subsidence then special consideration shall be given to the type of piping to be used and the type of joint to be adopted in order to minimize risk of damage due to settlement. Where piping has to be laid across recently disturbed ground, continuous longitudinal support shall be provided.

All joints between threaded connections shall be made water tight by using PTFE Tape and rubber or suitable sealing washer as per the Notice of No Objection by the Employer / Engineer. No threads shall be used to make the joints water tight. Status of bursting of water main running underground or inside the Tunnels shall be relayed to the station control room and OCC through SCADA. Provision shall be made at every bend, branch and dead end in a main to resist the hydraulic thrust. The water meters chamber shall be provided above ground level or as per the local regulations. Wherever possible, a separate chamber to house the double check valve assembly for the firefighting line shall be provided and located below ground level if it is technically feasible with a drainage facility to prevent flooding of the underground chamber. Location of the water meter chamber shall be easily

accessible for meter reading, unobstructed and shall be approximately 1m from the site boundary. Additional sub meters shall be installed as per the Notice of No Objection by the Employer / Engineer for the various other systems (Cooling Tower make Up, Landscaping, Station Cleaning etc.) Common water distribution pipes shall not be routed in commercial/retail areas.

Valves shall be provided to isolate each area / equipment from the system with the minimum disturbances to the system. Angle valves shall be provided at each fixture point. Rigid Copper tubes shall be used to connect the mixers & the angle valves. No flexible hoses shall be used. All valves and taps must be accessible for service and maintenance. Where valves or taps are installed above the ceiling or behind walls (seepage walls etc.) appropriate access panels must be provided in the ceilings or walls for maintenance and repair of the valves and taps. Control valves shall be provided at strategic locations for easy access. Adequate supports must be provided to the supply pipe in the vicinity of the bends. All the high points in the piping network shall be provided with an Automatic Air Release valve with a drain provision to the nearest Floor drain / drain point.

5.5.2.4 Water Supply Minimum Requirements

The contractor shall provide minimum water supply and drainage points in each room / area as per relevant codes and standard practice but not limited to the details / provisions as specified in the table below:

S.N.	Room/Area	Requirement	Remarks
1	Fire Water / tank/Pump room	One tap	
2	Cleaner Room/ Janitor Room	One tap with sink	
3	Refuse Store	One tap	
4	Concourse, Mezzanine (where applicable) & Platform Level Cleaning	One tap in each level	To be located away from Public view
5	Concourse Level & Platform Level	One tap	For Water Fountain or Water cooler
6	Bin Point/Bin Centre	One tap	
7	Staff Room	One tap with Sink or As required	As per the Station requirement (Toilets /Locker Rooms)
8	Toilets	Taps as necessary	Taps in WC cubicles with squatting pans to meet the water authority requirements

S.N.	Room/Area	Requirement	Remarks
9	Planter in Stations	Taps as necessary	To meet the Landscape specific requirements, if any.
10	All VAC Associated Plant (ECS System)	Taps as necessary	Near condensing unit - Near AHU - Near filter or As required
11	Ejector Room	One tap	
12	Waste Water Pump Room	One tap	
13	Sewage Pump Room	One tap	
14	Water Distribution Control Room	One tap	
15	Cooling Tower Room/Area	One tap	
16	Commercial Areas (Shops, kiosks etc.)	One tap off point	
17	Each access Staircase (Underground Stations Only)	One tap off point	For staircase Cleaning with a Trap in the lowest point
18	Station External Areas	One tap off point	For External Use.

5.5.2.5 Water Supply for Fire Fighting

The dedicated water storage required for the firefighting purposes shall be stored in the same plant room. The capacity required shall be as per NBC regulations and the local fire authority requirements. To avoid stagnation of water in the fire water storage tank, water from the municipal main for the domestic water requirement shall be passed through the fire water storage tank and then stored in the municipal/Domestic water storage water tank. Necessary overflow arrangements either in the tanks and or through piping arrangements shall be provided to achieve this.

5.5.2.6 Water Supply for Cooling Tower Make Up

Water for the use of cooling tower make-up shall be provided based on the storage volume required by the VAC (ECS System) Contractor. One metered water connection shall be provided by the Contractor up to the Cooling Tower Make up Water Tank. The interface shall be mutually agreed for the storage volume and location of plant and the provisions shall be made to satisfy the VAC (ECS System) requirements. The treatment required for the municipal water to be used for the cooling tower shall be part of the VAC Contractor's Scope.

5.5.2.7 Water Supply for Landscaping

The contractor shall provide water required for the roof gardens (wherever applicable) and the landscaped areas inside the station. The contractor shall provide a tap point with or without a hose assembly based on the requirement of each station. The landscaping requirement is a station specific requirement.

5.5.3 Drainage

5.5.3.1 General Requirements

The contractor shall design the system based on each station specific requirements. The pipes shall follow the lines of walls vertically and horizontally and shall be graded as necessary for drainage and venting of the system. The minimum distance between the pipe and any building structure / surface, fixing or pipe shall be a minimum of 100mm. All pipes shall be secured to the walls and under structure slabs with brackets or pipe hangers. All the pipe bends or branch connections shall be sufficiently supported. Any additional support requirement to suit the site conditions shall be provided by the Contractor.

Drainage pipe work runs shall in all cases be installed with a view to coordinate with other services, whether provided by the Contractor or not. Careful consideration must be given when designing the drainage schemes for the stations where low flow rates are expected. Self-cleaning velocities must be achieved minimizing the accumulation of solids inside the pipe and any blockages. A normal installation gradient of 1:50 should be maintained as a minimum. Any gradient less than this shall be proven by the Contractor and receive the Notice of No Objection of the Employer / Engineer prior to installation.

Traps shall be provided for all the fixtures. The depth of the water seal in each trap shall be as per the Notice of No Objection by the Employer / Engineer. In any case the depth of the water seal shall not be less than 50mm.

The piping length shall be minimized to achieve removal of wastes in the shortest time possible. The piping shall not be installed inside the concrete slab or any building structure. Places where it is un-avoidable, the Contractor shall obtain the Notice of No Objection of the Employer / Engineer prior to installation.

All bends used shall allow for the smooth flow of the wastes. Long radius bends shall be used. Angle that affects the smooth flow of wastes shall be prevented.

Proper venting of the system shall be designed by the Contractor. All the vent piping terminations shall be co-ordinated and installed in such a manner that it is concealed from public view and doesn't affect the aesthetics of the station building.

The piping subject to heavy loads shall be provided with suitable protection.

Flexible connection shall be provided by using suitable length of the pipe for the Underground piping connected to a solid structure (Manholes / Sump Pits / any structural walls) to withstand the movements caused due to settlements of the structures.

All manholes shall be provided with a suitable duty manhole covers. Cover material shall be as per the Notice of No Objection by the Employer / Engineer. The water proofing of the manhole shall be done either by applying FRP coatings or as per the Notice of No Objection by the Employer / Engineer. The channelling inside the

tunnel shall be done to achieve smooth flow of wastes inside the chamber.

Manholes inside the occupied area / within the stations shall be of dry type manholes. The covers for such manholes shall be screwed down recessed type to accommodate the finish of the floor where it is installed.

Suitable manhole access keys shall be provided.

Wherever possible, the manholes shall be located such that it is readily accessible for inspection and maintenance during the train operating times.

Proper access shall be provided in the underground & above ground piping for rodding and maintenance.

The distances between the manholes shall be as per NBC.

Any piping / accessories that are open to view (Flush valves / Mixers / Angle valves / Urinal flush piping arrangement / Bottle Traps) shall have chromium finish unless noticed otherwise.

A waste water sump shall be provided in the plant room for the drainage of Water Storage Tanks.

The collection of sewage shall be by gravity. The sewage from the station is connected to the existing Municipal (or the relevant agency) sewage network or as per the requirements of the local governing body, through a series of station sewage manholes.

In the absence of an existing municipal (or the relevant agency) network near the station, the Contractor shall design any one of the following two options as per the requirements of the local governing body.

OPTION - A

- a) Storage sump pit and pumping system as per the requirements of the local governing authority shall be provided by the Contractor. The minimum storage capacity of the sump shall be for 24 Hrs requirements. Suitable level controlled submersible pumps shall be provided to pump the sewage to the existing municipal (or the relevant agency) sewage manhole. The Contractor shall liaise with the local authorities for the following:

1. Final connection point with the existing Municipal (or the relevant agency) Sewage Network.
2. For the routing of the proposed pressure main.
3. For any rerouting / modification of existing network of piping or other services, which falls in the route of the proposed pressure piping
4. Any Traffic Diversion required when laying the pipes

All piping, Fittings, Valves, Accessories, Chambers and all other accessories etc. as required for the complete installation as per Local Authority requirements shall be provided by the Contractor.

The capacity of the pump shall be designed from the specific sanitary fittings provided in the station. The flow rate shall be based on the concentrated use of appliances, the on / off of pump per hour and the storage capacity of the sump.

A lifting system with guide rails & lifting chains shall be provided for the removal of the pump for the convenient maintenance / repair. The lifting chain and guiderails shall be of SS construction. The pump shall be submersible non-clog type suitable for handling raw sewage.

The pump sets shall be selected based on the following minimum requirements,

- A Head loss
- B Discharge based on 4Hrs of operation to empty the sump.
- C Pump efficiency to be not less than 95% of the maximum possible for the particular type of pump chosen
- D Pump shall be selected considering maximum life span based on corrosion analysis of the water or content of solid to be pumped
- E The motors shall be rated a minimum of 25% more than its rated KW or as per the applicable standards
- F The pump should be maintenance free with liquid level controlled automatic operation and capable of remote interface & monitoring
- G The motor shall be “H Class” insulated as per IEC Standard 600085 / BS EN 600085 with casing rated to withstand the splash of water on the equipment
- H The pump shall be noise and vibration free
- I The pump shall be of centrifugal and self-priming type
- J The pump shall be generally rated for 2900rpm or 3000rpm
- K The duty and standby pumps shall be identical
- L The Net Positive Suction Head (NPSH) of the pump shall always be lower than the atmospheric NPSH to avoid cavitation due to vaporization
- M Capacitor banks shall be provided for power factor improvements
- N 100% stand-by shall be provided for each installations
- O The pump shall be rated for continuous operation under all conditions
- P The motor shall have DOL starters for ratings less than 3.75KW and suitable star delta starters for higher ratings.
- Q Starter shall incorporate systems for protecting the motor from overload, short circuit, earth fault, under voltage and single phasing
- R Operation shall be possible by remote interfaces based on liquid level controllers fitted in the sump pits with adequate redundancy. There shall be provision for manual or remote operation for testing or emergency operation
- S Pump shall be provided with in-built protection against dry running, reverse

rotation pump failure

- T The sump capacity must take into account the dead storage of water and the free space required at the top of the sump
- U Automatic changeover switch shall be provided to change the duty, stand- by operation cyclically
- V The status of the pump operation and any trip or faulty operation shall raise an alarm and indicate the same in the SCR and OCC
- W Enough clearance shall be provided between the pump & wall and between the pumps and between the pumps and floor
- X The pit shall be provided with emergency tanker connection to drain the tank in case of pump failure

Discharge velocity shall be not less than 0.75m/sec and not more than 1.80m/sec. The pump shall have constant head flow characteristic and be suitable for long running hours based on site conditions. Suitable protective coatings shall be provided for the pump components to prevent corrosion.

Each pump shall have a complete set of discharge arrangement with gatevalves / non return valves and accessories.

A local control panel shall be provided. The dual power supply shall be provided so that even in case of emergencies the pumps shall remain operational. On / off of the pump shall be by the level of the sewage inside the tank. Pear drop control float switches shall be provided with control for high level alarm transmission to the SCR and OCC through SCADA.

Discharge of the pumped main shall be through the pressure breaking manhole or goose neck bend with invert above flood level to prevent any back flow.

OPTION - B

- b) The Contractor shall design and install a Septic tank to collect the sewage. The holding capacity of the septic tank shall be such that it can hold the volume for a minimum period of 3 Months for the number of occupants as per the station requirements. Periodic cleaning shall be based on the 3 Months storage requirements. Soak pit shall be installed next to the septic tank and the overflow is allowed to seep into the ground.

The septic tank construction with compartments shall be as per the relevant Indian Standards. Sufficient manhole covers shall be provided for cleaning and maintenance.

A tanker connection point shall be provided for the removal of the sludge.

The septic tank and the soak pits shall be located away from any kind of water sources. Proper venting system shall be provided to vent the foul gas generated, away from the station / public.

The drainage system shall be including but not limited to the following

A. Station Drainage

B. Tunnel Drainage

A STATION DRAINAGE

The track drainage shall follow the slopes provided within the track-work and the Contractor shall ensure that any water in this area is drained towards the Waste water sump pit located in the Platform level.

The number of Waste Water pumps (2Pumps or 3Pumps per set) shall be based on the maximum and minimum flow to the waste water sump pits. An Oil Interceptor shall be provided before the sump to remove the Oil / Grease from the Track Drainage.

The soil & Waste water from the Toilets / Locker Rooms / Lunch Rooms / Mechanical plant Rooms etc. shall be drained to the Sewage Sump Pit located in the Platform Level.

The number of Sewage pumps (2Pumps or 3Pumps per set) shall be based on the maximum and minimum flow to the waste water sump pits.

The station drainage shall be including but not limited to the following

1. Waste Water Drainage
2. Soil Waste Drainage
3. Vent Piping For both Waste & Soil Drainage
4. Rain Water Drainage
5. Ground Water Seepage
6. Testing and Emptying of Fire mains
7. Condensate from VAC (ECS system) Equipment / Plant Rooms
8. Cleaning Water from VAC (ECS system) Plant Room (Filter Cleaning / Floor Cleaning)

B TUNNEL DRAINAGE

The tunnel drainage shall be drained towards the lowest point provided inside the tunnels. A Waste Water Sump Pit of suitable capacity to hold the maximum volume expected during monsoon season, for a period of 24Hrs shall be provided at the lowest point.

Wherever possible, the water shall be discharged directly to the Municipal (or the relevant agency) Storm Water / Sewage Network. Where this is not possible the water shall be discharged to the nearest station waste water sump located in the Platform level.

The Tunnel drainage shall be including but not limited to the following

1. Ground Water Seepage
2. Tunnel Washing Water Drainage

3. Testing and Emptying of Fire mains
4. Condensate from Train Air Conditioning

5.5.3.2 Station Drainage

5.5.3.2.1 Waste Water Drainage

The waste water drainage system design shall comply with the NBC and local authority requirements.

The system design shall be done based on the station specific requirements. The entire area of the station where a water supply provision is made shall be provided with a drainage system to collect the waste water and dispose it off immediately.

The waste water shall be collected from the wash basins, kitchen sink, janitor's sink, tap points in Mechanical Plant rooms, planter drains, water coolers / drinking fountains, fire hose cabinet area, floor drains / channel drains provided in the concourse /Mezzanine/ platform areas for the station cleaning.

The waste water from each appliance / fixture shall be connected to the floor drain and then connected to the waste water piping / risers. No direct connection of fixture to the waste water piping or riser shall be done.

The condensate from VAC (ECS system) equipment and plants shall also be connected to the floor drains first and then connected to the waste water piping / riser. The floor drains where condensate drains are connected shall be insulated to avoid condensate water spillage.

Drainage is required for condensate water from all VAC (ECS system) associated systems (e.g., AHU Plant Room, VAC Plant Room etc.) including air conditioning from trains, ancillary and commercial areas. All condensate water shall discharge to the drainage system unless stated otherwise.

The location of the condensate points and volume of discharge shall be determined through co-ordination with the system-wide contractors. Floor trap being provided shall not be used for discharging water used for the cleaning of VAC equipment.

Any exposed condensate drain/pipe (including floor trap) beneath the suspended floor slab shall be insulated to prevent condensation.

All Floor drains in the Plant rooms (Plumbing / HVAC) shall be provided with a bucket type strainer.

The escalators serving the entrances shall have the lower escalator landing pits graded to a minimum fall of 1:200 towards the floor trap/waste connecting to the sewage/drainage system. The rest of the escalators shall have a dry sump at the downstream of the lower escalator landing adjacent to the escalator pit which shall be accessible outside the escalator truss.

For stations not located within a water catchment area, water in the escalator pits shall be discharged to the drainage system. If the station is located within a water catchment area, then it shall be discharged into the sewerage/sanitary plumbing system. The base of lift pit shall be graded to have a minimum fall of 1:200 towards the sump of 450mm by 450mm by 450mm.

Vent Shafts shall be detailed such that rainwater is neither drained nor blown into them. Provision shall be made at the ventilation shaft terminals to drain all rainwater into the drainage system. The base of the vent shafts/ducts shall not be allowed to accumulate any water and shall be graded to fall towards the floor waste at a gradient of 1:200 minimum.

The storage capacity of a water tank is the volume of water that can be drawn by the water booster/transfer pumps. Water tanks shall be designed to minimise dead water volume. The inlet and outlet pipes of the tank shall be located to avoid stagnation of water in the tank.

The base of the water tank shall have a minimum fall of 1:200 towards a 200mm minimum diameter drain-off pipe with puddle flange. This shall be installed at the base of the water storage tank to drain the water storage tank completely.

Overflow and drain-off water from storage water tanks shall not be discharged into the seepage channels directly. They shall be discharged directly to either a drainage sump or a pump sump.

Drainage channels of a minimum width of 100mm shall be provided in the under platform areas with a minimum gradient of 1:200. Discharge outlets (floor waste) of not less than 100 mm diameter shall be situated at not more than 10m centres. The floor finishes of the under-platform areas shall be made to fall towards these channels.

A cut off drain shall be provided across each entrance, at the top of the stairway and escalator. The collected water shall be discharged to the nearest surface drain. The structural recess for the cut off drain shall be 240mm wide with a minimum depth of 200mm deep, covered with a stainless steel grating. A catch pit shall be provided at the drain outlet, or as close thereto as can be arranged, to prevent debris from entering the drainage run. Where pipes pass through the joints between the station structure and the entrance, they shall be detailed to accommodate all movements.

The top of the cable trenches, valve chambers and maintenance pits shall be made to fall away to prevent water from flowing inside. The floors of cable trenches, valve chambers and maintenance pits shall be graded to have a minimum gradient of 1:200 towards the floor waste.

Structural movement joints are highly susceptible to water leakage and adequate provisions for the collection and discharge of all water leakage shall be provided.

A dry sump is a drainage sump without any outlet. Dry sumps shall not be provided

unless Notice of No objection is provided by the Employer / Engineer.

Where the direction of a horizontal pipe changes or where two horizontal pipes merge, a drainage sump shall be provided unless the pipes are accessible from below. Pipes that are buried or cast in concrete or located above the track are considered inaccessible from below. The design and provision of drainage sumps shall comply with sewerage and sanitary plumbing requirements.

Water in a drainage sump shall not be channelled such that its direction of flow turns through an angle of more than 90deg.

The waste water collected shall be routed to the Waste Water Pump Room / Sewage Water Pump Room located in the Platform level by a network of piping. From the Platform level the Waste Water / Sewage is pumped through the respective sump pump sets and connected to the Municipal Storm Water / Sewage Network in the street level. In the street level the waste pipe is connected to the manhole through a gully trap.

No waste water piping shall be connected to the manhole directly.

The piping material shall be as per the Notice of No Objection by the Employer /Engineer.

The minimum pipe size requirements are listed in the table below:

S.No	DESCRIPTION OF FIXTURES	MINIMUM SERVICE SIZES - in (mm)		
		Waste	Soil	Vent
1	Water Closet - Flush valves	-	100	50
2	Water Closet - Flush Tank	-	100	50
3	Urinal - Flush valve	50	-	40
4	Urinal - Flush tank	50	-	40
5	Wash basin	32	-	40
6	Janitor's Sink	40	-	40
7	Kitchen Sink	40	-	40
8	Water Cooler / Drinking Fountain	50	-	40
9	Bib Taps	50 / 75	-	40
10	Hose Bib taps	50 / 75	-	40

5.5.3.2.2 Drainage Minimum Requirements

S.No	Room/Area	Requirement	Remarks
1	Toilet Areas	Bottle Traps in Appliances + Floor traps	No of floor traps to suit the number of fixtures in the toilet
2	Water Closet Cubicle	One Floor Trap	
3	Janitors Room & Refuse room Concourse/ Mezzanine Level	One Floor Trap	
4	Cleaning	Floor Trap or Channel Drain	To suit the floor finish
5	Water Fountain & Water Coolers	One Floor Trap	
6	Lunch Room	Bottle Traps in Appliances + Floor traps	No of floor traps to suit the number of fixtures
7	Planter in Stations	Planter Drain as required	The type & Finish as per the Notice of No Objection by Employer / Engineer
8	All VAC associated Plant Rooms (ECS System)	Floor Drains as required	Floor trap with 1 x 1 m kerbed floor basin to be Located below water tap, bleed off and overflow. For outdoor cooling tower area, a cover to be provided for the floor trap to Prevent rain Water ingress
9	Seepage Water Pump Room	Floor Drains as required + Seepage Water Sump with Pump	
10	Sewage Pump Room	Floor Drains as required + Sewage Sump with Pump	
11	Water Distribution Control Room	Floor Drains as required + Drain Sump with Pump	

S.No	Room/Area	Requirement	Remarks
12	Cooling tower room area	Floor drains as required	Floor tap with 1 X 1m kerbed floor basin to be located below water tap bleed off and overflow. For outdoor cooling tower area, a cover top be provided for the floor trap to prevent rain water ingress.
13	Commercial Areas(shops, kiosks etc.)	Waste Pipe + Soil Pipe as required	
14	Each access staircase (Underground Stations only)	Floor drains as required	
15	Station external areas	Floor drains as required	For staircase cleaning with a trap in the lowest point.
16	Escalator Pit	Floor Drain as required	
17	Lift Pit	Sump	Sump to be connected to the drainage network
18	Vent Shaft / Duct	Floor Drain at the lower point	
19	Hose Reel	Floor Drain	
20	platforms	Two parallel channels run along the track direction For each platform with appropriate connection to the drainage system	For rain water blown onto the platform plus washing water

5.5.3.2.3 Soil Waste Drainage

The soil waste drainage system design shall comply with the NBC and local authority requirements.

The system design shall be done based on the station specific requirements.

The soil waste shall be collected from the water closets and shall be connected to the manhole in the street level through a network of piping. In the street level, the sewage pipe is connected to the existing Municipal sewage network through a series of manholes.

The piping material shall be as per the Notice of No Objection by the Employer /

Engineer.

5.5.3.2.4 Vent Piping for Waste & Soil Drainage

The waste & soil waste drainage system shall be sufficiently vented to comply with the NBC and local authority requirements.

A vent piping is taken from the First Manhole and is taken to the roof. The Waste & Soil pipes are cross vented with the Vent Pipe in each level above the fixture overflow level.

The vent piping is terminated with suitable vent cowl at the roof level.

All the vent piping terminations shall be co-ordinated and installed in such a manner that it is concealed from public view and doesn't affect the aesthetics of the station building.

The piping material shall be as per the Notice of No Objection by the Employer / Engineer.

5.5.3.2.5 Rain Water Drainage

The rain water system shall be designed to comply with the NBC and local authority requirements. The rain water system shall be designed based on the latest rainfall data available.

The rain water from the roof and pavement areas shall be collected and disposed-off as per the local authority requirements.

Due consideration shall be given to rain water blown into the tunnel or brought into tunnel by rolling stock.

The surface water from the pavement areas part of the station shall also be connected to the storm water network.

The storm water piping shall be connected to the Rain Water Harvesting pits through a series of manholes. The overflow from the rain water harvesting pits shall be connected to the existing storm water manholes.

The requirements, if any as per the Local authority to store the rainwater in sumps for usage after treatment shall be provided by the Contractor.

The design of rain water system including the gutter design and harvesting pits design shall be based on the latest rainfall data and as per NBC and shall be submitted by the Contractor by means of calculations to the Employer / Engineer for the Notice of No Objection.

The piping material shall be as per the Notice of No Objection by the Employer / Engineer.

5.5.3.2.6 Ground Water Seepage

The Contractor shall design and install a drainage system for the seepage water in the underground stations. The seepage water drainage system shall be designed on the basis of seepage water volume data as per the Noticed Contractor's geotechnical report.

All internal surfaces of structures shall be positively drained via channels, drains etc., either by gravity to existing storm water drainage or to wet sumps from where water shall be pumped to the storm water drainage to the approval of the local authorities and statutory bodies and to the Notice of No Objection by the Employer / Engineer .

In general the following guidelines shall be followed:

The storage volume of the Sump pit shall be for 24Hrs of the seepage water expected during the heavy monsoon seasons.

All water shall be directed so that the rails and rail fixings remain dry.

Seepage drainage channels shall be provided at the floor level along the internal sides of all earth-backed (or ground-backed) external walls. A drainage channel of 100 mm diameter shall be formed and laid to fall to not less than 1 in 200. Discharge outlets (floor waste) of not less than 100 mm diameter shall be situated at not more than 10m centres

Seepage drainage channels shall be lined with a suitable waterproofing membrane. Drainage channels, weep holes and outlets shall not pass through fire rated compartment wall.

Seepage drainage channels in floor finishes shall be at least 35 mm deep. A cavity of limited height shall be constructed to contain the drainage at the bottom of the wall if sufficient depth is not available in any floor finishes

The Contractor shall follow the following guidelines & the typical/indicative General Schematic issued with the Tender Documents when designing the Seepage Water Drainage;

- a) Drains shall be provided in the cavity wall every 10metres
- b) The drain is routed horizontally and vertically to the floor below and allowed to discharge free at the lower floor open drain and or to the next floor
- c) In the open drain a collection pit of size 200mmx 200mm shall be provided every 50metres.
- d) The pipe from the collection pit is connected to the manhole / chamber in the centre of the track of minimum 400mm x 400mm size provided every 50metres. The starting depth of the channel shall be minimum 450mm.
- e) The pipe from the manhole / chamber in the centre of the track is routed horizontally to the waste water collection pit.
- f) The slope for the drain shall follow the slope of the station wherever possible.

- g) An oil interceptor shall be provided before the waste water sump pit to prevent any oil/grease entry into the pit
- h) The water from the waste water sump pit is then pumped to the street level and discharged into the existing storm water network through a network of manholes.
- i) the Contractor shall co-ordinate with the track contractor for the interface in the track drainage.

5.5.3.2.7 Cavity Wall

For the purpose of establishing cavity wall, the requirements are categorized as described below. For any rooms not listed therein, proposals shall be submitted and agreed with the Engineer. Where required in any given rooms/areas, cavity walls need to be provided only along the external walls

Category I

Generally, these are rooms/areas containing sensitive E&M equipment (Equipment of system-wide contractors) requiring extra protection from dampness and moisture. Full height cavity walls shall be provided.

In addition, in rooms/areas that are accessible to the public, full height cavity walls shall also be provided to protect the architectural finishes from seepage water.

Category II

These are rooms/areas without an immediate need for cavity walls but which require provision for installation of such walls in the future. Ample space shall be provided in these rooms/areas for future cavity wall construction and the sizing of the rooms shall take this into account. All services/equipment mounted onto the earth-backed (or ground-backed) wall in such rooms/areas shall be designed such that it can be easily removed and mounted onto a cavity wall should the need arise. Ceiling services shall also be such that it will not obstruct the future construction of the cavity wall.

Category III

Cavity wall is not required.

For full height cavity walls, it shall be constructed as an inner lining with a seepage drainage channel confined to inside the cavity. Access panels of minimum 600mm x 600mm size placed at intervals not exceeding 10 meters shall be provided on the cavity walls to permit inspection and maintenance of the drainage system. The actual position shall be coordinated and located near a floor waste.

5.5.3.2.8 Guidelines for Cavity Wall Room Categorization

CATEGORY I

1. Telecom Closet (TC)
2. Signal Equipment Room (SER)

3. Station Control Room (SCR)
4. Telecommunications Equipment Room (TER)
5. PSD room
6. Store, Office and staff toilet
7. All Public Areas (including toilets)
8. RCC Drinking Water Tanks

CATEGORY II

1. Automatic Fare Collection Room (Ticket office)
2. AHU Room
3. Emergency Switch Room
4. Under-platform Exhaust Fan (UPE) Room
5. Uninterruptible Power Supply (UPS) Room
6. Permanent Way Store
7. ASS (Auxiliary sub-station)
8. Fire Pump Room
9. DB Room
10. Generator Room
11. Fuel tank
12. HV Switch Room / HV Switch Room (intake)
13. Clean Gas Room
14. LV Switch Room
15. Cooling Tower Room
16. Water distribution MCC room
17. First Aid Room
18. ECS Plant Room
19. Fireman's and Escape Stair
20. Fan Room
21. General Store
22. Air Intake Plenum
23. Water meter Kiosk
24. Smoke Extract Fan (SEF) Room
25. Equipment Store
26. Tunnel Ventilation Fan (TVF) Rooms

27. ECS Control Room

CATEGORY III

- 1 Ventilation Shafts
- 2 Lift Shafts
- 3 Trackside wall
- 4 Ventilation Passageways

5.5.3.2.9 Tunnel Washing Water Drainage

In the Tunnel Washing Water Drainage a maximum discharge rate of 10,800 litres/hr of the tunnel washing wagon shall be allowed for the tunnel sump and pump. The exact requirement shall be co-ordinated with the specialist system wide contractor

5.5.3.2.10 Testing and Emptying of Fire Mains

The volume of water discharged during testing and emptying of the fire main shall be determined in co-ordination with the System-wide Contractor and allowed for in the design of the tunnel Sump and pump

5.5.3.2.11 Condensate from Train Air Conditioning

Condensate from moving trains may be assumed to be evaporated

5.5.3.2.12 Condensate from ECS Equipment / Plant Rooms

Condensate from ECS Equipment / Plant Rooms shall be connected to the Waste Water Drainage as described in the Specifications.

5.5.3.2.13 Cleaning / Leakage Water from ECS Plant Rooms

Cleaning / leakage water from ECS Equipment / Plant Rooms shall be connected to the Waste Water Drainage as described in the Section: 5.3.7.2 above.

5.5.3.3 Tunnel Drainage

5.5.3.3.1 Ground Water Seepage

5.5.3.3.2 Ground Water Seepage shall be as described in the Specifications.

5.5.3.3.3 Tunnel Washing Water Drainage

In the Tunnel Washing Water Drainage a maximum discharge rate of 10,800 litres/hr of the tunnel washing wagon shall be allowed for the tunnel sump and pump. The exact requirement shall be co-ordinated with the specialist system wide contractor.

5.5.3.3.4 Testing and Emptying of Fire mains

The volume of water discharged during testing and emptying of the fire main shall be determined in co-ordination with the System-wide Contractor in any case the discharge of 2 hydrants shall be considered for 1 hour in the design calculations and allowed for in the design of the tunnel Sump and pump

5.5.3.3.5 Condensate From Train Air Conditioning

Condensate from moving trains may be assumed to be evaporated

5.5.3.3.6 Sump Pits and Sump Pumps (Seepage Water & SEWAGE)

The Seepage Water Sump and Pump sets shall be provided both in the station and the tunnel. The Sewage Sump and Pump sets shall be provided in the stations only.

5.5.3.4

5.5.3.4.1 Sump Pits

The Sump Pits shall be provided as follows

- A. Station Sewage Sump
- B. Station Waste Water Sump
- C. Tunnel Waste Water Sump

The Tunnel Waste water sump shall be of suitable holding capacity and shall be located at the very low point (or low points depending upon the vertical profile of the track/tunnel) within each running tunnel. If the pump sump location coincides with a cross passage, then only one pump sump shall be provided and it shall be located in the cross passage.

Station Sump Pits shall be located to suit the individual requirements of each station and to be located at strategic locations such that the total number of sumps is minimized. The utilization of every drainage pump sump shall be maximized to collect water from as many sources as possible

Sumps shall be accessible for inspection and maintenance at all times. Sump Pumps shall as far as possible not be located at the passageway or corridor. Each Sump Pump shall be located in a dedicated sump room.

Provisions shall be made in the design of the sumps for the discharge mains complete with valve assembly, power supply and monitoring cables to the pump.

Check valve of single flap type and a gate valve shall be provided on the discharge main of every pump. They shall be located above the sump such that they are accessible without the need to enter the sump and after removal of the access cover

The layout shall be designed so as to facilitate easy removal and replacement of pumps without entering the sump. Lifting facilities (e.g., overhead runway beam, eye bolt, Guide Rails with lifting chains etc.) and equipment shall be provided to enable easy lifting of the pumps. Adequate removable chain blocks shall be provided as applicable.

Access openings shall be provided directly above the pumps for easy installation and removal of the sump pumps. Access openings shall be fitted with aluminium chequered covers and provided with aluminium access ladders with extensible handhold up to 1150mm above access cover level.

A stainless steel screen shall be provided in the sump pit of every drainage sump immediately upstream of the sump. The location of the screen shall be such that a

maintenance worker standing at the access cover level can easily clear all debris trapped

The Sump Pit shall be waterproofed using an accepted waterproofing admixture or alternatively, using an accepted liquid membrane applied on the interior surfaces of the sump walls

The room sizes shown in the Architectural layouts are indicative only. The Contractor shall design the exact requirements to comply with the local authorities and to obtain the Notice of No Objection from the Employer / Engineer.

Lifting facilities (e.g., overhead runway beam or Guide rail system with lifting chain,, eye bolt etc.) and equipment shall be provided to enable easy lifting of the Sewage pumps. Adequate removable chain blocks shall be provided. Sufficient clearance all around the sewage sump pit shall be provided for ease of maintenance

Containment of over spillage of sewage from sump pump shall be considered. A sewage sump pump shall be provided in every sewage sump room and connected to the sewage pumping main

An Oil Interceptor shall be provided before the Waste Water Sump Pit to remove Oil / Grease from the Track Drainage.

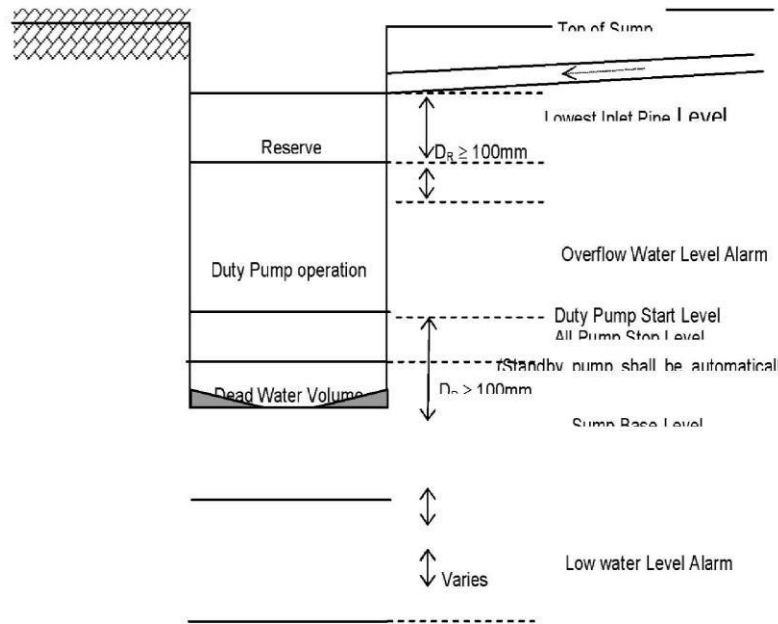
The structural design of sumps shall comply with the requirements/Contract Stipulations for Underground Structures with the sumps regarded as an underground structure.

5.5.3.4.2 Sump Sizing

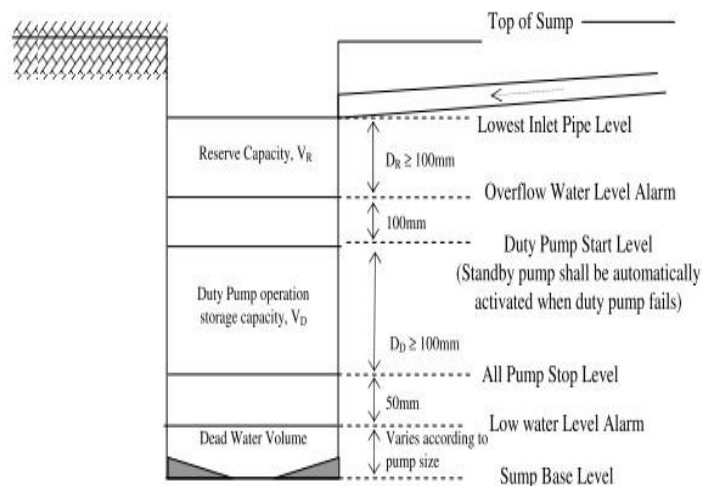
The size of each sump is determined based on the following parameters:

- A. Dead water volume
- B. Duty pump operation capacity
- C. Reserve capacity

The typical operating water levels of a pump sump shall be as shown in the Figure below.



Pump Operating Levels for Sump Sizing



Pump Operating Levels for Sump Sizing

1. Dead Water Volume is measured from the Sump Base Level to the Low Water Level Alarm and shall be minimized by haunching the base of the sump.
2. Duty Pump Operation Storage Capacity

The Duty Pump Operation Storage Capacity is measured from the All Pump Stop Level to the Duty Pump Start Level. The volume shall be computed from:

$$V_D = \frac{Q_{select} \times T}{4}$$

Where Q_{select} is the higher flow capacity of the selected pumps (see above). T is the time between 2 sequential starts (i.e., one complete start-stop cycle) and is computed from:

$$T = \frac{3600}{(\text{No. of Start / Stops per Hour})} \text{ seconds}$$

Total No. of Starts/Stops per Hour shall not exceed 10 and the level between the All Pump Stop Level to the Duty Pump Start Level shall not be less than 100mm.

3. Duty Pump Start Level to Overflow Water Level Alarm

The level between the Duty Pump Start Level and Overflow Water Level Alarm shall be set at 100mm

4. Reserve Capacity

The Reserve Capacity shall be measured from the Alarm Level to the Lowest Inlet pipe level. It shall be computed from

$$V_R = [(Seepage \times 2) + \text{Condensate (from stationary trains)}] \times (\text{response time of 6hrs or 24hrs depending on accessibility})$$

The level between the Overflow Water Level Alarm and Lowest Inlet Pipe Level shall not be less than 100mm. For Tunnel Sump Pit the response time shall be 24 hours.

For Station pump sumps, the response time will be taken as 24 hours if the sump is not accessible during train operation, and 6 hours otherwise.

Condensate water from stationary trains and station air conditioning plant, ancillary and commercial areas shall be determined through co-ordination with the system-wide contractors.

Accident/emergency inflow such as water tank overflow and occasionally large but manageable inflows such as track washing and fire main draining need not be considered in the computation of reserve capacity. Condensate from moving trains may be assumed to be evaporated.

5.5.3.4.3 Sewage Sump Pump

The sewage sump pump sets shall be provided to pump the sewage collected in the Platform level to the street level and connect it to the Municipal Sewage Network. Sewage pump sets shall be provided at the base level of underground stations for the collection and disposal of sewage from staff toilets, crew toilets, public toilets and waste water from plant rooms/areas.

All sewage and waste water from ground level or above shall be directly discharged into the main sewerage network by gravity as far as possible. All sewage generated below the ground level shall be collected in the sewage sump pits located in the lower platform level, by gravity through a network of piping.

Sewage pump sumps shall be located to suit the individual requirements of each station and to be located at strategic locations such that the total number of pump sumps is minimized. The utilization of every sewage sump pit shall be maximized to collect water from as many sources as possible.

Sewage pumping system shall be located in rooms specifically designated for this purpose and with direct access facilities for maintenance. A minimum of two pumps (1 duty & 1 standby pump) and a sump pit (Holding tank) shall be provided for each Sewage Pumping system.

For each sump pump, a control panel shall be placed at a convenient, easily accessible location and shall be constructed with a waterproof type enclosure.

The Sewage Pumps shall be of Non-Clog type with open impellers. The Pumps shall be centrifugal type vertically mounted close coupled to the fully submersible electric motor. Pump impellers, Shafts, studs, nuts, screws and washers shall be of the material as per the Notice of No Objection by the Employer / Engineer.

The efficiency of the pump sets shall be between 75% - 95% of the maximum efficiency for the pump. The sewage pump operation shall be based on the float switch arrangements.

Low Level & High Level alarm shall be provided and monitored in the OCR through the float switches.

The discharge pipes from the sump pumps shall be routed directly to the surface drains via the nearest and shortest route (e.g., vent shaft, service shaft/duct, entrance etc.). The water shall not be discharged to another drainage pumping system within the Works. Swan necks / Pressure breaking Manholes shall be provided at the appropriate locations. Flap valves shall be provided at the discharge ends. Discharge pipe shall be designed taking into consideration all the design guidelines in any case not less than 100mm Diameter.

For sewage pumps / waste water pumps, the minimum and maximum flow velocities allowed in the discharge pipe shall be 1.0m/s and 2.4m/s respectively. This is to ensure self-cleansing velocity and to prevent scouring of pipes. For each sewage pumping system, the pumps shall be designed for the peak sewage/waste water inflow generated

Discharge pipe work of minimum 100mm diameter shall consist of check valve of single flap type and a gate valve. They shall be located above the sump pits such that they are accessible without the need to enter the sump pits after removal of the access cover

Emergency Tanker Connection shall be provided in the Street Level at a suitable location for the emptying of the Sewage Sum Pits in case of the sewage sum pump sets failure. The emergency tanker connection shall be housed in a heavy duty cabinet or as per the Notice of No objection by the Employer / Engineer.

The Contractor shall obtain the necessary approval and provide sufficient protection to the Emergency Tanker Connection cabinet to the requirement of the Local Authorities and to obtain Notice of No Objection from the Employer / Engineer prior to the installation.

A lifting chain with shackles etc., shall be fitted to each pump which shall support the weight of the pump during installation and removal of the pump. The chain shall be of SS construction or as per the Notice of No Objection by the Employer / Engineer. The Pump sets shall be complete with boltless self-aligning duck foot assembly, which allows removal of the pumps without disturbing the pipework. Suitable guide rails shall be provided to facilitate the same. The Guide Rail shall be provided complete with all fittings and support brackets. The material of construction shall be SS or as per the Notice of No Objection by the Employer / Engineer.

The cables used for the Pump and the float switches shall be multi core and fully insulated. The cable shall be sealed and gland into the motor and the cable junction box sealed from the outside. Enough Cable length shall be provided to connect to the starters.

5.5.3.4.4 Waste Water Sump Pump (Seepage + Waste Water)

The waste Water sump pumpsets shall be provided to pump the Waste Water collected in the Platform level to the street level and connect it to the Municipal Storm Water / Sewage Network.

Waste Water / Sewage pumpsets shall be provided at the base level of underground stations for the collection and disposal of waste water from plant rooms, station cleaning water, ground water seepage and the waste water generated inside the tunnel by testing of fire main and or cleaning of the tunnel.

All Waste water from ground level or above shall be directly discharged into the municipal storm water / sewerage network by gravity as far as possible. All waste water generated below the ground level shall be collected in the waste water sump pits located in the lower platforms, by gravity through a network of piping.

Waste Water sump Pump shall be located to suit the individual requirements of each station and to be located at strategic locations such that the total number of sump pumps is minimized. The utilization of every waste water sump pit shall be maximized to collect water from as many sources as possible.

Waste water pumping system shall be located in rooms specifically designated for this purpose and with direct access facilities for maintenance.

A minimum of two pumps (1duty & 1standby pump) and a sump pit (Holding tank) shall be provided for each Waste Water Pumping system.

For each sump pump, a control panel shall be placed at a convenient, easily accessible location and shall be constructed with a waterproof type enclosure.

The sewage pump operation shall be based on the float switch arrangements.

Low Level & High Level alarm shall be provided and monitored in the OCR through the float switches.

For each sump pump, a control panel shall be placed at a convenient, easily

accessible location and shall be constructed with a waterproof type enclosure

The Waste Water Pumps shall be of Non-Clog type with open impellers. The Pumps shall be centrifugal type vertically mounted close coupled to the fully submersible electric motor. Pump impellers, Shafts, studs, nuts, screws and washers shall be of the material as per the Notice of No Objection by the Employer / Engineer.

The efficiency of the pump sets shall be between 75% - 95% of the maximum efficiency for the pump

The discharge pipes from the sump pumps shall be routed directly to the surface drains via the nearest and shortest route (e.g., vent shaft, service shaft/duct, entrance etc.). The water shall not be discharged to another drainage pumping system within the Works. Swan necks / Pressure breaking Manholes shall be provided at the appropriate locations. Flap valves shall be provided at the discharge ends. Discharge pipe shall be designed taking into consideration all the design guidelines in any case not less than 100mm Diameter.

For waste water pumps, the minimum and maximum flow velocities allowed in the discharge pipe shall be 1.0m/s and 2.4m/s respectively. This is to ensure self-cleansing velocity and to prevent scouring of pipes. For each waste water pumping system, the pumps shall be designed for the peak /waste water inflow generated

Discharge pipe work of minimum 100mm diameter shall consist of check valve of single flap type and a gate valve. They shall be located above the sump pits such that they are accessible without the need to enter the sump pits after removal of the access cover

Emergency Tanker Connection shall be provided at a suitable location for the emptying of the Sewage Sum Pits in case of the sewage sum pump sets failure. The emergency tanker connection shall be housed in a heavy duty cabinet or as per the Notice of No objection by the Employer / Engineer.

The Contractor shall obtain the necessary approval and provide sufficient protection to the Emergency Tanker Connection cabinet to the requirement of the Local Authorities and to obtain Notice of No Objection from the Employer / Engineer prior to the installation.

A lifting chain with shackles etc, shall be fitted to each pump which shall support the weight of the pump during installation and removal of the pump. The chain shall be of SS construction or as per the Notice of No Objection by the Employer / Engineer. The Pump sets shall be complete with boltless self-aligning duck foot assembly, which allows removal of the pumps without disturbing the pipework. Suitable guide rails shall be provided to facilitate the same. The Guide Rail shall be provided complete with all fittings and support brackets. The material of construction shall be SS or as per the Notice of No Objection by the Employer / Engineer.

The cables used for the Pump and the float switches shall be multi core and fully insulated. The cable shall be sealed and gland into the motor and the cable junction box sealed from the outside. Enough Cable length shall be provided to connect to the starters.

For all low point sumps (Tunnel Waste Water Sumps) where the starters are at a longer distance from the nearest station the cable shall go into a water proof isolation socket, which shall be cabled to the starter.

5.5.4 Sanitary Fixtures & Accessories

Sanitary Fixtures & Accessories shall be provided as per the requirement duly complying with the NBC and other standards.

The Sanitary wares & accessories shall comply with the relevant Indian Standards. The Sanitary wares shall be of water conserving / energy saving type and the flush tank for water closet shall be of dual flush type having two flushing volumes

The list of Sanitary wares shall be including but not limited to the following:

- A. Water Closet with Flush Tank and or Flush Valve
- B. Water Closet for Handicapped
- C. Asian Water Closet (as applicable)
- D. Wash basin – Pedestal or Counter Top type
- E. Wash basin for Handicapped
- F. Janitors Sink
- G. Kitchen Sink in the Lunch Room
- H. Shower tray (as applicable)
- I. Ablution tap / Hygiene Tap
- J. All mixers & Taps

The list of accessories shall be including but not limited to the following:

- A. Toilet paper holder
- B. Coat Hook
- C. Towel Rail / Ring
- D. Liquid Soap Dispenser
- E. Electric Hand Drier
- F. Mirror
- G. Waste Bins
- H. Tissue Dispenser

The type, colour, material and selection shall be submitted to the Employer / Engineer for Notice of No Objection.

5.6 Fire Detection & Alarm System

5.6.1 General Requirement

5.6.1.1 Scope of work

The scope of works of the Design & Build Contractor for the Underground Stations covered in this section shall be as under but not limited to:

- a) Analogue addressable Intelligent fire detection & alarm system

The Contractor is responsible for the design coordination of the Fire Detection & Alarm System with all the others Systems. The Fire Detection & Alarm System design shall be verified, tested, and commissioned to the requirements of respective BS-EN standards or Other Equivalent International Standards & VALIDATED as a complete system by the Contractor.

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

5.6.1.2 Responsibilities

The responsibilities of the Contractor shall be as follows but not limited to:

- A. Detailed Design of the systems / packages listed in the scope of works.
- B. Supply & Installation of the System / Equipment / Devices & Components and all other accessories required for the complete functioning of the system. Testing, Commissioning, Verification & Validation of the Systems Selection of

Plant to meet performance criteria and specification and all stipulations of the Contract documents with supporting calculations.

- C. Cable sizes, cable containment, voltage drop and electrical protective devices in accordance with the co-ordinated cable routing and the actual rating of Plant.
- D. 24V DC battery sizing calculations.
- E. Fault level discrimination
- F. EMC analysis and EMI control measures for the Works
- G. Acoustic and vibration isolation
- H. All software design
- I. Liaison with the Local Authority & getting approval
- J. All legal fees (or as chargeable by Authorities/Agencies) & statutory requirements

The Contractor shall also be responsible for the design co-ordination between services. The Compatibility of the Main Fire Alarm System with the following services shall be Verified, Tested, and Commissioned to the respective BS- EN standards & VALIDATED as a complete system by the Contractor:

- A. Fire Detection & Alarm System including VESDA
- B. Public Address/Public Information display & Voice Alarm System
- C. AFC system
- D. Emergency Lighting System
- E. Conveying Systems (Lifts & Escalators)
- F. TVS and ECS systems (AHUs / FAHUs / Smoke Extract Fans / Fire Dampers / Staircase Pressurization Fans, Tunnel Ventilation Fans, Chillers, Motorized Dampers, Exhaust Fans, FCU's)
- G. Fire Fighting Systems (Fire Pumps / Sprinkler Valves etc.)
- H. Clean Agent Fire Suppression System (Total Flooding & Panel Flooding)
- I. Automatic Doors /Access control
- J. PSD
- K. HV Power Supply SCADA
- L. M&E SCADA
- M. TVS SCADA
- N. Rolling Shutters
- O. Systems not listed above but that require Interfacing with the Main Fire Alarm System

The Contractor shall be responsible for checking and ensuring that the type of fire

protection system specified/provided complies with the codes of practice, standards, regulations and requirements of the statutory authorities.

The fire protection system schematic diagrams are for indicative purposes only and it is the Contractor's responsibility to ensure that the installation complies fully with the Employer's Requirements, all other Contract documents, relevant authority's requirements including relevant codes of practice.

All installation exceeding 680 mm in height must not protrude more than 100 mm in public area. Examples of such installation are fire extinguisher, Hose- reels, MAPs and SAPs etc..

Protruding objects shall not reduce the width required for an accessible route or manoeuvring space.

The maximum height of the bottom edge of free-standing objects with a space of more than 300 mm between supports shall be 680 mm from finished floor level.

5.6.2 Analogue Addressable Intelligent Fire Alarm System

5.6.2.1 General

All public areas, sub-ways and rooms in ancillary areas shall be protected by automatic fire alarm system except naturally cross-ventilated public areas and the buffer areas. Alarm bells and manual call points shall be avoided unless otherwise it is necessary to be located in the Station public areas. Manual call points shall be located along exit routes next to Hose-reels. Linear Heat Detection Cables shall be used for automatic fire detection system required to be installed in tunnels (in tunnels and train stabling areas/sidings). The fire alarm signal from the Linear Heat Detection Cables shall be transmitted to the SAP/MAP of the nearest station.

5.6.2.2 System Components & General Requirements of The fire alarm system

shall comprise the following:

- (a) Micro-processor based MAPs, SAPs and RPs.
- (b) Analogue addressable smoke detectors, heat detectors, combined optical and heat detector, VESDA and Linear Heat Detection Cables
- (c) Addressable manual call-points
- (d) Detectors and devices
- (e) Alarm bells & beacon lights
- (f) Colour mimic panels with LED indicators
- (g) Repeater panels
- (h) Batteries and chargers
- (i) Electrical wiring, conduits, trunking and accessories
- (j) Communication driver at the MAP for interfacing with the M&E SCADA.
- (k) Flow switches of the sprinkler system.

Voltage free fire alarm signals through voltage free normally close contacts from the fire alarm system to the ITBs. The Contractor shall supply and install all ITBs (except for M&E SCADA interface) and connecting cables between the fire alarm system and ITBs for all interfaces

All fire alarm panels shall comply with BS 5839-1:2002+Appendix 2:2008 and or BS EN 54 Part-2: 1997+Appendix 2:2006 Control & Indicating Equipment and UL and FM listed.

Each system shall provide at least 25 % spare capacity for future expansion as per UL 864, 9th Edition.

A main alarm panel shall be provided in each station to indicate the location where the alarm is being activated. The MAP shall be placed at a location within the station where the Pune Fire & Safety Department Personnel have first access when responding to a fire call.

For all underground stations, the MAP shall be located in the firemen staircase, Station Control Room or as directed by the local fire authority.

SAPs shall be provided at each floor of the station, each platform area as per the Contractor's design and as per the Notice of No Objection by the Employer / Engineer . A repeater panel shall be provided in each SCR and each fire- man staircase (ground level) as required by the local fire authority. Colour mimic panels with LED indicators shall be provided next to each MAPs, SAPs and at specific locations indicated in the approved Drawings.

The fire alarm system shall have the capability to process and evaluate incoming signals from addressable devices such as multisensor detectors, smoke detectors, heat detectors, combined optical & heat detectors, aspirating smoke detectors (VESDA), manual call-points, flow switches, Zone modules , interface modules etc. via Class "A" twisted pair screen cables addressable loop in separate galvanized steel conduits. The individual addressable loop shall comply with UL 864 and shall be monitored for open and short circuit fault. In the event of open or short circuit, all devices connected along the affected loop must be fully operational. Fault isolators shall be provided in front of the first point, after the last point, and between every ten (10) points along each addressable loop. "TEE-OFF" from the line or detector shall be strictly prohibited

Each addressable loop shall constantly scan to check the operation and status of all the field devices. In a fully loaded system, the average time to detect an alarm shall not be more than 5 seconds in case of alarm from detectors and 3 seconds in case of alarm from manual call points. Separate loops shall be provided for the alarm bells.

MAPs, SAPs and RPs installed at outdoors or exposed to weather shall be of double layer enclosure weatherproof construction and rated to at least IP55 for the station areas and or IP65 for the Tunnel Areas. The selection shall be based on Contractor's

design and as per the Notice of No Objection by the Employer / Engineer.

Unless otherwise specified, smoke detectors shall be of multisensor type. Detectors shall comply with BS 5445: Part 1, LPCB/ UL 864, 9th Edition listed or equivalent standard, multi-sensor.

Detectors shall not be located too close to the air-conditioning outlets or diffuser, which may cause condensation and false activation. Detectors shall be visible and accessible for maintenance

The following operational requirements shall be automatically instituted when any detector, manual break-glass call-point, clean gas system, panel flooding system or sprinkler system is activated:-

- A. The alarm signal shall be automatically transmitted direct or through clean gas Panels or Panel gas flooding system panel to the MAP, SAPs and RP giving both visual and audible indications at the MAP, SAPs and RP
- B. Fire alarm signals shall be sent to M&E SCADA via ITB
- C. Communication interface with M&E SCADA to report all status.

5.6.2.3 VESDA System (Very Early Smoke Detection & Alarm)

The VESDA system shall be provided for the Electrical Rooms, Signalling & Communication Equipment Rooms and rooms where Sensitive equipment are installed.

The Very Early Warning Smoke Detection System must be of a type submitted to, tested, approved, and/or listed by a Nationally Recognized Testing Laboratory (NRTL) as follows:

- UL (Underwriters Laboratories Inc), USA
- ULC (Underwriters Laboratories Canada), Canada.
- FM Approved

The VEP smoke detector shall be installed to comply with one or more of the following codes or standards:

- AS 1670.1-2004, AS1603.8 – 1996, ASNZS 3000
- Fire Industry Association (FIA), Code of Practice for Design, Installation, Commissioning & Maintenance of Aspirating Smoke Detector (ASD) Systems
- NFPA Standards, US
- NEC Standards, US
- Local codes and standards

The components of the VESDA systems are as follows:

- A. Aspirating Smoke Detector

- B. 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.
- C. Sampling Device
- D. 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.
- E. Sampling point
- F. The point at which an air sample is drawn into the sampling device.
- G. Response threshold value (RTV).
- H. 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.
- I. Transport time.
- J. The time it takes for aerosols to transfer from a sampling point to the smoke sensing element.
- K. Recovery
- L. 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.

5.6.2.4 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

5.6.2.5 Heat Detectors

Heat Detectors shall be of analogue addressable type and a combined rate of rise of 100C per minute and fixed temperature suitable for 24V DC operation. It shall comply with BS 5445: Part 5 Grade 1, UL 862, 9th Edition listed

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

The Heat detectors shall be installed in the Electrical Rooms / Mechanical Rooms

5.6.2.6 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.

The detector shall be fully operable between -20°C and $+70^{\circ}\text{C}$ and up to 95% relative humidity non-condensing. The Combined Optical smoke & Heat detectors shall be installed in the Electrical Rooms / Mechanical Plant room areas.

5.6.2.7 Multi Sensor Detector

- (a) 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.
- (b) The detector shall utilize advanced algorithms with time based analysis to provide early warning and an accurate analysis of alarm situations.
- (c) 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.
- (d) 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 -20°C and $+70^{\circ}\text{C}$ and up to 95% relative humidity non-condensing.

- (e) 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.

5.6.2.8 Duct Smoke Detector

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.

5.6.2.9 Optical fiber based Line Type Detectors (Linear Heat Detection Cables)

Optical fibre based linear heat detectors shall meet UL/FM standards and comply with BS EN: 54 Part 22 or LPC approved and of "class A" wiring loop. The detectors shall detect the specific temperature anywhere along the detector length, regardless of the sources of heat. The detectors shall be capable of withstanding severe temperature variations and structural variations

The line type heat detectors shall be installed in the Tunnel areas.

5.6.2.10 Isolator Module

Isolator modules shall be provided to automatically isolate wire-to-wire short circuits on loop. The isolator module shall limit the number of modules or detectors that may be rendered inoperative by a short circuit fault on the SLC (signalling line circuit) loop segment or branch.

5.6.2.11 Addressable Control Module

Addressable control modules shall be provided to supervise and control the operation of one conventional NAC's of compatible, 24 Vdc powered, polarized audio/visual notification appliances. Shall be UL 9th edition listed. Audio/visual power shall be provided by a separate supervised power circuit from the main fire alarm control panel or from a supervised UL listed remote power supply.

Control module shall provide an addressable output for a separately powered alarm indicating circuit or for a control relay and housed in covered galvanized steel or stove enamel steel box with sufficient size to house all modules.

The control module shall provide a supervised indicating circuit where indicated on the Drawings. Any open/short circuit fault shall be detected/highlighted/displayed at the FS control panel. Subsequent fire alarm signals shall activate the appropriate controls and signaling devices despite of the fault conditions.

The control module shall act as a control relay where required.

The control module shall contain a LED which blinks upon being scanned by the FS control panel. Upon activation of the module, the LED shall be latched on.

Status of control module shall be fed back to FS control panel and print out automatically once it is activated.

5.6.2.12 Control Zone Module

Control Zone module shall provide an addressable output for a separately powered alarm indicating circuit or for a control relay and housed in covered galvanized steel or stove enamel steel box with sufficient size to house all modules.

The control Zone module shall provide a supervised indicating circuit where indicated on the Drawings. Any open/short circuit fault shall be detected/highlighted/displayed at the FS control panel. Subsequent fire alarm signals shall activate the appropriate controls and signalling devices despite of the fault conditions.

The control Zone module shall act as a control relay where required.

The control Zone module shall contain a LED which blinks upon being scanned by the FS control panel. Upon activation of the module, the LED shall be latched on.

Status of control Zone module shall be fed back to FS control panel and print out automatically once it is activated.

5.6.2.13 Addressable Relay Module

Addressable relay modules shall be available for ECS control and other building functions. The relay shall be form c and rated for a minimum of 2.0 amps resistive or 1.0 amps inductive. The relay coil shall be magnetically latched to reduce wiring connection requirements, and to insure that 100% of all auxiliary relay or NAC'S (Notification Appliance circuit) may be energized at the same time on the same pair of wires.

5.6.2.14 Monitor Module

Addressable contact monitoring module shall communicate via the detection cable loop with the FS control panel for continuous monitoring of any NO or NC dry contacts connected including break glass/call station, flow switch and repeating dry contact signals from gas flooding system and gas detection system. LED indication shall be provided to show the status of the module

5.6.2.15 Hooter cum Strobe

All the areas of Underground station shall be provided with sounder cum visual strobe units rather than public movement area. Public movement area shall be provided with strobe unit.

The unit shall be wall mounted, approved colour, suitable for operation on 12V/24V with following features.

Visual Characteristics: The visual strobe shall consist of Xenon flash tube with associated lens / reflector. The feature selectable candela outputs (15, 15/75, 30, 75 or 110). The flash rate shall not exceeds two flashes per second (2Hz) and nor less than one flash per second (1 Hz) throughout the listed operating range of appliances.

The light pattern shall be disbursed so that it is visible above and below the strobe and from a 90 degree angle on both sides of the strobe.

Sounder pulse rate and decibel level above the ambient shall comply with NFPA standards. The unit shall be tapped for 1/4, 1, 2 and 4 watts outputs.

Strobe shall be placed wall mounted in corridors no more than 4570 mm (15 feet) from the end of a corridor with 30.48 m (100 feet) maximum distance between strobes. Where there is an obstruction to the viewing path in the corridors, such as a cross-corridor door or ceiling elevation change, consider the obstruction as defining a new corridor.

5.6.2.16 Fault Isolator Module

Fault isolator modules shall detect and isolate a short-circuited segment of a fault-tolerant loop.

The module shall automatically detect a return-to-normal condition of the loop and restore the isolated segment

Modules shall be provided for not more than 21 field addressable devices to limit the extent of devices affected in the event of a short-circuit. Fault isolator modules shall be provided for one detection line loop as per the standard.

5.6.2.17 Response Indicator

Response indicator of LED type shall be provided for above false ceiling and below false floor detectors and these shall be mounted outside / inside the rooms wherever asked for by the Contractor/Employer representative for indication of fire through detector in the room. The design & colour shall be as per the standard.

5.6.2.18 Fire Fighter Telephone

Minimum Features requirement but not limited to the followings:

- Provision for supervision control and annunciation of minimum 10 remote telephone jacks
- Built-in Auto-program feature
- Full System Status LED display
- On-board SLC circuit can be wired for class A (Style 6 or Style 7) or class B (Style 4) configuration.
- Support multi-phone jack Audio Circuit supervision.
- Certified for seismic application.
- Allow simultaneous operation of up to 10 Fire Fighter remote handsets.
- Fire Fighter Handset Cabinet is used to store five Fire Fighter Handsets.
- Control and Indicator:
- Auto-program and Accept the configuration after an auto-program is initiated.
- Answer Call, Trouble Silence, LED Indicators (visible with doors and dress panel open)

5.6.3 Fire Man Box

A dedicate lockable metal “Plan Box” of weather-proof construction shall be located next to the MAP. This box shall contain 2 sets of layout plans indicating all the firefighting equipment and facilities of minimum size A3 to help firemen to navigate the station. The cover of the box shall have sealing facilities to prevent vandalism and locked in position with a special key with the glass panel being clipped firmly in place. The box shall be of pleasing appearance and styling with red enamel finished

subject to Employer / Engineer Acceptance. The words “Building Layout Plans for Firemen, Break glass when necessary” shall be clearly printed on the box.

5.7 Firefighting system

5.7.1 General Requirement

5.7.1.1 Scope of work

The scope of works of the Design & Build Contractor for the Underground Stations covered in this section shall be as under but not limited to:

- A. Wet Main system
- B. Fire hose reel system
- C. Automatic fire sprinkler system
- D. Portable fire extinguishers
- E. 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.)

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

5.7.1.2 Standards

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 Float 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

5.7.1.3 Responsibilities

The responsibilities of the Contractor are as follows but not limited to:

- A. Detailed Design of the systems / packages listed in the scope of works
- B. Supply & Installation of the System / Equipment / Devices & Components and all other accessories required for the complete functioning of the system to get the Notice of No Objection from the Employer / Engineer. Testing, Commissioning, Verification & Validation of the Systems to get the Notice of No Objection from the Employer / Engineer . Selection of Plant to meet performance criteria and specification with supporting calculations
- C. Hydraulic Calculations
- D. Pipe sizes, sprinkler/Hose-reel pumping capacities and hydraulic pressure drop in accordance with the actual characteristics of the pipe work and equipment installed
- E. Automatic Clean gas total flooding system and or Panel Flooding System
- F. Cable sizes, cable containment, voltage drop and electrical protective devices in accordance with the co-ordinated cable routing and the actual rating of Plant
- G. 24 VDC battery sizing calculations.
- H. Fault level discrimination
- I. EMC analysis and EMI control measures for the Works

- J. Acoustic and vibration isolation
- K. All software design
- L. Liaison with the Local Authority & getting approval
- M. All legal fees & statutory requirements

The Contractor is also responsible for the design co-ordination between services. The Compatibility of the Main Fire Alarm System with the following services shall be Verified, Tested, and Commissioned to the respective BS- EN standards & VALIDATED as a complete system by the Contractor:

- A. Fire Detection & Alarm System including VESDA
- B. Public Address & Voice Alarm System
- C. Emergency Lighting System
- D. Conveying Systems (Lifts & Escalators)
- E. HVAC Systems (AHUs / FAHUs / Smoke Extract Fans / Fire Dampers / Staircase Pressurization Fans, Tunnel Ventilation Fans, Chillers, Motorized Dampers, Exhaust Fans, FCU's)
- F. Fire Fighting Systems (Fire Pumps / Sprinkler Valves etc.)
- G. Clean Agent Fire Suppression System (Total Flooding & Panel Flooding)
- H. AFC
- I. Doors with Access Control and Security System
- J. Traction SCADA
- K. TVS SCADA
- L. M&E SCADA
- M. Rolling Shutters
- N. PSD
- O. Exit and Emergency Signage system
- P. Systems not listed above but that require Interfacing with the Fire Protection System

The Contractor shall be responsible for checking and ensuring that the type of fire protection system specified complies with the codes of practice, standards, regulations and requirements of the statutory authorities.

The fire protection system schematic diagrams are for indicative purposes only and it is the Contractor's responsibility to ensure that the installation complies fully with the Employer's Requirements, all other Contract documents including relevant codes of practice.

All installation exceeding 680 mm in height must not protrude more than 100 mm in public area. Examples of such installation are fire extinguisher, Hose-reels, MAPs and SAPs etc

Protruding objects shall not reduce the width required for an accessible route or manoeuvring space.

The maximum height of the bottom edge of free-standing objects with a space of more than 300 mm between supports shall be 680 mm from finished floor level.

5.7.2 Portable Fire Extinguishers

The Contractor shall supply and install fire extinguishers in all stations in compliance with relevant BS EN Codes and Regulations.

The Contractor shall refer the finalized station layouts (Space Matrix) for the Underground Stations as agreed by the Engineer to design the fire extinguishers for the Individual rooms

Apart from the requirements as per finalized Space matrix, the contractor shall provide all the covered areas with suitable type of fire extinguishers.

In the Concourse, Mezzanine and Platform areas Fire Extinguishers shall be provided in a central location inside a suitably sized cabinet of construction as per the Notice of No Objection by the Employer/ Engineer. 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.

5.7.3 Wet Mains System

5.7.1.4 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 wet main is charged by the Fire Pump. The fire pump set shall have dual power supply. The wet mains shall be designed to achieve a pressure of 3.5 Bar at the remote hydrant point. The Contractor shall verify, 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.

The pipe work, angle valves, landing valves and associated supports for the tunnel Wet mains system shall not infringe onto the structural gauge of the tunnel. Landing valves shall be installed at not more than 1 metre above the side walkway level. All valves shall be leather strapped and locked. Reinforced bronze rings shall be provided on the leather straps

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 (or size of drain valves as per the Contractor's design and as agreed by the Engineer) 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 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.

The Breeching inlet shall be provided at strategic locations or as required by the Fire Brigade/relevant authority. The size of the breeching inlet shall be as per the requirement of local Fire Brigade/relevant. The Breeching inlet shall be housed in a metal cabinet as per the Notice of No Objection by the Employer / Engineer. Hydrants shall be provided inside the Tunnel according to the requirements of the local authority.

5.7.1.5 Fire Water Tank

- A. The firefighting system will draw water from the fire water storage tank. The storage tank will be directly supplied from the incoming Public water main after the station water bulk meter. 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 Capacity of the Fire Water Tank shall be based on the NBC requirements and the requirements of the local authority.
- C. The Contractor shall also include in his scope provision of the incoming water pipe up to the stop valve just outside the tank.
- D. Air vents and overflow fittings shall be provided for each compartment.
- E. The ladders, concrete platforms hand railings and access doors shall be supplied and installed.
- F. 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.
- G. Anti-vortex device for the Fire water tank shall be incorporated so that the effective capacity can be maximized.
- H. All pipe penetrations provided shall be complete with puddle flanges and cast in the tank wall.

- I. 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.
- J. All exposed openings for the tank and pipe ends shall be completed with insect screen

5.7.1.6 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.

5.7.3.4 Standby Fire Hoses

- A. The fire hose shall be of type as per the Notice of No Objection by the Employer / Engineer and acceptable to Maharashtra Fire Safety & Rescue Department/concerned local authority.

Non-recessed fire hose shall be housed within stainless steel (grade 316) Or finish Cabinets as per the Notice of No Objection by the Employer /Engineer

5.7.3.5 Fire Hose Cabinets

The Contractor shall be responsible for determining the no of hose reels and hose reel locations. The type of fire hose reel cabinet (recessed and or surface mounted) shall be designed by the Contractor. The Contractor shall also co-ordinate and shall provide recess on the wall or partition together with access doors.

The Contractor has to finalize the number of FHCs and its locations based on his final design and as per the Notice of No Objection by the Engineer and as agreed by the relevant authority. In addition , the Contractor shall provide FHCs in the Covered parking areas in some stations where applicable. Also EXTERNAL FIRE HYDRANTS shall be provided as per the Local fire authority's requirements.

5.7.3.6 Hose Reel Box (Tunnel Only)

The Fire Hose Reel Box shall be provided in the Tunnel Cross passages (and/or at other suitable locations)as per the system design. The Contractor shall be responsible for determining the no of hose reel box and hose reel box locations. The type of fire hose reel box (recessed and or surface mounted) shall be designed by the contractor and as agreed by the Engineer. The Contractor shall also co-ordinate and shall provide recess on the wall or partition together with access doors, as per the requirement.

The Contractor shall finalize the number of Fire Hose Reel Box and its locations based on his final design and as per the Notice of No Objection by the Engineer and as agreed by the relevant authority.

Each Fire Hose Reel box shall be provided with the following

- A. 4 Nos. 65mm Dia. or 40mm Dia., 30Metres Long Fire Hose complete with Quick Coupling on Each End, suitable For Tunnel Fire Fighting.
- B. 2 Sets of Quick Coupling Reducer
- C. 2 Sets of 65mm Dia. Adjustable Spray and Solid Stream Nozzles

The material of construction shall be as per the Notice of No Objection by the Employer / Engineer .

5.7.3.7 Fire Hose Reels

The hose reels shall meet the requirements of BS 5306.1 & BS EN 671 – 3. Hose-reel shall be provided in such a way that it covers the entire Concourse / Mezzanine/Platform areas. The hose reels system will be based on direct feed from the Fire Water Wet mains. 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) or equal material cabinets as per Notice of No Objection by the Employer / Engineer and galvanized steel or equal 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:

- A. Fastened only by means of spring lock.
- B. The door shall be labelled “Fire Hose-reel” and the label shall be submitted to the Employer / Engineer for acceptance.

Drainage points shall be provided within the hose-reel cabinets/recesses to allow draining of any residue water after usage. Co-ordination with the Civil Contractors on this requirement is necessary for providing drain channels.

5.7.4 Automatic Fire Sprinkler System

The automatic fire sprinkler system shall be based on BS EN: 12845 -2004 + Appendix-2 2009 with Ordinary Hazard Group I for ancillary areas and Ordinary Hazard Group III for commercial spaces and maintenance workshop areas.

Since Commercial areas exist only in few stations the Contractor has to design the system based on the station specific requirements. Where both commercial and ancillary areas exist in the station, design of the station sprinkler system shall be based on the higher hazard class.

The sprinkler system shall be divided into separate zones with each zone being monitored by a flow switch. Individual zone (individual flow switch) shall be provided for the sprinkler in the escalators pits adjacent to each other, lift shafts, commercial spaces and rooms/areas within close proximity. The zoning

of the sprinkler system shall be subject to the acceptance of the Employer / Engineer. The Fire Sprinkler System shall be fed from the Wet Main Fire Pump. The lift shafts and lift pits and the escalators, in the non- sprinkler protected areas (such as the public areas), shall be sprinkler protected. Cut-off sprinkler shall be installed in the protected passageway/staircase. The Contractor shall co-ordinate with other system- wide contractors with regards to the location and installation details of the sprinkler heads and routing of pipe work.

The sprinkler system shall be electrically monitored so that on the operation of any sprinkler head, the fire signal is automatically transmitted to the OCC & SCR through M&E SCADA via MAP. The Contractor shall provide an electrically controlled/supervised gate valve each for the pendent and upright layer of sprinklers for the commercial space. 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 the type as per the Notice of No Objection by the Employer / Engineer.

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

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 beams 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.

As per the Notice of No Objection from the Employer / Engineer 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

5.7.5 Pumps

The fire pumps shall be provided in compliance with the BS EN 12845 + APPENDIX-2.

The Fire Pump Set shall comprise the following for each station

- A. Two Electric Fire Pumps

B. One Jockey Pump

The Capacity of the Pump Set shall be designed by the Contractor for the station specific requirements and the calculations to be submitted to the Employer / Engineer for notice of No Objection. 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 acceptance.

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 as per the Notice of No Objection by the Employer / Engineer.

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.

5.7.6 Clean agent based flooding system for electrical panel

The scope covers Supply, Installation, Testing and Commissioning of Automatic clean agent based Flooding System complete for electrical panels (only for the Electrical Panels supplied under this Contract eg- Fire Pump, UPS, DG etc.) with flexible fire detection tubing, cylinder, valves, integration with Main Fire Alarm Control Panel for status monitoring etc. The scope of work includes, but not limited to the following

- Providing Direct Panel Gas Flooding System with flexible fire detection/

discharge tubing inside the panels.

- Clean agent storage cylinder for flooding gas inside the panels.
- Audio-visual annunciation devices for indicating incidence of fire.
- Any other item required to the successful commissioning of the system.

The electrical panel fire suppression system shall be complete with Direct Clean Gas storage cylinders for required capacities, extinguishing agent as specified, fire detection tubing, filling and end-of-line adaptors, pressure switches, control equipment, Clean Agent Cylinder/Valve Assembly, Cylinder Mounting Bracket and all necessary accessories to protect the Electrical panel in case of fire. The system will have an interface with Main Fire Alarm and Control Panel. In case of fire in the concerned Panel, indication of Fire / discharge status should come in Main Fire Alarm and Control Panel.

Design Requirements

All the detecting devices, alarm, indicating devices, containers and other related equipment shall have required approvals & Authorization.

All installations shall conform to NFPA requirements.

Clean Agent should be used with below mentioned properties

- (a) The Clean Agent should have Zero Ozone Depletion Potential. (ODP = 0)
- (b) The Clean Agent should not have Global Warming Potential of more than 1.
- (c) The Clean Agent should be a low pressure agent.

System Equipment

Fire Trace Tubing

The tubing shall be installed throughout the Electrical Panel with one end connected to the top of the Clean Agent container valve. The tubing shall be pressurized with Dry Nitrogen to 150 psig and maintains the system in the "OFF" position. The tube shall burst at temp. 100-120 degree C. The tubing shall perform three functions: Heat Detection, System Activation and Clean Agent discharge.

Clean agent Container

Design, fabricate, certify and stamp containers in accordance with the requirements of NFPA (DOT). Containers shall be standard model and size of ease of replacement and addition.

Each storage container shall be equipped with a nickel-plated brass valve, a pressure gauge to monitor container pressure, and a quarter-turn ball valve that interfaces with the detection tubing. The quarter-turn ball valve shall be kept closed at all times when the container is not in service.

All container valves shall be equipped with a pressure relief valve (rupture disc) device in compliance with DOT requirements.

Technical and Installation Requirements

Provide sufficient amount of Extinguishing Agent to Inert the Micro environment being protected considering the following when computing volume to verify suitability and to establish design limitations:

- Volume of hazard area.
- Specific volume of Clean Agent.
- Discharge time and flow rates.
- Design concentration and design factors.
- Detector/discharge tubing placement.

Interface system with main control fire alarm system and BMS.

All doors and holes in the enclosed/equipment should be closed or sealed to maintain the tightness of enclosure.

The clean agent based Pre-Engineered automatic direct fire suppression system shall be approved by required approvals & Authorization.

Each clean agent pre-engineered automatic system is equipped with its own detection/discharge tubing.

The unit shall be a self-contained and shall be equipped with its own non-electric automatic detection system to detect the fire and agent release system into the Electric panel to suppress the fire.

The Clean Agent is stored in DOT steel cylinders as a liquefied compressed gas, super-pressurized with Dry Nitrogen to 150 psig at 70oF. The ambient operating temperature range for all system components should be 0 degree C to 54 degreeC.

Each container is equipped with a nickel-plated brass valve, a pressure gauge to monitor container pressure, and a quarter-turn ball valve that interfaces with the Detection Tubing. In addition, the container valve shall be equipped with a pressure relief (rupture disc) device in compliance with DOT requirements.

Provide wall-mounted painted steel bracket to mount the container/valve assembly in a vertical (upright) position. Each bracket should be equipped with atleast two integral quick-clamp straps.

Install equipment as indicated on the approved shop drawings, and in accordance with requirements of NFPA-70 and NFPA-2001.

All the necessary accessories required for operation of system shall be part of supply from single Manufacturer for UL listing of system.

Make final connections between equipment and system detection tubing under direct supervision of factory trained and certified representative of manufacturer.

It shall be so designed that it does not affect the IP ratings of electrical panels. The Sub-Contractor has to coordinate with manufactures of electrical panels for provision of holes to run the tube and brackets for mounting the tube. The entry of tube inside the panel shall be though suitable size of connector.

The tubing shall be manufactured from specially processed polymer material to achieve the desired heat detection and delivery characteristics. Provide minimum two runs of fire trace tube along with any two sides of every compartment of the panel.

The tubing shall be capable of working even when contaminated with oil, dust and debris as long as the contamination will allow the heat to pass through the tube.

5.7.7 Clean agent based flooding system for Transformer enclosure protection

The scope covers Design, Supply, Installation, Testing and Commissioning of Automatic clean agent based indirect fire suppression system for Dry Type Transformer enclosure complete with storage cylinders, in-direct valves, detection tubing as per NFPA-2001 including its safety guidelines with respect to "Hazards to Personnel", electrical clearance and environmental factors in line with environmental considerations of Kyoto Protocol. The scope of work includes, but not limited to the following

- Clean agent storage cylinder
- Fire detection tubing and spray nozzles
- manual discharge facility
- Interface with BMS.
- Any other item required to the successful commissioning of the system

Technical and Installation Requirements

The system shall be a clean agent pre-engineered automatic indirect Fire Suppression System and shall be UL & FM Approved products and approval by Local Fire Authority.

The system shall be self contained and have its own non-electric automatic detection system, which when actuated shall automatically release the suppression agent into the transformer cabinet.

Interface system with BMS.

The system shall be complete in all respects. It shall include agent storage container, detection tubing, discharge nozzles, fittings manual release, abort stations, audible and visual alarm devices and any other operations necessary for a functional Clean Agent suppression system.

The System shall detect, control and extinguish the fire and also simultaneously give audio visual indication on the control panel.

Storage containers shall be located as near as possible to hazard area but shall not be exposed to fire.

Storage containers shall be carefully located so that they are not subjected to mechanical, chemical or other damage.

System Operation

The system must operate automatically and its operation shall be as per

following:

When the temperature of Fire Trace tube installed inside the Cabinet will increase to above 100 degree C or the detection tube comes in the direct contact of flame, the tube shall burst and initiates ILP Valve which allows the diffusion of extinguishing medium which is Clean Agent gas through strategically placed pipes & nozzles.

The system shall be designed for In Direct discharge of extinguishing agent through the pipes and nozzle when the tube rupture occurs. The diameter of tube for direct discharge shall be as per calculations and manufacturer recommendations but shall not be less than 6mm under any condition.

The Contractor shall carry out the piping Isometric design and validate the same with a hydraulic flow calculation generated by using hydraulic calculation software. The appropriate fill density to be arrived at basis of the same.

The design & calculation shall be checked & certified by manufacturers trained design engineer. The calculation is the only guarantee that the system shall work, provided the system is installed exactly as per the design.

These documents shall be prepared by a fully experienced person and qualified in the design of gas based fire suppression system.

Equipment Specifications

Cylinder

Design, fabricate, certify and stamp containers in accordance with the requirements of NFPA (DOT). Containers shall be standard model and size of ease of replacement and addition.

Discharge Hose

The Discharge Pipe should be high pressure braided hose with heavy duty adopters. The nozzle should be made of Brass/Gun Metal and should have 180 degree discharge pattern.

System and Detection Tube

The System will be UL/FM approved product

Clean Agent should be used with below mentioned properties

The Clean Agent should have Zero Ozone Depletion Potential. (ODP = 0)

The Clean Agent should not have Global Warming Potential of more than 1.

The Clean Agent should be a low pressure agent.

The detection tube shall be manufactured from specially processed polymer material to achieve the desired heat detection and delivery characteristics. The tube shall be capable of working even when contaminated with oil, dust and debris as long as the contamination will allow the heat to pass through the tube.

5.7.8 Automatic Clean Gas Total Flooding System Fully Integrated With Analogue Addressable Fire Alarm System

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

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.

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 recognised institutions and must be interchangeable. The automatic clean gas total flooding system shall be capable of being operated automatically and manually and shall comprise of but not limited to the following equipment:

- C. Analogue addressable Clean gas Panel (CGP) shall be with the following features:-
 - i. Microprocessor based and controlled by a program contained in non-volatile memory (ROM or EPROM).
 - ii. Adaptation to the stations requirements by entry of user data via a built-in keyboard provided on the CGP.
 - iii. Capability to process and evaluate incoming signals from individually addressable devices.
 - iv. Modular in design by means of plug-in cards. Each addressable line card shall have its own microprocessor based circuit, working independently from the central processor board in the CGP.
 - v. Fully standalone complete with power supply, charger and standby batteries.
 - vi. Fully compatible with all other fire alarm panels and able to communicate peer to peer with the similar type of communication

network links.

vii. UL and FM listed.

For the rooms to be protected with gaseous fire suppression system the Contractor shall refer the requirements in Fire Strategy Section of Outline Design Specifications and the station layout(the space matrix) as finalized by the Contractor and as agreed by the Engineer.

5.7.9 Interface Requirements

The Contractor shall be responsible to ensure that the various E&M systems supplied are properly interfaced and integrated with that of others for intended operations.

The Contractor shall liaise and co-ordinate with other SWCs to mutually agree the protocols to be used for all necessary data exchange and common interface required between the systems. The general interface required for the systems are listed but not limited to the following:

- Interface with SCR
- Interface with Active Voice Communication system Interface with OCC / BCC
- Interface with AFC and emergency gates
- Interface with Traction/Power supply SCADA)
- Interface with M&E SCADA
- Interface with TVS SCADA
- Interface with PSD
- Interface with HVAC System and associated SCADA
- Interface with Rolling Shutters Interface with Escalators / Elevators Interface with Electrical works Interface with the Civil works for space and structure requirements.
- And any other Interface as required.

5.7.10 Quality Assurance

The Quality Assurance shall be as per the Project Quality Manual/ Contract requirement.

5.8 SCADA CONTROL & MONITORING POINTS (Indicative)

Indicative BMS FIELD EQUIPMENT Controlling and Monitoring Points							
The bellow Points are tentative but not limited to the following.							
SI No.	Equipment / System Point Details	SIGNAL TYPE	AI	AO	DI	DO	Remarks
1	E & M Services						
	ASS & LV System Point Detail						Each
	Incomer ACB - Typical						
	Local/Remote status	VFC			1		
	Open/Close Status	VFC			1		
	Trip	VFC			1		
	Voltage(Red Phase)	4-20 mA	1				
	Current(3 Phases)	4-20 mA	1				
	kW	4-20 mA	1				
	kVA	4-20 mA	1				
	kWHr	4-20 mA	1				
	KVAR	4-20 mA	1				
	Breaker CLOSE command	VFC				1	
	Breaker open command	VFC				1	
	PF	4-20 mA	1				
	Lockout	VFC			1		
	Breaker Test position	VFC			1		
	Breaker Service position	VFC			1		
	Breaker Isolation position	VFC			1		
	Emergency trip status for main incomer	VFC			1		
	Multi-Function Meter for ACB's - Typical						Each
	Voltage(Between Phases)	4-20 mA	1				
	Voltage(Between Phase & neutral)	4-20 mA	1				
	Voltage(Between Phase & earth)	4-20 mA	1				
	Current(3 Phases)	4-20 mA	1				
	Frequency	4-20 mA	1				
	kW	4-20 mA	1				
	kVA	4-20 mA	1				
	kWHr	4-20 mA	1				
	KVAR	4-20 mA	1				
	UV OV for ACB's						
	Under Voltage status	4-20 mA	1				
	over Voltage status	4-20 mA	1				
	Outgoing for ACB's - Typical						Each
	Open/Close Status	VFC			1		
	Trip	VFC			1		
	voltage	4-20 mA	1				
	frequency	4-20 mA	1				

Indicative BMS FIELD EQUIPMENT Controlling and Monitoring Points							
The bellow Points are tentative but not limited to the following.							
SI No.	Equipment / System Point Details	SIGNAL TYPE	AI	AO	DI	DO	Remarks
	Control (Open & Close Command)	VFC				1	
	Lockout	VFC			1		
	Breaker Test position	VFC			1		
	Breaker Service position	VFC			1		
	Breaker Isolation position	VFC			1		
	Local/Remote status	VFC			1		
	(Outgoing) Multi-Function Meter for ACB's - Typical						
	Voltage(Between Phases)	4-20 mA	1				
	Voltage(Between Phase & neutral)	4-20 mA	1				
	Voltage(Between Phase & earth)	4-20 mA	1				
	Current(3 Phases)	4-20 mA	1				
	Frequency	4-20 mA	1				
	kw	4-20 mA	1				
	kVA	4-20 mA	1				
	kWHr	4-20 mA	1				
	kVAR	4-20 mA	1				
	Bus Section for ACB's - Typical						Each
	Open/Close Status	VFC			1		
	Open/Close Command	230 VAC				1	
	Trip	VFC			1		
	Voltage(Red Phase)	4-20 mA	1				
	Current(3 Phases)	4-20 mA	1				
	Lockout	VFC			1		
	Breaker Test position	VFC			1		
	Breaker Service position	VFC			1		
	Breaker Isolation position	VFC			1		
	Local/Remote	VFC			1		
	DG's PLC - Typical						Each
	Open/Close Status	VFC			1		
	Trip	VFC			1		
	Voltage(Red Phase)	4-20 mA	1				
	Current(3 Phases)	4-20 mA	1				
	Kw	4-20 mA	1				
	KVA	4-20 mA	1				
	KWHr	4-20 mA	1				
	KVAR	4-20 mA	1				
	Lockout	VFC			1		
	Local/Remote status	VFC			1		
	Feedback to stop DG to DG PLC	VFC			1		
	DG's ACB (All Incomer & Outgoing)- Typical						Each

Indicative BMS FIELD EQUIPMENT Controlling and Monitoring Points							
The below Points are tentative but not limited to the following.							
Sl No.	Equipment / System Point Details	SIGNAL TYPE	AI	AO	DI	DO	Remarks
	Breaker open/close Status	VFC			1		
	AC SUPPLY						
	AC Supply Failure	VFC			1		
	E Push Button	VFC			1		
	Main Incomer MCCB UPS - Typical						Each
	Open/Close status	VFC			1		
	Trip status	VFC			1		
	Main Incomer MCCB Very Essential Panel - Typical						
	Open/Close status	VFC			1		
	Trip status	VFC			1		
	UPS / CBS System						
	UPS System - Typical						Each
	UPS I/P Voltage	4-20 mA	1				
	UPS O/P Voltage	4-20 mA	1				
	UPS Battery Low Alarm	VFC			1		
	UPS Battery Charger Discharging Status	VFC			1		
	Fan Normal/Fail	VFC			1		
	Manual Bypass On/Off	VFC			1		
	Load on Battery	VFC			1		
	Load on Bypass	VFC			1		
	Dual Supply Healthy/Fault Status	VFC			1		
	On/Shut Down Status	VFC			1		
	Common Alarm	VFC			1		
	Battery failed status	VFC			1		
	Battery failed alarm	VFC			1		
	Charger failed status	VFC			1		
	Charger failed alarm	VFC			1		
	Inverter failed status	VFC			1		
	Inverter failed alarm	VFC			1		
	Second battery failed status	VFC			1		
	Second battery failed alarm	VFC			1		
	Second inverter failed status	VFC			1		
	Second Charger failed status	VFC			1		
	Second Charger failed alarm	VFC			1		
	Output bus voltage low alarm	VFC			1		
	UPS failed alarm	VFC			1		
	Trickle Charging Status	VFC			1		
	UPS Panel, Outgoing Breaker -						Each

Indicative BMS FIELD EQUIPMENT Controlling and Monitoring Points							
The below Points are tentative but not limited to the following.							
Sl No.	Equipment / System Point Details	SIGNAL TYPE	AI	AO	DI	DO	Remarks
	Typical						
	Breaker Trip Alarm	VFC			1		
	Breaker Close Status	VFC			1		
	Breaker Open Status	VFC			1		
	CBS - Typical						Each
	Dual Supply Healthy/Fault Status	VFC			1		
	Load on Battery	VFC			1		
	Load on Bypass	VFC			1		
	Manual Bypass On/Off	VFC			1		
	Common Alarm	VFC			1		
	Battery Low Alarm	VFC			1		
	On/Shut Down Status	VFC			1		
	Fan Normal/Fail	VFC			1		
	ATS DB - Typical						Each
	INC01 On/Off Status	VFC			1		
	INC01 Trip/Fault	VFC			1		
	INC02 On/Off Status	VFC			1		
	INC02 Trip/Fault	VFC			1		
	LIGHTING						
	Emergency Lighting - Typical						
	On/Off Status	VFC			1		1 per station/per level
	Auto/Manual & Trip Status	VFC			1		1 per station/per level
	On/Off Control	230 VAC				1	1 per station/per level
	Station Lighting - Typical						
	100%,33% & 66% Status	VFC			1		1 for Concourse and 1 for Platform
	33% Control	230 VAC				1	1 for Concourse and 1 for Platform
	66% Control	230 VAC				1	1 for Concourse and 1 for Platform
	100% Control	230 VAC				1	1 for Concourse and 1 for Platform
	On / Off Control	230 VAC				1	1 for Concourse and 1 for Platform
	A/M & Trip Status	VFC			1		For All Feeders/ Breakers/Circuit
	Photocell - Typical Service Road Light Operation						
	Enable / Disable Status	VFC			1		Per Zone/Portal
	Enable Control	230 VAC				1	Per Zone/Portal
	Disable Control	230 VAC				1	Per Zone/Portal
	Tunnel Lighting - Typical						
	Incoming Breaker Local/Remote Status	VFC			1		

Indicative BMS FIELD EQUIPMENT Controlling and Monitoring Points							
The bellow Points are tentative but not limited to the following.							
SI No.	Equipment / System Point Details	SIGNAL TYPE	AI	AO	DI	DO	Remarks
	Incoming Breaker Trip Alarm	VFC			1		
	Incoming Breaker Close Status	VFC			1		
	Incoming Breaker Open Status	VFC			1		
	Incoming Breaker Open/ Close Command	230 VAC				1	
	Incoming Feeder Line Voltage	4-20 mA	1				
	Incoming Feeder Line Current	4-20 mA	1				
	Outdoor Lighting - Typical						
	On/Off Status	VFC			1		1 per station
	Trip Status	VFC			1		1 per station
	On/Off Control	230 VAC				1	1 per station
	Signage Lighting - Typical						Each
	Incoming Breaker Local/Remote Status	VFC			1		
	Incoming Breaker Trip Alarm	VFC			1		
	Incoming Breaker Close Status	VFC			1		
	Incoming Breaker Open Status	VFC			1		
	Incoming Breaker Open/ Close Command	230 VAC				1	
	Incoming Feeder Line Voltage	4-20 mA	1				
	Incoming Feeder Line Current	4-20 mA	1				
	DG Set- Typical						Each
	DG Local/Remote Status	VFC			1		
	DG Set / Engine Start Feedback	VFC			1		
	DG common Fault Alarm	VFC			1		
	DG On/Off Command	24 VDC				1	
	DG Battery Voltage	4-20 mA	1				
	DG Output Voltage	4-20 mA	1				
	DG Output Frequency	4-20 mA	1				
	Incoming HT supply to ASS 1 & 2 transformers OFF status	VFC			1		
	Incoming HT supply to ASS 1 & 2 transformers OFF alarm	VFC			1		
	Incoming HT supply to ASS transformers ON	VFC			1		
	DG set failed to start or tripped alarm	VFC			1		
	Hours of operation	VFC			1		
	Not run for more than a week alarm	VFC			1		
	Starter battery voltage alarm	VFC			1		
	Lube oil pressure alarm	VFC			1		
	Fuel oil level alarm	VFC			1		
	Radiator water level alarm	VFC			1		
	Output voltage	VFC			1		

Indicative BMS FIELD EQUIPMENT Controlling and Monitoring Points							
The below Points are tentative but not limited to the following.							
Sl No.	Equipment / System Point Details	SIGNAL TYPE	AI	AO	DI	DO	Remarks
	Output voltage out of range alarm	VFC			1		
	Output frequency out of range alarm	VFC			1		
	DG Panel, Incoming Circuit Breaker- Typical						Each
	Incoming Breaker Local/Remote Status	VFC			1		
	Incoming Breaker Trip Alarm	VFC			1		
	Incoming Breaker Close Status	VFC			1		
	Incoming Breaker Open Status	VFC			1		
	Incoming Breaker Open / Close Command	230VAC				1	
	Incoming Breaker Close Command					1	
	Incoming Feeder Line Voltage	4-20 mA	1				
	Incoming Feeder Line Current	4-20 mA	1				
	Incoming Feeder Protection Relay Operation Status	VFC			1		
	Incoming Feeder Volt Ampere (VA)	4-20 mA	1				
	Incoming Feeder Frequency (Hz)	4-20 mA	1				
	Incoming Feeder Power Factor (PF)	4-20 mA	1				
	Incoming Feeder Kilo Watt Hour (KWhr)	4-20 mA	1				
	Incoming Feeder Volt Ampere Reactive (VAR)	4-20 mA	1				
	Main Fire Pump Panel, Outgoing Circuit Breaker- Typical						Each
	Outgoing Breaker Local/Remote Status	VFC			1		
	Outgoing Breaker Trip Alarm	VFC			1		
	Outgoing Breaker Close Status	VFC			1		
	Outgoing Breaker Open Status	VFC			1		
	Outgoing Breaker Open / Close Command	24VDC				1	
	Outgoing Feeder Line Voltage	4-20 mA	1				
	Outgoing Feeder Line Current	4-20 mA	1				
	Outgoing Feeder Protection Relay Operation Status	VFC			1		
	Spare Circuit Breaker - Typical						Each
	Outgoing Breaker	VFC			1		

Indicative BMS FIELD EQUIPMENT Controlling and Monitoring Points							
The below Points are tentative but not limited to the following.							
Sl No.	Equipment / System Point Details	SIGNAL TYPE	AI	AO	DI	DO	Remarks
	Local/Remote Status						
	Outgoing Breaker Trip Alarm	VFC			1		
	Outgoing Breaker Close Status	VFC			1		
	Outgoing Breaker Open Status	VFC			1		
	Outgoing Breaker Open / Close Command	24VDC				1	
	Outgoing Feeder Line Voltage	4-20 mA	1				
	Outgoing Feeder Line Current	4-20 mA	1				
	Outgoing Feeder Protection Relay Operation Status	VFC			1		
	DG Aux. Others Panel, Outgoing Circuit Breaker- Typical						Each
	Outgoing Breaker Trip Alarm	VFC			1		
	Outgoing Breaker Close Status	VFC			1		
	Outgoing Breaker Open Status	VFC			1		
	Main Fire Pump Panel						Each
	Mains Incoming Voltage	4-20mA	1				
	Dual Supply Healthy Status	VFC			1		
	Main Fire Pump						
	Running Feedback	VFC			1		
	Local/Remote Status	VFC			1		
	Trip Alarm	VFC			1		
	Motor Current	4-20 mA	1				
	Power	4-20 mA	1				
	Low Pressure Alarm	VFC			1		
	Main Hydrant Pump- Typical						Each
	Running Feedback	VFC			1		
	Local/Remote Status	VFC			1		
	Trip Alarm	VFC			1		
	Motor Current	4-20 mA	1				
	Power	4-20 mA	1				
	Low Pressure Alarm	VFC			1		
	Hydrant Jockey Pump - Typical						Each
	Running Feedback	VFC			1		
	Local/Remote Status	VFC			1		
	Emergency Stop Button Position	VFC			1		
	Trip Alarm	VFC			1		
	Motor Current	4-20 mA	1				
	Power	VFC			1		
	Low Pressure Alarm	VFC			1		
	Header Water flow status	VFC			1		
	Main Sprinkler Pump - Typical						Each
	Running Feedback	VFC			1		

Indicative BMS FIELD EQUIPMENT Controlling and Monitoring Points							
The below Points are tentative but not limited to the following.							
SI No.	Equipment / System Point Details	SIGNAL TYPE	AI	AO	DI	DO	Remarks
	Local/Remote Status	VFC			1		
	Emergency Stop Button Position	VFC			1		
	Trip Alarm	VFC			1		
	Motor Current	4-20 mA	1				
	Power	VFC			1		
	Low Pressure Alarm	VFC			1		
	Jockey Pump Hydrant & Sprinkler- Typical						Each
	Running Feedback	VFC			1		
	Local/Remote Status	VFC			1		
	Emergency Stop Button Position	VFC			1		
	Trip Alarm	VFC			1		
	Motor Current	4-20 mA	1				
	Power	VFC			1		
	Low Pressure Alarm	VFC			1		
	Header Water flow status	VFC			1		
	MOV for Fire Hydrant , Sprinkler , P & D, - Typical for Track, UG, Platform, PSB(platform Supervisory Booth) and Other Station Areas						Each
	Open / Close Status/ Position from field limit switch	VFC			1		
	Open / Close Control	230 VAC				1	
	Auto/Manual Status	VFC			1		
	Seepage and Sewage Pump- (Station & Tunnel)Typical						Each
	Seepage Pump On/Off Command	230 VAC				1	
	Seepage Pump Running Feedback	VFC			1		
	Seepage Pump Local/Remote Status	VFC			1		
	Seepage Pump Emergency Stop Button Position	VFC			1		
	Seepage Pump Trip Alarm	VFC			1		
	Seepage Pump Current	4-20 mA			1		
	Seepage and Sewage Sump Level -(Station & Tunnel) Typical						Each
	Seepage Sump Low Level	VFC			1		
	Seepage Sump Medium Level	VFC			1		
	Seepage Sump High Level	VFC			1		

Indicative BMS FIELD EQUIPMENT Controlling and Monitoring Points							
The below Points are tentative but not limited to the following.							
SI No.	Equipment / System Point Details	SIGNAL TYPE	AI	AO	DI	DO	Remarks
	Seepage Sump Ultra High Level (Overflow)	VFC			1		
	Domestic ,Bore well, Raw Water , Soft Water , Treated Water, Hydro Pneumatic water, Make up water Pump, - Typical						Each
	Pump On/Off Command	230 VAC				1	
	Pump Running Feedback	VFC			1		
	Pump Local/Remote Status	VFC			1		
	Pump Emergency Stop Button Position	VFC			1		
	Pump Trip Alarm	VFC			1		
	Pump Current	4-20 mA			1		
	Ejector Pump-Typical						Each
	Pump On/Off Command	230 VAC				1	
	Pump Running Feedback	VFC			1		
	Pump Local/Remote Status	VFC			1		
	Pump Emergency Stop Button Position	VFC			1		
	Pump Trip Alarm	VFC			1		
	Pump Current	4-20 mA			1		
	Handicap Toilet Alarm System						Each
	Normal / Fault Status				1		
	Alarm Status				1		
	RO Plant						
	Permeate Flow Rate	4-20 mA	1				
	Conductivity	4-20 mA	1				
	Raw water flow rate	4-20 mA	1				
	Operation Status	VFC			1		
	Trip Status	VFC			1		
	Local/Remote Status	VFC			1		
	On/Off Command	230 VAC				1	
	Fire/ Raw/ Treated/Domestic Water Tanks						Each
	Fire Water Tank Low Level	VFC	1				
	Fire Water Tank Medium Level	VFC	1				
	Fire Water Tank High Level	VFC	1				
	Fire Water Tank Ultra High Level	VFC	1				
	Raw Water Tank Low Level	VFC	1				
	Raw Water Tank Medium Level	VFC	1				
	Raw Water Tank high Level	VFC	1				
	Raw Water Tank Ultra high Level	VFC	1				

Indicative BMS FIELD EQUIPMENT Controlling and Monitoring Points							
The below Points are tentative but not limited to the following.							
SI No.	Equipment / System Point Details	SIGNAL TYPE	AI	AO	DI	DO	Remarks
	Treated Water Tank Low Level	VFC	1				
	Treated Water Tank Medium Level	VFC	1				
	Treated Water Tank high Level	VFC	1				
	Treated Water Tank Ultra high Level	VFC	1				
	Raw Water in Tunnel Area						Each
	Raw Water in Tunnel Area Low Pressure Alarm	VFC			1		
	Station Main Water Supply						
	Water Flow Status	4-20 mA	1				
	Inert Gas Flooding System- Typical						
	Auto/Manual Mode	VFC			1		
	System Healthy Status	VFC			1		
	Fire Mode Status	VFC			1		
	CO2 GAS Based Tube Protection System						Each
	System Healthy Status	VFC			1		
	Fire Mode Status	VFC			1		
	Water Leakage Detection System for Critical and Server Rooms						Each Room/System
	System Healthy Status	VFC			1		
	Fire Mode Status	VFC			1		
	Heat Linear Detector System for Tunnel						
	System Healthy Status	VFC			1		
	Fire Mode Status	VFC			1		
	Fire Detection and alarm system						
	Common Alarm	VFC			1		Per panel
	All Fire Zone Alarm including Gas Suppression System	VFC			1		Per Zone Each
	System Fault /Healthy/Maintenance Status	VFC			1		Per panel
	INTERFACE						
	Fire Detection and Alarm System						Fire Alarm related soft interface points will be taken care during project execution interface between Fire and SMS/ISMS
	PA & PID System (Communication)- Typical						
	Evacuation Active					1	

Indicative BMS FIELD EQUIPMENT Controlling and Monitoring Points							
The bellow Points are tentative but not limited to the following.							
SI No.	Equipment / System Point Details	SIGNAL TYPE	AI	AO	DI	DO	Remarks
	Evacuation de-active					1	
	Automatic Fare Collection (AFC)						
	Evacuation Active					1	
	Evacuation de-active					1	
	Platform Screen Door (PSD)- Typical						
	PSD System						per psd system
	Power Failure Alarm				1		
	UPS Failure Alarm				1		
	Monitoring System Fault Alarm				1		
	Station Platform						per station platform
	PSD Open Alarm				1		
	EED Open Alarm				1		
	PSD Close Alarm				1		
	EED Close Alarm				1		
	PSD Interlock Override Alarm				1		
	Drive Power Fault Alarm				1		
	MSD Open Alarm				1		
	Lamp Failure Alarm				1		
	PSL Door Open Command				1		
	PSL Door Close Command				1		
	Powered Doorset						per powered door set
	Open Status				1		
	Close Status				1		
	Manual Release Mechanism Alarm				1		
	DCU/Drive Fault Alarm				1		
	Local Control Mode				1		
	Escalator (ESC)- Typical						Each
	Escalator Operating Status						
	Power Failure				1		
	Up Direction of travel				1		
	Down Direction of travel				1		
	Escalator Stop				1		
	Escalator speed (0.5 , 0.65 m/s)				1		
	Escalator Fault						
	Fault				1		
	Fault Code		1				
	Remote Control Function						
	Stop					1	
	Start (up)					1	
	Start (down)					1	
	Remote Start override control				1		
	Fault Reset					1	

Indicative BMS FIELD EQUIPMENT Controlling and Monitoring Points							
The bellow Points are tentative but not limited to the following.							
SI No.	Equipment / System Point Details	SIGNAL TYPE	AI	AO	DI	DO	Remarks
	Speed Selection ((0.5 or 0.65 m/s)					1	
	Water Flow Switch (sprinkler system)	VFC			1		
	LIFT - Typical						Each
	Lift Operating Status						
	In Service / Out of Service				1		
	Emergency Alarm (Push Button Inside Lift car)				1		
	Lift Fault						
	Fault				1		
	Remote Control Function						
	Homing (Parking/Unparking) Control					1	
	Water Flow Switch (sprinkler system)	VFC			1		
	PST System						1 per OHL Section/ Per Zone
	Energize / De-energize				1		
	Essential & Very Essential Panel						Each
	Auto/Manual Status				1		
	On/Off Control					1	
	On/Off / Feedback Status				1		
	Integrated Backup Panel (IBP)						
	Auto/Manual Status				1		
	Evacuation Active					1	
	Evacuation de-active					1	
	System Enable Status				1		
	Blue Light Station						
	Evacuation Active					1	
	Evacuation de-active					1	
	System Enable Status				1		
	Access Control System, PA System, PIS System						
	Evacuation Active					1	
	Evacuation de-active					1	
	System Enable Status				1		
	Tunnel Ventilation Systems						TVS related points will be taken care during project execution interface between TVS and SMS/ISMS through TCP/IP
NOTE:	Recommendation :- Contact signal should be Hard wired, potential/Voltage free contact. All Equipment Emergency Push Button Switch status mandatory from ISMS/SMS						

Indicative BMS FIELD EQUIPMENT Controlling and Monitoring Points							
The below Points are tentative but not limited to the following.							
SI No.	Equipment / System Point Details	SIGNAL TYPE	AI	AO	DI	DO	Remarks
	<p>All Equipment Run Hour Calculation mandatory with reset button and Life Safety Equipment non -operational alarm from ISMS/SMS . Trained & History data applicable for All the control and monitoring points.</p> <p>Auto/Manual status indication represents the actual operating status of ECS & E&M control system and Services. Individual Auto/Manual selection and indication shall be provided for all equipment and systems. Steady signal indicate successful condition and flashing signal indicate mode operation in progress.</p>						

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 VII - Outline Design Specifications

S.06 FIRE STRATEGY FOR UNDERGROUND

June 2018

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6.1 Fire Strategy Introduction

This fire strategy is introduced to set the basic principles and compliance standards for the Pune Metro Project and thus introduce the equipment and services to be installed within the underground stations to minimize the risk of flashover and maintain a survivable environment in all instances. This strategy shall be taken forward into the technical specifications and demonstrated within the detailed design stages of the Pune Metro project. In the undertaking of this strategy consideration has been given to the environmental constraints that may impact upon how a fire related emergency may effectively be controlled to reduce risk to life, property, business and operation continuity. A prime influencing factor in deciding the fire protection measures to be adopted relates to intervention and the commencement of fire-fighting action. Locations of local authority fire service stations in comparison to the Pune Metro stations identify that current travel distances combined with local traffic conditions would suggest that attendance times may be wide ranging from a few minutes to 45 minutes +.

Pune Metro retains the prime responsibility for ensuring the safety of its customers and staff therefore in anticipation that intervention by the emergency services may reasonably be delayed, this strategy provides for internal resources both active and passive to deal with fire related incidents for a minimum period of 30 minutes. To fulfil this requirement protection measures on occasion exceed the prescriptive code requirements as these codes such as the UK Sub-Surface Regulations & NFPA 130 were designed for use in comparatively different environments with differing resource levels for example; London Underground Limited has an agreed pre-determined attendance with the local authority fire service of 3 appliance within 8 minutes of which 2 appliance must arrive within 5 minutes.

This strategy aims to provide an understanding of the intended equipment, resources and management functions to be introduced and their interaction to form a cohesive and robust system that compliments the achievement of this strategy; to protect life, property and mitigate losses to business through disruption.

6.2 References and Standards

The main basis for assessment of the fire strategy has been to follow the NFPA 130: 2017, as basic principles.

A risk based approach has also been adopted to compliment the NFA 130: 2016, Standard to introduce aspects of business continuity risk and mitigation into the overall fire strategy.

British (BS) and European (EN) standards are referenced for the purpose of compatibility involving fire alarms & detection systems and other associated equipment that shall form part of the main fire loop installations. Additional references are made of the BS & EN Standards in relation to construction materials and fire resistance properties within underground station environments.

6.3 Fire Alarm and Detection

6.3.1 Fire Detection & Installation Category

Several types of detection shall be employed within the stations that are most suitable for the environment, hazard and risk type. Prior to assigning the location of specific detection units, an initial assessment of the overall system specific to coverage requirements was undertaken. Following initial assessment of the fire alarm and

detection system category deemed appropriate for the project and shall meet the requirements of a category L1/P2 for underground stations.

Category L systems are automatic fire detection systems intended for the protection of life. The further subdivision is:

Category L1: detection systems installed throughout all areas of the underground stations.

Category P systems are automatic fire detection systems intended for the protection of property. The category P2 system shall be installed only in defined parts of the building. The objective of a category P2 system is to provide the earliest possible warning of fire so as to minimize the time between ignition and the intervention of fire-fighters; or areas in which the risk to property or business continuity from fire is high for example rooms containing signalling and communications equipment.

6.3.2 Fire Alarm System

The fire alarm and detection system shall conform to BS 5839-1:2002+A2:2008, BS 5839-8:2008, Code of Practice for Fire Detection and Alarms systems & Code of practice for system design, installation, commissioning and maintenance & BS EN 54-2 & BS EN 54-4.

To ensure rapid and unambiguous identification of the fire source an Analogue Addressable Fire Alarm and Detection System shall be installed within underground stations dependent on risk type. Installed detection and fire suppression systems shall relay information on their operating condition to the control panel located within the SCR. Voice alarms, emergency smoke extraction, tunnel ventilation, HVAC (ECS) and power shut down systems shall be fully operable from the SCR and or OCC through a networked and interfaced system.

The System shall be designed to provide 3 stages of alarm namely 1) pre-alarm warning or staff alarm. Early warning systems such as aspirating smoke detection shall report conditions which may (or may not) represent a fire. The purpose of which is to allow investigation thus preventing undue false alarms and evacuation of the stations 2) alert and 3) evacuation.

Mimic panels shall be installed within the SCR to provide topographic representation of the protected premises and their subdivisions, carrying indicating devices for each subdivision such that the indications of the fire alarm system can be rapidly related to the layout of the premises. A further Mimic panel shall be located within a Firefighting shaft for Fire Service use and located next to the main alarm repeater panel together with other emergency control panels for example emergency microphone and extraction/ventilation systems.

All systems that are required to be interfaced within the fire alarm and detection loop shall be fully compatible and validated as a complete operational system by the main Contractor responsible for the main panel and loop design and installation.

6.3.3 Activating Other Safety Measures

In addition to controlling alarm signals, the fire alarm main panel shall be programmed to activate other safety measures to include; disabling lifts, with the exception of escape lifts with fireman's switch designed for the purpose, activating sprinklers if of a pre-action type, activating extinguishing flood systems, operating emergency lighting in the fire escape routes, opening fire dampers, activating voice alarm address announcements, opening of AFC gates, closing smoke and fire doors, shutting down

plants such as AHUs, initiating extraction and tunnel ventilation systems etc.

Fire detection systems shall be used as indicated on the stations alarm system schematic complying with BS 5839-1:2002+A2:2008 and BS 5839-8:2008 and BS EN 54.

1. The following actions will be realized with the necessary command interfaces and by appropriate programming:
 - Audio and Video alarm signals to various spots,
 - Audio and Video alarm signal to the Station Control Room,
 - Firefighting command to the automatic firefighting systems,
 - Audio and Video firefighting pre-alarm and alarm signals inside the areas with automatic firefighting extinguishing,
 - Commands to get the fire dampers open/closed,
 - Commands to get the fans – motorized dampers open/closed,
 - Commands about automatic modes of any nature,
 - Transfer of alarm signals and commands to the BMS/SMS and M & E SCADA System,
 - Transfer of fault alarm and commands to the OCC,
 - Transfer of all the signals through a serial port to the personal computer of the fire detection management system,
 - The Homing of the lifts to the pre-specified level, depending on the alarm kind level.

6.3.4 Optical Smoke Detection

Intelligent optical smoke detectors to BS EN 54-12:2004 shall be installed within all areas to include false ceilings and raised floors of the underground stations not covered by combined detectors or heat detection. Where VESDA aspirating detection and Automatic Flood systems are also installed within the specific rooms of the underground stations; the optical unit shall act as a point detector. All systems whether suppression, detection or alarm shall be fully integrated within the main analogue addressable alarm loop. .

6.3.5 Combined Heat and Smoke Detectors

Intelligent multi sensor detectors shall be installed within Plant rooms as denoted on the fire detection schematic. This type of detector shall use the optical method of smoke detection along with a flat response heat detector.

6.3.6 Linear Cable Heat Detectors

A linear-type heat detecting cable which is able to detect changes in temperature along its length shall be installed within the tunnel and interfaced with the main alarm panel within the SCR and OCC. The cable detector shall be set for two temperature levels, stage 1 to give an alert on a rise in temperature and stage 2 to give a fire signal. Normal operating temperatures within the tunnels shall be investigated from which accurate alert warning and fire level warnings can be programmed. An Escalator Sprinkler Protection system (ESPS) will be provided to all the station escalators to offer protection against fire. A single zone linear heat detection system cable acting as stage 2 fire alert with a linear heat detection fire alarm panel shall be provided duly interfaced and integrated with station fire detection system.

6.3.7 Aspirating Systems

Aspirating Smoke detection of a VESDA type shall be installed, tested and commissioned to BS EN 54-20:2006 and shall be interfaced with the main fire alarm control panel located in the SCR.

Within rooms containing sensitive equipment such as computer rooms, telecommunications and signalling equipment it is important to detect smoke before the outbreak of flaming combustion. The purpose of which being to provide an early alarm for evacuation together with mitigating damage to expensive equipment that may impact on stations operational continuity. In these locations a VESDA aspirating system shall be installed. The Aspirating systems will consist of the following:

- An extremely sensitive detector (approximately 10-200 times more sensitive than a typical point detector) housed in a control unit.
- One or more pipes, drilled at regular intervals, installed throughout the area to be protected and connected to the detector (the holes serve as individual smoke detectors)
- A pump which draws air through the pipes to the detector where it is analyzed for the presence of smoke
- A filter to remove dust particles etc. which may be drawn into the pipes
- Appropriate electronic equipment to indicate the presence of smoke and control the operation of output relays etc.

Aspirating systems have an advantage over other types of fire detection systems in that the pipe-work can be readily positioned within raised floor voids and false ceiling areas. In addition, they are unaffected by high air flows. Unlike point detectors, which wait for smoke to reach them, air is drawn to the detector; therefore they can be used in areas where smoke detection would otherwise prove difficult. The control panels shall be configured to give three levels of response;

Level 1: notify responsible personnel that smoke has been detected

Level 2: switch off air vents and/or switch off power supplies to certain areas to prevent the fire from igniting

Level 3: indicates a general fire alarm condition and signal that a fire has been detected to other systems and communication centers same as point detectors

6.3.8 Alarm Sounders and Visual Alarms

In certain areas of the stations where noise levels are reasonably expected to be high for example, pump rooms, mechanical extraction plant etc. then traditional electronic alarm sounders shall be installed to EN 54-3 to ensure audibility. These sounders shall be supplemented by visual warning devices where ambient noise levels exceed 90 dB (A). To draw attention and alert members of staff who may be present in noisy areas the visual alarm signal shall flash at a rate within the range of 60 to 120 flashes per minute.

Visual warning devices shall also be installed within public areas to alert persons with impaired hearing in the event of a fire situation.

The visual fire alarm devices shall have the following characteristics in order to qualify as being appropriate to the hearing impaired or deaf persons. Visual alarm devices shall be connected to the dedicated fire alarm notification circuit. This circuit can be

activated manually as it acts as the public announcement speakers for the Hearing Impaired.

These key characteristics are identical to the state-of-the-art specification contained in the latest American fire alarm code (NFPA 72, latest edition). These are:

Flash Rate: The flash rate of visual notification are not to exceed two flashes per second (2 Hz) nor be less than one flash every second (1 Hz) throughout the listed voltage range of the device.

Pulse Rate: Maximum pulse duration is to be 0.2 second with a maximum duty cycle of 40 percent.

Pulse Duration: The pulse duration is to be defined as the time interval between initial and final points of 10 percent of maximum signal.

Effective Intensity: Lights used for fire alarm notification only or to signal the intent for complete evacuation shall be clear or nominal white and shall not exceed 1000 cd (effective intensity).

Lenses: Lights used to signal occupants to seek information or instructions shall be clear, nominal white or other colour as required by the emergency plan and the authority having jurisdiction for the area or building and/or the metro Operator.

Synchronization: The cumulative effect of seeing multiple flashing strobes in the field of view shall be of acceptable nature to the vulnerable persons to photosensitive epilepsy. An example of this would be an individual standing at the cross-point of an “L” shaped corridor that contains multiple strobes. During an alarm or test of a system, the person could be exposed to a cumulative flash rate that might increase the probability of seizure and photosensitive response. Although aggregate strobe flash rates in a fire system and their relationship to those persons with photosensitive epilepsy are not in any current law or standard, it is an issue that should be addressed with diligence when installing and/or upgrading fire systems.

Photometrics: The light output is required to comply with the polar dispersion requirements of ANSI/UL 1971, Standard for Signalling Devices for the Hearing Impaired, or equivalent.

6.3.9 Addressable Manual Call Points

Addressable Manual call points shall be manufactured and installed to BS EN 54-11:2001. The manual call point is a device to enable staff and members of the public to raise the alarm, in the event of a fire, by simply breaking a frangible element and thus activating the alarm system. The following shall be applied for the correct siting with the underground stations and tunnel environment:

- Operation of a breakglass call point shall initiate an alarm within 3 seconds of operation within the SCR and repeated within the OCC.
- Breakglass call points shall be located on exit routes and, in particular, on the floor landings or staircases and at all exits to the open air.

- Breakglass call points shall be located within the stations so that no person need travel more than 45 m from any position within the premises in order to operate one.
- Breakglass call points shall be located within the tunnel between emergency telephone points so that no person need travel more than 125 m from any position within the tunnel in order to raise an alarm.
- Call points should be located at a height of 1.4 m above the floor at easily accessible, well illuminated and conspicuous positions, free from obstructions.
- The method of operation of all call points in an installation shall be identical unless there is a particular reason for differentiation e.g. within public areas and tunnel where the call point shall be additionally protected from inadvertent operation by a flanged plastic cover.

In the event of manual call point operation within the public area immediate investigation shall be undertaken by station staff (through a pre-determined coded PA Message) rather than immediate evacuation. Investigation shall have an agreed time limit of three minutes which if exceeded shall initiate evacuation of the station with the following exceptions; (1) activation of an automatic detector in the vicinity of an MCP actuation, as fire conditions have essentially been confirmed and (2) operation of a manual call point (MCP) within staff areas which shall initiate immediate evacuation of the station.

6.3.10 Pre-Movement Time of the First Few Occupants

The time at which the first few occupants start to move towards an exit is particularly important because the evacuation process does not begin until this time is reached. The duration of the pre-movement stage varies upon several factors such as, occupancy type, the nature of the warning system and the implementation of the emergency management procedures.

In situations where pre-movement times are required to be as short as practicable a voice alarm significantly reduces the pre-movement time in settings where the occupants are unfamiliar with the emergency procedures.

6.3.11 Public Address and Voice Alarm System

An emergency voice alarm system shall be installed to meet the requirements of the following standards, BS 5839-9:2003, BS 5839-8:2008, BS EN 54-24:2008, BS EN 60849, BS EN 54-3:2001 Annex C, BS EN 54-16:2008 and in accordance with BS EN 54-4, requiring that voice alarm systems power supply equipment has two power supplies, a main (normal) power supply and a standby power supply.

Each station will be provided with a V1/V2 PA/VA system which shall be fully integrated with the main analogue addressable alarm system within the Station Control Room (SCR) and networked to the operational control centre (OCC). The system shall incorporate both a live and pre-recorded voice broadcast facility, controllable from both the SCR and the OCC control rooms. To maintain the integrity of the fire alarm interface, wiring shall be arranged such that a single fault on the wiring does not disable the interface between the fire alarm and detection system and the public address / voice alarm system.

Unlike an evacuation broadcast, which is intended to be understood and acted upon by all the building occupants, a coded alert broadcast system shall also be employed intended to be interpreted by certain members of the staff as a warning of a possible

fire condition and the need to investigate a specific room. Coded alert broadcasts shall be adopted in circumstances where an early warning system has operated such as VESDA but prior to operation of a secondary point detector and where a manual call point has been activated within a public area. In these instances a member of staff would be required to investigate within a pre-determined time (To be agreed with Local Fire Service/relevant Authority) and report to the SCR of actual conditions e.g. fire, fault or safe. Failure to acknowledge the alert/warning alarm within the programmed timeframe or actuation of a further detector shall immediately initiate the stations evacuation sequence.

The format of the coded messages shall be agreed with the Employer/Engineer.

The PA/VA Emergency microphones shall be located near to telecommunications workstation within the SCR for trained staff use and additional PA/VA microphones specifically for Fire Service use shall be located within one Fire fighting shaft next to the VA/PA repeater alarm panel at all underground stations. The emergency microphone(s) shall provide for an all zone broadcast and in the event of an emergency the emergency microphones shall override all other broadcasts.

To further assist with fire fighting communications a leaky feeder system providing TETRA radio coverage will also be provided in all underground stations areas and within the tunnel. The Fire Service will also be provided with TETRA handsets to enable full communication with station staff from the tunnel environments.

6.4 Means of Escape

6.4.1 Objectives of Escape Design

The objectives of the escape design for the Pune Metro Project is to ensure the stations be designed and constructed so that there are appropriate provisions for the early warning of fire that means of escape routes can be safely and effectively used at all material times without the need for outside assistance except where particular assistance may be necessary, e.g. for people with disabilities whereby management arrangements shall be provided for such assistance without reliance on the fire brigade, whose arrival may be delayed.

Basic to the philosophy of means of escape design is that it shall be possible to turn one's back on the fire and to move away from it. This is achieved by providing a minimum of two escape routes that are well separated either spatially or by fire resisting construction. To prevent public access into routes that do not lead to an emergency exit route, all doors which do not form part of, or give access to, the means of escape shall be kept locked at all times when the part of the premises to which the door gives access is neither in use by any person who is at work nor available for use by members of the public.

6.4.2 Travel Distances

The means of escape design for underground stations will be based on compliance with NFPA 130 :2016 , and NFPA 101 codes with a comparative analysis made relative to BS 9999:2009 standard that requires that the escape routes capacity shall facilitate evacuation in the event that an escape route becomes unavailable for use.

In the underground stations, the concourse level is deemed as a point of safety due to the ventilation and engineered systems that shall be installed. These engineered systems shall ensure that the concourse remains a smoke free environment in the

event of a fire involving a train, technical room, passenger luggage or waste.

6.4.3 Exit Routes and Sizing

6.4.3.1 Underground Station

Exit routes within the underground stations are provided at two levels, level 1) from platform to concourse (in case of 3 level stations, platform to Mezzanine and then to Concourse) and level 2) from concourse to street level. The indicative Employer's drawings of underground stations show the indicative locations of the routes. The escape route provision for underground stations consists of stairways and escalators and 2 emergency (protected) escape stairs located at either end of the platform. Escape routes from concourse to street level consists of stairways to street level. Independent of the escape routes designed for public use one fire-fighting staircase is available from street level to SCR at concourse level. This particular staircase is designed for fire-service personnel. In the event of an evacuation all normal access/egress stairs and escalators are designed for use as emergency exit routes. An escape lift is also available from platform and concourse levels operable using Fireman's switch, however this provision is not included within exit route and occupancy calculations. If the escalators are to be used for evacuation (i.e. escalator operation reversed in the direction of evacuation) then as per clause 5.5.6.3.2.6. of NFPA 130: 2016, code, one escalator at each level shall be considered as being out of service.

6.4.3.2 Tunnel Exits

The trains shall be designed to permit end evacuation (from the train's cab to the track bed). Exit routes from the tunnel are via the track bed (between the two rails of the track) from which passengers shall enter a protected Cross-passage (to be provided complying the provisions of NFPA 130: 2016) which (if provided) shall be located at every 244 m (the maximum distance) from a station (platform end, where emergency escape stair is located) or portal access point. Egress from the tunnel to street level is available through station accesses and tunnel portals. In long tunnel sections(tunnels between two consecutive stations) where a mid-ventilation shaft is provided to ensure presence of only one train in one ventilation section , an emergency stair direct to street level is to be provided within the shaft and located within the 2 Hr protected cross passage. Tunnel cross-passages shall be protected with jet fans to prevent the ingress of smoke when doors are opened.

6.4.4 Exit Capacity & Evacuation Timing

The exit sizing strategy, exit capacity and design width calculations shall be based on the stipulations contained in the Outline Design Specifications for Architectural Works (Section VII, Sub-Division 4 of the tender documents).

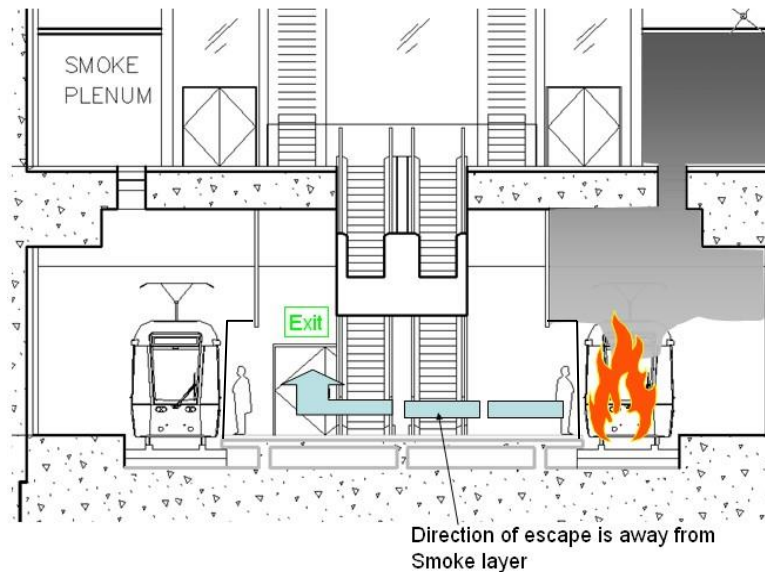
The objective of the escape route design is to successfully achieve escape from the platform within 4 minutes and to reach a place of safety within 6 minutes as per the NFPA 130: 2016 code. The strategy shall also consider the effect on evacuation timings should an escape route become unavailable for use due to a fire on the platform or Mezzanine (where applicable) or concourse. In these instances trains would either not stop at the incident station or alternatively be moved, therefore the occupancy levels would be restricted to platform load alone. This then would represent an escape route capacity capable of evacuating the platform within the stipulated time for the underground stations.

In conclusion station designs shall meet the NFPA 130: 2016 requirement to enable reaching a point of safety within 6 minutes and exit from the platform level within 4 minutes.

6.4.5 Smoke Extraction System at Tunnels and Stations

The design shall be with an extract system above each track which will prevent smoke spread from a train on fire to the platform areas. Each track at platform level shall be divided into a smoke reservoir that will run the length of the station and platform. The extraction system and plenum ducting shall be located within the reservoir directly above the track location. The siting of the smoke exhaust at street level shall be subject to evaluation of risk affecting the clean air intake. The efficiency of the emergency extraction and ventilation and the sizing of the installation shall be determined during the detailed design of stations utilizing Computational Fluid Dynamics CFD and SES modelling of the twin tunnels and the station environments including special configurations at terminal stations and within cross-overs.

The smoke reservoir will ensure, in the event of a train fire that passengers shall effectively step onto the platform and into a smoke free environment. The addition of full height Platform Screen Doors (PSD) will provide a further advantage in limiting the possibility of smoke spreading to the platform area. The extraction system must remain fully operable till the fire is extinguished. The emergency ventilation can be controlled from either the SCR or the OCR (OCC).



Indicative Figure

Smoke extraction shall also be provided at platform & concourse (and at Mezzanine level, where applicable) areas within the underground stations to provide smoke extraction up to a 2 MW fire. Combustible materials on the platform & concourse levels (and also at Mezzanine level, where applicable) shall be designed to be minimal and further protected by automatic suppression systems, therefore the remaining risk of fire is predominantly passenger based. It is expected that the largest passenger based combustible that could enter the station would be a large suitcase. Although ignition is unlikely and would probably be associated with a malicious act, fire tests conducted on suitcases generally reveal a Heat Release Rate of approximately 2 MW with a

resultant smoke plume that is capable of obscuring nearby exit routes, hence the provision of extraction shall be required. The fire in this instance would be readily extinguished by station staff using either the provided hose-reels or fire extinguishers.

6.4.6 Smoke Extraction System

The design of the proposed Metro carriages will ensure that this design fire size is not exceeded. This will be demonstrated through the Rolling stock supplier appraisal and test results. The compliance of the train to NFPA 130 with regard to cable toxicity and EN 45545 will be sought in order to make sure that the propagation of a fire will be reasonably slow and will stay within the proposed fire load. The Fire behavior of all components will be checked in respect to the classification for the non toxicity of the smoke.

The design of the smoke extraction has to be capable to cope with the actual fire load of a train. The evaluated fire load may be between a range of 5 MW to 40 MW as this is dependent on the construction materials used within the train. The actual loading shall be confirmed by the supplier during detailed design however in all respects this must comply with the NFPA 130 code for rolling stock. Because of the linear shape of the train the fire load does not affect the train in its full length immediately therefore a subjective fire load of minimum 10 MW shall be considered for extraction purposes.

6.4.7 Escape Lifts

A Lift of an escape type shall be provided at each level within the underground stations. The lifts shall be provided with Fireman's switch. Upon actuation of an alarm the lift shall ground to the designated level, and by operating the Fireman's switch the lift can be used for the evacuation of mobility impaired passengers. The lifts when under an alarm conditions shall and can only be operated by a member of staff. An evacuation lift, where provided, should always be available for evacuation purposes. Wherever practicable it needs to be a lift used routinely as a passenger lift and not one used solely for evacuation or occasionally as a lift for transporting goods. It should be designed and installed in accordance with the relevant provisions in BS 8300, BS EN 81-1 or BS EN 81-2, and BS EN 81-70.

6.4.8 Escalators

Upon receiving an alarm, the alarm control panel shall stop all escalator movements including the escalators travelling in the direction of escape. Escalators travelling in the direction of escape will come to a slow stop until clarified that passengers are not being taken into a fire situation e.g. from underground platform to concourse; upon confirmation that it is safe to do so the escalators in the direction of escape shall be restarted manually by station staff. Visual aids such as flashing lights and designated sound shall be used to warn passengers of a restart which shall be slow and without jerking.

6.4.9 Emergency Lighting

Emergency lighting will be provided in accordance with BS 5266-1:2005 including the tunnels. Backup power shall be made available to ensure the continuous operation of 4 hours. Emergency lighting is provided to ensure that during failure of a building's main lighting system there remains a level of artificial illumination which will allow safe and unambiguous egress from the stations and tunnels. A minimum of 25-50 lux is to be maintained all along the evacuation route as specified in the Outline Design

Specifications.

- at each exit door
- near intersections of corridors
- near each staircase so that each flight of stairs receives direct light
- near each change in direction (other than on a staircase)
- near any change in floor level
- near fire-fighting equipment
- near each fire alarm call point
- near first aid equipment
- To illuminate exit and safety signs and as required by the enforcing authority.

In the above list 'near' is taken to be within 2 m, measured horizontally. Additional escape lighting shall be installed at other locations including the following:

- Blue-Light stations located at cross-passage (and/or other suitable locations) locations and entrances to the stations from the tunnels
- Lift cars; although not considered as part of the escape route, emergency lighting is required since failure of the normal lighting could result in persons being confined in a small dark space for an indefinite period
- Toilets with areas exceeding 8 m²
- External areas in the immediate vicinity of exits.
- Tunnel lights are to be provided within the tunnels and shall be spaced at not more than 15 meters interval and with minimum specified illumination level. 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.
- Illuminated Tunnel Evacuation Signage System (ITESS) and Cross Passage Evacuation Signage (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.

6.4.10 Signage

All emergency exit and directional signage shall conform to the following requirements BS 5499-10:2006, BS 5499-5:2002, BS 5499-6:2002, BS 5499-11:2002, BS 5499-4:2000, and BS 5499-2:1986

Exits are marked with pictographic exit signs depicting a running man. These signs shall be located so that they are not obscured by the building contents. BS 5499 deals with the design and construction of fire safety signs. In certain circumstances, e.g. where direct line of sight of an exit is not possible and doubt may exist as to its position, a direction sign (or series of signs) shall be provided. There are also requirements for other notices, e.g. 'FIRE DOOR — KEEP SHUT' on doors etc.

6.5 Structural

6.5.1 Compartmentation

The division of the areas into fire compartments is intended to limit fire spread. Two

main areas have been determined within the stations; the public area [platforms, concourse, Mezzanine (where applicable) and staircases accessible by the passengers] and the technical areas (technical and operation rooms, only accessible by registered staff).

Fire compartmentation is only suitable in technical areas, it consists of a station section or a section of another structure separated from the adjacent areas by walls, floors and doors. All the openings are in a position to be blocked in a fire incident, e.g. the air ducts will be blocked by fire dampers.

Fire resistance periods are selected for specific areas, according to the size of the fire received from a neighboring area and the required protection rate according to the specifications of the NFPA 130 Standard, as shown in the following table. Fire compartmentation is also required to be provided along cable routings or for other material likely to generate smoke or fire.

	Areas / Rooms	Fire Rate (Minutes)
1	Bearing structure elements surrounding fire compartments and fire resistant escape corridors;	120
2	Doors, dampers, fire air duct in walls surrounding fire compartments and fire resistant escape corridors;	90
3	Electrical rooms.	120
4	Doors, air duct fire dampers of the areas, as in Item 3 above, if incorporated in the walls surrounding the fire compartments.	120
5	Non-bearing partition walls of staff store rooms except rooms.	60
6	Doors within non-bearing partition walls of rooms, as in Item 5 above.	60
7	Non bearing partition walls in store rooms, plant rooms and corridors in non public areas	120
8	Doors within non-bearing partition walls in rooms, as in Item 7 above.	90

Any room containing an electricity generator, transformer, switchgear, or machinery for operating an escalator, passenger conveyor or lift, or storage shall be separated from other parts of the station by a two hour fire resisting construction. A two hour fire separation between public and staff areas shall also be maintained as per NFPA 130.

Fire doors fitted with both intumescent and smoke seals shall be installed to all compartmented areas to BS 476 Parts 11 and 22 with a 1 ½ hour fire rating. Where fire doors are not required to be held open these shall be permanently locked for example service risers and signed as such. Fire doors in constant use for example by members of staff within staff only areas shall be fitted with automatic self closures. Fire doors on exit routes within the public areas that are required to be held open shall be automatic in operation and linked to the fire alarm system however, closure delays with manual override facility is to be installed to prevent hindrance during initial evacuation.

Fire fighting shafts, emergency exit staircases and tunnel cross-passages will be enclosed in a construction achieving a 2hr fire resistance.

At the points where ventilation air ducts enter the fire compartment perimeters, fire dampers will be installed with equal fire resistance so as to prevent fire and smoke from spreading into other fire compartments. All the openings intended for cables and pipes etc. between two successive fire compartments (adjoining each other) will be fire Stopped.

Smoke control is achieved with the use of the ventilation system, which shall be designed in such a way as to extract smoke upon a fire incident, as described in detail in the relevant specification of the ventilation and exhaust smoke system.

All the openings, including ventilation air ducts and passageways, between the Metro limits and neighboring structures, where there are free access, shall be protected by fire-rated doors, fire-rated grilles, fire dampers etc., as required in each individual case.

6.5.2 Linings

All surface linings will achieve Class 0 (national class) or Class B – S3,d2 (European class) surface spread of flame in accordance with IBC. Materials will also be compliant with the UK Fire Precautions (Sub-surface Railway Stations) Regulations 2009 and or material/product classified as Class A2-s3, d2 or better in accordance with BS EN 13501-1:2002 Fire classification of construction products and building elements, Part 1 – Classification using data from reaction to fire tests.

6.5.3 Concealed Spaces

Where cavities or voids exist, cavity barriers will be provided to ensure that undivided voids do not exceed 20m in either direction in accordance with International Building Code (IBC).

6.6 Fire Suppression & Fire-Fighting Facilities

6.6.1 Sprinklers, Water-mist & deluge

An automatic sprinkler system will be installed in each station and will comprise fire service inlets, pump sets, pump controls, sprinkler heads, pipe work and associated valves, flow switches, pressure switches, water motor alarm gong, water tank and level switches. Note that certain devices are common to the standpipe system such as fire water tanks, pump sets, and pump controls (mainly located in the Fire Pumping Room).

The sprinkler system will be installed to the OHIII class standard of the BS 5306 Part 2. Water will be fed from the fire tanks through fire fighting pumps.

Water supply for the sprinkler system will be taken from the fire water tanks with a central splitter dedicated to the sprinkler system. The tank shall be fitted with high/low level alarm detection, which shall be monitored by the Station Fire Alarm Panel and Repeater Panel.

The following areas have been identified for installation of automatic fire suppression systems of water mist or sprinkler type.

- All storage rooms
- Rooms that may be used for storing refuse pending its disposal
- Staff canteens and locker rooms

- Diesel Generator rooms; should a diesel generator be located with the open and a risk exists that the products of combustion may impede escape from any of the stations exits then these generators shall be protected with a fast response deluge system.
- Escalator machinery space (Type dependent on escalator); in this instance sprinkler systems may be replaced with another type of automatic suppression such as 227ea however this shall be based upon the provision of a Very Early Smoke Detection system (VESDA), point detection and interface with the main fire alarm panel.

The Escalator Sprinkler Protection system shall be provided to all the station escalators to offer protection against fire and shall comprise;

- A multi-zone linear heat detection system cable acting as stage 1 fire alert with a linear heat detection fire alarm panel,
- A single zone linear heat detection system cable acting as stage 2 fire alert with a linear heat detection fire alarm panel,
- A multi-jet control actuation system from the ESPS fire alarm panel.

The system is designed for the protection of escalator steel truss. The area considered for protection will comprise of the upper and lower tread areas within the truss work down the length of the zone plus a percentage of the open sides (25%). Open side wall sprinkler heads will be used and controlled by multiple jet controllers. The system shall be installed and tested to BS 7273-Parts 5 & 3 Code of practice for the operation of fire protection measures and BS EN 12845:2004+Amendment 2:2009 Fixed fire-fighting systems; automatic sprinkler systems. Design, installation and maintenance

6.6.2 Automatic Clean Gas Protection

All automatic clean gas suppression systems shall be installed to BS EN 15004 & BS EN 10294 and fully integrated into the main analogue addressable alarm panel. A combination of total flood or localized panel flood systems shall be employed within the following areas; generators, transformers, switchgear, UPS and DC Battery System, signalling and communications equipment rooms as fire within these sensitive areas may cause severe disruption to normal station operation for extended periods thus affecting business continuity. The type of suppression system shall be appropriate for the type of risk and equipment within the room that it is covering for example 227ea or alternative clean agent flood systems for the sensitive equipment type and fire rating class.

Automatic fire suppression systems shall be fully integrated with other forms of fire alarm and detection equipment installed such as smoke detection units etc. The automatic flood systems shall be actuated upon the operation of two smoke detectors such as the VESDA and an optical smoke point detector. This dual alarm operation reduces the risk of false alarms and inadvertent gas discharge. Discharge time shall be within 8-10 seconds.

Upon actuation of a single smoke detector, probably a VESDA unit as this provides very early warning; an alert alarm signal shall be initiated. The alert signal shall then initiate staff investigation within a pre-determined time (3 minutes) however where a second alarm is confirmed the system shall operate. A system for manual operation (Within or externally to the room) shall also be provided should investigation identify smoke conditions prior to actuation of a second detector head.

6.6.3 Fire Fighting Shafts

Fire fighting Shafts shall be provided in all underground stations. The shaft will be designed in accordance with BS 9999:2008 with a two hour fire resistance and consist of a fire fighting stair, lobby and wet fire main. The shaft will be pressurized in accordance with BS EN 12101-6:2005 Smoke and heat control systems; Specification for pressure differential systems. The fire-fighting shafts shall be located at each end of the platform and concourse levels and accommodate a disabled refuge as per BS EN 10201-6 and BS 5839-9:2003. CCTV and a call point linking the refuge with the SCR shall be installed for disabled persons use.

6.6.4 Wet Fire-Fighting Main

A complete fire hydrant and hose reel system will be installed in the station. The system will include fire service breaching inlets, fire pump sets, water tank with level switches, all necessary valves, pipe work, hydrants, hose reels, pump motors with starter panels and all controls. An isolating valve will be installed to control the hydrant mains (). The valve will be both lockable and addressable.

A tunnel fire fighting system will be provided throughout the entire length of the tunnel. Water supply to the system will be from the station fire hydrant and hose reel system. An isolating valve will be installed at each station to control the tunnel wet fire main. The valve will be lockable and addressable.

The wet fire-fighting main with twin fire service outlets shall be installed at each landing level [concourse, Mezzanine (where applicable) and platform].

Within the underground stations the fire main shall be located within the fire-fighting shafts/protected lobby as per BS 9999:2008. The outlet coupling shall be of and instantaneous type. The 150mm minimum diameter wet fire main shall be extended to the entire length of the tunnel with fire service outlets located every 100 meters apart.

The fire-fighting mains systems will comply with BS 9990:2006 Code of practice for non-automatic fire fighting systems in buildings. The fire mains shall be pressurized to achieve 3.5 Bar at the end of twinned (Dividing breach) 45mm fire service hose with branch at a length of 100 meters. This pressure will be required to ensure an effective fire-fighting can be maintained using an AWG fire-fighting Branch-pipe.

Access for positioning of fire appliance to connect to inlets for supplementing the stations internal water supply tanks for underground stations shall be maintained at the ground level.

6.6.5 Hose Reels

Hose reels shall be provided within underground stations to ensure that all floor areas within the stations are reachable by the water jet. The provision and installation of the fire-fighting hose reels shall be in accordance with BS EN 671-1, BS 5306-1, BS 5306-3, BS 5306-8 and BS EN 3-7.

6.6.6 Portable Fire Extinguishers

Fire Extinguishers shall be provided and installed as per BS EN 3-8:2006, BS 5306-3:2009 Code of practice for Fire extinguishing installations and equipment on premises - Commissioning and maintenance of portable fire extinguishers; and BS 5306-8:2000 Code of practice for Fire extinguishing installations and equipment on premises; Selection and installation of portable fire extinguishers. In general the minimum requirements shall be as follows:

Public Areas	1 piece per F.C. /F.S. Pa, 6kg
Station Control Room	2 pieces, CO ₂ type, of 6kg capacity
Ticket Office	2 pieces, CO ₂ type, of 6kg capacity
Substations	2 pieces, CO ₂ type, of 6kg capacity
Pump Rooms	2 pieces, CO ₂ type, of 6kg capacity
Ventilation Rooms	2 pieces, CO ₂ type, of 6kg capacity
Lift Plant Rooms	2 pieces, CO ₂ type, of 6kg capacity
Other Equipment Rooms	2 pieces, CO ₂ type, of 6kg capacity
Technical Corridors	2 pieces, CO ₂ type, of 6kg capacity
Staff Areas	as required by the Fire Brigade / relevant authority.

6.6.7 Staff Fire-Fighting Equipment

Fire fighting equipment shall be provided within the stations and tunnels for trained staff consisting of;

Within 1 fire-fighting shaft (Underground Station)

- 2 Self contained breathing apparatus sets (SCBA) with Atmosphere gauge, Talley, Distress Signal Unit (DSU) and Lifeline. The cylinders shall be of 1800 litres capacity and charged to 204 Bar with 2 spare cylinders.
- 1 Breathing apparatus entry control board (Clock, whistle, china-graph)
- 3 fire-fighters protective clothing including, helmet, flash hood, boots and gloves
- 3 torches

Within both fire-fighting shafts (Underground Station)

- 4 lengths of 45 mm diameter fire-fighting hose with instantaneous couplings
- 1 AWG or equivalent sized nozzle fire-fighting branch-pipe.

.Within the Tunnel Cross-passages (and/or at other suitable locations)

- 4 lengths of 45 mm diameter fire-fighting hose with instantaneous couplings
- 1 AWG or equivalent sized nozzle fire-fighting branch-pipe

The staff fire-fighting teams shall be expected to don protective wear and SCBA prior to entering the tunnel environment.

6.7 Instruction & Training

A staff training manual shall be produced detailing the stations emergency procedures and training syllabus for each level of staff in relation to position. The areas covered shall include:

- Means of escape in case of fire. This would require that the members of staff know the means of escape from the relevant areas of the station to which they have access. If, for any reason, certain escape routes are not available e.g. due to out-of-hours construction or maintenance work, the members of staff who are within the station should be made aware of the alternative routes that are available
- Action to be taken in the event of a fire. This would ensure that the members of staff are fully aware of the actions that they would be expected to take in the event of a fire. This would include any assistance that they need to give in evacuating the station, or any other actions that might be necessary
- The location and use of fire fighting equipment. This would ensure that the

members of staff know the location, type and usage of all fire fighting equipment that they might use in the areas of the station to which they have access. It would specifically include portable extinguishers, but need not include equipment that is solely for the use of fire fighters (unless part of that member of staff's responsibility includes fire fighting).

- The location and operation of the means for giving warning of fire and actions to be taken in the event of a pre-alarm

Station managers/relevant staff shall receive the basic training as well as a more detailed training programme. The detailed training shall include the procedures based upon fire type and location that the station manager/relevant staff would need to carry out in the event of an evacuation of the station, which would include the arrangements and procedures:

- to supervise an evacuation, including instructions and coordination of all staff within the station
- Initiating the stations emergency fire-fighting teams
- for calling the fire and rescue services
- for meeting the fire fighters when they arrive and ensuring that they are given all relevant information in order for them to deal with the incident
- for preventing members of the public from entering or re-entering the premises
- for advising members of the public on what action they should take if there is a fire (including the procedures for identifying and assisting in the evacuation of any people with disabilities)
- for ensuring that the means of escape is immediately available
- If the design of the station is such that adjacent areas (such as tunnels) evacuate through the station, the training should include the relevant procedures for these eventualities.

A fire drill must be held for staff every six months (maximum) to refresh them in action to be taken if there is a fire. Fire drills shall be scheduled to ensure at least one third of staff have attended one in the preceding six months. Fire drills must be held when members of the public have access to the premises i.e. when the stations are open in order to increase the realism of the drills. However, genuine evacuations e.g. due either to actual incidents or false alarms can be used in the place of a drill, as long as information on the evacuation is recorded and debriefed afterwards (in the same way as would be required for an evacuation drill).

Specialist training courses in fire-fighting techniques and SCBA usage must be undertaken for all persons who are required to undertake such duties such as the designated emergency team members. These members shall be made up from the normal station personnel but in the event of a fire shall undertake the role of a fire-fighting team. The minimum of 3 emergency team members must be available within each station for each shift.

6.8 Fire Scenarios

The tunnels themselves are virtually free of combustible equipment and thus it can be said that a minimal fire load exists as such in the tunnel as the majority of equipment is contained within the stations, and not in tunnels themselves except for cables specified for their resistance and the non toxicity of the combustion fumes. Cross

passages will contain a few electrical items forming part of the surveillance and detection systems such as fire detection sensors and CCTV to enable correct appraisal of any alarm reported to the SCR or OCC.

The following sections are intended to provide an understanding of how the station design, active and passive engineered systems work together in a range of incident types.

6.8.1 Fire Onboard a Train

Heat detection facilities onboard the train shall activate a warning system and alert the driver of a potential overheat in the onboard systems and equipment. This system is designed to alert the driver in situations where passengers may not be onboard or at times where occupancy may be low due to time of day. The automatic system is supplemented by an intercom facility whereby the passengers can alert the train operator directly in the case of visual fire or smoke conditions. Intercom facilities shall be installed in all cars.

In all cases, a fire onboard the train will be more effectively treated inside a station therefore the procedure in case of activation of the fire alarm onboard the train shall be to immediately inform the OCC and continue the journey until the next station stop. The OCC shall initiate the stations emergency evacuation plan and associated systems including, smoke extraction (underground stations) voice alarm, mobilisation of emergency fire teams and informing the emergency services (Local Fire Service/relevant authorities).

In case of immobilisation of the train within the tunnel (Fire affecting safety function thus stopping the train), the driver will report to the OCC and confirm the current position and incident situation. Should power failure occur location information shall be available on the marker boards/signage fixed on the tunnel lining. The operator shall act to contain/extinguish any fire with the available fire equipment if safe to do so i.e. no risk to himself/herself or passengers. The OCC shall advise how to proceed with the evacuation of the train passengers to the nearest available cross passage/station to the train. This decision shall be based upon the location of the onboard fire.

Evacuation of the train shall be via the emergency egress doors located in the front and rear cab of the train. The egress doors lead directly to the track bed (between the two rails of the track). The train operator shall assist persons that may be mobility impaired.

On reaching the cross passage (or station directly), passengers will be able to access the adjacent tube and designated point of safety from which a final exit can be reached (Ventilation shaft, station or portal). To ensure passenger and emergency crew safety within the second tube during evacuation the OCC, through the train control system functions shall stop all traffic in both directions during the alarm period.

According to the location of the fire onboard the train and position of the cross passage/station, directional emergency ventilation will be activated to maintain critical air velocity within the tunnel (to be determined during detailed design CFD and SES modelling) to assist passenger evacuation through maintaining a smoke free environment. As the train will be stationary the piston effect will not be applicable thus allowing directional smoke control through activation of the ventilation system, in effect the smoke shall be forced in the opposite direction to the nominated escape route. Activation of the ventilation shall be available within the SCR and from the OCC

emergency desk. As the ventilation system shall be designed to be reversible & operable from the SCR/ OCC it shall further assist the emergency services in gaining access to the seat of the fire quickly and without enduring unnecessarily harsh conditions from the effects of the fire. During Evacuation, the traction power supply in the tunnel will be switched off.

6.8.2 Fire within a Station (Train Born)

Upon receiving an alarm call from the Train operator, the SCR and or OCC shall activate the ventilation system to manage the smoke within the stop and initiate the station full evacuation plan including activating the voice alarm system, emergency smoke extraction, AFC Gates opened, closure of vent ducts below platform, initiate fire teams and check call to the fire services. The OCC will stop operation of trains during the alarm through the train control system functions. The emergency smoke extraction system shall be designed to withstand the temperatures expected and provide extraction for a minimum period of 2 hours.

Upon reaching a station the train operator will proceed with the evacuation of the train and assist in directing the remaining passengers located at platform level to the nearest available escape routes leading to the designated point of safety namely the concourse level. Persons with impaired mobility shall be directed to refuge areas within the protected fire-fighting shaft and fire escape stairs located at either end of the platform (underground) whereby they shall await further assistance from emergency teams. In addition to the refuge areas within the underground stations, all stations shall be provided with a lift specifically designed for escape purposes. This lift shall be operated only under the control of station staff.

Emergency teams shall where safe to do so (dependant on if the fire has spread from its point of origin, smoke conditions, access etc.) commence fire-fighting action with the available fire-fighting equipment such as portable fire extinguishers/hoses and branches until the arrival of the emergency services who shall then take ultimate control of the incident.

6.8.3 Fire within a Station (Technical Room)

Technical rooms are all monitored by very early smoke detection apparatus (VESDA), optical smoke point detection and protected by automatic gas suppression systems such as FM200. Activation of a VESDA or optical head shall initiate the alarm in the SCR and OCC.

As the technical rooms are available with VESDA and automatic fire suppression, immediate evacuation upon a single actuation will not be required but rather initiate staff investigation as detailed in the following paragraph. The automatic flood system shall operate automatically in the event that a fire is confirmed on the actuation of an optical detector; alternatively, the flood system can be operated manually should the need arise. The pre-alarm investigation reduces the risk of false alarms and evacuation disruptions. Evacuation shall be initiated immediately following multiple detector head actuation and/or manual call point operation within this staff only restricted area.

Upon activation of an alarm within a technical room, the SCR will take the lead in confirming the alarm. The specific room shall be investigated by a member of staff to confirm the current condition; this investigation shall be initiated through a Coded PA Message. A pre-determined time limit to be agreed by Local Fire and Rescue

Service/relevant authority shall be programmed within the Main Fire Alarm for which early warning investigation must be carried out; failure to confirm the area safe to the SCR within the time limit the fire alarm system shall automatically initiate the station evacuation sequence including specific room control function e.g. plant shutdown etc.

The OCC will stop operation of trains during the alarm through the train control system functions and liaise with Local Fire Brigade/relevant authority.

6.8.4 Fire within a Station (Non Public Area)

All non public areas are protected with automatic detection and or automatic suppression systems such as sprinklers. Actuation of a single head would initiate an investigation as described previously however multiple head would initiate station evacuation. In the event of manual call point operation within a non public area this shall initiate immediate evacuation of the station as fire conditions have essentially been confirmed by a member of staff.

6.8.5 Fire within a Station (Public Area)

In the event of manual call point operation within the public area immediate investigation shall be undertaken by station staff (through a pre-determined coded PA Message) rather than immediate evacuation. Investigation shall have an agreed time limit of for example; three minutes which if exceeded shall initiate evacuation of the station with the following exceptions; (1) activation of an automatic detector in the area of an MCP actuation, as fire conditions have essentially been confirmed.

Smoke extraction shall also be provided at platform & concourse (and at Mezzanine level, where applicable) areas within the underground stations to provide smoke extraction up to a 2 MW fire. Combustible materials on the platform & concourse (and at Mezzanine level, where applicable) levels are designed to be minimal and further protected by automatic suppression systems, therefore the remaining risk of fire is predominantly passenger based. It is expected that the largest passenger based combustible that could enter the station would be a large suitcase. Although ignition is unlikely and would probably be associated with a malicious act, fire tests conducted on suitcases generally reveal a Heat Release Rate of approximately 2 MW with a resultant smoke plume that is capable of obscuring nearby exit routes, hence the provision of extraction shall be made. The fire in this instance would be readily extinguished by station staff using either the provided hose-reels or fire extinguishers.

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 VII - Outline Design Specifications

S.07 General Site Planning and Design

June 2018

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7.1 General

7.1.1 Purpose and Scope

The purpose of this Section is to include other criteria and requirements not included elsewhere and necessary for the full development of the station areas.

7.1.2 Statutory Approvals

- (1) The Contractor shall make all applications to the necessary statutory authorities, etc (including Heritage Committee, wherever required) constituted by the Govt. of Maharashtra or Govt. of India for necessary approvals of the structure. All drawings and documents submitted for approval shall be those of the Contractor, who shall prepare all materials in the format required by the concerned authorities/agencies to grant the necessary approvals.
- (2) Three dimensional 1:200 scale models of the stations shall be provided together with computer generated perspective views in colour and sample boards of the proposed architectural finishes, if required by the Employer or Engineer.

7.1.3 Security Requirements

- (1) The Permanent Works shall be sufficiently robust to restrict, to acceptable levels, their vulnerability to accidental or malicious damage.
- (2) All security measures shall be subject to the Notice of No Objection from the Engineer.
- (3) There will be in-built security against unauthorised access and/or vandalism to the various parts of the Works, by the Contractor.

7.1.4 Durability and Maintenance

The design shall ensure, by means of the appropriate choice of structural forms, details and materials that the structure shall remain in a serviceable condition over its life, with due regard to its location and the environmental and climatic conditions prevailing. In particular, the following shall apply:

- (1) Only materials and details having a proven record of durability in similar conditions shall be used.
- (2) Maintenance requirements shall be minimised by appropriate detailing and the selection of suitable materials that will reduce weathering and staining as far as possible. Particular care shall be taken with regard to the following
 - a) Structures shall be detailed so as to draw/shed surface water in such a way that ponding and streaking do not occur and details which encourage the accumulation of debris or dust shall be avoided. Details shall be designed for ease of maintenance.
 - b) Access shall be provided for inspection and maintenance to all elements of the structure.

7.1.5 Road Pavements

Road pavements for reinstatement of roads excavated by the Contractor shall be designed to current codes and standards, to the satisfaction of the owners of the road such as National Highway Authority of India (NHAI)/ Maharashtra Public Works Department/ Pune Municipal Corporation/Maharashtra State Road Corporation Limited etc..

7.2 Site Design

- (1) The Contractor shall take all necessary steps during site possession to protect adjoining properties, fences, public roadways, footpaths, etc. and shall be held responsible for making good any damage to the same, or the replacement by an acceptable equivalent should the material be no longer obtainable in the market.
- (2) Demolition and site clearance shall be carried out in such a manner as to cause as little inconvenience as possible to adjoining properties and the public; the Contractor will be held responsible for any claims arising there from and shall bear all such claims directly without causing any cost and time implications to the Employer.
- (3) The Contractor shall take all necessary precautions during demolition and site clearance not to disturb existing electricity supply cables, drains, gas pipes, water supply pipes, ducts, telephone cables, radio and television relay lines, hydraulic pressure mains and other service pipes and fittings across the site. Where necessary, the above service lines and fittings shall be properly protected.
- (4) Before work commences or during the progress of the demolition and site clearance works, should the Contractor discover any cables, pipes or fittings which are liable to be damaged during the progress of the works or may obstruct and impede the progress of the works, he shall arrange for the diversion and /or protection of the cables or pipes or fittings etc..
- (5) The Contractor shall provide and erect all necessary protective screens, hoarding, shoring etc. that may be required, of a sufficiently substantial nature to prevent damage, nuisance or disturbance by debris or dust or noise to adjoining properties, public roadways or persons or traffic passing nearby. Such protective hoarding shall be erected by the Contractor on the perimeter of the worksite.
- (6) The hoarding shall be erected once the Contractor takes charge of the worksite, prior to the commencement of any site work.
- (7) Entrances and exits shall be suitably positioned, so that the least inconvenience is caused to traffic and pedestrians.
- (8) Adequate warning signs shall be posted at conspicuous locations on the hoarding to alert the public of the construction in-progress. Particular attention shall be given to exits for heavy machinery and vehicles leaving the site. The blasting works, wherever permitted by the Engineer, will be adequately noticed to the public in advance and warning signs or other measures shall be provided to notify the public before blasting work is commenced.
- (9) The Contractor shall design for, provide, erect, maintain and dismantle all necessary underpinning, shoring or other forms of support to safely protect any and all properties(EBS) adjoining the works area and access ways under the Contractor's possession.
- (10) The Contractor shall be responsible for restricting his workmen only to the site under the Contract and shall prevent trespassing into adjoining properties and existing buildings in which work is not in progress. He shall undertake properly, substantially and effectively to reinstate and make good all damages arising there from and shall indemnify the Employer / Engineer against all claims for damages as no responsibility or liability whatsoever shall be undertaken by the Employer / Engineer in respect of any of the foregoing.
- (11) The Contractor shall not obstruct any rights of way during the progress of the works.

- (12) The public shall be provided with safe and suitable access to all buildings and around the area of works at all times.
- (13) The disposal of materials and rubbish by burning on site or burying in the ground will not be permitted under any circumstances.
- (14) All rubbish& excavated material on the site and in buildings under demolition shall be removed off site to an approved dumping ground. All rubbish shall be removed within one month after it is accumulated. Particular attention is directed to clearing out the open drains. They shall be kept entirely free from blockage at all times.

7.2.1 General

- (1) This section lists the main principles and standards for urban design, site design, and landscaping at stations. This includes basic design principles, vehicular and pedestrian circulation, and parking. Circulation patterns for traffic within station sites and on approaching streets shall be determined on a site specific basis for each station site. Three conditions shall always be considered:
 - a) Integration of stations and associated buildings/structures with the existing urban fabric, respect for local traditions, where applicable, and minimising visual intrusion into the urban landscape.
 - b) Separation of traffic modes to allow convenient, safe, and rapid access to and from station facilities.
 - c) Accommodation of passenger design loads.

7.2.2 Access Modes

The passengers will arrive at and depart from the stations via five basic modes of transport. In order of priority for station access, modes of transportation are as follows:

- a) Pedestrian Walk-in;
- b) Scooter and Cycle (where parking facilities are available);
- c) Bus;
- d) Taxi, Auto-Rickshaw, Cycle-Rickshaw and Car Drop-off;
- e) Car (where Parking facilities are available).

7.2.3 General Site Circulation Parameters

- (1) Pedestrian Link.

Entrances shall cater to the pedestrians. In most cases, the station will be tied by a pedestrian link to the podium level of adjacent development. Various ground circulation systems will be located below the level of the pedestrian podium.

- (2) Entrance Conditions.

An entrance shall be visible from the bus-loading area, if possible, and at a minimum shall be easily accessible from the loading area.

- (3) Property Development (wherever applicable).

Station and property development circulation shall be separated.

- (4) Orientation.

Site circulation layouts shall be simple and direct, allowing easy orientation for drivers and facilitating the movement of pedestrians.

(5) Parking Layout.

Station parking areas (wherever, provided) shall be laid out so that queuing for parking will not obstruct bus circulation or automobile and taxi drop-off areas.

(6) Intersections.

Where conditions permit, roadways shall be one-way circulation, with turning loops eliminating intersections within the site.

(7) Sightlines.

Sightlines at merges or intersections shall be left clear.

7.2.4 Pedestrian Access

From Adjacent Streets

Station entrances shall be provided such that there is direct and safe approach for pedestrians from all adjacent streets.

(1) Crossing Traffic

Right-of-Way. Pedestrians shall have the right-of-way over vehicles at crossings of internal roadways.

(2) Visibility.

Pedestrian crossings shall have good visibility for both pedestrians and drivers.

(3) Refuge Area.

Pedestrian crossings at streets wider than four traffic lanes shall have a refuge area in the median.

(4) Path Direction.

A pedestrian's path from a parking stall to the station entrance shall be as direct as possible. Where possible, the use of natural light shall serve to identify this route. The coefficient of directness, i.e., length of path divided by straight line distance, shall not exceed 4, preferably 2.

(5) Kerb Cuts.

At all pedestrian crossings, kerb cuts shall be provided for Persons with Special Needs, such as wheel chair users. All kerb cuts shall be marked with signs.

(6) Markings.

Pedestrian crossings shall be emphasised with textured pavement or crosswalk markings. Where major pedestrian paths cross roadways, the paving material, or a material of similar colour, shall be carried across the roadway to emphasise the pedestrian right-of-way.

(7) Number of Crossings.

The parking pattern (wherever applicable) shall be designed to allow pedestrians to walk toward the station with a minimum of traffic crossings.

(8) Minimum Dimensions.

Minimum dimensions of pedestrian walkways and crosswalks shall comply with the IRC requirements.

7.2.5 Vehicular Access

(1) Traffic Distribution.

Vehicular entrances shall be located to distribute traffic loads evenly over the site.

(2) Entrance Location.

Vehicles shall enter from secondary roads, where possible, with provision for sufficient waiting and stacking space.

(3) Separation of Types.

Entrance and exits from station parking (wherever applicable) shall be separated, where possible, from those of bus and auto drop-offs.

(4) Number of Entrances.

The number of vehicular entrances along any one street shall be kept to a minimum.

(5) Turning Lanes.

Where required for traffic mitigation, turn lanes shall be provided for entering or exiting vehicles. Left turns into and out of the station are preferable to right turns.

(6) Emergency Vehicle Access

Emergency vehicle access shall be provided to all building structures, especially the station entrances. Station access roads and parking lot (wherever applicable) perimeter roads shall accommodate emergency vehicles including fire trucks.

(7) Auto Drop-off

A drop-off and pick-up zone, preferably with boarding on the left hand side, is required adjacent to the main entrance of the station. A kerb cut shall be provided within or adjacent to this area for Persons with Special Needs. The location of the kerb cut shall be marked with signs.

Where site area permits, a parking area for persons waiting to pick up passengers shall be conveniently located close to the pick-up zone. This parking area shall provide good visibility of the station exit and shall permit convenient re- circulation of vehicles.

7.2.6 Station Parking (wherever applicable)

(1) Area.

Station parking areas shall be provided for the number and modes of vehicles as required

(2) Locations.

Normally parking shall be provided at ground level.

(3) Aisle Direction.

The direction of the parking aisles shall be determined by the needs of both the pedestrians and the vehicles. In most cases, the aisles shall be perpendicular to the station entrance. Where site conditions dictate parallel aisles, provision shall be made for pedestrians to cross the parking row.

(4) Angle of Parking.

Standard 90° parking is preferred.

(5) Wheel Stops.

Wheel stops within each parking space shall not be used as they are a maintenance problem.

(6) Landscaping.

Where station parking is provided at-grade, landscaping shall be used to sub- divide the

parking area.

(7) Special Needs Parking.

Parking designated for Persons with Special Needs shall be located as close to the station entrance as possible. Roadway crossings from these spaces to the station entrance shall be kept to a minimum.

(8) Numbering.

All public parking places shall be numbered.

7.2.7 Taxi and Bus Lay-Bys

Bus lay-bys shall be provided at stations to facilitate passenger transfers to bus transport as per standards in consultation with the Police Department/Transport Department/agencies. Additional bus lay-bys shall be designed to suit site specific requirements and demand forecasts.

7.3 Landscaping (wherever applicable)

7.3.1 Purpose and Scope

The purpose of this section is to include design criteria and requirements of landscaping works, wherever applicable.

7.3.2 Station Areas

The design shall include in the station design for the provision of appropriate planting (wherever applicable) to enhance and soften the appearance of the station box and the approach structures.

7.3.3 Irrigation

The purpose of the following criteria is to provide efficient water use through proper design and management of landscape irrigation (wherever applicable). Landscape irrigation systems shall conform to local codes and practices.

(1) Co-ordination with Plant Material.

Irrigation systems shall be organised so that non-drought tolerant planting shall be watered separately from the rest of the landscaping.

(2) Location.

Sprinklers and sprays shall not be used in areas less than 2500mm wide. Drip and bubbler devices shall be used with the minimum flow rate necessary to water plant materials.

(3) Valves and Circuits.

Valves and circuits shall be separated based on water use.

(4) Trees.

Drip or bubbler irrigation systems shall be required for trees.

(5) Sprinkler Heads.

Sprinkler heads shall have matched precipitation rates within each control valve circuit. Sprinkler head spacing shall be designed for head-to-head coverage

(6) Check Valves.

Serviceable check valves shall be required where elevation differential may cause low

head drainage.

(7) Runoff.

Irrigation systems shall be designed for minimum runoff and overspray to non-irrigated areas.

(8) Water Budget.

Plans shall include a water budget that includes the following:

- Estimated annual water use (in litres) and area irrigated (in square metres);
- Precipitation rates for each valve circuit;

(9) Quick-Disconnect Valves.

In parking, podium, and other areas, quick-disconnect valves shall be provided for washing pavement and watering trees in pockets.

7.3.4 Fountain (wherever Applicable)

Stations having large urban planning and traffic integration areas shall be provided with a properly designed fountain preferably integrated with a traffic island and planting. Such fountain shall be provided with coloured lighting to enhance the architecture of the station area after sunset.

7.4 Utilities

- (1) The Utilities information provided in the Tender Document is indicative only. The Contractor shall confirm the locations of the existing services in the Works Areas prior to any excavation.
- (2) The contractor shall be responsible for temporary diversion of utilities (such as water, sewer, electrical and telecommunication utilities etc.) within the works areas based on the construction sequence. Where adequate space is not available adjacent to the footprints of the proposed stations, the utilities may have to be diverted within the station-box itself to facilitate the construction of diaphragm/secant piles wall. The Contractor shall submit utility diversion schedule based on his construction sequence.
- (3) Such of those utilities, which are not permitted to be temporarily diverted by the utility agencies, shall be properly supported and adequately protected during the construction/excavation of stations/other structures duly ensuring that no damage, whatsoever, is caused to them.
- (4) The contractor shall closely co-ordinate with utility agencies for the relocations and diversions of the services, temporary or permanent, such that the Contract Works are carried out in accordance to the agreed master programme.
- (5) The Contractor shall follow the requirements of the utility agencies for the construction, diversion, or restoration of the utility services. The Contractor should follow the guidelines or code of practice of the concerned utility agencies. Where guidelines and code of practice are not available from the concerned utility agencies, relevant IS shall apply.
- (6) The Contractor shall ensure that the existing service connections to the adjacent properties are maintained in good condition at all times.
- (7) The Contractor shall provide protective measures to retain the utilities (such as sewer mains, Water Supply Mains, Transformers etc) located in/adjacent to the construction area. For temporary utility diversions, the Contractor shall reinstate the concerned

utility to the original or agreed location in consultation with the concerned utility department.

- (8) Contractor shall evaluate the effects of utilities under or in the immediate vicinity of the contract works. Where necessary, the contractor will be required to make modification to his design to minimize the impact to those utilities.

- (9) Storm Drains

The contractor shall manage the storm water drainage for the affected portion of drain during the construction period. The Contractor shall also submit a management plan to the Engineer and PMC (or the concerned Department/Agency) for agreement. The Contractor shall reinstate the disconnected portion of storm water drain to the original or agreed location in consultation with the Engineer and PMC (or the concerned Department/Agency). The storm water drain shall be constructed as per the specifications of the concerned Department/Agency.

7.5 Environmental Requirements

7.5.1 Sustainable Development & Environmental Considerations

7.5.1.1 General

- (1) Goals

The Contractor shall consider the Five Pillars of environmental sustainability in all aspects of the development and operation of a new station:

- Energy Efficiency
- Material and Resource Conservation
- Indoor Environmental Quality (IEQ)
- Best Operations and Maintenance
- Water Conservation and Site Management

- (2) The goal, in the application of these pillars, is to create an environmentally responsible mass transit system that is appreciably ahead of current standards and practices when compared with a similar transportation system. The Metro Stations created by this effort shall become a model for a healthier and ecologically responsible environment where the people enjoy the benefits of a “green” environment.”

- (3) By applying such strategies to the design of Metro Stations, the Contractor (and his designer) shall demonstrate the improvements and efficiencies of the design compared to existing standards or practice with respect to the Five Pillars.

7.5.1.2 Enforcement

- (4) Although significant success has been made in India in developing and enforcing environmental regulations in many areas, there still remain a number of areas that have not yet seen the promulgation of environmental standards and regulations. Many of these areas have a high potential for adverse environmental impact if allowed to go unregulated. As the PMRC undertakes to build this Metro system it shall institute and enforce adequate environmental standards to provide for the protection of the people and the environment.

- (5) Environmental Impact Assessment

The Contractor shall comply with all applicable Indian laws and regulations to mitigate the adverse environmental impacts from the construction / renovation activities.

Based on the Environment Impact Assessment (EIA) report or as necessary, the contractor shall conduct an analysis of the environmental impacts and implement suitable measures to mitigate the adverse impacts so as to comply with all the environmental standards and regulations. All appropriate categories/areas, such as air quality, noise, water quality, etc, are to be considered in the environmental analysis. The Contractor shall be responsible for the total compliance of the Environmental Protection safeguards as elaborated in the OSHE Manual, Part-II: Environmental. The Contractor will have to undertake Environmental Monitoring and Audit during construction to measure the environmental impacts. Should the impact measurements exceed the respective limits set forth in EIA Report or any other relevant standard/document, the Contractor shall be required to review and implement effective measures so as to ensure that the impact of the construction works will not exceed the respective limits set forth in the EIA report or any other relevant standard/document.

(6) Environmental Management System

The PMRC and the Contractor shall have in place an Environmental Management System (EMS) to ensure the management support for mitigating the environmental consequences of the operations at the world class stations in conformance with ISO 14001. A policy statement from top management; identifying impacts and goals to mitigate them; assigning roles and responsibilities; providing appropriate and adequate training; preparing and maintaining documentation; monitoring and correcting environmental problems; and management review aimed at continuous future improvement, are the major elements of an ISO 14001 EMS, that has been widely adopted by the internationally both in government as well as the private sector, and is quite popular and well-recognized in India.

The Contractor's personnel should receive appropriate level of environmental training to ensure necessary knowledge, skill, and competency for understanding the environmental issues as and when they arise, and to provide solutions to meet the environmental regulations and requirements, thereby minimizing the adverse environmental consequences from the Metro construction works.

7.5.1.3 Environmental Certification

The Contractor shall obtain certification for the project under the Leadership in Energy and Environmental Design (LEED), Green Building Rating System™ (USA) an internationally accepted benchmark for the design, construction, and operation of high performance energy efficient buildings. The Contractor should aim for a Platinum level certification. If conditions associated with the construction of metro make it infeasible to attain a LEED's Platinum certification the Contractor shall document the reasons and in no case should the certification be less than the lowest LEED certification available. LEED promotes a whole building approach to sustainability by recognizing performance in the five pillars of environmental design and human health mentioned above, and provides a road map to measure and document success for energy savings

References

- a) Ministry of Environment and Forests
- b) National Building Code (India)
- c) Bureau of Energy Efficiency BEE (India)

- d) Energy Conservation Building Code (India)
- e) Leadership in Energy and Environmental Design (LEED), USA.
- f) The Energy and Resource Institute (TERI) Recommendations and Mandates
- g) SO 9001, International Standards Organization, Standard for Quality
- h) ISO 14001, International Standards Organization, Standard for Environmental Management System

7.5.2 Energy Efficiency

The ways in which energy is expended shall be examined from the earliest stages of design through the daily operation of the system. Compliance with Energy Conservation Building Code (India) shall be the minimum requirements.

7.5.2.1 Respond to Demand

Optimize energy consumption by designing systems and operational strategies that respond to changes in demand. Metro Stations generally have peak patronage levels twice a day, with less patronage at off-peak times. Systems should be designed and operated to mimic the patronage curve or occupant load, producing energy savings in comparison to designing them for peak loading only.

Strategies

- a) Station Configuration: Respond to Demand: Vertical Circulation Elements
- b) Entrances: Showcase Sustainability: Entrances
- c) Lighting : Showcase Sustainability - Lighting

7.5.2.2 Maximize Energy Performance

Employ available technologies and design/operational strategies that will provide a net reduction of 30% in the amount of energy consumed by an equivalent Metro Station that only conforms to the minimum statutory and regulatory requirements.

Strategies

- a) Station Configuration: Elevator and Escalator Resource Conservation
- b) Station Configuration: Respond to Demand: Vertical Circulation Elements
- c) Communications: Communications Technology Review
- d) Lighting: Increase Natural Light
- e) Lighting: Lighting Energy Consumption Level
- f) Signage: Technology Review

7.5.3 Energy Consumption

7.5.3.1 Utilize Thermal Assets

Reduce energy consumption by utilizing the thermal mass to aid environmental control. Elements, such as the concourses, platforms, tracks, major structural elements, and the surrounding earth, can be used as thermal batteries for anticipated cooling and heating loads. Thermal mass storage can be used to reduce energy consumption consumed in environmental control, even when it is not capable of carrying the whole load.

Strategies

- a) Ventilation and Energy Conservation: Thermal Mass Storage
- b) Ventilation and Energy Conservation: Geothermal Heat Pumps

7.5.3.2 Reduce Equipment Energy Consumption

Use energy models to determine energy loads and to evaluate opportunities for reducing energy consumption as well as operational costs. All equipment to be of the highest energy star rating available in accordance with BEE Standards under Indian Energy Conservation Act

Strategies

- a) Station Configuration: Elevator and Escalator Resource Conservation
- b) Ventilation and EC: Ventilation Equipment Energy Consumption Level
- c) Communications: Communications Technology Review
- d) Communications: Reduce Thermal Pollution from equipment
- e) Lighting: Reduce Lighting Energy Consumption Level
- f) Lighting: Integration of Emergency Fixtures
- g) Signage: Technology Review for Lowest Consumption Technology

7.5.3.3 Reduce Energy consumption

Use energy modelling systems, such as DOE-2 (US Department of Energy – 2) to reduce energy consumption by a minimum of 30% against code.

- (1) Encourage On-Site Energy Production - Reduce the demand for energy by employing the use of renewable energy sources supplied within the project site. An example would be providing photovoltaic panels at entrances, roof, etc.
- (2) Meet 10% of the peak load of the station complex by renewable energy sources.
- (3) Encourage Clean Energy Sources - Encourage the use of energy sources that produce little or no pollution.

Strategies

- a) Station Configuration: Elevator and Escalator Resource Conservation
- b) Ventilation and EC: Ventilation Equipment Energy Consumption Level
- c) Communications: Choice of Communication Equipment and Thermal Pollution from Equipment
- d) Lighting: Lighting Fixtures
- e) Signage: Choice of Signage Equipment to reduce energy consumption
- f) Entrances: Showcase Sustainability – Entrances
- g) Lighting: Showcase Sustainability – Lighting

7.5.4 Material and Resource Conservation

Selection of building material is important in sustainable design because of the extensive network of extraction, processing, and transportation steps required for processing them. Activities to create building materials pollute the air and water, destroy natural habitats, and deplete natural resources. These are also factors in the products transportation and the final disposal of the materials.

Salvaged, recycled content, local and renewable materials minimize the impact of natural resource consumption.

7.5.4.1 Efficient Material Use

Plan an efficient layout that minimizes the amount of material used over the entire project.

Strategies

- a) Station Configuration: Optimize Vertical Circulation Elements
- b) Station Configuration: Efficient Space Planning
- c) Utility and Systems Interface: Optimize Plant Room
- d) Utility and Systems Interface: Integration of Utilities
- e) Communications: Communications Technology Review
- f) Communications: Equipment Obsolesce
- g) Materials and Finishes: Integration of Noise Attenuation with Structure
- h) Acoustics: Integration of Noise Attenuation with Structure
- i) Signage: Technology Review

7.5.4.2 Encourage Collection of Recyclables

Reduce the amount of material waste generated by encouraging recycling, providing facilities and supporting public education strategies and signage.

Strategies

- a) Operations and Maintenance: O&M Plan to Address Recycling
- b) Signage: Signage to Support Recycling Initiatives
- c) FF&E: Showcase Sustainability – FF&E
- d) Institute an effective Solid Waste Management Program at the Stations

7.5.4.3 Institute an effective Solid Waste Management Program

Ensuring public awareness and stiff enforcement can result in proper and adequate solid waste management system. The Contractor shall put in place an integrated solid waste management program that complies with published and/or appropriate national and local solid waste management requirements. The Program must allow for an effective management of solid waste in a way that is protective of human health and the environment, while making the station aesthetically more pleasing and acceptable to travellers and staff. The Program shall include:

- a) Segregating, (separate collectors for paper, plastics and other recyclable waste streams) storing, transporting, recycling, treating, and disposing of solid waste.
- b) Storage shall be reduced where applicable by the use of solar compactors.
- c) Incentives for solid waste reduction and for use of recycled and environmentally friendly/preferable material
- d) Responsibilities for the different elements of the solid waste management program
- e) Goals for future reduction in the rate of solid waste generated by using the 3R formula (Reduce, Reuse, Recycle).

The numbers, sizes, and locations of receptacles for segregated solid waste would be in accordance with the minimum requirements included in The Municipal Solid Wastes (Management and Handling) Rules, Ministry Of Environment and Forests, Government of India, and the information collected during the operation of the station.

7.5.4.4 Reuse Construction Waste and Conserve Resources

Minimize construction waste and conserve resources. Direct all usable waste materials into the construction process and all recyclable waste materials into the manufacturing process.

Strategies

Materials and Finishes: Selection of Finish Materials

7.5.4.5 Specify Products with Recycled Content

Reduce the use of raw materials by specifying recycled products or those with recycled content.

Strategies

- a) Station Configuration: Choice of Escalators and Elevators
- b) Communications: Choice of Communication Equipment
- c) Materials and Finishes: Selection of Finish Materials
- d) Lighting: Lighting Fixtures
- e) Signage: Choice of Signage Equipment
- f) FF&E: Showcase Sustainability – FF&E
- g) FF&E: Choice of Furniture, Fixtures and Equipment
- h) Institute an effective Solid Waste Management Program at the Stations which includes a component for all recyclable waste.

7.5.4.6 Eliminate Chlorofluorocarbons (CFCs)

Reduce ozone depletion by eliminating the use of refrigerants and solvents that contain CFCs and the use of insulation materials that employ CFCs in their production.

7.5.4.7 Specify Local/Regional Materials and Equipment

Reduce the environmental impact associated with the transportation of building materials by specifying those that have been manufactured locally.

Strategies

- a) Materials and Finishes: Selection of Finish Materials
- b) Lighting: Lighting Fixtures
- c) Signage: Choice of Signage Equipment
- d) FF&E: Showcase Sustainability – FF&E
- e) FF&E: Choice of Furniture, Fixtures and Equipment

7.5.4.8 Encourage Links with Alternative Transportation

Limit the use of non-renewable fuel sources and associated pollution by encouraging walking, bicycle riding, and the use of vehicles powered by alternative sources.

Strategies

- a) Entrances: Intermodal Connections
- b) Entrances: Showcase Sustainability – Entrances
- c) FF&E: Showcase Sustainability – FF&E

- d) Power sources in parking area for electric cars.
- e) Parking for bicycles

7.5.5 Indoor Environmental Quality

Indoor environmental quality (IEQ) strategies include issues related to indoor air quality (IAQ), such as ventilation effectiveness and control of contaminants, illumination, acoustics, vibration, occupant control of building systems and day lighting. All of these issues have the potential to enhance the indoor environment and optimize the health, comfort and productivity of building occupants.

7.5.5.1 Effective Ventilation

Employ design strategies to provide fresh air intakes that enhance the health and productivity of the Metro Station environment.

Strategies

- a) Ventilation and EC: Natural Ventilation
- b) Ventilation and EC: Respond to Demand: Ventilation –Including use of CO2 sensors in air tempered spaces.
- c) Ventilation and EC: Station and Facility Management System
- d) Ventilation and EC: Air Filtration

7.5.5.2 Specify Low VOC Emitting Materials

Specify materials and finishes, including flooring and furniture, that contain no known carcinogens, have low levels of volatile organic compounds (VOCs), are non toxic and chemically inert, to reduce the amount of indoor air contaminants that may be irritating or unhealthy to occupants.

Strategies

- a) Operations and Maintenance: Maintenance Materials
- b) Ventilation and EC: Inert Materials
- c) Materials and Finishes: Selection of Finish Materials
- d) Signage: Choice of Signage Equipment
- e) FF&E: Choice of Furniture, Fixtures and Equipment

7.5.5.3 Control Chemical and Pollutant Sources

Develop methods to prevent the risk of chemical or other pollutants from being introduced into the Metro Stations. These methods include both measures employed in the design of the system and strategies used in the operation and maintenance of the system. In addition to ensuring compliance with the applicable emissions standards, provisions must also be made to minimize the environmental and health impacts of these pollutants by appropriate and available active or passive operational controls.

Strategies.

- a) Entrances: Walk-Off Grilles
- b) Ventilation and EC: Air Intake Location at least 8 m away from any potential source of air contaminants.

7.5.5.4 Maximize Day lighting

Implement strategies to maximize daylight. Where possible, integrate indoor space with the outdoor environment to improve the environment for occupants.

Strategies

- a) Entrances: Entrance Orientation
- b) Entrances: Showcase Sustainability – Entrances
- c) Materials and Finishes: Increase Natural Light
- d) Lighting: Increase Natural Light
- e) Lighting: Showcase Sustainability – Lighting

7.5.5.5 Reduce Noise and Vibration.

The impacted areas and the degree of noise and vibration impact shall be clearly delineated in the environmental documents, such as the Environmental Analysis or the Environmental Assessment Statement. The noise and vibration data shall be collected on site by taking measurements using acceptable equipment and data collection protocols. Appropriate prediction models shall be used, where necessary, to predict the noise and vibration levels from future operations. The environmental document will also identify any mitigation measures to meet the requisite noise and vibration standards in place.

Minimize the amount of noise and vibration generated by selecting quieter equipment and technologies.

Strategies

- a) Ventilation and EC: Noise Attenuation
- b) Materials and Finishes: Integration of Noise Attenuation with Structure
- c) Acoustics: Integration of Noise Attenuation with Structure

7.5.6 Operations and Maintenance

- (1) Modern Metro Stations are highly complex structures, both physically and technologically. They must serve the needs of the travelling public during normal and emergency situations and must be operable and maintainable with minimal resources.
- (2) A holistic approach requires a design strategy that optimizes energy efficiency. Efficient operations and maintenance will require performance monitoring coupled with active progressive maintenance programs. These will need to take advantage of the data that is available from each of the systems, and be centrally monitored. The PMRC stations will operate 7 days a week, 365 days a year. Therefore, the materials and finishes in the stations must be durable and easily maintainable and allow repair/replacement with minimal shutdown of service.

7.5.6.1 Specify Low Maintenance Materials

Specify materials that require minimal maintenance during lifespan to conserve cleaning resources and enhance durability. Painted surfaces are discouraged at new stations, and finishing materials shall have a minimum life cycle of 35 years (50 years where possible). Materials should be locally sourced where possible.

Strategies

- a) Operations and Maintenance: Maintenance Materials

- b) Materials and Finishes: Selection of Finish Materials
- c) Signage: Selection of Materials
- d) FF&E: Choice of Furniture, Fixtures and Equipment

7.5.6.2 Commission Systems and Equipment

Ensure that the building systems operate efficiently as intended through periodic testing and calibration.

Strategies

- a) Ventilation and EC: Station and Facility Management System
- b) Communications: Commissioning Communication Systems

7.5.6.3 Station Systems Monitoring

- (1) Provide a permanent monitoring system to provide feedback for the comparison, management, and optimization of equipment for energy efficiency.
- (2) Provide an ongoing system to guarantee accountability for maintaining performance standards in the operation and maintenance of the Metro Stations.

Strategies

- a) Operations and Maintenance: Performance Monitoring
- b) Ventilation and EC: Station and Facility Management System
- c) Utilities and Systems interface: Station Systems Monitoring – Utilities
- d) Communications: Performance Monitoring – Communications

7.5.6.4 Selection of Materials

Select durable and easily maintainable finishes. Select maintenance materials (e.g., lubricants) that are environmentally friendly.

Strategies

- a) Operations and Maintenance: Maintenance Materials e.g. Biodegradable Lubricants for Escalators and Elevators, cleaners and solvents for maintenance
- b) Communications: Choice of Communication Equipment e.g. UPS system
- c) Lighting: Lighting Fixtures and Lamps

7.5.6.5 Prevent Collection of Dust

Design forms and equipment that require minimal cleaning.

Strategies

- a) Materials and Finishes: Design for Ease of Maintenance
- b) FF&E: Choice of FF&E

7.6 Other Environmental Requirements for Design and Construction

7.6.1 General

- (1) The Contractor shall be responsible to produce a report on the various environmental issues that need to be considered and the methods of overcoming these issues. The following is a guide and touches on important requirements that need to be addressed as part of the Contractor's scope.

- (2) The construction works and permanent works shall also limit directly or indirectly, to acceptable levels, the contamination of soils and groundwater arising from products such as sewage, oils, detergents, ground treatment, slurry, concrete and bentonite, which are among those deemed to be harmful to the environment or to the health of the local population.
- (3) The levels of contaminants shall be measured accurately in potable water sources close to the works, which include wells, rivers, sea and pumped water. The levels of contaminants should not exceed the recommended values from the local Authorities or where this is not available, from the World Health Organisation.
- (4) The construction of the works shall maintain an adequate level of noise control consistent with the requirements of the local Councils and / or Authorities.
- (5) The design of the Permanent Works shall minimise noise emission due to operation of the railway. The design of all parts of the structures shall minimize as far as practicable the radiation of noise and vibration caused by the passage of trains. Particular attention shall be paid to the minimisation of noise at the low end of the acoustic frequency spectrum.
- (6) Noise values shall be maintained at the following levels for the duration of the temporary works unless agreed to differently by the Engineer:

7.6.2 Noise Control

- (1) Noise levels due to mechanical equipment and related services will be controlled to the design objectives agreed with the Engineer and local Authorities in all occupied areas and their supporting spaces. The agreed requirements are considered to be the minimum precautions necessary to achieve these objectives. The entire installation shall operate without objectionable noise as determined by the Engineer.
- (2) The Contractor shall carry out design and installation with due consideration on vibration, vibration induced noise, airborne noise including the control of all noise breakout via pipe works.
- (3) The Contractor shall bring to the attention of the Engineer any requirements which, in the Contractor's opinion, are not achievable. Otherwise, the requirements are deemed to be complied with and the Contractor shall bear all costs of remedial works to achieve the agreed on design objectives on noise mitigation and control.
- (4) The Contractor is to ensure that in the selection of all equipment to be supplied, the lowest available sound power levels are adopted. Sound levels shall not exceed those agreed on. Additional noise control devices shall be allowed for to restrict levels to the agreed criteria.
- (5) The Contractor shall guarantee that these agreed to levels are not exceeded.
- (6) All noise levels specified must include allowance for the so called 'room' effect. Therefore any catalogue or certified data including room effect allowances or the like shall be modified to show that the noise criterion from this effect has been considered.
- (7) Noise emanating from mechanical plant and crossing the site boundaries shall not exceed statutory requirements.

7.6.3 Design Objectives for Noise

(1) Temporary Works

- a) The Contractor is to seek the Engineer's notice and guidance on a comprehensive noise mitigation programme. The levels are not to exceed the agreed-upon values.
- b) The following tables provide minimum levels of compliance that may be used in-lieu of those that may be obtained from detailed noise impact studies:

Table 7.6.3 – 1

Type of the affected buildings	Maximum permissible noise level for construction sites (reckoned as an equivalent continuous noise level over a period of 12 hours) in dB(A)	
	7 am – 7pm	7 pm -7 am
(a) Hospitals, Schools, institutions of higher learning, homes for the aged sick etc	60	50
(b) Residential buildings located less than 150m from the construction site where the noise is being emitted	75	--
(c) Buildings (other than those in paragraphs (a) and (b))	75	65

Table 7.6.3. – 2

Type of the affected buildings	Maximum permissible noise level for construction sites (reckoned as an equivalent continuous noise level over a period of 1hours) in dB(A)		
	7 am – 7 pm	7 pm -10 pm	10 pm - 7 am
(a) Hospitals, Schools, institutions of higher learning, homes for the aged sick etc			
(b) Residential buildings located less than 150m from the construction site where the noise is being emitted		65	65
(c) Buildings (other than those in paragraphs (a) and (b))			

Table 7.6.3 – 3

Type of the affected buildings	Maximum permissible noise level for construction sites (reckoned as an equivalent continuous noise level over a period of 5 minutes) in dB(A)		
	7 am – 7pm	7 pm -10 pm	10 pm - 7 am
(a) Hospitals, Schools, institutions of higher learning, homes for the aged sick etc	75	55	55
(b) Residential buildings located less than 150m from the construction site where the noise is being emitted			
(i) On Monday to Saturday			
(ii) On Sundays and public holidays	90 75	70 55	55 55
(c) Buildings (other than those in paragraphs (a) and (b))	90	70	70

(2) Permanent Works

- a) The Design Objectives based on the usage of the spaces are as follows. The specified criteria shall apply to all areas as measured at a level 1.5m above the floor. Where plant rooms are encountered, the measurement shall be at a similar height from the floor but at not less than 1m and not more than 1.5m from the plant room walls. The Engineer's determination shall be final in case of dispute.
- b) The Contractor shall offer all noise generating systems and control based on the relevant Indian Standards or British Standards. Where measured noise is rumbling, tonal or 'groaning', the measured NC should be read as plotted NC+5. When the emitted noise from any equipment carries rumbling, tonal and 'groaning' content, the plotted NC must be 7 points lower than the specified criterion to be considered as meeting the criteria.
- c) In-lieu of other criteria, the following minimum levels of compliance may be used:

	Area	Criteria
a	Inside Pump Rooms	70-75 dBA
b	Inside Plant Rooms	75- 80 dBA

7.6.4 General

The design of the Permanent Works shall minimise noise emission due to operation of the railway. The design of all parts of the structures shall minimise as far as practicable the radiation of noise due to vibration caused by the passage of trains. Particular attention shall be paid to the minimisation of noise at the low end of the acoustic frequency spectrum.