DESIGN CONSTRUCTION AND OPERATION OF TWIN TUNNEL FROM FILM CITY GOREGAON TO KHINDIPADA (AMAR NAGAR), MULUND INCLUDING BOX TUNNEL (CUT & COVER) AT FILM CITY, ELECTRICAL, MECHANICAL AND ASSOCIATED WORKS.

Volume 4

Outline Design Specification

Brihanmumbai Municipal Corporation

Mumbai, Maharashtra, India

Chief Engineer (Bridges),

Office of the Chief Engineer (Bridges)

5B Bhandar, Bhandup Complex Store Building,

Darga Road, Khindipada,

Mulund (West), Mumbai- 82. India

Website: https://mahatenders.gov.in

DESIGN CONSTRUCTION AND OPERATION OF TWIN TUNNEL FROM FILM CITY GOREGAON TO KHINDIPADA (AMAR NAGAR), MULUND INCLUDING BOX TUNNEL (CUT & COVER) AT FILM CITY, ELECTRICAL, MECHANICAL AND ASSOCIATED WORKS.

Outline of Tender Documents

	Disclaimer
Volume 1	**Bidding Guidelines**
Section I	Notice of Intimation to RFP e – Tender Notice
Section II	Instructions to Tenderers (ITT)
Section III	Form of Tenders
Volume 2	**Condition of Contracts**
Section IV	General Conditions of Contract shall be "FIDIC Conditions of Contract for Plant and Design-Build – First Edition 1999" (GCC)
Section V	Particular Condition of Contract
Volume 3	**Employer's Requirement**
Section VI	Section A – General
	Section B – Functional
	Section C – Design
	Section D – Construction
	Appendices 1 to 19
Volume 4	**Outline Design Specification**
Volume 5	Outline Construction Specification
Volume 6	Tender Drawings
Volume 7	Pricing Document
Volume 8	Reference Document

Note: The Tenderers, whilst compiling their rates, must carefully consider all the requirements of the documents listed above & **all governing codes published by BSI and IRC if the activities not covered by Indian codes then current available International codes will be applicable** and all these documents will form part of the Contract.

Volume 4

Table of Contents

Sr. No.	Description	Page No.
SECTION 1: ROAD WORKS		
	GENERAL	
1.1	Applicable Codes, Standards & Publications	
1.2	General consideration of planning, design and construction	
2.	DESIGN	
2.1.	General	
2.2.	Geometric Design	
2.3.	Drainage System	
3.	PAVEMENT DESIGN	
3.1.	Rigid Pavement	
3.1.1.	Design	
3.1.2.	Durability	
3.1.3.	Safety and Serviceability	
3.1.4.	Design Traffic	
3.1.5.	Concrete Strength	
3.1.6.	Rigid Pavement Design	
3.1.7.	Details of Joints	
3.1.8.	Dowel Bars & Tie Bar	
3.1.9.	Temperature Consideration	
3.1.10.	Embankment soil and characteristics of subgrade and subbase	
4.	MATERIALS	
4.1.	General	
4.2.	For Rigid Pavement Work	
4.2.1	Cement	
4.2.2	Aggregates	
4.2.3	Dry Lean Cement Concrete	
4.2.4	Cement Concrete Pavement (Pavement Quality Concrete)	
4.3.	Flexible Pavement Work	
4.3.1	Subgrade and Sub-Base Material (Flexible)	
5.	PAVER BLOCKS	

6. SIGNAGE

SECTION 2: TUNNEL WORKS

GEOTECHNICAL, FOUNDATIONS AND TUNNEL WORKS

1. GENERAL, STANDARDS AND CODES

1.1 Purpose and Scope

1.2 Codes, Standards, and Regulations

1.3 Design Considerations

2. Site Investigations and Laboratory Investigations

2.1. Site Investigations

2.1.1. General Conditions

2.1.2. Investigation Requirements

2.2. Investigation Methods

2.2.1. Geologic Studies

2.2.2. Geophysical Surveys

2.2.3. Exploratory Drill holes

2.2.4. Other Ground-Investigation Methods

2.2.5. Groundwater

2.3. Laboratory Testing Methods

2.3.1. General Methods

2.3.2. Index/Classification Testing of Soil Samples

2.3.3. Strength Testing of Soil Samples

2.3.4. Consolidation Testing of Soil Samples

2.3.5. Permeability Testing of Soil Samples

2.3.6. Chemical Testing of Soil and Groundwater Samples

2.3.7. Testing of Rock Specimens

3. BORED TUNNEL

3.1. Method Statement

3.2. Types and General Methods of Analyses

3.3. Design Considerations

3.4. Loads

3.5. Loading Conditions

3.6. Flotation

3.7. Heave and Settlement

3.8. Tunnel Lining

3.9. Segmental Linings
3.10. Segment Details
3.11. Conventional Tunnel Lining
3.12. Tunnel Boring Machine (TBM) and Shields
3.13. Waterproofing
3.14. Underpinning of Existing Structures
3.15. Cross Passages
3.16. Sumps in Running Tunnel
3.17. Ground Treatment and Temporary Support
4. SETTLEMENT AND BUILDING PROTECTION
4.1. General
4.2. Minimising Ground Movements
4.3. Prediction of Ground Movements
4.4. Structure Condition Survey
4.5. Assessment of Impact on Structures
4.6. Staged Assessment
4.7. Monitoring
4.8. Building Damage Classification
4.9. Limiting Construction-Induced Vibrations at adjacent Existing Building Structures
4.10. Submissions
4.11. Types of Instrumentation
4.12. Monitoring and Reporting
4.13. Frequency of Monitoring
4.14. Protection, Maintenance and Repair
4.15. Removal
SECTION 3: CIVIL WORKS
1. INTRODUCTION
2. CIVIL STRUCTURES
2.1 **Utility Duct, Water Main Line below tunnel road** and Cut and Cover Tunnel
2.1.1 Utility duct
2.1.2 Water Main Line
2.2 Loads and Requirements
2.2.1 General
2.2.2 Nominal Loads

2.2.3 Design Loads
2.2.4 Dead Loads
2.2.5 Superimposed Dead Loads
2.2.6 Imposed Loads
2.2.7 Vehicular Live Load
2.2.8 Fatigue
2.2.9 Dynamic
2.2.10 Vehicle Collision Load
2.2.11 Wind
2.2.12 Temperature
2.2.13 Seismic Loads
2.2 Deflection Criteria
2.3 Durability
2.4 Concrete Sub-Structure
SECTION 4: E&M WORKS
1. General Requirement
2. Street lightening for at grade road and in the open duct area.
2.1. Scope of work
2.2. Minimum Basic requirement criteria of all elements.
2.3. Design Services
2.3.1. Lighting Poles:
2.3.1.1. Octagonal pole
2.3.1.2. Conical pole
2.3.2. Street Lighting Fittings:
2.3.3. Street Light Control Panel/Feeder Pillar:
2.3.4. Pole Foundation:
2.3.5. Earthing works:
2.3.6. The following work will be carried out by the Contractor:
2.3.7. Documents to be submitted by the Firm / Agency:
2.3.8. Safety Measures:
2.3.9. Cable Sizes:
2.3.10. Cable Laying :
2.3.11. Termination:

2.3.12. Testing:
2.3.13. Documents:
2.3.14. Certificates:
2.3.15. Commissioning:
2.3.16. Warranty
3. Tunnel lighting
3.1.1. Scope of Work
3.1.2. Responsibilities
3.1.3. Design Services
3.1.4. System Description
3.1.4.1. General
3.1.4.2. Low voltage power distribution system
3.1.4.3. Low voltage switchboards
3.1.4.4. Spare Protective devices
3.1.4.5. Lighting System
3.1.4.6. Small power system
3.1.4.7. Emergency Power Supply
3.1.4.8. Lightning protection system
3.1.4.9. Earthing and bonding system
3.1.4.10. M & E SCADA Interface System
3.1.4.11. Uninterruptible Power Supply (UPS)
3.1.4.12. Diesel Generator
4. Tunnel Ventilation
4.1. Introduction
4.1.1. General
4.1.2. Definitions
4.1.3. Codes and Standards
4.1.4. Computer software
4.1.5. Purpose and Scope
4.1.6. Relevant Documents
4.2. Overview of the Project
4.2.1. General
4.2.2. Key Challenges for Tunnel ventilation system

4.3. Scope of Work
4.3.1. General
4.3.2. Description of Works
4.3.3. Scope of Design
4.3.4. Control Centre:
4.3.5. Design Submission:
4.3.5.1. Concept Design
4.3.5.2. Preliminary Design
4.3.5.3. On Site Design (Final Design)
4.3.6. Lead Design Checker (LDC)
4.3.7. Scope of Work of Supply
4.4. Points to be noted
4.4.1. General
4.4.2. Design parameters
4.4.3. TVS Performance criteria
4.4.4. Control and Monitoring Systems
4.4.5. Degree of Redundancy and Degraded Modes
4.4.6. Equipment Response Time
4.4.7. RAMS requirements
4.4.8. RAMS Specifications
4.4.9. RAMS Mission
4.4.9.1. Reliability Requirement
4.4.9.2. Availability Requirements
4.4.9.3. Maintainability Requirements
4.4.10. Safety Requirements
4.5. Functional Requirements
4.5.1. Normal Operating Conditions
4.5.2. Cooling Tunnel at Night
4.5.3. Congested Operations
4.5.4. Emergency Conditions
4.5.5. Control & Monitoring
4.5.6. Functioning Mode
4.5.6.1. Normal, Congestion, Fire Emergency Mode
4.5.6.2. Degraded Mode
4.5.6.3. Switching Mode

4.6. Inspection, Testing and Commissioning
4.6.1. General Requirements
4.6.2. Sequence of Tests
4.6.3. Type Tests
4.6.4. Factory Acceptance Tests
4.6.5. Installations Tests and Inspection
4.6.6. Partial Acceptance Tests (PAT)
4.6.6.1. General
4.6.6.2. Local Functional Tests
4.6.7. System Acceptance Tests
4.6.7.1. General
4.6.7.2. Prerequisites for SAT
4.6.7.3. System Acceptance Test Requirements
4.6.8. Integrated Testing and Commissioning
4.6.8.1. General
4.6.8.2. Integrated Testing & Commissioning of TVS equipment
4.6.9. Service Trials
4.6.9.1. General
4.6.9.2. Pre requisites for Service Trials
4.6.9.3. Service Trials Requirements
4.7. Installation
4.7.1. Construction & Installation Plan
4.7.2. Method Statement
4.7.3. Temporary Works
4.7.4. Health and Safety
4.7.5. Installation Work
4.8. Drawings and Records
4.8.1. General
4.8.2. Circuit Diagrams
4.8.3. Cable Records
4.8.4. Earthing
4.9. Asset Identification
5. Plumbing
5.1. General Requirement
5.1.1. Scope of Work

5.1.2. Responsibilities .....
5.1.3. Additional Standards, Codes and Regulations for Plumbing .....
5.2. Drainage .....
5.2.1. General Requirements .....
5.2.2. Tunnel Drainage .....
5.2.2.1. Rain Water Drainage .....
5.2.2.2. Ground Water Seepage .....
5.2.2.3. Seepage Water Drainage; .....
5.2.2.4. Testing and Emptying of Fire mains .....
5.2.2.5. Sump Pits and Sump Pumps (Seepage Water) .....
5.3. Fire Detection & Alarm System .....
5.3.1. General Requirement .....
5.3.1.1. Scope of work .....
5.3.1.2. Responsibilities .....

DESIGN CONSTRUCTION AND OPERATION OF TWIN TUNNEL FROM FILM CITY GOREGAON TO KHINDIPADA (AMAR NAGAR), MULUND INCLUDING BOX TUNNEL (CUT & COVER) AT FILM CITY, ELECTRICAL, MECHANICAL AND ASSOCIATED WORKS.

Volume 4

Section 1

Roads

Brihanmumbai Municipal Corporation

Mumbai, Maharashtra, India

Chief Engineer (Bridges),

Office of the Chief Engineer (Bridges)

5B Bhandar, Bhandup Complex Store Building,

Darga Road, Khindipada,

Mulund (West), Mumbai- 82. India

Website: https://mahatenders.gov.in

SECTION 1: ROAD WORKS

1. GENERAL

This Document sets for the Specifications and Standards adopted for "**DESIGN CONSTRUCTION AND OPERATION OF TWIN TUNNEL FROM FILM CITY GOREGAON TO KHINDIPADA (AMAR NAGAR), MULUND INCLUDING BOX TUNNEL (CUT & COVER) AT FILM CITY, ELECTRICAL, MECHANICAL AND ASSOCIATED WORKS.**" from Goregaon to Mulund. The Contractor shall make himself fully aware of the Project Site with regard to the features of the proposed works, such as location, layout, geometry, right of way, existing accesses, cross drainage work, etc. including the constraints at the site such as limitation of right of way, existence of adjoining property, existing structures, utilities, etc. The proposed tunnel length starts at CH.2+136 and end at CH.8+835. The design and construction of Goregaon Mulund Link Road (GMLR)Project comprises of 3+3 Lanes carriageway and bored tunnel exit at Mulund. The project facilities shall meet the Standards, Specifications and Quality measures specified in this Document.

The Project report, reference document, drawings and any other information provided by the Employer shall be used by the Contractor only for reference purpose and for carrying out further investigations. The Contractor shall be solely responsible for undertaking all the activities, that are necessary for the delivery of the project, such as planning, surveys, investigations, design, construction planning and management, traffic operation, safety to the users/abutting property holders and shall have no claim against the Employer for any loss, damage, risk, costs, liabilities or obligations arising out of or in relation to the project report and other information provided by the Employer.

For Codes and Standards refer to Section 1, Volume 5.

The version of the standards, codes, and regulations shall be the latest version effective One Month prior to the Date of Submission of RFP.

Reference to the Standard Codes of Practice from:

MORTH	Ministry of Road Transport and Highways
IRC	Indian Road Congress
BMC	Brihanmumbai Municipal Corporation

1.1 Applicable Codes, Standards & Publications

Code No.	Title
IRC: 6-2017	Standard Specifications and Code of Practice for Road Bridges
IRC:37-2012	Guidelines for the Design of Flexible Pavements
IRC:38-1988	Guidelines for Design of Horizontal Curves for Highways and Design Tables
IRC:SP:112-2017	Manual for Quality Control in Road and Bridge works
IRC:58-2015	Guidelines for the Design of Rigid Pavements for Highways
IRC:92-2017	Guideline for Design of Interchanges in Urban areas
IRC:106-1990	Guidelines for Capacity of Urban Roads in Plain Areas
IRC:SP:23-1983	Vertical curves for Highways
IRC:SP:41-1994	Guidelines on Design of At-Grade Intersections in Rural and Urban Areas
IRC:SP:42-2014	Guidelines on Road Drainage
IRC:SP-49-2014	Guidelines for the Use of Dry Lean Concrete as Sub-base for Rigid Pavement
IRC:SP-50-2013	Guidelines on Urban Drainage
IRC:SP-63-2018	Guidelines for the Use of Interlocking Concrete Block Pavement
IRC:SP:61-2004	An Approach Document on Whole Life Costing for Bridges in India
IRC:SP:92-1985	Guidelines for the Design of Interchange in Urban Areas
IRC:86-2018	Geometric design standards for urban roads and streets
IRC: SP-87-2013	Manual of Specifications & Standards for Six Lining of Highways Through Public Private Partnership.
IRC:16-2008	Standard Specification and code of Practise for Prime and Tack Coat (Second Revision)
IRC:19-2005	Standard Specification and code of Practise for Water Bound Macadam (Third Revision)
IRC: SP-63-2018	Guidelines for the use of Interlocking concrete Block Pavements.
IRC: 35-2015	Code of Practise for Road Markings

Code No.	Title
IRC:67-2001	Code of Practise for Road Signs

Note;

IRC Codes and Guidelines maybe subject to review. Hence the latest revision shall be adopted for the design. Where design standards are not specifically mentioned, the priority order of Design Standards is,

1) Indian Road Congress (IRC), IS Codes 2) British Standards (BS) or AASHTO LRFD 3) Internationally-recognized standards

If there are no standards for specific design items for the Goregaon Mulund Link Road Project in the codes listed above, equivalent international standards shall be applied after obtaining Notice to Proceed from the Engineer.

1.2 General consideration of planning, design and construction

The Project has been planned as an "access-controlled highway" where access to the highway shall be provided only at pre-determined locations from existing roads through properly designed entry/exit ramps and or from interchanges. In doing so, the Contractor shall take measures to overcome the physical and operational constraints and plan, design and construct the Project Highway using appropriate methods, management techniques and technologies.

2. DESIGN

2.1. General

This Outline Specification for Road Works shall be read in conjunction with complete Bid Document including NIT, ITT, Employer's Requirements General Conditions of Contract of (FIDIC), Particular Conditions of Contract, Outline Design and Construction Specifications, Employer's Drawings, Addendums etc.

The Design Specifications and parameters are in reference to IRC and MORTH Specifications. If a specification of any item is not available in this tender document, it should be referred from relevant IRC /MORTH Publications.

2.2. Geometric Design

Geometric design of Alignment for Main Carriageway of Highway is as per Table 2.1.

Table 2.1 : Geometric Design Criteria

Sl. No.	Description	Details
1	Design Speed	80 Km/hr
2	Lane Configuration	3+3
3	Single lane Width	3.5 M
4	Paved Edge strip width	0.5 m
5	Paved Shoulder	2.75m
6	Radius of Horizontal Curve	Min = 400 m
7	Maximum Super elevation	5%
8	Safe stopping Sight distance Safe intermediate distance Safe overtaking distance	120M 240M 470M
9	Min Length of Vertical Curve	60M
10	Cross fall / Camber	2.5%
11	Vertical Clearance	5.5 M
12	Vertical Gradient	
12 A	Transition Ramp	Max =4.2%
12 B	Tunnel	Max = 3.0%

The Geometric design of the Highway alignment conform to IRC:86 and IRC: SP:87 except as otherwise indicated in this document. The alignment is shown in the tender Drawings. The Contractor shall:

1) Verify and develop a detailed alignment to meet the standard operational and technical criteria referred elsewhere in this Contract.
2) Review the alignment with respect to the design and construction proposals and shall also satisfy that there is no conflict with any existing structures (both underground and above ground) which are to be preserved.
3) The Contractor is permitted to propose minor deviations in horizontal & vertical alignment to suit his construction proposals, but he must demonstrate that any such deviations do not reduce the technical and operational performance.

The Contractor needs to verify the Contract boundaries while proposing any change in vertical and/or horizontal alignment. Such deviations shall require a Notice to Proceed from the Employer/Engineer in-charge subject to the following conditions: -

- There is no extra cost to the Employer,
- Changes proposed are absolutely essential to suit the specific design.

- The deviation shall be better than the reference design given in the Employer's Drawings.
- There is no change to the Contract boundaries.

2.3. Drainage System

Contractor to carryout Drainage Design, Analysis and prepare the effective drainage Network using any standard software in accordance with codal provision IRC: SP: 42 and IRC: SP: 50 or suitably international codes wherever required.

Contractor also need to study the requirement of the sump tanks and its pumping considering proper capacity design vs runoff.

Surface runoff from transition ramp, cut and cover, and tunnel should be duly connected to the bored tunnel for due discharge.

This stretch of Road is having considerable gradient to the road. The design of road drainage system such as surface drainage for pavement, median, shoulder shall be carried out in accordance with IRC: SP: 42 and IRC: SP: 50.

Surface runoff from the main Highway shall be discharged through longitudinal side drains, which shall be designed for adequate cross section, bed slopes, invert levels, Runoff Storage underground tank of sufficient capacity and stored drain water shall be pumped off with proper manner. Dimensions of the drain shall be wide enough to take the runoff.

3. PAVEMENT DESIGN

3.1. Rigid Pavement

The Rigid Pavement is proposed for the merging lane (CH. 2+540 to CH. 9+190 ,), tapering as 1 in 20, to the Goregaon Mulund Link Road. The following parameters be adopted wherever rigid pavement is required, and as directed by the Engineer.

Table 2: Design Parameters for Rigid Pavement

Sr. No.	Description	Details
1	Design Life	30 Years
2	Traffic Intensity per day (CVPD)	4800 vehicle/ day *
3	Annual Traffic Growth Rate	5%
4	Temperature Differential	21 ºC
5	Flexural Strength of Concrete	4.5 MPa
6	Subgrade CBR	8%

Note: * indicates the minimum value to be adopted for CVPD for the year 2022, If after detailed traffic demand modelling the value of CVPD increases, higher of the two value should be utilised.

3.1.1. Design

The rigid pavement shall be designed as per IRC 58 to withstand the design CVPD. The minimum thickness of various layers of the rigid pavement shall be as stated in the Employer's Drawings. If the design thickness based on the traffic study projected for the design life, carried out during detailed design stage is found to be more than the minimum thickness mentioned in Employer's drawings, higher of the two shall be provided

3.1.2. Durability

Durability to be checked with consideration as per IRC: 112 section 14

Goregaon Mulund Link Road shall not only be safe but also durable. This would mean that deteriorating effects of climate and environment in addition to the traffic shall be duly considered in design. The pavement structure shall be designed such that deterioration over its design service life does not impair the performance below that intended, having due regard to the service environment and anticipated level of performance. Durability recommendation for a concrete mix with 20 mm size aggregate for 'severe' exposure conditions, maximum water cement ratio shall be 0.45, minimum cement content shall be 360 kg/cu.m, minimum grade of concrete shall be M40 and minimum concrete cover shall be 45 mm.

3.1.3. Safety and Serviceability

In order to achieve safety and serviceability, all designs furnished by the Contractor shall be safe to ensure that the Project or any part thereof (for example embankment, pavement, retaining structures, bridges, culverts etc.) does not collapse (global stability) nor its serviceability/performance (for example settlement, roughness, undulations, deflections, etc) deteriorates below acceptable level as prescribed in MORTH /IRC Publications.

A detailed traffic study was carried out by the DPR consultant engaged by the Employer and the report prepared by him is enclosed in Volume-8 as a reference document. The Employer does not claim the correctness of the data, conclusion or drawings given in the report. The contractor has to verify the design and all other details with his own sources/investigations before using the data contained therein.

An initial traffic intensity of 4800 CVPD on the proposed Highway is adopted. As per IRC: SP: 87, Annual growth rate of Commercial vehicles shall be taken to be a minimum of 5%.

As per guidelines, (IRC: 58/Clause 5.5.2.3) 25% of the total traffic in the direction of predominant traffic may be consider for the Bottom up cracking fatigue damage analysis. where in the case of Top down cracking (IRC: 58-Clause 5.5.2.3) 50% of design traffic of bottom up cracking analysis is considered.

Traffic growth rate shall be established for each category of commercial vehicles to be considered for design of pavement. For traffic projections, the procedure outlined in IRC: 108 may be followed. The Contractor shall adopt a realistic value of the rate of traffic growth, provided that annual rate of growth of commercial vehicles shall not be adopted less than 5%.

3.1.4. Design Traffic

A detailed traffic study was carried out by the DPR consultant engaged by the Employer and the report prepared by him is enclosed in Volume-8 as a reference document. The Employer does not claim the correctness of the data, conclusion or drawings given in the report. The contractor has to verify the design and all other details with his own sources/investigations before using the data contained therein.

An initial traffic intensity of 4800 CVPD on the proposed Highway is adopted. As per IRC: SP: 87, Annual growth rate of Commercial vehicles shall be taken to be a minimum of 5%.

As per guidelines, (IRC: 58/Clause 5.5.2.3) 25% of the total traffic in the direction of predominant traffic may be consider for the bottom up cracking fatigue damage analysis. where in the case of top down cracking (IRC: 58/Clause 5.5.2.3) 50% of design traffic of bottom up cracking analysis is considered.

Traffic growth rate shall be established for each category of commercial vehicles to be considered for design of pavement. For traffic projections, the procedure outlined in IRC: 108 may be followed. The Contractor shall adopt a realistic value of the rate of traffic growth, provided that annual rate of growth of commercial vehicles shall not be adopted less than 5%.

3.1.5. Concrete Strength

The design of concrete slab shall be based on the Garde M40 with minimum flexural strength of 4.5 MPa. It shall be derived from the characteristic compressive strength of concrete.

3.1.6. Rigid Pavement Design

- The flexural strength of Pavement Quality Concrete (PQC) shall be 4.5 MPa (MORTH 602.3.3) and minimum cement content should be 360 kg/cum. The PQC shall rest over Dry Lean Concrete (DLC) sub-base of designed thickness.

- The DLC will meet the minimum cement content and compressive strength of 15 MPa in 28 days, and 10 MPa within seven days, and minimum cement content should be 150kg / cu.m.as prescribed in IRC: SP: 49. The DLC will extend beyond the edge of PQC at a slope of 1:2 on either side.
- Below DLC layer, a properly designed drainage layer constitute WMM and Granular Sub Base (GSB)of designed thickness shall be provided throughout the road width. It shall be designed to obtain a drainage coefficient of not less than 30m per day.
- Rigid pavement has to be designed for the critical stress condition. Stresses due to combined action traffic load and temperature differential between the top and bottom fibres of the slab is considered for the design of concretes lab. Fatigue damage analysis is to be done for following two stress combinations

- Bottom up cracking – Load + Positive temperature differential
- Top down cracking – Load+ Negative temperature differential

3.1.7. Details of Joints

Design of joints shall be in accordance with IRC: 58 section 7

One of the major components of concrete pavement is the spacing and layout of joints as it has significant effect on the pavement performance. All the joints also need to be effectively sealed and maintained well for its better performance.

i) Contraction Joints

Contraction joints are transverse joints which relieve the tensile stresses in concrete pavements. Contraction joints shall be perpendicular to the control line and/or to the dimensions and details shown on the drawings. Provision of transverse joints (3mm to 5mm) shall be arranged while setting up the formworks. Alternately, the joint can be formed by pressing a mild steel T-section into the fresh concrete. Due care is to be exercised to remove bulging which may affect the riding quality. Metal strips of 3 mm to 5 mm width can also be placed before placement of concrete. HDPE strips 3 mm to 5 mm wide also can be used for creating contraction joints. The joint spacing of a concrete pavement depends upon the type of coarse aggregates and the average temperature fluctuation in different seasons. The spacing of contraction joints should be limited to 4.5m to prevent top-down cracking during the night hours.

ii) Construction Joints

Construction joints should, as far as possible, be placed at the location of

contraction joints except in case of emergency when a key joint may be used. Transverse construction joints shall be placed wherever concreting is completed after a day's work or is suspended for more than 90 minutes. These joints shall be provided at the location of contraction joints. At all construction joints, steel bulk-heads shall be used to retain the concrete while the surface is finished. The surface of the concrete laid subsequently shall conform to the grade and cross-sections of the previously laid pavement.

iii) Expansion Joints

Expansion joints are transverse joints to allow expansion of concrete slab due to rise in average temperature in summer months. Bitumen shall be hot poured to seal the joints. A thin synthetic rope should be inserted into the groove to prevent sealing compound from entering into the cracks.

iv) Longitudinal Joints

Longitudinal joints are required in pavements of width greater than 4.5m to allow for transverse contraction and warping. Longitudinal joints shall be provided at the locations shown on the drawings or where directed by the Engineer. The joints shall be parallel to the control line and/or to the dimensions and details shown on the drawings. Bitumen shall be hot poured to seal the longitudinal joints. The line of longitudinal tied joints shall not deviate from the designed position at any point by more than 10 mm. The line shall also not deviate from a 3 m straightedge by more than 10 mm having made due allowance for any planned curvature.

3.1.8. Dowel Bars & Tie Bar

Dowel bars shall have built an integral part of transverse joints. They are usually mild steel round bars of short length, whose half-length is bonded into concrete on one side of the joint and its other half-length is prevented from bonding with concrete. Detail design of dowel bars is to be done by Contractor as per IRC 58 :2015.

Tie bars shall use across the joints of concrete pavements wherever it is necessary or desirable to ensure firm contact between slab faces or to prevent abutting slabs from separating. Deformed tie bars are proposed at joints. Detail design of Tie bar is to be done by Contractor.

3.1.9. Temperature Consideration

Temperature differential between the top and bottom fibres of concrete pavements causes the concrete slab to curl giving rise to stresses. As far as possible temperature differential values estimated realistically, for the given site using geographical parameters and material characteristic should be used for analysis. In the absence of any local data, the

maximum temperature differential values given in IRC:58 may be adopted for the pavement design. The maximum temperature differential during the night is nearly half of the day temperature.

3.1.10. Embankment soil and characteristics of subgrade and subbase

The CBR of embankment soil placed below the 500 mm select subgrade should be determined for estimating the effective CBR of subgrade and its modulus of subgrade reaction k value for design.

The modulus of subgrade reaction 'k' which is defined as the pressure per unit deflection of the foundation as determined plate load tests. The k value is determined from the pressure sustained at a deflection of 1.25 mm. As the plate load test is time-consuming and expensive and therefore the design of k value is often estimated from soaked CBR value. The relationship between the CBR value at different soaked CBR and k value has been given in IRC:58. A minimum CBR of 8% has been recommended for the 500 mm select soil subgrade.

If the CBR of the 500 mm thick compacted subgrade is significantly larger than that of embankment below it, the effective CBR is to be determined as per method described in IRC:58.

The subgrade needs to be protected by providing separation and drainage layers of Granular Sub Base (GSB). The details of separation and drainage layers have been given in IRC:58.

To provide a uniform, stable and permanent support to the concrete slab it is laid over a subbase layer of Dry Lean Concrete (DLC) with minimum thickness of 150 mm having 7 - day average compressive strength of 7 MPa. Cement treated subbase with recycled or marginal aggregated have also been recommended in IRC:58. The interface layer can be made smooth to reduce the interlayer friction by providing a de-bonding interlayer of polythene sheet white or transparent having a minimum thickness of 125 micron. The k values of different types of subbase have also been given in IRC:58.

4. MATERIALS

4.1. General

Sourcing of all materials as well as compliance with environmental requirements under the applicable laws in respect of all works to be executed under the Bid Document shall be the sole responsibility of the Contractor. All materials, whether natural (such as earth, gravel, sand, aggregates etc.), processed (such as bituminous and concrete mixes), or manufactured (such as cement, steel, bitumen etc.) shall be incorporated into the work only if they are tested from recognised NABL lab and found to meet the requirements of

this Tender Document or, in the absence of any provision in this Tender Document, conform to the best industry practice.

4.2. For Rigid Pavement Work

4.2.1 Cement

- The cement 43 grade conforming to IS 1182 -1989, IS 12269- 1987, IS 455 and IS 1489 – Part 1 shall be used.
- The Engineer may give Notice for usage of Sulphate Resistance Portland cement conforming to IS 12330, if the soil around concrete pavement has soluble salts like sulphates in excess of 0.5 per cent.
- In all cases cement shall meet 28 days strength requirements of IS 1182 -1989 and 12269-1987

4.2.2 Aggregates

- **Fine Aggregates**

  The fine aggregate shall comply with Clause 602.2.6.3 of MORTH Specifications for Road and Bridge Works.

- **Coarse Aggregates**

  Coarse aggregates shall comply with Clause 602.2.6.2 of MORTH Specification except that the maximum size of the coarse aggregate shall be 26.5 mm, and aggregate gradation shall comply with Table 600-1 and Table 600-2 of MORTH Specification for Road and Bridge Works.

4.2.3 Dry Lean Cement Concrete

- **Moisture Content:** The optimum water content shall be determined and demonstrated by rolling during trial length construction and the optimum moisture content and degree of compaction shall be got approved from Engineer. While laying in the main work, the lean concrete shall have a moisture content between the optimum and optimum +2 percent, keeping in view the effectiveness of compaction achieved and to compensate for evaporation losses.
- **Cement Content:** The minimum cement content in the lean concrete shall not be less than 150Kg/cum of concrete. If this minimum cement content is not sufficient to produce concrete of the specified strength, it shall be increased as necessary without additional cost compensation to the Contractor.
- **Concrete Strength**: The average compressive strength of each consecutive group of 5 cubes made in accordance with Clause No. 903.5.1.1 of MORTH Specifications

shall not be less than 10 MPa at 7 days. In addition, the minimum compressive strength of any individual cube shall not be less than 10 MPa at 7 days. The design mix complying with the above Clauses shall be got approved from the Engineer before 30 days of commencement of work and it shall be demonstrated in the trial length for construction of 150 mm thick Dry Lean Concrete.

4.2.4 Cement Concrete Pavement (PQC)

- **Cement Content**

  Cement as per clause 4.2.1 above is used, the quantity of cement shall not be less than 360 kg/cum. If this minimum cement content is not sufficient to produce concrete of the specified strength, it shall be increased as necessary by the Contractor at his own cost.

- **Concrete Strength**

  The characteristic flexural strength of Pavement Quality concrete shall not be less than 4.5 MPa unless specified otherwise. Target mean flexural strength for mix design shall be more than 4.5 MPa + 1.65s, where s is standard deviation of flexural strength derived by conducting test on minimum 30 beams. The design mix complying with the above Clauses shall be got Noticed from the Engineer before 30 days of commencement of work and it shall be demonstrated in the trial length for construction for 300 mm thick Pavement Quality Concrete.

- **Steel for Dowels and Tie Bars**

  Steel shall conform to the requirements of IS:432 and IS: 1786 as relevant. The dowel bars shall round MS Bars conform to IS:432 of Grade I. Tie bars shall be High yield Strength Deformed bars conforming to IS:1786 and grade of Fe 500 or plain bars conforming to IS:432 of Grade I. The steel shall be coated with epoxy paint for protection against corrosion.

4.3. Flexible Pavement Work

The flexible pavement is proposed for the Goregaon Mulund Link Road after the exit of tunnel near film city road and Khindipada junction.

4.3.1 Subgrade and Sub-Base Material (Flexible)

Sub grade:

A sub grade CBR value of 8 % has been considered for the design of pavement. Sub grade is to be compacted in layers of loose thickness of 200 mm to a minimum of 98 % of maximum dry density of modified proctor compaction tests.

Sub-Base:

Sub-base 200mm thick granular type (GSB) has been recommended for the pavement. The GSB layer which also acts as drainage layer shall be continued over the full formation width. The sub-base material should have a minimum CBR of 30% at the highest anticipated moisture content when compacted to a minimum of 98 % of maximum dry density in the modified proctor Compaction Tests. Particle size and plasticity requirements of sub-base materials should be as specified in the technical specification.

Base:

250mm thick Wet Mix Macadam (WMM) has been proposed as base for carriageway. The minimum CBR value of granular base material should be 25% and the Plasticity Index less than 5 %. The gradation and compaction criteria of base materials should be as per the technical specification.

5. PAVER BLOCKS

The interlocking concrete paver tiles shall conform to IRC SP-63. They shall be tested as per the code.

The compressive strength requirement of concrete paver block shall be minimum 47.2 MPa (N/sq.mm) for 28 days (Testing as per IS-15658) after applying the correction factor as per IS-15658. The Concrete grade of paver tiles shall not be less than M40. Design mix concrete shall be adopted. Size, shape color, laying pattern etc. shall be Noticed by the Engineer. For acceptance, the average of compressive strengths of 8 pavers shall be minimum 47.2 MPa. Any paver in the tested lot shall not have compressive strength less than 40.1 MPa.

6. SIGNAGE

The signage details provided in the Employer's Drawings are indicative. The road, Traffic and Safety sign, marking drawings provided therein are for reference purpose and the Contractor shall design the sign and markings as per IRC 67, 35 and another relevant IRC and get the same Noticed by the Engineer.

DESIGN CONSTRUCTION AND OPERATION OF TWIN TUNNEL FROM FILM CITY GOREGAON TO KHINDIPADA (AMAR NAGAR), MULUND INCLUDING BOX TUNNEL (CUT & COVER) AT FILM CITY, ELECTRICAL, MECHANICAL AND ASSOCIATED WORKS.

Volume 4

Outline Design Specification

Section 2

Tunnel Works

Brihanmumbai Municipal Corporation

Mumbai, Maharashtra, India

Chief Engineer (Bridges),

Office of the Chief Engineer (Bridges)

5B Bhandar, Bhandup Complex Store Building,

Darga Road, Khindipada,

Mulund (West), Mumbai- 82. India

Website: https://mahatenders.gov.in

SECTION 2: TUNNEL WORKS

GEOTECHNICAL, FOUNDATIONS AND TUNNEL WORKS

1. GENERAL, STANDARDS AND CODES

1.1 Purpose and Scope

The purpose of this section of these Design Criteria is to establish the minimum requirements for geotechnical site investigations, studies, analyses, and preparation of geotechnical reports and the design recommendations for earthworks, foundations, structures, and substructure design, and the design for bored tunnel

The Contractor shall be responsible for determining for his design purposes the Geology and the Geotechnical parameters of the sub-surface strata along the route to facilitate design of foundations, earthworks, deep excavations, slope stability, embankments, earth retaining structures and bored Tunnel.

1.2 Codes, Standards, and Regulations

Except where specifically permitted otherwise by the Engineer in writing, the Contractor's design of the Bridge structure shall be in strict accordance with the following design standards and/or specifications applicable.

Indian Standards		
(i) SP 36 (Part 1)	:	Compendium of Indian Standards on Soil Engineering (Laboratory Testing)
(ii) SP 36 (Part 2)	:	Compendium of Indian Standards on Soil Engineering (Field Testing)
(iii) IS 1080 (1986)	:	Code of Practice for Design and Construction of Shallow Foundations on Soils.
(iv) IS 1200 (Part 1)	:	Methodology of measurement of Building and Civil Engineering Works.
(v) IS 1892	:	Code of practice for Sub surface investigations for foundations.
(vi) IS 1904	:	Design and construction of foundations in soils – General Requirements
(vii) IS 2386 (Part 1 to Part 8) 1963	:	Methods of Test for Aggregates for Concrete.
(viii) IS 2720	:	Method of Test of Soils
(ix) IS 2911 (Part 1) 1979	:	Code of Practice for Design and Construction of Pile

			Foundations.
(x)	IS 3067 (1988)	:	Code of Practice for General Design Details and Preparatory Work for Damp-Proofing and Water-Proofing of Buildings.
(xi)	IS 1322: 1993	:	Code of practice for Bitumen felts for water proofing and damp-proofing
(xii)	IRC: SP:91-2019	:	Guidelines for Road Tunnels.
	And all reference list provided on page 143 of SP 91:2019		
(xiii)	IS 16471 : 2017	:	Guidelines for Protection of below ground structures against water from the ground.
(xiv)	IS 12054 : 1987	:	Code of practice for application of silicone - Based water repellents.
(xv)	NPFA 502-2020	:	Standard for Road Tunnels, Bridges, and Other Limited Access Highways

British Standards Institution			
(xvi)	BS EN 1744-1	:	Code of Practice for Tests for chemical properties of aggregates.
(xvii)	BS 1377	:	Code of Practice for Methods of Test for Civil Engineering Purposes.
(xviii)	BS EN ISO 17892	:	Code of Practice for Geotechnical investigation and testing. Laboratory testing.
(xix)	BS EN ISO 22476	:	Code of Practice for Geotechnical investigation and testing. Field testing.
(xx)	BS EN 1997	:	Eurocode 7. Geotechnical design
(xxi)	BS 5930	:	Code of Practice for Ground Investigations.
(xxii)	BS 6031	:	Code of Practice for Earthworks.
(xxiii)	BS 8000	:	Code of Practice for Workmanship on construction sites
(xxiv)	BS 8002	:	Code of Practice for Earth Retaining Structures.
(xxv)	BS 8004	:	Code of Practice for Foundations.
(xxvi)	BS 8081	:	Code of Practice for Ground Anchorages.
(xxvii)	BS EN 1990	:	Eurocode. Basis of Structural design
(xxviii)	Standard Method of Measurement for Civil Engineering Works,		

Others

xix) American Society for Testing and Materials (ASTM), Section 4 : Construction, Volume 04.08 : Soil and Rock I, and Volume 04.09 : Soil and Rock II, 1995.
xxx) International Society for Rock Mechanics (ISRM), Suggested Test Methods, (various dates).
xxi) Tunnelling
xxii) All aspects of tunnelling shall comply with the requirements of:
xiii) BS 6164: Safety in tunnelling in the construction industry.
xiv) CIRIA Report 80A A review of instruments for gas and dust monitoring underground.
xxv) CIRIA Report 44 Medical Code of Practice for working in compressed air.
xvi) CIRIA Report 81 Tunnel water proofing

Note;

IRC Codes and Guidelines maybe subject to review. Hence the latest revision shall be adopted for the design. Where design standards are not specifically mentioned, the priority order of Design Standards is,

1) Indian Road Congress (IRC), IS Codes
2) British Standards (BS) or AASHTO LRFD
3) Internationally-recognized standards

If there are no standards for specific design items for the Goregaon Mulund Link Road Project in the codes listed above, equivalent international standards shall be applied after obtaining Notice to Proceed from the Engineer.

1.3 Design Considerations

In his design the Contractor shall take adequate measures to minimise the amount of differential settlement of road surfaces around below ground level works.

All deep excavations shall be stabilized with any suitable means.

The slopes of all permanent cuttings and excavations shall be so designed that they are capable of supporting vegetation and shall be stabilised where necessary. In particular, soil slopes shall be hydroseeded or turfed. Where necessary, soil slopes shall be pitched with stones or brick on edge.

2. Site Investigations and Laboratory Investigations

All Site Geotechnical Investigation Shall Be as Per IRC : SP:91/Chapter 3

2.1. Site Investigations

2.1.1. General Conditions

Subsurface Conditions

Regional engineering geology aspects for the area of the Road alignments are generally documented by the Geological Survey of India.

Seismic Conditions

Detailed, seismic loading and ground-acceleration criteria are discussed under Structural, of these Design Criteria. Consideration of design-level seismic forces in the design of temporary structures is generally not required, except that such designs shall ensure public safety and cause no loss or damage to adjacent projects or properties.

The effects of the design seismic event on the stability of slopes and on the potential for liquefaction of soils shall be taken into account in the design.

2.1.2. Investigation Requirements

Existing information shall be supplemented with project-specific site investigations (SI). The intent and objectives of the SI shall be to collect all pertinent and reliable data and information required to produce a safe and economic design and to meet tender and construction requirements.

For the purpose of these Criteria, the term SI shall be considered to include, but not be limited to, the following.

- Compiling and reviewing pertinent existing geologic data.
- Compiling and reviewing pertinent existing geotechnical data supplied and from adjacent projects.
- Compiling and reviewing pertinent existing foundation, structure, substructure, and related data from adjacent projects.
- Performing a detailed field reconnaissance.
- Performing geophysical surveys.
- 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, geophysical surveys, slope protection strappings, and core holes of retaining walls and other existing manmade structures.

- Performing laboratory testing of soil, rock, and groundwater samples collected from the ground investigations (including chemical testing to identify potentially corrosive conditions).
- As a minimum, the soils investigation program shall consider the locations and lateral and vertical extent of:
- Major structures (crossing structures, bored tunnel, portal structures, retaining structures,,-etc.).
- Earthworks (soil and rock excavations, embankment fills, land reclamations, areas requiring ground improvement, borrow pits and areas, disposal areas, etc.).
- Existing adjacent structures that may be influenced by proposed construction works (i.e., structures – adjacent to, above, or below excavations or tunnel – that may be affected by construction works such as dewatering or structures deemed to have poor structural integrity; structures containing sensitive equipment or materials; structures with historic/cultural significance, etc.).
- Significant engineering geology features that may influence the proposed construction works (i.e., principal faults, shear zones, persistent jointing; mass wasting, landslips).

Ground investigations, as part of a comprehensive soil investigation programme, shall be conducted according to IS1892 or BS 5930.

The depths of investigation borings shall be consistent with the nature and extent of the proposed construction works.

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 investigations relative to the proposed construction works shall be prepared and submitted for review and acceptance prior to undertaking the work. Revisions to the SI programme, if required, shall be submitted for review and acceptance.

All Consultant-produced ground-investigation data shall be prepared up to 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.

2.2. Investigation Methods

2.2.1. Geologic Studies

Geologic 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.

Project-specific geologic maps shall be prepared at about 1:5,000 scale, and geologic cross-sections shall be prepared at about 1: 5,000 scale, both horizontal and vertical. Suitable base maps for geologic maps shall be utilised.

2.2.2. Geophysical Surveys

Geophysical surveys shall be accomplished where appropriate to provide additional site-specific information on depths and characteristics of overburden soils and bedrock.

Geophysical survey methods may be used to obtain subsurface information for planning other detailed SI studies, and for extending information between investigations.

2.2.3. 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 or BS 5930. Full-time monitoring by qualified geotechnical personnel is required not only to direct the drilling, sampling, and coring, but also to prepare field drill hole records.

2.2.4. Other Ground-Investigation Methods

Other ground-investigation methods commonly employed include, but are not limited to, the following:

- Field testing: Standard Penetration, cone penetration, vane shear, pressure meter, permeability/water absorption, impression packer/discontinuity survey, acoustic borehole imaging, in situ density, N-Schmidt hammer, plate load testing.
- Field instrumentation: piezometers, inclinometers.
- Trial pits with/without block sampling.
- Inspection pits.
- Geocore probes.
- Hand auger borings.
- Coring through rock, retaining walls or other manmade features.

- Slope protection stripping.
- Pumping tests.
- Groundwater sampling.

2.2.5. Groundwater

Piezometers shall be installed during ground investigations to measure current and seasonal fluctuations in groundwater levels. The SI programme shall incorporate the details of a groundwater observation plan, including locations and details of piezometer installations and frequency and duration of observations. It should also include chemical analysis of ground water. Full-scale groundwater pumping tests shall be conducted to develop design parameters for construction dewatering schemes, where required

Groundwater information shall be interpreted, and recommendations for design groundwater levels, including differential levels that may develop across structures shall be provided.

2.3. Laboratory Testing Methods

2.3.1. General Methods

The laboratory testing programme shall be developed considering not only the particular site conditions and project requirements, but also the applicable design standards, codes, regulations, and related publications. Prior to undertaking the work, detailed plans/proposals for the laboratory testing programme shall be prepared and submitted for acceptance along with technical specifications and standard forms, outlining the proposed staffing and reporting formats and the types and numbers of tests proposed. Revisions to the laboratory testing programme, if required, shall be submitted for review and acceptance.

All Consultants-produced laboratory test data shall be prepared using internationally accepted standards e.g. AGS format, latest version. 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.

2.3.2. Index/Classification Testing of Soil Samples

All index/classification test procedures for soils shall comply with the requirements of IS 2720/BS 1377. Tests shall include the determination of natural moisture content, specific gravity, particle size distribution (with and without hydrometer), Atterberg limits, insitu bulk and dry density, and dry density and moisture content relationships.

2.3.3. Strength Testing of Soil Samples

Strength-test procedures for soils shall include single- and multi-stage, consolidated-drained and consolidated-undrained triaxial tests; unconsolidated undrained triaxial tests; laboratory vane shear tests; and pocket shear meter tests, all according to IS 2720 (Part 11). Unconfined compressive strength testing for soils shall be according to IS 2720 (Part 10)/ASTM D2166, and consolidated drained direct shear testing shall be according to IS 2720 (Part 13)/ASTM D3080.

2.3.4. Consolidation Testing of Soil Samples

Consolidation test procedures for soils shall be based on one-dimensional, consolidation methods according to ARE 2720 (Part 14) or Clause 3 of BS 1377: Part 5, with some minor modifications as accepted.

2.3.5. Permeability Testing of Soil Samples

Laboratory test procedures of soil permeability shall include constant-head permeability methods for granular soils, generally according to IS 2720 (Part 17 or 36) or ASTM D2434, and variable-head permeability methods for cohesive soils, generally according to Soil Testing for Engineers by T. William Lambe. Permeability of in situ materials shall be measured by either constant-head or variable-head methods, using standpipe piezometers installed during the ground-investigation programme.

2.3.6. Chemical Testing of Soil and Groundwater Samples

Chemical test procedures for soils and groundwater shall include, as appropriate: determinations of resistivity, redox potential, pH, chloride ion content, sulphate ion content, total sulphate content, total sulphide content, organic content, and carbonate content, according to IS 2720 or BS 1377 or BS 812, or both, and identification of other potentially corrosive conditions.

2.3.7. Testing of Rock Specimens

All rock testing shall be according to applicable IS or ISRM suggested methods. Tests shall include the determination of natural moisture content, porosity, density, adsorption, unconfined compressive and tensile strength, strength of rock joints, mineralogy, and special tunnel boring machine (TBM) bore ability testing.

3. BORED TUNNEL

GENERAL

3.1. Method Statement

The Contractor shall prepare and submit to the Engineer for his consent, a detailed design report including calculations, schedules and drawings for tunnel construction, prior to the commencement of such works. Additional information shall be supplied upon request of the Engineer. The Report shall explain the basis of the design, design assumptions, and design parameters of all civil, and structural works to be undertaken.

The Contractor shall prepare a method statement presenting full details of the design, the materials, equipment, plant and operations involved in the construction of bored and submit to the Engineer as part of the Design Report. The Contractor shall ensure that ground movements and changes to the piezometric pressure which may affect adjacent roadway tracks, subway, utility services and any adjacent buildings, surface or underground structures are kept to a minimum.

3.2. Types and General Methods of Analyses

The running tunnel shall comprise single-track 3 Lanes tunnel approximately one tunnel diameter (external) apart. This Criterion may not apply in areas of poor ground, where greater clear distances may be necessary.

The top of road alignment is shown on the Tender plan and profile drawings. Tunnel shall be circular shape.

The Contractor shall be responsible for the safety and security of excavations at all times during the execution of the Contract. The Contractor shall present to the Engineer details of his proposed methods for excavation, and spoil Disposal removal. No excavation shall take place until the Employer Representative's consent has been obtained.

Excavation shall be carried out in a uniform and controlled manner; over-cutting shall be kept to a minimum. In water-bearing strata the Contractor shall use such methods and take such steps as are necessary to control flows and maintains the stability of the excavation.

Where the Contract specifies limits to surface settlement and/or protection in respect of existing service or structures, the Contractor shall provide calculations demonstrating that the method of excavation will result in compliance with those requirements. Details of the monitoring arrangements that are proposed for the recording of movements and the verification of the degree of any settlement or damage to services or structures shall be in accordance with Standard.

Bored tunnel for the Road Corridor will be in rock and soil and will be excavated using tunnel boring machines. Initial tunnel support will generally include precast concrete segments, shotcrete/wire mesh, rock bolts, lattice girders, steel sets, or forepoles wherever necessary.

Geometries and stability of rock wedges affecting tunnel support requirements, including completely /highly weathered rock with controlling remnant rock jointing or other structure, shall be determined analytically, generally using stereographic projection, finite element method or vector methods. Analyses shall consider planar sliding along individual joints and block sliding, or fallout, along joint-set combinations. Analyses shall provide for both static and dynamic loading conditions.

3.3. Design Considerations

All permanent structures shall be design using IRC 112 and BS 8110

The method of analysis of the permanent lining shall take into account the proximity to the face at the time of installation and the potential for additional ground loads as the face advances.

The design method for the analysis of the bored tunnel linings 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. The method of analysis shall conform Compressibility of the ground, durability aspects that shall include impermeability, electrical resistivity of concrete, ASR resistance and sulphate resistance as per ~~to~~ the guidelines of the International standards.

Where permanent (secondary) lining is installed inside a temporary primary lining.

Permanent lining design shall consider all loads as described in Subsection 3.4 and any additional ground loads from time-dependent ground strains. If the life of the temporary lining is less than the design life for the Project, then the Contractor shall design the secondary lining ignoring the contribution of the temporary support for structural purposes.

Due account shall be taken of the degree of flexibility of the linings to be used in the various soil conditions and taking account of the size, proximity, timing and method of construction of adjacent excavations. The inherent lining flexibility may have to be reduced in order to maintain acceptable values for the deflection of the lining.

The Contractor shall at his own expense conduct soil investigations where his designs or method statements identify that it is necessary or prudent to do so to enable him to identify all 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.

If the Contractor intends to carry out additional ground investigation from the surface, beyond the limits of the worksite, 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, although the Employer will provide assistance where it appears that this would be beneficial.

If surface access for ground investigation 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 found as construction proceeds. The Contractor shall also identify how his tunnel design and construction activities will be modified to recognise the deficiency of ground information prior to tunnel driving.

During tunnel driving ground investigation data shall be kept under constant review and reinterpreted as more detailed information becomes available, to maintain up to date predictions of the ground likely to be encountered. This review shall be fully integrated into the construction risk control and management systems and should typically include:

a. detailed geological logging of the ground exposed during construction

b. probing ahead of and around the tunnel face, if the ground changes or expected to change.

c. interpretation of fresh data and correlation with previous information

d. prediction of ground conditions likely to be encountered.

Ground information from all construction activities shall be collated and interpreted.

The geotechnical design parameters adopted and the method of analysis of the lining shall be subject to the consent of the Employer prior to commencement of design.

The design life required shall be obtained by the use of durable materials, corrosion protection, resistance to or avoidance of wear etc. All underground works shall be designed to achieve the following minimum design lives with minimum or zero maintenance as per BS EN 1990:

(a) Main structure resisting ground and groundwater loads:	100 years
(b) Non-structural components	50 years
The design Fire Resistance Period shall be 4 hours.	

The Contractor shall design all necessary linings for tunnel and shafts including temporary linings. If any proprietary methods, materials or components are proposed to be used the Contractor shall be responsible for demonstrating their fitness for purpose to the full satisfaction of the Employer.

The Contractor shall determine the configuration of rings, segmentation and details of joints and fixings etc. 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:

Ring configurations,

segment size and form,

Fixing details including:

- ring to ring fixings,
- segment to segment fixings,
- For fixing all equipment's to be installed under this Contract.
- for fixing equipment required by Designated Contractors etc. to suit segment position,
- handling and installation.
- Holes, recesses and fixtures for other system components
- Designs shall allow for tolerances in production and installation of segments.

Other components:

- grout hole valves,
- gaskets,
- bedding and packing materials.

Instrumentation and monitoring to demonstrate performance of the installed linings.

The Contractor shall submit for the consent of the Employer a comprehensive schedule of tests to establish the quality and performance of all elements of the tunnel lining, including:

- segment materials,
- permeability,
- production tolerances,

- 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.

3.4. Loads

The method of analysis shall consider in situ ground stresses and shall provide evidence and/or measurements to the Employer in support of the parameters adopted in the design.

Analysis shall be undertaken of the additional ground loadings imposed by adjacent structures on the underground structures and due account taken of the additional stresses in the design of the underground structures.

Where the tunnel is adjacent to buildings and other structures, analysis shall be provided to ensure that no loss of support can occur which endangers the stability of the buildings and structures and that settlement will be within standard specified limits.

All tunnel sections shall have permanent, durable, structural linings, generally consisting of bolted steel segments, pre-cast concrete segments, or cast-in-situ, plain or reinforced concrete.

Linings shall be designed to withstand all environmental loadings and effects without detriment. In general, tunnel linings shall be designed to fulfil the following requirements and to resist the following loadings.

- Superimposed surface loads from traffic, existing structures over and adjacent to the tunnel, and any specified future loads.
- Soil/rock, water, and seismic loads.
- Roadway loads.
- Structural requirements for resisting buckling.
- Long- and short-term ground yield or squeeze.
- Unequal grouting pressures.
- Adjacent tunneling or excavation.

- Openings in, or extensions to, the lining.
- Long- or short-term loads induced by construction.
- Temperature Rise/Fall and shrinkage.
- Handling loads, including impact, especially in the case of unreinforced segments.
- Jacking forces, where appropriate.

3.5. Loading Conditions

The design of the linings for the tunnel shall be fully compatible with the Contractor's proposed method of construction. The principal method is expected to be shield driven tunnel (TBM) with permanent precast concrete lining.

The design shall also take into account all loadings, the requirements of the overall schedule, the need for further investigations as necessary, and contract limitations with regard to ground movements and de-watering.

The tunnel alignment shall generally follow the alignment shown on the Tender Drawings

All components of underground structures shall be proportioned to withstand the applied loads and forces as follows:

a. Dead load comprises the self-weight of the basic structure and secondary elements supported and the weight of earth cover. The depth of cover shall be the actual depth or as per contractor safe design assumption. The maximum depth to tunnel axis shall be used.

b. Traffic surcharge shall be equivalent to Class AA/70R loading of IRC 6.

c. Loads from existing or known future adjacent structures above or within the area of influence, which will remain in place above the tunnel, or any specified future loading. The applicable foundation load shall be computed based on the height and type of occupancy or use. For known future small buildings, a minimum load based on a dead and live load of 50 kPa (up to 2 storey)/110Kpa (3 to 7 storey) at the foundations shall be used.

d. Additional support, ground treatment or additional lining thickening shall be provided unless it can be shown that adequate provision already exists.

e. Where provision for a specific future structure is not made a minimum surcharge of 50 kPa at the existing or design ground level.

f. Hydrostatic pressures ignoring pore pressure relief obtained by any seepage into the tunnel. Two ground water levels shall be considered.

1. Normal
2. One metre above 200-year Flood level or 1.5m above known HFL

Loads and load changes due to known construction activity in the vicinity of the tunnel, such as the excavation of underpasses, basements, pile groups, bridges, diaphragm walls and cable ground anchors.

The design of the tunnel linings shall take into account the proximity of the tunnel one to another, the sequence and timing of construction and the proximity of adjacent structures and utility services.

3.6. Flotation

For floatation check, the water table is assumes to coincide with the Ground level.

Where the bored tunnel is relatively shallow they shall be checked for the possibility of flotation due to differential water pressure at representative typical locations.

The Contractor shall include in the design of the bored tunnel structures suitable methods for countering the uplift due to displaced water.

3.7. Heave and Settlement

All tunnel designs shall be checked against flotation and heave in accordance with the methods specified above. Wherever these checks indicate a critical case the Contractor, at shall carry out a more rigorous analysis. Such analysis shall clearly show the factor of safety achieved by the design and shall be to the consent of the Employer.

3.8. Tunnel Lining

The permanent tunnel linings shall be bolted segmental precast concrete, except in case of cross-passages, enlargement of tunnel and bored tunnel where cast-in-situ lining shall be used.

Alternative types of lining may be proposed subject to the consent of the Engineer.

The Contractor shall take into account, inter alia, the following when considering the design of lining:

a. The internal diameter shall take account of the need to accommodate the Road Traffic requirement, Ventilation duct including Traffic signage and E&M fitting to be provided by the E&M contractor.

b. Due allowance for relative movement between tunnels as described in Subsection 4.11.

c. The stiffness of the lining shall be sufficient to limit the maximum allowable deflection to on radius to 25mm. The distortional loads adopted shall also take account of the speed of reloading of the horizontal and vertical ground pressure and in the case of the shallow tunnel, the ability of the ground above the tunnel to generate sufficient passive resistance to maintain stability of the lining.

d. Stresses induced by grouting.

e. The reinforcement for segmental concrete lining shall be detailed such that no electrical continuity will exist across the circle joints. To prevent the stray current effects and to inhibit the corrosion, Micro silica shall be added into concrete. Such concrete shall be tested in accordance with ASTM C 1202 and DIN 1048. RCPT value shall not exceed 1000 coulombs and water permeability shall not be more than 10 mm. However, reinforcement for in situ concrete lining or other structures shall be bonded to mitigate stray currents. Similarly, SGI lining segments shall be bonded to mitigate stray current effects. The bonding will be part of the corrosion control system to be installed by the Contractor. The corrosion control system shall be designed and installed by the Contractor with the Engineer's consent. The system shall be tested to demonstrate its proper function.

f. Blind holes and other fixings shall be necessary for the installation of internal construction, brackets and equipment, such holes or fixings shall be detailed such that they have no adverse effect on the integrity, water tightness or design life of the linings.

3.9. Segmental Linings

The Contractor shall take into account, inter alia, the following when considering the design of linings:

a. a segment shall be considered as a short column subjected to axial load and bending moment. The design of the segments shall be adequate for all temporary loads during stacking, lifting, erection and impact.

b. 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.

c. the width of segments shall be consistent with the capacity of the circle bolting arrangements to withstand the shear forces induced in linings built with staggered joints.

d. the lengths of segments shall be chosen with regard to bending stresses during handling and erection and the long-term stresses due to deflection and thrust. In the design for

handling and erection a safety factor of 5.0 shall be applied to the self-weight of the segment combined with zero axial load.

e. Opening of longitudinal joints.

The design of linings shall include suitable taper 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 tunnel.

f. Drilling for fixing at pre-determined points on the lining may be permitted.

3.10. Segment Details

1. Gasket grooves

Gasket grooves shall be provided around all joint faces of each segment and key in accordance with the dimensions as approved by the Employer. The design shall incorporate sealing gaskets in the segmental design.

2. Concrete cover

Where reinforcement is incorporated into the segments the minimum cover to all reinforcement, including link steel, shall be provided as 50mm on all sides.

3. Grout holes

Grout holes shall be provided in segment as per design excluding the key and shall be of a nominal 50 mm diameter.

4. Logo

BMC logo at minimum 5% segments required

5. Mould for segment

All Mould for casting segment should be new fabricated material with prior approval from Employer/Engineer –in-charge.

3.11. Conventional Tunnel Lining

Arch/ lattice girders, base plates, ties and connections shall be formed from steel conforming to Standards. Arch girders shall be rolled to suit the dimensional requirements of the approved design.

The Contractor shall provide dimensional details of the arches/ lattice, calculations regarding imposed loads and design and such other information.

1. Spiels, Dowels and Rock bolts

   Spiels shall be steel rods or tubes of diameter not less than 25 mm of steel.

   Rock dowels shall be un-tensioned 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.

   Rock bolts shall be tensioned bar manufactured out of one of the followings: solid steel bar, slit or deformed steel tube, glass fibre reinforced resin rods.

   Alternative materials shall be subject to the consent of the Employer in charge.

2. Sprayed concrete

   Materials for sprayed concrete shall comply with Concrete Materials section of the Construction Specification.

3. Waterproof membranes

   Waterproof membranes shall consist of an impermeable heat welded sheet of one of the following materials: high density polyethylene (HDPE), soft polyethylene chloride (PVC), ethylene copolymerical bitumen (ECB). Materials for sprayed concrete shall comply with Concrete Materials section of the Construction Specification.

   The membrane as supplied shall be of such dimensions and shape as will result in the minimum of on-site seam welds. The loosely laid pvc sheet shall have a minimum thickness of 2 mm +/- 10% or as per design requirement based on site condition. Materials for sprayed concrete shall comply with Concrete Materials section of the Construction Specification.

4. Cavity grouting

   General purpose cement grout with suitable admixture shall be mixed in accordance with the proposed design mix and purpose of use. Grout shall be used within one hour of mixing.

3.12. Tunnel Boring Machine (TBM) and Shields

The Contractor shall be fully responsible for the selection, design and supply of tunnelling machines, shields and backup equipment. The TBM shall also meet all the requirements as specified in Employer Requirements and Outline Construction Specification.

Tunnelling machines shall be robust with adequate safety margins for the anticipated duty, designed and manufactured to comply with all safety standards.

The Contractor shall submit to the Employer for his consent, a programme for the provision, factory inspection, testing, transport, erection and commissioning of TBM or shield. The Employer's consent does not, however, absolve the contractor of his responsibility to use appropriate equipment and complete the work as scheduled.

Tunnelling Machines 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. Test running will also be required at site following assembly, prior to commencement of tunnel driving.

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.

The Contractor shall provide and maintain a complete list of the names of persons and their duties, responsible 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.

For TBM breakthrough in launching/ retrieval shafts, soft eye should be used with Fibre reinforcement only.

3.13. Waterproofing

During construction in water bearing ground, the seepage water shall be controlled by suitable means and design should provide for the same. The Contractor shall obtain the Employer's prior agreement to the process he intends to adopt. Pumping of large quantities of water such that the piezometric pressure in the vicinity is within permissible safe limits and contractor is required to get permission from related authority.

Groundwater leakage rates shall not exceed 0.1 litre/m^2/day and 0.2 litres/m^2/day for segmental lining and in-situ lining respectively. For any 10m length of tunnel the water ingress rate shall not exceed 0.2 litre/m^2/day and 0.4 litres/m^2/day for segmental lining and in-situ lining respectively.

The design shall incorporate two sealing gaskets in the segment design. Materials for sealing gaskets shall be one gasket of hydrophilic material and one gasket of elastomeric type. Materials shall have acceptable fire performance for use on an underground roadway.

Notwithstanding the above limits on groundwater leakage rates, the design shall aim to ensure that no loss of ground occurs through any part of the structure. All grouting holes shall be fitted with non-return valves with double sealing rings.

3.14. Underpinning of Existing Structures

Where the construction of tunnel or other underground works would necessitate removal of existing support or foundations to existing structures the Contractor shall carry out investigations of the extent of the existing works, their design and loading conditions. The Contractor shall design and carry out such works as are necessary to maintain the integrity of the structure at all times including its design life. No work shall commence prior to the consent 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 Price.

3.15. Cross Passages

"Passenger emergency evacuation design for cross passages between running tunnels which are constructed by bored method shall be in accordance with the requirement relevant IRC SP91 specifications. Blasting is restricted for Tunnel alignment due to Sanjay Gandhi National Park terms and condition.

The locations of cross passages should be as per IRC guideline, wherever possible, shall be chosen to avoid critical sections of the alignment where their construction could have an adverse effect on adjacent structures. The c/c spacing between the cross passage should not be more than 300 meter.

3.16. Sumps in Running Tunnel

Sumps shall be located at every low point within each running tunnel.

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.

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.

The reserve capacity of a groundwater seepage sump shall be calculated on the basis of the area of tunnel lining applicable to the sump in accordance with the following formula.

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

Where,

V_R = Volume of reserve, m^3

A = Tunnel lining area, m^2

v = Maximum leakage rate, $l/m^2/day$

t = Maximum response time, (day)

F.O. S = Factor of Safety

For running tunnel low point sumps, the response time "t" shall be 24 hours and the factor of safety shall be 1.5.

The sump design shall include outlets for the longitudinal drainpipe 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 as approved. Permanent discharge mains shall be installed as well as embedment of conduits for permanent electric power cables to the pumps.

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 recommendation for consent. The layout shall be such as to facilitate easy removal & replacement of pumps.

The linings of the sumps shall be designed for the appropriate ground and groundwater loads.

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.

3.17. Ground Treatment and Temporary Support

For all bored-tunnel sections, a plan shall be prepared, based on all of the available data, of the anticipated need for and methods of providing the following.

- Ground treatment at break-in / break-out locations
- Ground treatment in advance of the tunnel excavation.
- Temporary support during tunnel excavation.

This information and the assumptions on which it is based shall be shown on the design drawings. The effect of tunnelling activities on structures located above the line of the tunnel shall be determined and any remedial action necessary to minimise the settlement of these structures shall be implemented prior to tunnel excavation.

A detailed materials and workmanship specification shall be provided for the use, if any, of shotcrete, or rock bolts, or both as part of any final/permanent liner or support system for tunnel.

4. SETTLEMENT AND BUILDING PROTECTION

4.1. General

The Contractor shall design both his temporary and permanent works to ensure that ground movements at the ground are kept to an absolute minimum. The Contractor shall use proven techniques. Good workmanship is essential to restrict ground loss.

The Contractor shall be responsible for the control of all ground movements and for any resulting damage to buildings, bridges and roads. The Contractor's attention is drawn to the General Conditions of Contract and Employer's Requirements relating to repair of damage should any arise as a result of the Contractor's construction activities.

The Contractor shall take due regard of the presence of utilities over and adjacent to the Works. The Contractor shall carefully and regularly monitor the ground adjacent to open cut excavations and along tunnel drives to determine the rate and magnitude of any settlements.

Settlement shall be limited such that any individual structure or buildings shall not suffer damage greater than "Slight" as defined in the Damage Classification Table 8.1.

Settlement to Important Structures, Bridges, Heritage Buildings shall be limited to "Negligible" as defined in the Damage Classification Table 8.1.

The general approach to settlement control and building protection shall involve the procedures described below.

4.2. Minimising Ground Movements

Construction from the surface shall be undertaken with due regard to the settlement associated with the particular method chosen. In particular, the following methods will not be permitted:

1. Use of ground anchors beneath adjacent buildings.
2. Non-recoverable timber ground support.

Ground water lowering by pumping is not prohibited by either the current Delhi Government Laws or Regulations. However, the Contractor shall take adequate precaution in using this method which shall only be used inside cut & cover tunnel after the walls have been installed. Necessary approval will be required from local Water Board who will offer guidance on disposal of water.

4.3. Prediction of Ground Movements

The Contractor shall obtain consent from the Employer for his proposed methods of supporting and predicting settlements adjacent to structures. Proven methods based on practical experience shall be used.

The Contractor shall provide predictive assessments of the anticipated ground movements when making submittal for consent of his proposed method of construction of particular sections of tunnel.

4.4. Structure Condition Survey

The Contractor shall undertake a condition survey of all structures within the zone of potential influence as determined by the Contractor's analysis which are anticipated to incur movements in excess of the action level for Stage 1 specified below. `Structures` includes all surface and sub-surface structures including historical monuments, buildings, bridges, roads, tunnels, utilities, culverts and sewers.

4.5. Assessment of Impact on Structures

The Contractor shall provide an assessment of the effect of the predicted movement on all structures within the zone of influence.

Settlements shall be limited as defined in Sub-Section 8.1 above.

Each building shall be categorised into one of the risk categories, in accordance with criteria listed in column of the Damage Classification Table 8.1.

Depending upon the level of risk, precautionary and protective measures shall be proposed by the Contractor and put into effect after consent from Engineer.

4.6. Staged Assessment

Assessment of the effects of settlement shall be undertaken in one, two or three stages, depending upon the findings at each stage, as described below: -

- Stage 1

  The effect of building foundations on the pattern of settlement is ignored. Any structure where the predicted settlement is less than 10mm and the predicted ground slope is less than 1/500 need not be subject to further assessment. All other structures within the zone of influence shall be subjected to a Stage 2 assessment.

- Stage 2

Structures subject to settlement from bored tunnel 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.

- Stage 3.

  All structures which are placed in Category 3 or above in the Damage Classification Table 8.1, during the second stage assessment, shall be subjected to a further settlement assessment. A structural survey shall be undertaken by the Contractor to determine the structural form and condition of a building, followed by an analysis of how individual elements of the building would be affected by the predicted settlement. 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 Employer for his consent.

4.7. Monitoring

Monitoring of ground settlement shall be carried out during construction by the Contractor, to check that the ground is behaving as predicted. The Contractor shall submit for the Employer consent a monitoring system and procedures to immediately detect movements.

The extent of monitoring of structures shall be carried out on a case-by-case day to day or more frequent basis depending upon the assessment of risk of damage. Special attention shall be paid to the Sanjay Gandhi National Park area, Tulshi and Vihar Lakes, historical buildings, sensitive structure, underground water tunnel, vent shaft, wells located along the alignment. Monitoring shall begin prior to commencement of the Works to enable base-line values to be determined accurately and shall continue until all settlements due to the underground works, as shown by the monitoring, has effectively stopped for a period of three months.

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 Existing Building Structures 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 Existing Building Structures.

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.

Vibration recording devices shall be provided to monitor for vibrations which may cause damage to the proposed constructions and Existing Building Structures. 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 Existing Building Structures.

The Contractor shall make monitoring results available for inspection by the Employer at the construction site offices.

4.8. 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 Buildings	Approx[2] Crack Width(mm)	Max Tensile Strain %
0	Negligible	Hairline cracks.		Less than than 0.05
1	Very Slight	Fine cracks easily treated during normal redecorations. Perhaps isolated slight	0.1 to 1	0.05 to

		fracture in building. Cracks in exterior brickwork visible upon close inspection.		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
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 or 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. Utility services disrupted.	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 lose bearing, walls lean badly and require shoring. Windows broken by distortion. 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 analysis.

2. Crack width is only one aspect of damage and should not be used on its own as a direct measure of it.

4.9. Limiting Construction-Induced Vibrations at adjacent Existing Building Structures

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 Existing Building Structures shall not exceed the values in the Table below:

Peak Particle Velocities in mm/sec (Max. Allowable) at Adjacent Existing Building Structures

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

NOTE: Contractor to produce confirmation/approval letter for chose design limit of vibration from SGNP before execution of work.

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

4.10. **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 Existing Building Structures 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 (for both in bored TBM and NATM

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 for both in bored TBM and 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.

4.11. **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 5millimetres.

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 Existing Building Structures 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. Inclinometers, strain gauges and extensometers in the ground and within diaphragm walls (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 (to be proposed by the Contractor for the acceptance of the Engineer) 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 (or retaining structure) and/or into a hard stratum.

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 Existing Building Structures where tilt has been identified as being critical.

19. Crack meters shall be installed to monitor existing and new cracks on applicable Existing Building Structures.

4.12. **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 Existing Building Structures, 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 both in bored TBM main Tunnel and NATM for Cross Passages 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 Existing Building Structures /Instrument/parameter for Geotechnical and Bored tunnel works/ parameter and control parameter for both in bored TBM and NATM works. "Action Level" shall be set at 0.8 times the serviceability limit value defined for the monitored Existing Building Structures /Instrument/parameter for Geotechnical and Bored tunnel works/ parameter and control parameter for both in bored TBM and NATM works. "Alarm Level" shall initially be set at the serviceability limit value defined for the monitored Existing Building Structures /Instrument/parameter for Geotechnical and Bored tunnel works/ parameter and control parameter for both in bored TBM and 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 (for both in bored TBM and NATM 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 8.1

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.

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 Existing Building Structures 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.

4.13. 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.

4.14. 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.

4.15. 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 Existing Building Structures 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.

DESIGN CONSTRUCTION AND OPERATION OF TWIN TUNNEL FROM FILM CITY GOREGAON TO KHINDIPADA (AMAR NAGAR), MULUND INCLUDING BOX TUNNEL (CUT & COVER) AT FILM CITY, ELECTRICAL, MECHANICAL AND ASSOCIATED WORKS.

Volume 4

Outline Design Specification

Section 3

Civil Structures

Brihanmumbai Municipal Corporation

Mumbai, Maharashtra, India

Chief Engineer (Bridges),

Office of the Chief Engineer (Bridges)

5B Bhandar, Bhandup Complex Store Building,

Darga Road, Khindipada,

Mulund (West), Mumbai- 82. India

Website: https://mahatenders.gov.in

SECTION 3: CIVIL WORKS

1. INTRODUCTION

This section covers the Outline Design Specifications for civil structures including transition ramps, box culverts, glazed steel roof for transition ramps, ventilation plant rooms, tunnel launching and retrieval shafts, cantilever promenade etc. The Specifications given herein shall apply for all structures (above ground and below ground), unless noted otherwise.

For Codes and Standards, refer to Volume 5, Section 3.

2. CIVIL STRUCTURES

2.1 Utility Duct, Water Main Line and Cut and Cover Tunnel

2.1.1 Utility duct

Constructing cut and cover tunnels in urban areas often encounters public and private utility lines such as water, sewer, power, communication, etc. Often, utilities are not located where indicated on existing utility information. Therefore, it is important to identify and locate all utilities in the field prior to excavation. Great care must be taken when excavating in the vicinity of utilities. Utility duct shall include utilities required inside tunnel and other utilities also. The Contractor shall prepare and submit to the Engineer for his consent, a detailed design report including calculations, schedules and drawings for utility duct construction, prior to the commencement of such works. For Utility duct analysis shall be undertaken of the live load of pedestrian and all other loads as per requirement.

2.1.2 Water Main Line

All pipes shall be laid to lines and grades as shown on the Drawings and to 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 BS 8010 Section 2 “pipe lines on lands: Design, Construction and Installation” The type of bedding and minimum clear cover to the pipes shall be as shown on the Standard Drawing or elsewhere in the Contract Document but not limited to what is shown therein. All pipes shown below PQC need to design throughout length including IRC and all other loads.

2.2 Loads and Requirements

2.2.1 General

Unless specified otherwise the design of concrete and steel elements shall conform to IS 456, IS 800 & IRC 112, IRC 24, respectively.

2.2.2 Nominal Loads

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

Dead loads (including notional loads)	DL
Superimposed Dead loads	SIDL
Imposed Loads	IL
Vehicular loads	RL
Fatigue	FG
Dynamic	DY
Wind Loads	WL
Temperature loads	TE
Seismic Loads	EQ
Construction/Erection	ER
Shrinkage	SH
Creep	CP
Movement/ Distortion	MD
Earth Pressure	EP
Surcharge	SR
Hydrostatic	WP
Accidental	AC
Redundancy	R

2.2.3 Design Loads

Design shall include all of the following loads

2.2.4 Dead Loads

Self-weight of the materials shall be calculated in accordance with IS 875:1987 Part 1

2.2.5 Superimposed Dead Loads

Super imposed dead load includes:

(1) Concrete fill minimum thickness of 300mm to support the RC wearing coat (transition ramp structures)

(2) Curbs and Railing loads.

(3) Any finishes/toppings on structure.

2.2.6 Imposed Loads

Pedestrian imposed load shall be not less than 6kPa. For other imposed loads refer to NBC.

2.2.7 Vehicular Live Load

2.1.1.1 Vertical Load

(1) Each component of the structure shall be designed/checked for all possible combinations of loads in accordance with IRC-6 2017.The structure shall resist the effect of the worst combination.

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

2.1.1.2 Horizontal Load

(A) Braking and Traction

Braking load is taken as 15% of the unfactored vertical loads.

Traction load is taken as 18% of the unfactored vertical loads.

Transverse/ longitudinal seismic condition, only 50% of gross tractive effort/braking force shall be considered.

(B) Centrifugal Force

Design Speed for various radii of curvature shall be as stipulated in the Schedule of Dimensions – refer Volume 3, Appendix 18.

2.2.8 Fatigue

The nominal loading for the design of members in accordance with fatigue requirements shall comprise trains with six individual cars each having four axles, the axle loads and vehicle lengths as specified in IRC 6-2017.

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

2.2.9 Dynamic

Impact factor for longitudinal analysis shall be 1.2 while for transverse analysis the same shall be 1.67

2.2.10 Vehicle Collision Load

The impact on crash barrier due to collision shall be considered at critical locations for the appropriate quanta of impact loads specified in IRC 6: 2017 It is required to mitigate impact effects on elements that may be adversely affected without enhancements.

2.2.11 Wind

Wind loading may affect the surface elements of underground structures such as vent-shafts and Transition ramp structure. It is also a factor on temporary structures during construction. IS 875: Part 3/IRC 6 shall be applied to determine the appropriate design wind loads in combination. Wind effects from venting in below-ground areas shall be designed appropriately.

2.2.12 Temperature

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 (e.g. 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 strains shall be mitigated to avoid losses in preloading and subsequent excessive deformations in structural members.

2.2.13 Seismic Loads

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 do not provide sufficient guidance.

The zonal demarcations for levels of seismicity shall be evaluated as per IS 1893

The structure is required to be evaluated as an "important service and community building" for the purpose of "functional use" as stated in IS 1893.

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

2.2.13.1 Seismic design for above-ground structures

Earthquake design shall follow the seismic requirements of IS 1893

(1) Design Base Shear

(a) 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:

$$V_B = A_h W$$

Where

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

W = Seismic weight of the building calculated according to Cl. 7.4.2 of IS1893 Part 1

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

$$Ah = Z/2 \times I/R \times S_a/g$$

Provided that for any structure with T ≤ 0.1 s, the value of Ah will not be taken less than Z/2 whatever be the value of *I/R*

Where

Z = Zone factor. The project site falls within Zone III. Zone factor

(Z) of 0.16 shall be taken as per IS 1893 (Part 1).

I = Importance factor shall be taken as 1.5.

R = Response reduction factor shall be as per Table 7 of IS 1893,

S_a/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 (Ta) 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 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 Part 1.

2.2.13.2 Seismic design for underground structures

The lateral earth pressure for external walls of underground structures for seismic load case shall be evaluated in accordance with Section 8 of IS1893.

Evaluation of seismic loads shall conform to the relevant Indian Standards or to other relevant seismic standards when the Indian Standards may not be applicable.

2.2.14 Construction/Erection

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 shall be taken into account. Allowances shall be made in the permanent design for "locked-in" stresses caused in any member during construction.

2.2.15 Shrinkage and Creep

Provisions shall be made for the effects of shrinkage and creep within concrete structures. 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.

2.2.16 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 limits adhered to in the relevant codes or acceptable to the relevant Authority. These may be architectural, structural, performance or other types of limitations currently in force.

2.2.17 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. The Contractor shall deduce the earth pressure coefficients based on his geotechnical investigations. The available ground investigation records are provided in Volume 8 of the Contract for reference purposes only.'

2.2.18 Groundwater

Loads due to water pressure shall be calculated using a unit weight of 10 kilo Newtons per cubic metre for fresh water and a unit weight of 10.3 kilo Newtons per cubic metre for sea-water.

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.

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.

The effects of flotation loads shall be allowed for in the design both in the temporary and permanent design stages.

2.2.19 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.

Whereas for final design accidental load should be calculated as per IRC 6

2.2.20 Redundancy loads

The temporary structure shall allow for the effects of a "one-strut failure" condition. A single strut 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.

2.2.21 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 the serviceability of the structures for the design life of the structures.

2.2.22 Loading Combinations

All load combination should be as per IRC 6 2017 Annexure B, Contractor to Prepare Design Basis which should include chapter for basic load and its combination.

Each component of the structure shall be designed and checked for all possible combinations of applied loads and forces.

2.2.23 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.

"Construction" - during and immediately after construction of the Works.

"Service/Operation"- during general operation of the completed facility.

"Accidental" - during "Construction and/or "Service/Operation" when adjacent work and future development (where known) may alter loading conditions.

"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 of lateral loading shall be considered for the Construction and Service/Operation condition.

2.2 Deflection Criteria

The deflection limitations imposed in IS and IRC (rigorous/stringent limits prevail) shall be followed for Concrete and Structural Steel elements respectively.

2.3 Durability

Clauses 2.6.1 to 2.6.3 of this section stipulate durability requirements for underground structures. For above-ground and structures the following contents shall be adopted.

(1) The exposure condition for the above-ground structures shall be "severe" as defined in Table 3 of IS :456-2000

(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 Beam	200
3	RC Walls	160
4	RC Columns	300
5	Blockwork 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.

IRC 112 Chapter 14 requirement also need to satisfy.

2.4 Concrete Sub-Structure

(1) Foundation types shall generally be End bearing pile foundation. Spread foundation shall be permitted if founding stratum is at a shallow depth. Other types of foundation can be proposed to the Engineer by the Contractor for his approval, but no raking pile will be permitted.

DESIGN CONSTRUCTION AND OPERATION OF TWIN TUNNEL FROM FILM CITY GOREGAON TO KHINDIPADA (AMAR NAGAR), MULUND INCLUDING BOX TUNNEL (CUT & COVER) AT FILM CITY, ELECTRICAL, MECHANICAL AND ASSOCIATED WORKS.

Volume 4

Outline Construction Specifications

Section 4

E&M Works

Brihanmumbai Municipal Corporation

Mumbai, Maharashtra, India

Chief Engineer (Bridges),

Office of the Chief Engineer (Bridges)

5B Bhandar, Bhandup Complex Store Building,

Darga Road, Khindipada,

Mulund (West), Mumbai- 82. India

Website: https://mahatenders.gov.in

SECTION 4: E&M WORKS

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 – approach and 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.

1.1 Scope of E&M works

The total scope is subdivided into following activities,

a. Street lights
b. Box and Twin Tunnel lightening
c. Ventilation for Box and Twin Tunnel lightening
d. Fire fitting
e. Water and Plumbing.

1.2 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 control gear 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 + APPENDIX-2	Fixed firefighting systems. Automatic sprinkler systems. Design, installation and maintenance
	BS EN 15004-1	Fixed firefighting systems. Gas extinguishing systems. Design, installation and maintenance
	BS EN 3	Standards for Portable Fire Extinguishers
	BS EN 54 Part 1- 24	Standard for Fire Detection and Alarm System and Components
	BS EN 54: Part 20	Fire detection and fire alarm systems Part 20: Aspirating smoke detectors
	BS EN 545	Specification for Ductile iron pipes, fittings, accessories and their joints for water pipelines. Requirements and test methods
	BS EN 5839	Code of practice for the design, installation, commissioning and maintenance of voice alarm systems
	BS EN 600085 :	Electrical insulation. Thermal evaluation and designation

	Class B, 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 firefighting systems. Hose systems. Hose reels with semi-rigid hose
	BS EN 671-3	Fixed firefighting systems. Hose systems. Maintenance of hose reels with semi-rigid hose and hose systems with lay-flat hose
	BSI	British Standards Institute
	BSP	British Standard Pipe threads
	CIE	International Lighting Commission
	CCITT	International Telegraph and Telephone Consultative Committee (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 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, 2008
	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, 2010 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 Project shall be governed by all latest applicable local codes, regulations, standards and requirements issued by all the applicable local authorities and statutory bodies.

1.3 Abbreviations

ACRONYM	DESCRIPTION
ELECTRICAL	
HV	High voltage
MV	Medium voltage
LV	Low voltage
ac or AC	Alternating current
dc or DC	Direct current
kVA	Kilo volt-amp
kW	Kilowatt
V	Volt
A	Amp
FRLS	Flame Retardant Low Smoke
SCADA	Supervisory Control and Data Acquisition
MCB	Miniature Circuit Breaker
MCCB	Moulded Case Circuit Breaker
ACB	Air Circuit Breaker
ELCB	Earth Leakage Circuit Breaker

MCC	Motor Control Centre
ASTS	Automatic Source Transfer System
TC/TB	Terminal Connector/Terminal Block
ACOS/ATS	Automatic Change Over Switch/ Automatic Transfer Switch.
COS	Change Over Switch
MDB	Main Distribution Board
SDB	Sub Distribution Board
CP	Control Panel
SWA	Steel Wire Armoured
MS	Mild Steel
SB	Switch Board
PP	Power Panel
XLPE	Cross Link Poly Ethylene
PVC	Poly Vinyl Chloride
HT	High Tension
LT	Low Tension
CT	Current Transformer
PT	Potential Transformer
HRC	High Rupturing Capacity
APFC	Automatic Power Factor Control
PF or pf	Power Factor
UPS	Uninterruptible Power Supply
DG or GEN	Diesel Generator
I/C or i/c	Incoming
O/G or	Outgoing

o/g	
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
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

2. Street lightening for at grade road and in the open duct area.

2.1. Scope of work

Overall scope of Firm / Agency shall be design, manufacture, packing, delivery at site with all accessories, items, equipment complete, installation, testing, commissioning of the entire street lighting system and obtaining Statutory approvals for the at grade road and tunnel approaches. The Firm / Agency shall coordinate with local supply authority for supply to Pillar Boxes necessary to cater to all street lighting distribution networks. As such the scope of Firm / Agency shall start from design, fabrication, supply at site, installation, testing, commissioning of Pillar Boxes and to complete all downstream distributions for obtaining required numbers of electric meters. All the materials shall be brand new and the Firm / Agency shall follow all the relevant Indian Standard Codes, International Codes as applicable and the Indian Electricity Rules and Acts as amended up to date together with this document.

The document here provides the basic specification for the equipment, components, instruments, and auxiliaries, accessories to achieve the control, protection, and requirement of the system and the job in totality shall be as per best practices with relevant I.S. specifications and National lighting codes,2010 and PWD specifications for Electrical work

2.2. Minimum Basic requirement criteria of all elements.

Sr.No.	Element	Requirement
01	Street lights	LED fitting 130-150 watt with weatherproof luminaries.
02	Minimum illumination	Illumination level of average 40 Lux for at grade / in cut portion along with approaches and 40 to 50 Lux for road junctions
03	Electric supply	415-volt three phase 50 Hz. four wires
04	Cables	Shall be 1100 Volt grade, minimum 25 sq. mm 4 core ISI mark, armoured, XLPE insulated PVC sheathed stranded Aluminium conductor
05	Pole	7 to 10-meter height octagonal/conical steel poles 7 to 10-meter height octagonal/conical steel poles. Pole Bracket-decorative type.
06	Street Light Control Panel/Feeder	The control panel shall be made from 14 SWG CRCA

	Pillar	
07	Earthing works:	The G.I. or Copper earth plate of size 60x60xO.06cm shall have separate pit at least 1.6 meters depth with 40 Kg charcoal and salt with alternate layers along with vertically placed earth plate of given size but not more than 9 meters @ min depth of 1.5 m from GL

2.3. Design Services

The street lighting installation for the project shall be carried out by use of outdoor type, LED fittings of 130-150-watt, weatherproof luminaires (IP 66), to be mounted on 7 to 10-meter height octagonal/conical steel poles as approved by the Engineer hot dip galvanized inside & outside. Electric power supply at 415 volt, three phases, four wires, 50 Hz for each circuit shall be fed from the designated feeder Pillar Box. Electric power shall be distributed to the street lighting poles through electric cables laid below ground and/ or through HDPE pipe buried under ground and/ or through GI pipe laid in crash barrier and shall be so distributed that equal load balance in all three phases is achieved.

Individual control MCB with Pole junction box shall be provided on each pole. The terminal box shall be weather proof, having gasketed cover. Moreover, Junction Boxes shall be inserted in crash barrier near each pole for looping main cable and branching of the pole distribution.

The street light poles shall be earthed individually with Rod electrode type earth station & 2 Nos. of G I wires shall be used for earthing purpose or else for poles on crash barrier two nos. earthing shall be connected with the earth network for each pole.

Electric cable required for the street lighting installation shall be 1100 Volt grade, minimum 25 sq. mm 4 core ISI mark, armoured, XLPE insulated PVC sheathed stranded Aluminium conductor. For automatic ON/OFF operation of the street lights,

programmable type automatic timer shall be provided in the street light feeder pillars. They should have energy saving feature.

All street lights shall be controlled from the outdoor type street light control panel/feeder pillars the locations of which shall be decided as per site suitability and approval of the BMC during detail engineering and execution period. The location of the Feeder Pillar Box shall be decided during execution depending on the location of availability of supply point from supply authority.

2.3.1. Lighting Poles:

2.3.1.1. Octagonal pole

The Octagonal Poles shall be designed to withstand the maximum wind speed as per IS 875. The top loading i.e. area and the weight of fixtures are to be considered to calculate maximum deflection of the pole and the same shall meet the requirement of BSEN 40-2- 1 & 3.

Pole Shaft: The pole shaft shall be made from sheet steel confirming to BSEN 10025 having yield strength of 355 N/sqm and silicon content less than 0.04%.

The octagonal pole shaft shall be continuously tapered with single longitudinal welding. There shall not be any circumferential welding. The welding of pole shaft shall be done by Submerged Arc Welding (SAW) process. All octagonal pole shafts shall be provided with the rigid flange plate manufacture from MS FE410 confirming to IS:2062 of suitable thickness with provision for fixing 4 foundation bolts. This base plate shall be fillet welded to the pole shaft at two locations i.e. from inside and outside. The welding shall be done as per qualified MMAW process approved by Third Party Inspection agency.

Pole sections: The Octagonal Poles shall be in single section (upto 12 meter). There shall not be any circumferential weld joint.

Galvanization: The poles shall be hot dip galvanized as per BSEN ISO 1461 standard with average coating thickness of 70 micron. The galvanizing shall be done in single dipping.

Door opening: The octagonal Poles shall have door of approximate 500 mm length at the elevation of 500 mm from the Base plate. The door shall be vandal resistance and shall be weather proof to ensure safety of inside connections. The door shall be flush with the exterior surface and shall have suitable locking arrangement. There shall also be suitable arrangement for the purpose of earthing. The pole shall be adequately strengthened at the location of the door to compensate for the loss in section.

Welding: The welding shall be carried out confirming to approve procedures duly qualified by third party inspection agency. The welders shall also be qualified for welding the octagonal shafts.

Fixing Type: The Octagonal Poles shall be bolted on a pre-cast foundation with a set of four foundation bolts for greater rigidity. Top Mountings: The galvanized mounting bracket shall be supplied along with the Octagonal Poles for installation of the luminaries. Bracket should be as per approve design.

Pole Testing Facility: The Manufacturing unit shall have in house pole testing facility for validation for structure design data. The Pole testing facility shall be as per BSEN 40 – 2 1 & 3.

Manufacturing: The pole manufacturing and galvanizing unit shall be ISO 9001:2000& ISO 14001 certificate to ensure consistent quality & environment protection

2.3.1.2.Conical pole

Detail Technical Specification for Street Lighting with Conical Poles

Design: The Conical Poles shall be designed to withstand the maximum wind speed as per IS 875. The top loading i.e. area and the weight of fixtures are to be considered to calculate maximum deflection of the pole and the same shall meet the requirement of BSEN 40-2- 1 & 3.

Pole Shaft: The pole shaft shall be made from sheet steel confirming to BSEN 10025 having yield strength of 355 N/sqm and silicon content less than 0.04%. The pole shaft shall have circular cross section and shall be continuously tapered with single longitudinal welding. There shall not be any circumferential welding. The welding of pole shaft shall be done by Submerged Arc Welding (SAW) process. All Conical pole shafts shall be provided with the rigid flange plate manufacture from MS FE410 confirming to IS:2062 of suitable thickness with provision for fixing Foundation bolts. This base plate shall be fillet welded to the pole shaft at two locations i.e. from inside and outside. The welding shall be done as per qualified MMAW process approved by Third Party Inspection agency.

Welding: The welding shall be carried out confirming to approve procedures duly qualified by third party inspection agency. The welders shall also be qualified for welding the Conical shafts.

Pole sections (Conical): The Conical Poles shall be in single section (up to 12 meter). There shall not be any circumferential weld joint.

Galvanization: The poles shall be hot dip galvanized as per BSEN ISO 1461 standard with average coating thickness of 70 micron. The galvanizing shall be done in single dipping. Fixing Type: The Conical Poles shall be bolted on a precast foundation with a set of four foundation bolts for greater rigidity.

Top Mountings: The galvanized mounting bracket shall be supplied along with the Conical Poles for installation of the luminaries. Pole Testing Facility: The Manufacturing unit shall have in house pole testing facility for validation for structure design data. The Pole testing facility shall be as per BSEN 40 – 2 1 & 3

Pole Bracket: The decorative type bracket shall be hot dip galvanized after fabrication. The bracket shall be manufactured in line with the bracket design enclosed. The bending of the pipes shall be without any kinks / visible marks. Arms shall be symmetrical. The pole bracket shall be suitable for erection of street lighting luminaire. Pole bracket shall be made from 60 mm diameter 'B' class galvanized Iron pipes. A stopper shall be provided with 3 nos. holes at 120 degrees for proper fixing of the bracket on the pole top.

2.3.2. Street Lighting Fittings:

Led Street Light Fittings Specification - Wattage - 130-150W LED light fixture - Epoxy powder coated pressure die-cast aluminium housing with weatherproof gasket for LEDs and control gear compartments. Pressure die-cast aluminium frame with heat resistant toughened clear glass fixed with SS screws. - LED specification – make - CREE LED / Equivalent - Colour temp. – 5700K ±300K - Lens – make – Led Link / Equivalent - In addition to built-in 5kV surge protection in driver, it is equipped with 10kV external surge protection. - Input voltage range: 140–310V AC.- Side entry mounting for 50 to 60 mm OD pipe bracket. - Top maintenance – Access to driver is from the top. - Ingress protection: IP66.

All the luminaires shall be mechanically strong, electrically safe, chemically inert of atmospheric pollution, vibration proof and aesthetically good. The spread throw and glare control mark of the luminaries shall be compatible to the lane width.

2.3.3. Street Light Control Panel/Feeder Pillar:

The control panel shall be suitable for outdoor installation and all relevant codes of practices shall be applicable. The pillar shall be weather proof and water proof and shall be suitable for IP65.The control panel shall be made from 14 SWG CRCA sheet steel The control pillar shall have 2 separate compartments with separate doors. One compartment shall be for incoming supply switch gears and energy meter etc. and shall have sealing arrangement. The other compartment for consumer use shall have control

and power switchgears for outgoing. All the equipment in the pillar box shall be erected on 2mm thick galvanized iron plate, and this plate shall be properly connected to the earth bar. Energy saving features shall also be there. All power and control wiring inside the control pillar shall be with stranded copper conductor wires with lugs / ferrules as per requirement and clamped at both the ends. For termination of incoming and outgoing cables, epoxy insulators with studs and locknuts shall be provided.

A detachable gland plate made out of 3 mm thick galvanized iron/Aluminium sheet shall be provided at the pillar bottom. Timer control for switching streetlights ON/OFF is required to be provided. Contractor to provide KWH meter and CT's as approved by the power supply company and get the same calibrated before installation. Certificate shall be submitted after commissioning the equipment. Entry of cable to pillar box shall be from bottom and PVC shrouds shall be provided between phases, distributors. Feeder pillar foundation shall be M30 Grade Concrete, 500 mm above ground level.

2.3.4. Pole Foundation:

The pole foundation shall be of concrete grade M30 and size shown in the drawing with necessary excavation in all types of soil, murum or rock. An octagonal shaped plinth of size shown on the drawing above ground level shall be provided. The plinth shall be plastered smoothly and painted with 2 coats of Cement paint from all sides. The plinth shall be of concrete grade M30 and it shall be cast along with foundation. The foundation shall have 2/3/4 nos. of G I class B pipe embedded for cables. The design for the pole foundations for the poles required to be grouted in bridge slab and shall be got approved from the Engineer and such arrangement shall be made during slab casting.

2.3.5. Earthing works:

This specification covers requirement of earthling and lightening protection system. The specifications cover complete supply, installation, testing and commissioning of the above system. The earthling system shall meet the requirement of IS 3043 And also includes local regulations in force. Lightening protection system shall be done in accordance with IS: 2309.

All installations of earthling shall conform to IE Rules 1956 and its amendments from time to time, IS 3043 latest edition and amendments, IE Rules & the relevant regulations of the electricity supply authority concerned. The G.I. or Copper earth plate of size 60x60xO.06cm shall have separate pit at least 1.6 meters depth with 40 Kg charcoal and salt with alternate layers along with vertically placed earth plate of given size but not more than 9 meters away from side wall at depth necessary to reach moist earth surface but with minimum depth 1.5 meter from the finished ground level up to

the top vertical edge of earth electrodes. Each earth pit or as required should be provided with 12 mm dia GI pipe 2000 mm long or more depending upon the depth of pit to cover the vertical edge of earth plate (with top end of pipe provided with a closed top coupler). To facilitate watering concrete compartment should be made with funnel and cover prate as per rules provided to I.S. regulation. After installation the earthling resistance of each earth plate should be measured by earth resistance megger in the presence of Engineer in charge three days after the completion of earthling work and the value should conform to regulation. Earth leads taken out should be connected to nearest switchgear.

All the earthling shall be in accordance with Indian Electricity rules and I.S. 3043. The earthling conductor shall be of G.I. as specified in schedule of quantities. Each earth pit shall have test link joint by to nut bolts on either side separate pits shall be provided for lightning conductors. Whenever earthling strips run along a wall or side of a trench, suitable clamps at half-meter distance shall fix these. The portion of strip along the side wall of the tunnel should be laid 600 mm below the ground ' level. The surface of the electrode strip shall be painted with two coats of bitumastic paint from the electrode up to connecting point of the ring earth on the side wall. Colour of the paint shall be approved by E.I.C. The earthling clamps for supporting earth strips shall be of such design so as to avoid bimetallic action between strip and clamp.

Earthling of L.T. switch gears and panels shall be done with two Nos. G.I. strips {G.t. wires of size specified in schedule 'B'. Ground wire strip shall enter/ terminate on ground lugs provided on the equipment's or shall be fastened on the foundation bolds and frame of equipment's.

All Non-Current Carrying Metal Parts of Panels, Lighting Fixtures, Junction Boxes, Distribution Boards, S.F.U., D.P. Structure Lightning Arrestors Transformer Body Transformer Neutrals Sub-Panels Shall Be Efficiently And Distinctly Connected To Earth. Earth resistance at earth electrode shall be less than one ohm all times the earthing system for feeder pillar & poles shall follow IS 3043.

2.3.6. The following work will be carried out by the Contractor:

The work to be carried out under this contract comprises of design, manufacture, inspection / testing, supply, transportation, storage, erection, testing commissioning of street lighting system with galvanized octagonal poles distances not exceeding 25 m on either side of the ROB, on one side of ROB, slip road, with feeder pillars for controlling the luminaires. The poles using 8 SWG GI wire to be run along with the cable, cabling to the individual fittings / poles AYFY / YFY/ XLPE armoured / PVC flexible cable.

Illumination scheme shall be designed to ensure illumination level of average 40 Lux for ROB along with approaches and 40 to 50 Lux for road junctions. Street lights shall be planned on alternate circuit basis.

The Contractor shall carryout and complete the said work under this contract in every respect in conformity with the current rules and regulations of the local electrical authority, the Indian Standard Institution and with the directions of and to the satisfaction of the Engineer in charge. The Contractor shall furnish all the labour and install all materials, appliances, equipment necessary for the completion and testing of the whole electrical installation as specified herein and shown on the drawings and bill of materials. This also includes any material, appliances, equipment not specifically mentioned herein or noted on the drawings as being furnished or installed but which are necessary and customary to make the installation complete in all respect. Further all the liaison work with the Supply Authorities for obtaining electrical load sanction, obtaining the release order from supply authority and all other co-ordinations with other authorities as and when required, shall be done by the contractor without any extra cost. Firm/ Agency has to submit detail drawings to the Engineer for approval before commencement of work. All the drawings are to be prepared in Auto CAD (Latest release only).

The Contractor shall also be responsible for getting approvals from the various bodies such as Supply Authority, Electrical Inspector, etc. and any other statutory bodies as and when required. The cost invoked for getting the necessary approvals is to be included in the cost of the overall work.

2.3.7. Documents to be submitted by the Firm / Agency:

a. All catalogues of all the major items e.g. luminaires, auto-timers, MCCB, MCB, Cables, Octagonal pole etc.
b. The voltage drops calculation of the cabling network.
c. Earthing test Report.
d. Lighting design output by software / actual lux level report
e. Feeder Pillar Box GA with all technical details.
f. Single Line Diagram for the street lighting distribution network.

Barring above BMC may ask for any other documents relevant with the project work and the same shall be submitted. The tender document drawing(s) provide(s) basic guideline and the Agency shall have the responsibility to design the system following the standard guidelines and the guidelines laid in this document and the works shall be executed after the drawings and documents are approved by BMC.

2.3.8. Safety Measures:

Suitable scaffolding arrangement shall be provided for workmen for all works that cannot be safely done from the ground. When a ladder is used, it shall be of rigid construction made either of good quality wood or steel. The steps shall have minimum width of 450 mm and a maximum rise of 300 mm. Suitable hand holds of good quality wood or steel shall be provided and the ladder shall be given an inclination not steeper than ¼ to 1 (1/4 horizontal and 1 vertical).Scaffolding or staging more than 4 meters above the ground floor, swing or suspended from an overhead support or erected with stationery support shall have a guard rail properly attached, bolted, braced and otherwise secured at least one meter high above staging and extending along the entire length of the outside and end thereof with only such openings as may be necessary for the delivery of materials. Such scaffolding or staging shall be so fastened to prevent it from swaying from the structure. Working platforms, gangways and stairways shall be so constructed that they do not sag unduly. Every opening in a working platform shall be provided with suitable means to prevent fall of persons or materials by providing suitable fencing or railing.

2.3.9. Cable Sizes:

Based on the total load as per the lighting design, Firm / Agency shall select suitable size of cables so as to ensure that the total voltage drop from the feeding point up to the last lighting fixture on any circuit shall not exceed 5% of the system voltage shall consider distance from the feeding point up to the street lighting feeder panel. Firm / Agency shall submit the voltage drop calculations to evaluate the correctness of the cable sizes selected before execution of work.

2.3.10. Cable Laying :

This is to define requirement for the installation, testing and commissioning of the cabling system. The cable laying shall be from supply point to the feeder pillar panel and from feeder pillar panel to street lighting poles. The cable from supply point up to the feeder pillar shall be laid underground in excavated trench/RCC pipe & HDPE pipe. The trench shall be at least 0.9 meter. Deep and 0.4mtr. wide. Sand cushioning of 20 mm shall be provided before laying the cable. The cable shall be protected with good quality bricks on all the sides. At road crossings, the cable shall be laid in 100mm dia RCC Hume pipe of NP-2 class. The cable from feeder pillar to the lighting poles shall be laid in suitable sized HDPE pipes buried at the depth of 0.9meters. Loop at least 1 Meter shall be provided on either side of the pole. Cables shall be laid in complete, uncut lengths from one termination to the other. All temporary ends of cables must be protected against dirt and moisture to prevent damage to the insulation.

2.3.11. Termination:

All XLPE cables up to 1.1KV grade shall be terminated at the equipment's by means of compression type cable glands of aluminium. They shall have a screwed nipple with conduit electrical threads and check nut. Cable leads shall be terminated at the equipment terminals, by means of crimped type solderless connectors as manufactured by M/s. Dowell Electro Works or approved equivalent.

2.3.12. Testing:

Before energizing, the insulation resistance of every circuit shall be measured from phase to phase and from phase to ground.

a. Installation, Testing & Commissioning of Street Lighting Installation:
   The specifications cover the requirement of installation, testing and commissioning of electrical equipment related with street lighting installation.
b. Standards:
   The electrical equipment installation work shall comply with the latest applicable standards, regulations, rules, safety codes.
c. Principal Parameters:
   The installation, testing and commissioning of the electrical equipment shall be carried out in accordance with general technical requirement furnished below.
d. General Technical Particulars:
   The contractor shall furnish all tools, welding equipment, testing equipment, kits etc. required for installation, testing and commissioning of the equipment. The contractor shall co-operate with other contractors at site so as not to obstruct activities of others. The work shall be carries out strictly as per the instructions and layout Drawings. The contractor shall carryout touch-up painting on the equipment if required. The paint shall be supplied by the contractor. The contractor shall ensure workmanship of good quality, employee shall also be skilled careful and experienced.
e. Installation Scope:
   The contractor shall install, test and commission all the equipment either furnished of supplied by him. All material necessary for completion of the work including hardware, consumable shall be provided by the contractor. The equipment shall be installed in a neat workman like manner so that it is levelled, plumbs & properly aligned and oriented. No equipment shall be permanently bolted down to the foundation or structure unless the alignment has been checked and accepted. Care shall be taken in handling the equipment to avoid any distortion to the supporting structure or damage to the delicate instruments & electrical parts. The contractor

shall use crane for lifting & placing the outdoor equipment on structure. No part of existing structure shall be used to lift any equipment without prior permission of the Engineer- in-Charge. Foundation of poles shall be constructed. However minor modifications to the foundations wherever found necessary for proper installation shall be carried out by the Firm / Agency. The foundation bolts pockets shall be cleaned before placing the bolts & the equipment on the foundation concerning of bolts shall also, he included in the scope of this contract. Before commissioning of street lighting following points to be checked & ensured for safe & successful commissioning.

1. Check any physical damage, tightness of all nuts, clamps & terminals.

2. All the fitting, earthing arrangements are properly connected.

3. Lux level illumination check.

4. Voltage drop checking.

5. Current to be measured at the incoming in the junction box.

6. The earthing measurement at each pole.

7. Cable are property connected & crimped.

8. Tightness of connections.

f. Documents, Certifications, Drawing:

The intent of this specification is to give guideline to contractor to furnish all relevant papers and list of spares for continuous performance of installation. Nothing shall absolve contractor for not furnishing documents or paper that have not been specially stated herein.

2.3.13. Documents:

All relevant documents for maintenance like manuals, procedures, etc. of all electrical equipment's erected by contractor shall be furnished in two sets.

2.3.14. Certificates:

The contractor shall also submit certificate issued by the original manufacture towards guarantee of materials supplied. As-built drawing of the complete installation. Including location of feeder pillar, distribution control panel, poles, main switches, cable routing, connection, diagram circuit, conductor size length test results, reading, etc.

2.3.15. Commissioning:

a. Testing of equipment's:

All equipment's before installation on site shall be tested and such results need to be submitted to the BMC as well as Local Power distributor/Supplier. Nothing shall absolve the contractor from performing any test that the contractor has been called up by the BMC

b. Manufacturers Tests:

The contractors shall specifically Perform all test such as routine test, type test on all equipment's in the presence of BMC & Local Power distributors/Suppliers officials, all cost incidental to such test shall be deemed to have been included in the specific item of that equipment.

c. Pre-commissioning Tests:

All test required or called by the local electricity supply authority, Government officials and as laid in relevant Indian Standard Specifications, Rules Regulations & Acts shall be strictly completed.

d. Commissioning:

The contractor shall obtain the written permission or sanction for commissioning of the electrical equipment if required from I.E. & L. Department of Government of Maharashtra. All cost, visit fees, etc. incidental for abstaining the sanction to be to the contractors.

2.3.16. Warranty

All supplied equipment's shall have minimum 2 years written warranty from manufacturer and authorised distributor /convertor issued for field performance, this warranty certificate in original should be submitted to Engineer- in-Charge.

3. Tunnel lighting

3.1. General Requirement

3.1.1. Scope of Work

The scope of work in this sub-section will include the guidelines and methodology for design of electrical works for Tunnels including cross passages, ventilation shafts/other shafts 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: Bus way, cable, conduit, raceway, Brackets, trunking etc;
2. Low Voltage switchboards: Main, sub-main, distribution boards, load centre, etc;
3. Tunnel Lighting system including lighting control system: Interior, exterior, sign illumination, exit & fire exit, Emergency Lighting, Tunnel lighting Cross Passage Lighting, road lighting;
4. Illuminated Tunnel Evacuation Signage System (ITESS) and illuminated cross passage Evacuation System (XPES).
5. Small power system for Tunnels: 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

3.1.2. 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 / Equipment / 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 equipment 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.

3.1.3. 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, subsystems 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 equipment layout plans, cable routings, and other documents necessary to facilitate the design interface co-ordination with designated/interfacing contractors. These plans shall be prepared at appropriate times and in sufficient details to permit successful coordination.

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. 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 Mumbai 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 based on the percentage of system capacity used by the Contractor. All cost associated with measures taken to ensure compliance to the harmonic's limits shall be deemed included in the contract.

j) The Contractor shall take measurements of the harmonic's 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.

3.1.4. System Description

3.1.4.1. 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;

1) Phase A: Red ,
2) Phase B: Yellow,
3) Phase C: Blue,
4) Neutral: Black,
5) Ground: Green or Yellow Strip Green,
6) Emergency Lighting Cable: Orange

3.1.4.2. Low voltage power distribution system

1. 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 tunnel 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.

2. Essential loads shall receive power supply from standby Diesel Generator sets for box tunnel, twin tunnel & cross passages. It shall be comprising of the following in addition to the critical loads:
   - Fire Fighting system;
   - Tunnel Ventilation system;
   - Uninterruptible Power Supply (UPS);
   - Emergency small power outlet;

3. Very essential (Critical) loads shall receive power supply from UPS with 2 hours 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;
   - Master clock system;
   - Closed circuit television (CCTV);
   - PC work stations in CR;
   - 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;

- 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 tunnels and cross passages. Maximum voltage drops for all circuits from main low voltage switchboards to the equipment, 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 90ºC and for maximum short circuit temperature of 250ºC. Full size neutral cables shall be provided for the power cables connecting Auxiliary transformer to main low voltage switchboard and to sub-main low voltage switchboards. Fire resistant cables shall be used for life safety purpose 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 MDB/EMDB/DB.

3.1.4.3. Low voltage switchboards

Transformers shall be provided by the Contractor to maintained the desired characters for tunnel lightening. Contractor shall have to 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 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.

The power factor correction equipment (APFC), including capacitor bank, shall be installed to improve power factor up to 0.95. Capacitor bank shall be a low loss type

less than 0.5 watts per kVAR. Permanently connected discharge resistors shall be provided across the terminations sized to ensure safe discharge of the capacitors to less than 50V within 1 minute after disconnection.

The Main distribution panels and sub-main distribution panels shall be floor standing, meta-clad in Form 3b/4a type with separation panels. These switchboards shall be designed and manufactured in accordance with IEC60439 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.

Main busbars sizing shall be rated according to the design load with 25% spare capacity and to match the transformer capacities and be arranged to refer to 100% phase, 100% neutral and 50% ground busbars. The busbar shall be made of copper and arranged in the form of R – Y – B from front to back of panels and/or from left to right. Interrupting current capacity rating (Ic) of main busbars shall be followed to the incoming ACB rating and transformer capacities. Adequate spare protection devices shall be provided on every busbar segment of the LV Main switchboard for future load growth with the following minimum capacity of spare feeders,

3.1.4.4. 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 Main switchboard and 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 Main 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.

The total harmonic voltage distortion at each main low voltage switchboards shall not exceed 5%. 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. An automatic transfer switch shall get operated to transfer the emergency power load (essential load) to the generator in case of normal power supply failure.

3.1.4.5. Lighting System

Generally, all lighting fixtures shall be applied with 240V 1-phase 50Hz power supply. The major lighting source will be fluorescent lamp, energy saving, high efficiency, low loss and high-power factor. The colour temperature of the fluorescent lamp shall be 4,000ºK and the colour rendering index (CRI) shall be 80 minimum. All Emergency Exit signs (including ITESS and XPESS) and 50% of the Emergency lighting fixtures in 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 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. 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), 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. 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 type with housing and Fire-Resistant low smoke halogen-free type and of non-combustible materials.

Emergency Luminaires inside the Launch box 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), Tunnel Ventilation room 150-200 25-50, ECS and other plant Rooms 150-200 25-50 Tunnel Area (including cross-passages).

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 road users ensure that each activated directional arrow is uniformly lit and clearly visible from the highway 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 vehicles.

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

vii. Power Supply , Cabling and Accessories

- The power for the ITESS & XPESS shall be supplied from the 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.

viii. 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 Control Room CR. CR located shall have control over.
- A drawing indicating the provision of control circuit grouping is to be prepared by the contractor and got it approved by the Engineer.

2. Tunnel Lighting

i. Tunnel lights shall be of IP65 weatherproof type and IK-10 industrial 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:

- HW/TW (Head Wall/Tail Wall) – 2- position key override switch comprising with pad lockable cover.
- Tunnel lighting control panel (TLCP) at SCR
- TCC via M & E SCADA

v. The 2-position key override switch shall have the following selection option:

- LOCAL - It will effectively switch “ON” the tunnel lighting
- REMOTE - It will switch “OFF” the tunnel lights, which could then be switched “ON” either by CR or TCC control.

vi. Control of the tunnel lighting via TCC shall only be possible when TLCP at CR 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.

- Control at HW/TW,
- Control at CR,
- Control at TCC,

viii. Tunnel lighting connection shall be of plug and socket type.

ix. By default, tunnel lighting shall be in "OFF" mode.

x. 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.

xi. Tunnel lighting control panel (TLCP) shall be provided in the CR for local control of the tunnel lighting at CR.

xii. 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 CR/TCC

3.1.4.6. Small power system

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.

3.1.4.7. Emergency Power Supply

Emergency power supply for stations and Tunnels shall be comprised of standby diesel generator and uninterruptible power supply (UPS). Standby generator with suitable capacity will be provide for 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 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

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.

3.1.4.8. Lightning protection system

A lightning protection system is required to; protect all street lights as well as box and twin tunnel lightening. 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 any top object / point 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. 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.

3.1.4.9. Earthing and bonding system

1. 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.

2. 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.

3. 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 wire laid 300mm below base slab/ground level. The earth rod is made up of two lengths of 1.8m, 16mm diameter copper bond steel rods coupled together with silicon aluminium bronze coupling and copper wire joints are by exothermic weld and must be inspected before backfilling.

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, CS 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 water stop 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 over sheath 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.

3.1.4.10.M & E SCADA Interface System

1. General

The Contractor shall Design the M & E SCADA Interfacing system as indicated in the drawings and the Specifications herein.

2. 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.

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, Tunnel Ventilation and 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.

3. 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 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 Analog 4 – 20 mA Analog 4 – 20 mA Dry contact (NO or NC) Dry contact (NO or NC), 20A, Pulse accumulator 250V Override switch Momentary-pulsed and Photocell contact Mechanically latched Transducer sensors Etc
h) If the CPU transmission network fails but power to RPU does not, the RPU shall continue to monitor all changes of state or value and shall retain the most recent values for 30 minutes and the RPU shall also maintain all analog set points and command positions.

3.1.4.11.Uninterruptible Power Supply (UPS)

1. General:

Tunnel shall have two nos. Uninterruptible power supplies (UPS) with individual battery banks of 2 hours battery autonomy with battery manager to have interoperability of the battery bank for UPS are designed to provide back-up power for systems essential. The following systems are to be backed-up by UPS source:

a) Telecommunication system;
b) Fire detection and Alarm system;
c) Signalling/ signages system;
d) Closed circuit television (CCTV);

e) PC work stations in CR;
f) M & E SCADA; Power Supply SCADA, TVS SCADA
g) Emergency lightings
h) Tunnel and Cross passage lighting
i) Tunnel and cross passage emergency evacuation signage lighting
j) Exit and emergency signage
k) Blue light stations provided by Power Supply Contractor

2. Material Description

a) The equipment and/or components shall be fully tropicalized and designed to operate 24 hours a day, 365 days a year.
b) The UPS system shall be true online double conversion system consisting of rectifier/charger, inverter, static bypass transfer switch, manual bypass switch, battery bank, sealed valve regulated lead acid batteries and other equipment necessary for completion of the system. The UPS shall be a dual unit parallel-redundant type with configuration, and suitable for continuous operation.
c) 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.
d) 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

e) Operation Mode

i. Normal Mode
- During normal mode operation, the AC supply line from the auxiliary supply shall supply power to the rectifier/charger. Simultaneously, the regulated power shall be used to float-charge the batteries while it supplies the inverter.
- The inverter shall invert power for supplying critical loads within specified parameters.

ii. Emergency Mode

- 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.
- 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.
- 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.

iii. Bypass Mode

- Automatic Bypass

  (a) 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.

- Manual Bypass

  (a) 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.

  (b) 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.

iv. 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.

f) Protective Devices Requirement

The following protective devices and system shall be equipped within the UPS system:

- Switches with Fuse for main AC input protection
- Switches with Fuse for AC output protection
- Alarm warning system for the Rectifier, Charger, Inverter and Bypass Switch
- Phase sequence, Reverse Power Relay, Earth fault, Low battery voltage, Self-diagnostic annunciation system.

g) Performance Requirement

(1) Overload : >110% for 60 minutes

: > 125% for 10 minutes

: > 150% for 1 minute

(2) Overall efficiency : > 90% at 50% load to 100% load

(3) Back-up time : 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 ± 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%

3. Inverter Unit

(1) The unit shall be a transistorized solid-state type, IGBT, which is designed for Pulse Width Modulation technology interconnected with 3 phases isolation transformer and filter capacitor.

(2) Output terminal of the unit shall be bus-bars type with a neutral bus size not less than 1.4 times of the rated current.

(3) Electrical characteristics of the unit shall be as listed below:

(a) Rated output power (kVA) : As applicable ((at power factor 0.92 lagging and up to 0.99)

(b) Output voltage, Transient and recovering

(i) Steady state : 415 Volts ac ± 1%, 3Ø, 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 : < ± 2.0°

(c) Output frequency

(i) Steady state : 50 Hz ± 1%

(ii) Free running : 50 Hz ± 0.1%

(iii) Slew rate (df/dt) : < 1 Hz/sec

(d) Output harmonic distortion (THDU)

(i) 100% linear load : < 3%

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

4. 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.

5. 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.

6. 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.

7. 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:

(a) Rectifier : Off, Over Temperature, Failure

(b) Inverter : Off, Over Temperature, Failure

(c) Battery : On Load, Over Temperature

(d) Load on Bypass

(e) Overload

8. 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 Control Room and TCC respectively.

(3)The UPS and Battery management software shall be provided complete with license number and documentation.

3.1.4.12.Diesel Generator

1. General

The Contractor shall supply, install, connect, test and commission a complete system of Prime duty type diesel generator sets to meet the load requirements for all essential loads as mentioned in these Specifications/Contract.

2. Standard and Reference

The diesel generator sets shall comply with the following codes and standards:

(1) BS 5000 : Specification for rotating electrical machines of particular types or for particular applications

(2) BS 5514 : Reciprocating internal combustion engines

(3) BS 4999 : General requirements for rotating electrical machines

(4) IS 1460 : Automotive Diesel Fuels

(5) IS 4722 : Rotating Electrical Machines

(6) IS 13364 : Specification for ac generators driven by reciprocating internal combustion engine

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

3. Material Description

5.4.3.12.3.1 The scope shall include, but not be limited, to Design, manufacture, supply, including all transportation, storage, loading / unloading, insurance, installation, testing, commissioning and safe custody till handing over of the sound attenuated Diesel Generator sets. The DG sets shall be complete with the following:

1) Sound attenuated weatherproof enclosures

2) Ventilation and illumination system for acoustic enclosure.

3) Engine with Radiator

4) Brush less alternator provided with suitable automatic voltage regulator conforming to IS 4722, BS 5000. The alternator shall be self-excited, self-regulated, self-ventilated type.

5) Residential type of silencer

6) Bank of starting batteries with battery charger for trickle boost and charging

7) AMF Panel with load switches (one for feeding Essential Power Panel and one for Fire Pump Panel)

8) Anti-vibration mounting pads

9) All piping system between engine and radiator

10) Piping system for fuel line from engine to day tank (internal and external tanks both). The pipes shall be MS pipes of 25 mm diameter or braided flexible.

11) The day tank with a maximum capacity of 990 litres or sufficient for one shift operation at full load.

12) Provision of necessary signals for Tunnel Management System (TMS)

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 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 equipment 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.

4. Component

1) Diesel Engine

i. 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.

k) The DG set shall be suitable for working in parallel with another DG set by installation of an auto-synchronizing panel at a later stage (not included in this Contract).

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.

ii. Cooling

1. 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.
2. Water-cooled with fan and radiator, with engine driven circulating water pump, thermostat, temperature gauge with high temperature alarm / trip. Cooling water circuit shall be fitted with corrosion inhibitors.
3. A thermostatic valve should by-pass the coolant in the primary circuit until a pre-set operating temperature is reached.
4. 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.

5. The DG sets, if installed inside the tunnel 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 tunnel, 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 tunnel and for obtaining the Notice of No Objection from the Engineer and the relevant statutory authorities.

iii. 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.

iv. 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.

v. 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 tunnel 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 structure shall be less than 3 m from ground level. Passage of exhaust pipes through walls or the roof shall be sleeved and shall be shrouded to prevent ingress of rain of vermin. Exhaust emission control shall be as per Central Pollution Control Board (CPCB) regulations and all other statutes.

f) Exhaust piping shall be fabricated from class 'B' MS pipes upto 150 mm dia conforming to IS 1239 of size suitable to limit backpressure to within permissible limit. The insulation thickness shall be as per standard to achieve a maximum temperature of 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 confirm to the latest Regulation of the Central Pollution Control Board (CPCB).

vi. 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.

vii. Sound Attenuating Acoustic Enclosure

a) Sound Attenuating Acoustic Enclosure should have pleasant and aesthetical looks and should be able to bring the sound noise to tolerable limits of 75 decibels when measured at a distance of 1 meter away from the set.

b) The DG set should be supported on a base frame in an MS Sheet enclosure with suitable ducting for air inlet and outlet. The door and enclosure should be given corrosion resistant treatment and painted to be weatherproof and long lasting. Resin bonded Glass / Mineral / Rock wool of high density (greater than 45 Kg / Cu. M) with minimum thickness of 75 mm covered with perforated MS Sheet should be provided and covered with tissue paper. Enclosures should be provided with durable locking system with doors duly gasketed with neoprene rubber.

c) Exhaust gases should be taken out from the DG Set by means of MS Pipe and a noise suppressor.

d) Proper care should be taken for engine heat rejection in order to have safe working temperature inside the enclosure by provision of fans etc, as required. The design aspect should ensure free and uninterrupted flow of suction and exhaust air in order that the temperature rise of the enclosure with respect to the ambient is less than 7°C.

e) The enclosure shall comply to the latest regulation of the Central Pollution Control Board (CPCB).

viii. 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:

- Steady state speed band: + 1% or + 0.25% of nominal speed,
- Transient frequency change on application or rejection of 60% load: ± 8%,
- Recovery time to steady state speed band on application of 60% load: 10 seconds,
- 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.

ix. 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 0ºC. 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:

- Battery charge / discharge current,
- Boost charge / trickle charge selector,
- On / Off switch,
- 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.

x. 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.

xi. Emissions

The DG set emissions shall confirm to the latest regulation of the Central Pollution Control Board (CPCB).

2) Alternator

i. 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.

- The neutral point shall be brought out separately and earthed permanently.

- The band of voltage regulation shall be ± 1% from no load to full load and under varying load conditions.
- The overload capacity shall be 150-300 % for 10 seconds. Limitation, if any, shall be highlighted by the manufacturer.
- 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.

3) Excitation system

a) The main exciter shall receive power from a permanent magnet generator through separate auxiliary windings on stator via Automatic Voltage regulator. The AVR shall be of solid-state circuitry and shall provide regulated voltage to the exciter compensating for all normal variations. The main exciter output is fed to the main motor windings via a rotating 3-ph bridge rectifier assembly, which shall be protected, from voltage surges, short circuit, overload and diode failures. The AVR and control gear shall be mounted in a component box on the side of the machine. Electrical connections to the AVR shall be taken through a multi way plug and socket.

b) Voltage regulation shall be within one percent under all conditions of load, power factor and temperature including cold to hot variation. There shall be no radio or television interference. Line voltage waveform shall be as true as possible with a total harmonic distortion not exceeding 3% on 3-Phase load.

c) The excitation system and engine governor should be such that the alternator is capable of starting up induction motors having a starting kVA of not less than 1.8 times the alternator rated kVA. Manufacturer should indicate the voltage dip and duration under such conditions as required under equipment data.

d) The neutral of each generating set shall be earthed solidly to ground with facility for isolation through a fully rated contactor or manual switch .

4) 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:

- Upon main power failure, the generator shall receive 3 kick-starts and the generator breaker shall close only after building up of requisite voltage.
- Hold the Mains Contactor or Breaker open.
- On restoration of power, AMF logic should make change over from DG set to main supply and trip the engine after a pre-set time delay.

d) The AMF Panel should therefore comprise:

- 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.
- Battery charger with normal and trickle charging facility and an isolating switch.
- Over load and Earth Fault protection for the generator set.

5) Protection / Annunciation

Protection and annunciation system conforming to latest standards like BS/IEC or IS with soft control and touch resets shall be designed and provided comprising of following but not limited to:

a. Overload and short circuit trip for the DG set
b. High temperature for cooling water trip If applicable.
c. Alarm in case the DG set is not run for one week at a stretch
d. Earth fault
e. Reverse power relay
f. Low battery voltage
g. Fault indication alarm through suitably designed Annunciator within built hooter
h. Fuel low level alarm
i. Meters and Indicators shall be as follows

- Meter

Generator	
Battery	0 - 24V Voltmeter
	0 - 5A Ammeter for charge
	0 - 75mA ammeter for trickle charge

- 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	-

- Auto-Manual change over switch

Start-Stop Reset	Buttons	Start-Stop Reset
Alarm Reset	Buttons	Alarm Reset
Lamp testing	Buttons	Lamp testing

6) 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.

7) Control System

The control system shall work on suitably supplied 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
   - Voltmeter ,
   - Phase sequence indication ,
   - Ammeter,
   - KW Meter,
   - Frequency Meter,
   - Battery Voltmeter
   - Common Fault Alarm Signal,(
   - KWH meter,
   - Power factor meter

b. Counters
   - Hours Run Counter

c. Controls
   - Emergency Stop Button,
   - Run/Off-Reset/Auto Control Switch,
   - Lamp Test/Reset Push Button,
   - 3 Attempt Start Timer,
   - Terminals for Remote / Emergency Stop,
   - Interface to Remote Annunciator,
   - Voltmeter Phase Selector Switch,

- Ammeter Selector Switch

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

9) The annunciation alarm shall be repeated to the control room through Tunnel Management System (TMS).

5. Installation

The DG including associate equipment shall be installed in the DG Room at locations as approved by the Engineer.

The instructions from the manufacturer shall be followed for the installation, size of cables and conduits.

6. Testing and Commissioning

a) 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.

b) 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.

c) 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.

d) Test proving the satisfactory performance of all operating gear, safety functions and controls shall be carried out.

e) Performance test at site shall include (but not limited to) the following test acceptance criteria:

- Voltage variation ± 1%,

- Voltage regulation ± 1%,
- Frequency regulation ± 1%,
- Maximum water temperature ± 5% of guaranteed performance
- Minimum lube oil pressure ± 5% of guaranteed performance,

f) 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.

4. Tunnel Ventilation

4.1. Introduction

4.1.1. General

This Technical Specification describes the requirements of the Tunnel Ventilation System (TVS) Tunnels for the GMLR Project of BMC.

The Technical Specifications (Outline Design Specification) and Outline Construction Specification) and the Tender Drawings (indicative) 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 TVS Works for Road Tunnels and associated cross passages, wherever applicable and 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. In case of any conflict/ ambiguity among/within the contract specifications/ clauses, more stringent shall prevail. In case of contradiction between various standards mentioned in the contract, the latest and most stringent shall prevail. All codes and standards mean their latest version, if nothing is specified then requirements (of design, installation, testing, commissioning etc.) shall be governed by the relevant British or equivalent International or Indian Standards. In case of any conflict/ ambiguity among the mentioned documents, the Contractor shall always seek advice from the Employer/ Employer's representative, the instructions/decision of the Employer/ Employer's representative shall be final and binding to the Contractor.

4.1.2. Definitions

In this Particular Specification (PS), the following list defines terms shall have the meanings ascribed to them below

Word	Definition
Command	The facility to perform or modify a function of the System.
Controller	Any of the Employer's staff authorized by the Employer to control
Corrective Maintenance	Maintenance performed to correct the Occurrence of equipment or system fault
Drawings	The drawings issued and forming part of the Contract.
Deep Sink	The thermal reservoir formed by the soil/rock around a tunnel
Ducting or Ductwork	Shall include duct, dampers, fittings, flexible connectors, flexible duct, supports, insulation, test holes, and associated items
Equipment	A part of the Permanent Works
Failure	A failure is an event which causes loss of function or performance within any part of the tunnel ventilation system and requires a maintenance intervention to restore full functionality and performance.
Install	shall include to erect, mount and connect, complete with associated accessories, testing and commissioning.
Mean Time to Repair / Restore (MTTR)	The average time being required to repair a piece of equipment, system or subsystem to restore to its proper working conditions
Meantime between Failure (MTBF)	The average time between failures causing service delays for a piece of equipment, a system or a subsystem.
Operating Hours	Revenue service operating hours, for everyday of the year: from 05:00 am to 12:00 pm including reduced frequency operation hours after 12:00 pm.
Piping or Pipework	Shall include pipes, tube, fittings, flanges, valves, pipework Controls, strainers, hangers, supports, unions, traps, drains, insulation and associated items
Preventive Maintenance	Periodic or regular maintenance performed in order to prevent the occurrence of equipment faults in the future. This shall include First, Second- and Third-Line Maintenance
Reliability	The measure of ability to rely upon equipment and systems to

	perform their intended function. The measure of reliability is MTBMA.
Safety-Critical	Failure of the system, sub-system or equipment will directly lead to a situation with the potential to cause harm, injury, damage to property, plant or equipment, damage to the environment, or economic loss.
Specification	This Technical Specification
Sub-system	A part of the Ventilation and Air conditioning Works as defined in this Contract
Supply	shall include to purchase, procure, acquire and deliver complete with associated accessories
System	The Permanent Works.
Third Line Maintenance	The workshop maintenance and where the major components and assemblies removed during second line maintenance are maintained and overhauled
Type Test	Functional test of the as-built component, assembly or system under environmental conditions similar to those to be encountered in the Permanent Works Workstation The collection of processors, screens
Workstation	The collection of processors, screens and input devices necessary to provide one Controller with the necessary System displays and commands.
Wiring	shall include conduits, trunkings, wire, boxes and associated items
Wrong-Side Failure	A failure of a safety-critical system or subsystem.

4.1.3. Codes and Standards

a. The Standards, Codes, Regulations and Guidelines listed in this section shall take precedence as they are listed. Any non-compliance shall be fully justified by the Contractor and approved in writing by Employer/ Engineer in charge.

b. Unless otherwise stated, the safety and environmental control system design shall be governed by all applicable local standards, codes, regulations and guidelines. In case any requirement from one of the listed international Standards, Codes, Regulations and Guidelines is more stringent, the said standard shall take precedence to the local counterpart. The one more stringent prevails.

c. NFPA 130 (Latest) - Fixed Guide Way Transit Systems: British Standards or other internationally recognized standards as approved by the Engineer In charge. Ventilation and air conditioning systems for tunnels are to be based on the current "Handbook" series published by the American Society of Heating, Refrigeration and Air Conditioning.

d. Fans shall be rated in accordance with the "Standard Test Code for Air Moving Services" and the "Test Code for Sound Rating Air Moving Devices" of the Air Moving and Conditioning Association Inc., USA.

e. Noise criteria shall be as described herein and in the current four volume "Handbook" series published by the American Society of Heating, Refrigeration and Air Conditioning Engineer (ASHRAE).

f. The standards to be followed during construction, and installation of the Tunnel Ventilation System shall be generally as listed, except where specific requirements are given in the Specification, which shall take precedence. The Contractor may propose alternative or additional standards for review by the Engineer In-charge at least 60 days application.

g. All codes and standards shall be submitted in English language. The design of any one system shall be to a single code or specification. The parallel use of different codes for particular items or components shall not be allowed.

Minimum parameters to be achieved / maintained are as follows,

Parameter	**To be achieved / maintained**
change of air pressure at entry / exit	Should be <500 Pa/s
Pressure on other tunnel installation of equipment	Should be <2.0k Pa
The Minimum air flow in the tunnel shall	< 85 M3 /s , fan capacity 85 M3 /s@1750 Pa
Fresh air intake for pressurization	At least 4 m away from exhaust outlet / grille
The TVF shall achieve a MTBF	MTBF of no less than 40,000 hr.
The dampers shall achieve a MTBF	> 20,000 cycles.

International Standards

Standard	Standard Description
AFBMA	Anti-Friction Bearings Manufacturers Association
9	Load Ratings and Fatigue Life for Ball Bearings.
11	Load Ratings and Fatigue Life for Roller Bearings
AMCA	Air Movement and Control Association
210	Laboratory Methods of Testing Fans for Rating
300	Test Code for Sound Rating of Air Moving Devices
301	Method for Publishing Sound Ratings
ANSI	American National Standards Institute
S12. 34	Survey Methods for Determination of Sound Power Levels of Noise Sources.
B 46. 1	Surface Texture, Surface Roughness, Waviness and Lay, Part 1
C 1	Specification of General Requirements of a Quality Program
S12.36	Survey Methods for Determination of Sound Power Levels of Noise Sources
Z49.1	Safety in Welding and Cutting
Z55.1	Grey Finishes for Industrial Apparatus and Equipment
AWS	American Welding Society
D1.1	Structural Welding Code - Steel.
ASTM	American Society for Testing and Materials
A 36	Structural Steel
A123	Zinc (Hot Galvanized) Coatings on Products Fabricated from Rolled, Pressed and Forged Steel

	Shapes, Plates, Bars, and Strip.

4.1.4. Computer software

Each Computer Software used for numerical simulation supporting the Contractor's design shall be approved by the Engineer In charge prior its use. The Contractor shall submit a list of such software including the name, vender, design purpose, version and date of last release. Statements and validation data may also be attached to the list in supporting the approval by the Engineer In charge. Any software used in any stage of design and construction shall be made available to the Engineer In charge and handed over with License (validity of 2 years) without any additional cost to BMC and Training of 2 weeks man days Off shore (Foreign) and one week onsite shall be provided for software simulations.

4.1.5. Purpose and Scope

a. This Specification describes the minimum standards of the Tunnel Ventilation System (TVS). The performance requirements and design criteria in this document as well as all the parameters in the tender design represent the minimum requirements from the Client that must be satisfied. It is the Contractor's responsibility to verify their adequacy in their own design.
b. Any relaxion to the minimum requirement in this document and the tender design shall be fully justified and approved by the Employer/ Engineer Incharge.
c. The Works to be executed under the Contract include the design, manufacture, verification, delivery, installation, testing, commissioning and technical / maintenance support including training of personnel for a complete, integrated Tunnel Ventilation System, including all fans, dampers, Sound attenuator, air compressors, Local and Main Programming Logical Controller, HMI workstation and VCP equipment, associated power supply and control & monitoring cables necessary to deliver the requirements of this Specification.
d. The purpose of the Tunnel Ventilation System (TVS) is to provide an acceptable environment within the tunnel for the road users under normal and congested operation conditions. To provide a tenable environment and an effective means of controlling smoke flow during emergency condition.

4.1.6. Relevant Documents

a. This Particular Specifications shall be read in conjunction with the General Conditions of Contract (GCC), the Special Conditions of Contract (SCC), the General

Specification (GS), the Employer's Drawings and any other document including standalone specifications of various sub-systems forming part of the Contract.

b. In the event of a conflict between the GS and this Specification, this Specification shall prevail.
c. In case of contradiction or discrepancy between technical specification and any other standard/code, contractor shall incorporate whichever is more stringent. Where question remains on which requirement is more stringent, contractor submit the issue to Engineer In-charge in writing. The decision of Engineer In-charge shall be considered to be final.
d. The Contractor shall always immediately seek advice from the Engineer In-charge in the event of conflicts between Specifications.
e. The priority order of documents is as indicated (sorted from highest to lowest priority):
    - Employer's design Requirement ODS and OCS Specification.
    - Employer's requirements
    - International Standards referenced herein.
    - Other International Standards

The prevailing latest relevant standards at the time of submission of design/documents shall be followed.

4.2. Overview of the Project

4.2.1. General

This section gives an overview of the Project. Information provided in this section is for reference only. For project overview, refer to Section 6-A General Specifications, Chapter-1, General Description of the Project.

4.2.2. Key Challenges for Tunnel ventilation system

Due to existence of Sanjay Gandhi National Park there is no possibility of any ventilation shaft can be provided and as such it become mandatory for the Contractor to design the ventilation system for 4,700 m without any availability of shaft.

The tunnel ventilation system shall be designed for three modes of operation: normal mode, congested mode and emergency mode (fire in tunnel).

The Contractor is deemed to be familiar with the prevailing local climatic conditions in Mumbai during certain times of the year. The tunnel Ventilation system shall be

designed by the contractor to maintain acceptable temperature in tunnel by considering those specific weather conditions of Mumbai climate and by minimizing the use of mechanical ventilation for saving energy. Outside and Inside temperature design criteria are detailed in this document. The large quantity of gases produced due to vehicles in operation is also one of the major constraints for the design of the ventilation system in normal and congested modes.

In certain sections of tunnel, it may be difficult to introduce tunnel cooling in congested mode. The Contractor is encouraged to consider alternative design solutions, for example utilising the deep sink and geothermal cooling of tunnel walls. The technical viability, long term impact to the deep sink, initial investment, operational and maintenance cost shall all be taken into consideration.

Tunnel emergency fire ventilation system shall be designed to control the smoke management in case of fire in tunnel.

The Contractor shall achieve the required system reliability, availability, maintainability and safety (RAMS) during design and construction phases of the project. The safety requirements of the System will be verified by analysis and simulation during the design phase.

The Contractor is required to submit the necessary testing methodology so that the system RAMS can be demonstrated during commissioning.

The size of the TVS technical rooms shall be optimized (within control room in the Iceland in the connector of box tunnel and twin tunnel).

All equipment and materials shall be suitable for use in the local climate and operating conditions. All equipment/system shall be suitable for operation with dry bulb temperature up to 50°C and relative humidity of up to 95%. Electrical equipment shall be protected from trivialize effects.

4.3. Scope of Work

4.3.1. General

a. The scope of works in this contract to be executed shall include all required items starting from design stage till the commissioning, testing and handing over. It is the responsibility of the Contractor to verify the adequacy of equipment's ratings, quantities to satisfy the relevant performance requirements and ask for any alteration as required to the Engineer Incharge. No cost escalation, apart from provided in the contract, whatsoever will be provided on this account.

b. The Services to be performed by the Contractor shall include, but not be limited to, the following:
   i. Design, manufacture, delivery, system assurance, installation, coordination, inspection by statutory authority, testing, commissioning, activities and operations to be carried out during Test Running and rectification of defects during the Defects Liability Periods of Complete Tunnel Ventilation System.
   ii. Technical supports for the operation and maintenance of the TVS
   iii. Supports for training.
   iv. Training of the Employer's engineers and training instructors, operations staff, maintenance staff and engineering staff.
   v. Decommissioning, removal and/or disposal of temporary works.
   vi. Prototyping and prototype testing.
   vii. Manpower, equipment and all necessary tools for work execution, installation and commissioning.
   viii. Defect Notification period after testing, commissioning and handover from the issue of completion certificate.

c. In a general manner, all works, facilities and services to ensure a perfect and complete execution of works under this scope and according to relevant codes, standards and to this Specification that the Tunnel Ventilation System shall be a complete system that is safe, operable, reliable and readily maintainable.
d. The Contractor shall be responsible for system sizing and the submission of all calculations and design basis adopted to the project for the consent of Engineer In-charge. All details of computer software used for designing, system sizing, calculations etc, and complete print out of all steps, procedure and assumptions involved in detailed design shall also be submitted to ensure complete understanding.
e. The software shall be made available to the Engineer In-charge with no additional cost to BMC. The contractor shall also confirm the general adequacy of the space requirements within voids or service ducts, openings, main routes etc.
f. The Contractor shall verify that TVE equipment (TVS, ECS, SCADA, Electrical) fits in the given plantrooms as per the architectural plans in Volume 7 of the tender document. Any requests from Contractor for larger plantroom after award of contract shall be supported by full justification and subject to the approval by the Engineer, prior to the implementation.
g. Engineering studies and comparative evaluations shall be performed to ensure that the design incorporate all features to achieve optimum performance. In addition,

the TVS design shall be reliable, energy & cost efficient with due considerations to the local climate and operational conditions, safety, ease of operation and maintenance. Design documents shall be prepared and submitted to explain the rationale of the proposed designs. All basis, assumptions, norms and supporting documents used for design should be properly detailed in the design procedure.

h. The Contractor shall be responsible for:
   i. The detailed development of the design contained in the Specification and the Drawings, to the extent necessary for the satisfactory coordination and installation of the equipment, functioning of the system, the satisfactory execution of the Works under the Contract, and coordination and integration with other systems (by the same contractor or other Designated Contractors).
   ii. The selection and/or design and manufacture of equipment to comply and perform in accordance with the design requirements contained in the Specification and the Drawings.

Statutory Approval

The Contractor shall comply with all statutory approval requirements, in particular to local fire authority, local government requirements and approval in relation to smoke/fire handling for all systems, equipment and material provided under the Contract. The Contractor is also responsible to seek approval of the system and equipment from the above authorities under the Contract which shall apply but not be limited to the following:

a. The Smoke control system for tunnel fire emergency including all the fire rated enclosure.
b. The tunnel fire ventilation system including all relevant equipment and material related. Should these statutory approval requirements be in conflict with the Specification the Contractor shall notify the Engineer Incharge in writing giving details of such conflict and proposed method of resolution as deemed appropriate.

4.3.2. Description of Works

The Works are located in different parts as box tunnel and main twin tunnel:

a. Box Tunnel ch. 2+920 to ch.3+940
b. Twin tunnels of 4,700 m from ch. 4+140 to ch.8+830

The major works to be executed include:

a. Tunnel ventilation system including TVFs, OTEFs, UPASFs & TBFs.

b. Tunnel ventilation system associated equipment including pneumatic dampers, silencers, acoustic treatment, ductwork, nozzles, pneumatic system, etc. to form a complete functional system.
c. Electrical works including cables, motor control centres (electrical Switchboard panels), VSDs, sub-main distribution system, fire rated enclosure for control cables (where required), etc. to form a complete functional system.
d. TVS, ECS & E&M control and monitoring system including servers, PLCs, RTUs, field devices, control cables, Direct digital control (DDCs) etc.
e. Interface and integration with Designated Contractors
f. Cable containment system within TVS plant rooms and FAN niches, computer room and signal equipment room, transformer room, etc.
g. BMS SCADA system for tunnels, mid ventilation shafts.
h. Integrated SCADA system for the whole line in TCC.
i. Testing and Commissioning
j. Painting, labelling and identification

4.3.3. Scope of Design

General

a. The Contractor shall undertake all detail design work and shall produce all Design Data necessary to develop the Drawings and Specification to the extent required for the satisfactory execution of the Works. The Contractor shall also refer to Section 6-A of the General Specification regarding design requirements.

b. All subsystems, equipment to be used for the TVS shall be of proven design and used types in other road tunnels elsewhere.

c. The designed tunnel heat load shall include but not limit to the following sources:
   i. Heat emission from tunnel lighting in normal condition.
   ii. Heat emission from the electrical equipment in tunnel.
   iii. Ground thermal properties:
   The Contractor shall investigate the soil property during the detail design stage to propose the thermal properties as an input parameter for numerical simulation.
   iv. Coordination, liaison and integration with other disciplines including electrical, acoustics and vibration, communications and controls, structural, signalling and civil, architect. Tunnel Network (including portals, tunnel) Environment Engineering Analysis (using any suitable single dimensional

simulation tool like SES) and utilization of CFD simulation for the underground sections of the project shall be carried out and the results shall be implemented into the design primarily for assessing system size and operating performance.

d. The Network Simulation shall be used to verify the installed TVS equipment based on the design scenarios listed.
e. Applying the Network Simulation, combined with CFD simulation, the Contractor shall verify the usefulness of an Under Platform Air Supply (UPAS) system for the efficient operation of the OTE exhaust system.
f. In congested mode, the Network models shall be run to demonstrate that the air flow of fans proposed by the contractor can maintain the required air temperature in tunnel. 3D CFD simulations shall be carried out to yield more accurate estimation of the stratified temperature field.
g. In emergency mode, the Network as well as CFD simulations shall be carried out to verify that the TVS operation proposed by the Contractor matches the functional requirements in case of vehicle fire for each tunnel ventilation sections.
h. CFD simulations shall be carried out for the worst fire scenarios in stations to verify that the tenability along all egress paths can be maintained during station evacuation. Those calculations shall be coupled with evacuation simulations by the contractor. The results of those simulations shall be used as an input of the Risk analyses required in RAMS specifications.
i. In normal mode, the Network Simulations shall be performed for the evaluation of aerodynamic and thermodynamic behaviour of the tunnel ventilation network:
    i. Air temperatures and velocities shall be calculated inside the tunnels for a typical summer day and for the design outdoor condition in summer. Those calculations shall demonstrate that the concept design proposed by the contractor is in accordance with allowable temperature in tunnels.
    ii. Short and long term deep sink phenomena shall also be considered during those investigations. For this issue, specific studies shall be performed to determine and evaluate the appropriate strategy for cooling the tunnels at night all along the year in order to benefit efficient deep sink effects during the day especially in summer.
    iii. The infiltration and exfiltration airflow rates from the PSD shall be analyzed. The results shall be used for ECS design input as the heat load to the station.
    iv. The pressure transients on cross passage doors in the tunnel shall be analyzed and results shall be shared with the BMC.

v. Requirement of cooling dumping tonnage shall be envisaged with simulation study and the same shall be incorporated in station ECS heat load.
vi. Both tunnels congestion with vehicles in each ventilation zones shall also be evaluated. Critical analysis of congestion temperature inside the tunnels on rolling stock air conditioning performance shall be verified.

j. The production of Design Data shall include, but not be limited to, the preparation of:
   i. Installation drawings which shall clearly show the final arrangements, route, positions and coordinated relationships of all elements of the Works based on final equipment selections, final design details and final fixing arrangements.
   ii. Fabrication/shop drawings which shall clearly show the fabrication, construction, assembly and fixing arrangements of each element of the Works which is to be manufactured, constructed or assembled by the Contractor.
   iii. Requirements and comments on CSD/SEM which shall show the final structural requirements based on final equipment selections, final fixing arrangements and final design details. These requirements and comments on CSD/SEM shall be dimensioned and of suitable scale and sufficiently detailed to identify all openings, penetrations, sleeves, plinths, sockets, anchors, lifting beams, access panels and the like which are to be provided by the civil Designated Contractors.

k. The Contractor shall ensure that all equipment to be provided under the Contract shall be of a suitable size for the installation into the plant room provided. Any deviations in this respect shall be notified to the Engineer Incharge within 21 Days from receipt of the relevant Drawings.
l. The Contractor shall liaise through the Engineer Incharge with the relevant Designated Contractors to finalise all cable route details and installation drawings. The Contractor shall undertake all design checks necessary to ensure that all cables are of a suitable size and type for the equipment to be provided under the Contract. Any deviation in this respect shall be notified to the Engineer Incharge within 21 Days from receipt of the relevant Drawings.
m. The Contractor shall perform acoustic design on the resultant noise level of the fan and acoustic control system based on his proposed equipment in accordance with the noise criteria at the locations of noise sensitive receivers specified in particular

specification. The fan system to be evaluated shall include fans, flexible connectors, transitions, silencers, dampers, guide vanes, volume control dampers and sliding plate dampers provided under the Contract and all items provided under civil Designated Contracts including concrete ventilation ducts, ventilation shafts, plenum and louvers. The acoustic calculations shall form part of the Design Data to be submitted.

n. To achieve a complete daisy-chain redundant communication network of remote I/O units of the TVS control system, the Contractor shall review the indicative control cable route and coordinate through the Engineer Incharge with the services Designated Contractors and submit a complete control cable route for approval. The dual redundant network cables shall run in different fire compartments and shall each be enclosed by separate fire rated and insulated enclosure to avoid any fire or mechanical damage to a particular location leading to total failure of the TVS control system.

o. The Contractor shall design all the electric-pneumatic equipment and associated component for the control of all motorised dampers to be provided under the Contract. The design shall include air compressors, air receivers, air treatment panels, pipe works and control panels, the operational requirements and modular arrangements of motorised dampers stated in the Specification.

p. The Contractor shall check with the Interfacing Contractor/Designated Contractor that the fault levels at the MCCs are within the rated fault capacities of the MCCs. The Contractor shall notify the Engineer Incharge and shall liaise through the Engineer Incharge with the relevant Designated Contractor to modify the services or the Designated Contract Power Supply System if the rated fault capacities of the MCCs are exceeded.

q. The Contractor shall coordinate with the relevant Designated Contractors and provide the control and monitoring points in accordance with Specification to meet the TVS control and monitoring requirements.

r. The Contractor shall ensure that his design submissions satisfy the intended purpose of this Specification.

s. The Contractor shall be responsible for the design and construction of the equipment and routing of cables and pipes to be included in the Contract. The Contractor shall be responsible for taking action to adjust the TVS plant installed on Site to suit the performance requirements of equipment as stated in this Technical Specification.

4.3.4. Control Centre:

The maximum instantaneous power demand of MCCs shall be within the limits of the LV power supply from the transformers or LV switch boards. The Contractor shall notify the Engineer Incharge and coordinate with the Designated Contractor to modify the LV power supply system in the event that the limits are exceeded.

4.3.5. Design Submission:

The contractor shall submit equipment design data for approval in progressive stages to the Engineer Incharge in accordance with approval design and manufacture programme. Design shall include, but not limited to drawings, equipment, calculations, catalogue, samples, method statement, proposals documentation and information and all other relevant design documents in accordance with the specification.

The design submission shall include but not limited to the followings:

a. Concept Design

b. Preliminary Design

c. On Site Design (Final Design)

4.3.5.1. Concept Design

The contractor shall firstly amend basic calculations performed during bidding phase for each mode of operation for estimating the size of TVS equipment. The revised calculations shall be done considering revised input data provided by other contractors in interface with TVS.

The contractor shall prepare and demonstrate the complete TVS model for the complete underground section based on the information provided by Engineer Incharge and interfacing contractors.

Coordinated with the Civil engineers, the Contractor shall verify that the aerodynamic design of the portals, tunnel cross section and shafts satisfy relevant international standards and guidelines. The passengers in the vehicle shall not suffer from severe aural discomfort when the vehicle passes through the underground sections of the project.

The model shall be carried out with proven and latest version of validated tunnel ventilation software (SES). The Contractor shall submit a specific note indicating the functionalities of the software and validation results for notice of no objection by the Engineer Incharge for using the proposed software.

The latest version of SES simulation along with CFD for the whole Underground section of GMLR shall be the scope of work for this Contract.

The Contractor shall submit Concept Design Report at the end of this phase to Engineer Incharge for Notice of No Objection. It shall include but not limited to:

a. Project description.
b. All applicable Design codes, regulations, standards and guidelines.
c. Complete set of design parameters, including but not limited to, local climatic data, local geothermal condition, operational schedule and limitations, project alignment, station and tunnel architecture etc. Proper reference and source of information should be quoted for each parameter.
d. Designer's assumptions and the basis for each assumption.
e. A complete list of design scenarios for each of the normal, congested and emergency operation mode
f. A detailed design description of the TVS and control philosophy. It shall include but not limited to TVS system configuration and operational description for the most onerous scenarios.
g. Performance requirements, acceptance criteria, design margin or safety factor for each TVS design element quoting the relevant design codes, regulations, standards and guidelines or best engineering practice;
h. The assessment of pressure changes when the vehicle enters, leaves a portal and passes an air shaft;
i. Input data of all ventilation related computer simulations that shall be previously submitted to the Engineer Incharge for notice of no objection before starting simulations.
j. The TVE Contractor shall carry out tunnel network (including portals, tunnel) environment simulation by SES Software based on worst case scenario and report the analysis for
    i. Normal operation mode
        - The tunnel cooling concept for normal operation if required in the design;
        - The impact of the project on the deep sink over 100 years or till the time when thermal equilibrium status has been established, whatever comes first;
        - Typical temperature and air flow profiles (min, max, temp-time curve etc.) in each tunnel ventilation section and ventilation shaft;
    ii. Congestion mode
        - The tunnel cooling concept for each congested design scenario;

- The temperature profile (at the minimum, the temperature variation in time for the worst affected condenser inlet starting from the time when the vehicle stops) in each congested tunnel ventilation section and linked stations for the worst design scenario in congestion mode;

iii. Fire emergency mode in tunnel

- The hot as well as cold (for commissioning purpose) longitudinal air velocities in the vehicle annulus and the corresponding thrust requirement at the outlet of Saccardo nozzle or other proposed fan assembly.

k. The Contractor shall carry out CFD simulation based on the worst-case scenario and report the analysis on

- Temperature distribution in the tunnel areas during time of normal operation mode;

l. Verification of NBC compliance for spaces where air pressurization is used as smoke control measure

m. Control & Monitoring system Architecture.

n. Method statements for tests to be carried out during commissioning to demonstrate the compliance of the TVS design;

o. Pressure loss calculations in tunnel, shafts and fan assemblies against the most onerous operational scenarios.

p. The designed parameters of all proposed fans such as, but not limited to, duty point, fan diameter and shaft power.

q. TVS schematic drawings, TVS typical technical room drawings.

r. Major TVS plant and equipment proposed, rating, size, performance, surface treatment, maintenance and replacement, installation method etc.

s. Schematics on interconnection between items of TVS plant and interfacing requirements with various Contracts.

t. Requirements and comments on CSD/SEM which shall show the final structural work requirements based on final equipment selections, final fixing arrangements and final design details. These requirements and comment on CSD/SEM shall be dimensioned to suitable scale and sufficiently detailed to identify all location and size of openings, penetrations, sleeves, plinths, sockets, foundations, anchors, lifting beams, raised curbs and cast-in items provided by the Contractor, access panels and the like which are to be provided by the civil Contractors.

u. Openings, plinths, fixing details of plant and equipment onto structures and road surfaces etc.

v. Software requirement specification and the software verification and validation plan.

w. TVS functional description. This functional description shall include ventilation control philosophy for each operating mode. For all scenarios using mechanical ventilation, the functional description shall briefly detail if needed the regulation principles that will be integrated in the ventilation control & monitoring system for the adjustment of tunnel fans flow rates to match velocity requirements in tunnels.

Details of equipment provided shall be in accordance with the Specification and Drawings. No alternatives shall be allowed without the permission of the Engineer Incharge.

The Contractor shall verify that the proposed Tunnel Ventilation System will satisfy Employer's performance requirements under clause 4 for all operation modes and meet all acceptance criteria with reasonable design margin and safety factors.

4.3.5.2. Preliminary Design

The Preliminary Design Submission shall consolidate all design information and proceed with the design and equipment selection for the TVS including all TVS Plant, acoustic systems, electrical supply and TVS controls etc.

The Preliminary Design Submission shall include, but not be limited to, the following general requirements. The Engineer Incharge can require additional submissions should he consider necessary during the development of the design.

a. Drawings

i. All systems, electrical and control schematics.
ii. All layouts including mechanical, electrical, control and installation details
iii. Sections and elevations at critical areas.
iv. Fabrication drawings issued by manufacturer including Dampers, fans, MCC and TVS controllers etc.
v. Interfacing diagrams with other Designated Contracts.
vi. Configuration of TVS control computer system.
vii. All necessary logic and flow diagrams for the TVS control system computer software.
viii. Detailed layout and capacity of remote input/output units, programmable logic controller and the daisy-chain redundant communication network.
ix. Cabling and wiring connections showing cable types, sizes and loads.
x. Label schedules, wordings and formats of the labelling of equipment.

xi. Equipment schedules.
xii. Operation mode tables.
xiii. Typical installation or supporting arrangement drawings of equipment.

b. Equipment

i. Fans.
ii. Silencers, dampers, nozzles, OTE dampers.
iii. Motors
iv. Motor control centres, variable frequency drive and relevant components.
v. Pneumatics equipment, i.e. air compressors, air receivers, pipe works, valves, E/P panel etc.
vi. UPS equipment including heat dissipation rate.
vii. Electrical distribution equipment, i.e. distribution boards, fuse switches, MCCB etc.
viii. Cables and relevant accessories.
ix. Earthing equipment.
x. All TVS control equipment including hardware and software.
xi. Booster transformer.
xii. Capacitor bank and power factor correction controller.
xiii. Cable tray, trunking, conduit and electrical accessories.

c. Design calculations

i. Detailed estimation of the duty points for all the fans in the TVS
ii. Detailed pressure loss calculation for DRD shafts in estimation of draft relief efficiency.
iii. Determining Saccardo Nozzles outlet size, angle and efficiency and verification of the same by CFD simulation
iv. Verification of compliance with acoustic and environmental requirements.
v. Pneumatic system design including pipe sizing.
vi. Structural verification of fans/equipment support.
vii. Power loading assessment.
viii. Cable sizing and voltage drop.
ix. Transformer calculation.
x. Grading of motor and all other protection devices.
xi. Discrimination of MCC overcurrent protection devices and upstream overcurrent protection device of main LV switchboard or HV power supply system.

xii. Fan starting sequence.
xiii. Protection scheme design.
xiv. Loading verification of UPS.
xv. Motor Starting Current and time characteristics.
xvi. 400V AC supply for motor starter circuit for each individual MCC.
xvii. Consolidated control and monitoring point list.
xviii. Specification of all control hardware and overall system reliability.
xix. Design and test specification of tailor-made or customized software package.
xx. Initial Detailed Interface Specification and Detailed Interface Test Plan with Designated Contract as specified in Section 6-A.

d. Sample

i. Complete list of samples to be submitted.
ii. Sample of major component which shall include but not be limited to the following:
iii. Access panel.
iv. Emergency stop for smoke extraction fan and UPSF.
v. Fire rated material.
vi. Instrument test hole.
vii. Full size SPD, VCD and wire mesh.
viii. Damper section including actuator and limit switch.
ix. Vibration isolation pads.
x. Flexible connector.
xi. Spring isolator.
xii. Plug valve.
xiii. E/P relay.
xiv. Pressure regulator.
xv. Pneumatic pipe.
xvi. Emergency stop switch for MCC.
xvii. Cable tray and accessories.
xviii. Conduit system and accessories.
xix. Earth tape and accessories.
xx. Cables with cable termination accessories.
xxi. MCB board and MCB unit.
xxii. Isolator.
xxiii. Auto changeover switch.
xxiv. Pressure switch.

xxv. Control switch and push button.
xxvi. Relay.
xxvii. Control and instrumentation cable.
xxviii. Fibre optic cable.
xxix. Cable Tie.
xxx. Fasteners.
xxxi. Fire rated gasket.

Preliminary design will also include amended design calculations considering more accurate design assumptions if required and also comments from the Engineer Incharge since the concept design.

The contractor shall repeat the computer simulations already performed in concept design stage if significant design changes have been made in the primary design stage.

Cold flow network and CFD simulation results corresponding to critical operational scenarios that to be verified in commissioning stage.

The contractor shall submit Preliminary Design Report for Notice of No Objection to the Engineer Incharge.

The Contractor is required to submit the first draft report of their RAMS study.

Detailed Civil design requirements for the TVS system shall be fully determined at the end of this design stage.

The Preliminary Design Submission shall be further developed to the level of Final Design specified in the following section.

4.3.5.3. **On Site Design (Final Design)**

The Onsite design phase will incorporate all the changes and comments from the preliminary design. This phase will culminate with complete design submissions including:

a. Update of Information as listed in previous phases.
b. TVS functional analysis based on functional description including:
   i. Refined TVS control scenarios for normal, congested, fire emergency and maintenance modes including control logics, control requirements, the input methods as well as the criteria of controlled parameters such as air

flow/velocity and air temperature. They shall be programmed in the Central TVS TCC/ SCADA system and Local PLC.

ii. Ventilation scenarios algorithms that will be programmed inside TCCTVS SCADA and including regulation process of ventilation rates according to velocity and temperature measurements in tunnels. This shall include degraded modes.

iii. Local control & monitoring of equipment in local PLC including ventilation scenarios that can be activated locally for maintenance or in case of communication failure between TCCand station TVS SCADA.

iv. Ventilation scenarios in degraded modes.

v. Software design studies based on CENELEC standard and according to the SIL 2 requirement.

c. Drawings including TVS layout, TVS schematics, operating mode tables, TVS technical rooms including arrangement of equipment, Power supply and control & monitoring architectures and cables arrangements.
d. Detailed technical specifications of TVS equipment including fans, dampers, sound attenuators, Aerofoils, Programming Logical Controllers, Power Supply Distribution Panels, cables etc.
e. RAMS study reports.

The Final Design Submission shall include, but not be limited to, the following general requirements in addition to any other particular requirements given in the Specification:

a. Confirmation or amendment of the previous Design Submissions.
b. Detailed fabrication/shop drawings.
c. Detailed installation drawings, and coordination with other Designated Contracts.
d. Detailed wiring diagrams, schematic diagrams.
e. Operation mode tables of TVS for congested and emergency operation.
f. Detailed disposition of cables within the tunnels.
g. Detailed specification on custom software, where applicable.
h. Other minor E&M material and equipment proposals not submitted under the previous Design Submissions.
i. Room/equipment layout drawings of TVS plant rooms and TVS control rooms.
j. Graphic for system monitoring and control.
k. Equipment and Cable Schedules.

l. Detailed description of proposed Factory Tests in accordance with this Technical Specification including estimated timing and location.
m. Detailed description of proposed testing, Commissioning and Integrated Tests in accordance with the Specification.
n. Operation and maintenance manuals.
o. Training plan for system Operation and maintenance.
p. Any other full and final information relating to the design and installation required under the Contracts.
q. Room/equipment layout drawings showing the adequacy of TVS plant rooms and TVS control rooms.

4.3.6. Lead Design Checker (LDC)

a. The Contractor shall engage an Independent Lead Design Checker (LDC). The LDC shall be a company or an individual outside the design team.
b. Independent design assessments are the same in scope and purpose to design assessments except that they are performed by suitably qualified and authorised persons who have no involvement in developing the design. Thus, the designer or supervisor of a team responsible for developing a design cannot perform an independent design assessment, but a competent and authorised person from another team may do so.
c. The LDC shall review the following documents produced by the contractor's design team to ensure compliance to applicable design standards list in this requirement
    i. Tunnel ventilation concept.
    ii. Tunnel ventilation modelling (Network Simulation modelling) including all input parameters and simulation results
    iii. CFD modelling including all input parameters and simulation results.
    iv. Confirming and validating adequacy of Tunnel Ventilation System the local and national safety law and legislation, National Building Code as well as all other applicable national and international safety standards.
    v. Confirming and validating adequacy of Smoke Extraction System for tunnel.
    vi. Lead Design Checker shall also carry out the Fire Hazard Analysis for Various fire scenarios in Tunnel to meet NFPA (latest) compliance.
    vii. Equipment selection.
    viii. Plant room layout and space requirements with the maintenance provisions.
    ix. Interface and system integration documents.
    x. Operating Mode Tables.
    xi. Control strategies for the TVS.

xii. TCC SCADA control strategies and master operating mode tables.

xiii. Drawings.

xiv. RAMS analysis including safety certification of SIL level of SCADA systems.

d. Following the review, the Lead Design Checker shall submit a design review report summarizing the review findings together with the actions to be taken by the design team addressing the comments.

e. The LDC shall ensure that all the design for the complex structures comply with all the necessary standards and regulation taking the potential affect into consideration specially on safety, quality and durability of the works.

f. The LDC is required to submit a monthly report to the Contractor and a copy to be submitted to the PM for a notice of no objection. Upon receiving a notice, a copy shall be officially forwarded to the PM for records.

g. The monthly report shall cover all design verification conducted by the LDC. The report shall be accompanied with a copy of the 'Design Certificate', duly certified by the LDC and designer. In addition to above requirement mentioned shall also be fulfilled.

4.3.7. Scope of Work of Supply

The Contractor shall supply all equipment and facilities necessary to meet the requirements of this technical specification, including, but not limited to:

a. Control equipment, including accessories / components.

b. Tunnel Ventilation Fans (TVFs), including motors and terminal boxes.

c. Hanging arrangement/GI supports and foundations if required.

d. Tunnel ventilation system dampers (TVSD) and Saccardo Air Nozzles.

e. Tunnel booster fans.

f. All auxiliary equipment such as: conical fan inlets and outlets, sound attenuators, ducts, inspection covers & access doors.

g. All cables and cabling necessary for the Works.

h. Enclosures and supporting brackets for housing and fixing equipment.

i. Power supply and distribution panel, circuit breakers, and isolators.

j. All equipment associated with any interfaces required to ensure operation within the performance requirements.

k. All special test equipment and tools, including data configuration tools.

l. Maintenance tools.

m. All equipment necessary to carry out factory and on site testing and commissioning.
n. Compressed Air System including copper piping and solenoid valves to operate pneumatically operated TVS Dampers (TVSD).
o. Minor civil works like grouting of equipment, cutting and finishing good openings in brick walls.
p. Any other equipment/material requited for the satisfactory completion of work.
q. All software, appropriately safety validated, verified and certified, to meet the requirements of the Specification.
r. All software and hardware required for data logging.
s. Necessary spares during DNP.

4.4. Points to be noted

4.4.1. General

The latest versions of the specifications/ codes should be followed in respect of all standards at the date of submission of the design documents.

4.4.2. Design parameters

The design outdoor environmental conditions in normal, congested and emergency modes are as following based on ASHRAE-2017 (1% criteria) Climate Design Information.

a. In summer: 40°C for the Dry Bulb temperature / 22.4°C for the Wet Bulb temperature
b. In monsoon: 32.3°C for the Dry Bulb temperature / 29.1°C for the Wet Bulb temperature. **Note:** Shall be as per latest ASHRAE/ IMD.
c. The minimum heat emission from the traffic of 4800 PSU to be considered.

The maximum number of peoples 200*5 = 1,000 nos.

The operational requirements:

a. Operational speed is 100 Km/h.
b. Contractor shall interface with relevant agency for getting the final data before simulations.

4.4.3. TVS Performance criteria

a. In tunnel fire emergency, tunnel fire ventilation velocity in the incident tunnel section shall exceed the critical velocity and create smoke free path in the upstream.

b. In any design fire emergency scenario, the Contractor shall verify that the tenability along any path of egress in the concerned tunnel satisfies the criteria in the latest version of NFPA 130.
   i. The maximum rate of change of air pressure experienced by the passengers on board is 500Pa/s when the vehicle is entering/leaving a tunnel portal;
   ii. The pressure on other tunnel installation of equipment shall not exceed 2.0kPa.

c. In normal mode, the TVS shall be designed to maintain the maximum dry bulb temperature of 38°C inside the tunnels. To achieve this objective, the average wall surface temperature in a tunnel shall not exceed 38°C. The tunnel wall surface temperature is defined as the average concrete temperature with in the first 55 mm of tunnel lining. In satisfying this design criteria, night time tunnel cooling ventilation should be considered by the designer.
d. In congested mode, the TVS shall be designed to keep the maximum air dry bulb temperature to be less than 42°C inside the tunnels. Sensitivity Analysis for temperature up to 46OC shall be performed and supply of airconditioned air along with fresh air from TVF fans shall be provided.
e. A minimum of 10% the total heat load from vehicles shall be added as a margin for the TVS design.
f. The ventilation system used to pressurize the non-incident tunnels.
g. The Minimum air flow in the tunnel shall not be less than 85 M3/s and minimum Fan capacity shall be 85M 3 / s @ 1750 Pa and in case higher capacity is needed same shall be provided as per simulation results without any additional cost to NCRTC.
h. Sound attenuators shall be fitted to the fans to satisfy the following Noise criteria.

External at tunnel Portals on both sides.	55 dBA (with PSD closed) 65 dBA (with PSD open)
Tunnel / Trackway (1m above road level)	85 dBA

i. For the measurement of emergent noise, residual noises generated by urban activities without activation of RRTS ventilation system shall be known. Those residual noises shall be initially measured by the contractor. The residual noise shall correspond to the sound pressure level that is statistically exceeded 90%

within the representative measurement time period (from 7 am to 11 pm for the day and 11 pm to 7 am for the night).

j. The size of TVS ducts used only in case of mechanical ventilation shall be maximised to reduce pressure losses and energy consumption on the TVS fans.

4.4.4. Control and Monitoring Systems

a. The primary control and monitoring system for TVS shall be performed at TCC/BCC. The secondary control and monitoring system for TVS shall be performed at Control Room (CR).

b. All these systems shall be equipped with automatic, manual, local and remote operation modes. The alarms and signals from the equipment at CR using SCADA shall be transmitted to the TCCvia communication network of fibre optics transmission system (FOTS).

c. Safety Integrity level 2 (SIL 2) shall be provided for the TVE SCADA (control equipment) system. Its core function is to manage the environment within the tunnel for operation of trains and to sustain safe conditions at different operating scenarios.

d. The command signals will be initiated at TCC/CR and relayed up to the relevant equipment through PLC for operation. The feedback signal is received through supervisory control and data acquisition (SCADA) whether the command is implemented or not. The control from TCC/CR is generally performed using 'mode tables' for each system. This table defines the sequence of the desired equipment that needs to operate based on the event.

e. In the event that control from TCC is not possible owing to any reasons, the remote control via. CR would be performed. The TCC will also be used for logging the alarm status, fault occurrences, and other maintenance related data for the above systems.

f. The head end equipment and software in the TCC shall be provided by Contractor. All the control points in the stations shall be passed to the TCC.

g. Control and monitoring facilities

h. Equipment involved in safety shall be controlled locally by means of dual redundant programmable logic controllers (PLCs) with local intelligence able to play scenarios controlled either at central level or at station level.

i. For security reasons, equipment shall also be controlled locally in manual mode with hard wired controls.

j. The Contractor shall provide necessary hardware, software and data, so that the control and monitoring functions for the TVS can be performed.

k. The Contractor shall provide control sequencing to provide safety of equipment and passengers during emergency situations and especially during evacuation of passengers.

l. The TVS shall be completed and equipped with provision for automatic, manual, local and remote controls so that the fans and motors can be operated from a Control Room (CR) or from the TCC.

m. The following three control levels shall be available:

   i. Direct control

      To control equipment in case of control system failure. This control level is ensured by hard-wired control panel close to the equipment VCP/IBP panel.

   ii. Local control:

      A terminal shall be configured to control operations of the tunnel emergency equipment. This terminal shall be able to control smoke extraction scenarios.

   iii. Central control:

      Control of TVS equipment shall be also possible via the SCADA.

n. The priority of control levels shall be as follows:

   - Central control shall supersede Local control which itself shall supersede direct control.

o. The programmable logic controllers that will control emergency equipment shall operate together as per mode table.

p. Temperature monitors will be installed by the Contractor in the tunnel at a suitable distance.

4.4.5. Degree of Redundancy and Degraded Modes

a. The SCADA system shall be of Hot standby PLCs and servers in each station. In the TCC SCADA system shall be hot standby.

b. TVS shall have provision of installed equipment such as if a TVF, OTEF, UPASF or PLC fails in a Tunnel ventilation plant, the initial performances and associated functionalities required for emergency situations as specified in section 5 are not degraded.

c. TVS shall have provision of installed temperature sensors in each inter-station tunnel such as the initial performances and associated functionalities required for emergency situations as specified in section 5 are not degraded when a sensor is initially unavailable and in addition by considering that a sensor can fail due to the thermal effects of the fire.

d. For the development of ventilation scenarios inside the TVS SCADA system, the minimum degraded modes corresponding to the following events shall be considered:
   i. Fan failure (mechanical failure, no power supply.): Appropriate actions shall be integrated in the SCADA to activate properly the redundant fan.
   ii. Damper failure: Appropriate actions shall be integrated in the SCADA to activate the appropriate scenario that enables by-passing the damper when possible.
   iii. PLC failure: In that case the redundant PLC shall control the ventilation equipment.

4.4.6. Equipment Response Time

a. The ventilation system fans that are designated for use in fire emergencies shall be capable of satisfying the emergency ventilation requirements to move tunnel air in either direction as required providing the needed ventilation response.
b. Individual emergency ventilation fan motors shall be designed to achieve their full operating speed in no more than 30 seconds from a stopped position when started across the line and in no more than 60 seconds for variable speed motors.
c. The emergency ventilation system shall be designed to be capable of reaching full required air flow rate in the tunnel within 180 seconds.

4.4.7. RAMS requirements

a. The reliability and maintainability processes and procedures shall be planned, integrated and developed in conjunction with the operating environment, and the design, development and production functions to permit the most effective and economic achievements of the systems and equipment design objective.
b. The system shall meet or exceed the requirements of CENELEC Standards EN50126 & EN50128 or equivalent international standards for Reliability, Availability, Maintainability and Safety of railway equipment and software.

4.4.8. RAMS Specifications

nil

4.4.9. RAMS Mission

a. The contractor shall perform Safety studies applied to equipment & systems supplied in the contract. Contractor's safety studies shall cover the design,

development, manufacturing, testing, installation, commissioning, operation and maintenance phases of the system.

b. The safety studies shall include all the life cycle phases as described in the IEC62278/EN50126.
c. The Contractor shall consider in his safety program the operational modes (including degraded modes) and failures that may lead to a catastrophic or critical hazard.
d. The Contractor shall consider in his safety studies the operating conditions as defined in the Global Operating and Maintenance specification, as well as other information provided by the Engineer In charge during the detailed design phase.
e. The contractor shall set up a Safety organization and shall perform a safety assessment and report in accordance with specifications detailed in Appendix 21

   The Contractor shall perform a RAM assessment and report that shall demonstrate the achievement of the RAM requirements of the System in accordance with methodology .

4.4.9.1.Reliability Requirement

a. The Reliability measure for the TVS shall be the Mean Time Between Failure (MTBF) or Mean Cycle Between Failure (MCBF).
b. The TVF shall achieve a MTBF of no less than 40,000 hr. The OTEF, TBF and UPSAF shall achieve a MTBF of no less than 100,000 h. The time period corresponds to the time for which the fan operates.
c. The dampers shall achieve a MTBF of no less than 20,000 cycles.
d. The PLCs shall achieve a MTBF of no less than 100,000 h.
e. Variable Speed Drive shall achieve a MTBF of no less than 50,000 h.
f. Electrical/Electronic relays in electrical cabinets shall achieve a MCBF of no less than 100,000 cycles.
g. Maintenance actions shall include investigations where no fault or failure is identified. The Reliability and availability of the TVS shall be demonstrated by the Contractor in accordance with the processes defined in codes / requirements

4.4.9.2.Availability Requirements

a. The Contractor shall be responsible for providing a System design, maintenance procedures, and defining the recommended spares holdings to ensure that the Availability requirements of the TVS shall be achieved.
b. The measures for Availability shall be Mean Time of Unavailability expressed in day per year.
c. The availability objectives of equipment that are involved in safety functions detailed in section shall be defined by the contractor in accordance with the

Safety Level required and defined through safety studies performed by the contractor as specified. However, the availability of the TVS shall be at least 99.99%.

d. As the tunnel ventilation system might be used at night, for the purposes of availability calculations the Contractor shall assume that the operating hours are 24 hours a day for 365 days a year.

h. The availability of the TVS shall be demonstrated by the Contractor in accordance with the processes defined in codes / requirements

e. Perturbation Analysis

i. A detailed System perturbation analysis shall be performed stating the types of failures that could cause service interruptions and the failure management actions required to mitigate the effect of these failures.

ii. The service interruption analysis shall document all failure modes capable of causing revenue service disruptions.

iii. Operational actions, System design features or maintenance strategies that can reduce the impact of potential service interruptions shall be submitted to the Engineer In charge for notice of no objection.

iv. The Contractor shall perform RAM studies in order to demonstrate that the availability requirements are fulfilled. The Contractor's RAM studies shall take into account the maintenance plan and the reliability specifications of his system.

4.4.9.3.Maintainability Requirements

The TVS equipment shall be designed and constructed to maximize the maintainability of the system.

1. The Contractor shall identify how the various system/fans, sub-system, assemblies and components have been designed to facilitate maintainability which shall include as a minimum the following features:

a. All equipment installed shall have adequate clearance/access for maintenance and future replacement.

b. The layout of the equipment shall be planned to make provision for easy accessibility for routine inspection of components like actuators of dampers and cable termination box of motors.

c. All control and monitoring panels shall have easy and adequate access for maintenance and replacement of internal components.

d. The contractor shall define and ensure suitable safety interlocking methodology for carrying out maintenance activities.

e. All maintenance operations shall require access from one direction only.
f. Power On and miscellaneous alarm/fault indicators shall be provided and installed at a suitable location so that visual inspection can be conducted in a convenient manner.
g. The system shall provide means of speedy recovery of component failures and reducing maintenance down time by the provision of identification, isolation and/or localization of faults.
h. All control and monitoring panels shall be provided with a lamp test button.
i. The design of electronic circuits and sub-assemblies shall be based on easily replaceable modules where possible such modules shall be "plug-in" and tray mounted with simple, accessible securing devices.
j. Maximum use shall be made of self-test facilities by means of built-in test equipment or circuits. Layout shall be such that modules/assemblies/components may be removed by withdrawal straight through access doors or panels. Standard plugs and sockets shall be used throughout with security pin coding to prevent inadvertent use of equipment meant for other units.
k. When use of external test equipment is required, test points shall be designed for ease of access.
l. Local control panel - LCP (Electrical) shall be provided near the TVS Equipment's in the fan room.

2. System and Equipment design:

a. The System shall be designed to maximize Availability during traffic hours, to minimize the amount of maintenance required to maintain the System and to ensure that any maintenance can be carried out with the minimum amount of time, the minimum amount of skill and at a minimum cost.
b. The contractor shall provide details of corrective and preventive maintenance activities.
c. The Contractor shall specify, for each TVS Replaceable Unit (TVSRU), the mean time needed to recover to a normal operation configuration. 90% of these recovery times shall be lower than this specified value.
d. The possibility of disassembly of each TVSRU shall not interfere with other TVSRUs except noise attenuators and aerofoil that shall be able temporary disassemble for specific heavy maintenance on fans.
e. The system shall be designed in order to keep available the function of smoke exhaust in any ventilation plant during operating hours when proceeding to any maintenance actions in Tunnel ventilation technical rooms.

f. Accessibility to test and diagnosis interfaces, to event recorders shall be effortless. Their access shall be designed and located in that way.
g. The Contractor shall design the System in order to allow most of the maintenance workload to take place during Business Hours.
h. The System shall inform the operator of any failure, dysfunction or disrupting event that could Occur on the System. The understanding of diagnosis data by maintainers shall be easy and shall not require any specific expertise of the system.
i. Diagnosis data shall indicate which TVSRU are suspected as responsible of the detected failure.
j. Maintenance documentation shall support maintainers for diagnosis data interpretation. A link between the maintenance documentation and diagnosis data shall be established.
k. The Contractor shall identify each TVSRU with tags containing the following data: name, serial number and part number.
l. The Contractor shall identify with tags: cables, connectors, relay, switches, fuses, circuit breakers, test spots as well as any devices that the maintainer should have to manipulate.

3. Mean Time to Restore:

a. The maintainability measure for the TVS shall be Mean Time To Restore (MTTR).
b. The required MTTR shall be achieved for failures of the whole System or any part of the System, whether service affecting or not.
c. The MTTR measurement shall include on site diagnostics and rectification of the failure (including software re-boot) up to the point that the System is restored to full functionality. In the event that the failure cannot be rectified, the measurement shall include the time necessary to remove the failed piece of equipment from the System and replace it with a functioning module.
d. The MTTR does not include the time taken for designated personnel to arrive on site (access time) to begin local diagnostic activities or the time taken for the replacement parts to be delivered to site.
i. The maintainability requirements of the TVS shall be demonstrated by the Contractor in accordance with the processes defined in codes / requirements
e. However, the maximum MTTR are required:
f. Maximum 6 hours for auxiliary and electronic components
g. Maximum 2 days for heavy mechanical replacement (fan, fan motor, blades, casing, damper)

4. TVS Replaceable Unit Replacement

a. If the weight of any TVSRU exceeds allowable weight to be handled by maintenance operators, the Contractor shall provide specific handling tools.

b. The Contractor shall equip each piece of equipment to be handled by handling and anchoring supports.

c. The Contractor shall design pieces of equipment robust enough to support successive removals and assembly in workshop.

5. Service Life

a. All components, materials, control & monitoring equipment, software and other support required to repair and operate all TVS shall be available for at least 10 years from the Employer's Taking over of the Works or Section.

b. All updated components shall be fully backward compatible with the originally installed component.

c. The Contractor shall notify the Employer in writing prior to deleting any component of the System from general availability and submit written assurances that it can provide functionally identical replacement units during the life cycle of TVS. The notification period for the deletion of the component and written assurances shall not be less than the lead time for ordering or manufacturing the component plus twelve months. Whenever applicable as required by CENELEC, the Manufacturer shall have to produce a Safety Certification for the same.

6. General Maintenance Requirements

   a. The contractor shall adapt maintenance procedures according to the technical level of Maintenance staff that will be employed by the operator.

   b. The Contractor shall define in the maintainability prediction studies, the unavailability and maintainability times of each failure of the system. The Contractor shall perform all tests that the Employer shall require before and after the revenue service, in order to control the times defined by the Contractor. If the times measured during the tests are higher than the times defined by the Contractor, the Contractor shall update the RAM studies. In case of abnormal situation, if the time needed by the O&M Company to recover is higher than the one defined in the prediction studies and the Contractor demonstrates that the required recovery time should have been lower, then the responsibility of the Contractor is limited to the part of unavailability corresponding to the demonstrated necessary time to recover.

4.4.10. Safety Requirements

a. The contractor shall provide a TVS system that covers the following safety functions:
    i. Keep acceptable temperature in tunnels compatible with working temperature conditions of vehicle air conditioning system and with evacuation of passengers in case of congested mode.
    ii. Control smoke propagation in case of fire in tunnel to keep environment conditions compatible with evacuation of passengers.
b. The operation of TVS shall not lead to an unsafe condition in tunnel. The safety performance requirement shall be achieved with a calibration/inspection interval of not less than 1 year.
c. The safety of the TVS shall be demonstrated by the Contractor in accordance with the System Safety requirements.
d. The safety level of each safety function of the TVS shall be defined and demonstrated by the Contractor in accordance with the system safety requirements. Nevertheless, the minimum SIL 2 level is required for TVE SCADA including PLCs and VCP. This includes also IBP. This excludes HMIs implemented in workstations used for the control & monitoring by operators in TCC or CR.
e. All TVS equipment shall be protected from damage or reliability degradation due to vibration, shock and other atmospheric conditions.

4.5. Functional Requirements

4.5.1. Normal Operating Conditions

For the ventilation capacity of the OTE, please consider the followings:

a. OTE capacity: design at the bidding phase according to the Subway Environmental Design Handbook (p3-55).
b. UPAS capacity: Make up air should be more than 85% of the OTE capacity. Those values are given for reference only. The final flow rate of the track exhaust fans shall be provided without any cost revision as per the results of the study carried out by the contractor during the detailed design.

The Tunnel Ventilation Fans, Supply Fans shall be equipped with inverters (Variable Speed Drive). In order to save energy, the OTE system shall be able to operate at flow rates lower than its maximum capacity to suit the operational requirements.

The contractor shall submit a methodology and take approval of engineer in charge on the operational philosophy of VSD .

4.5.2. Cooling Tunnel at Night

Tunnel ventilation at night (non-revenue time) when the outside temperature is lower than that of the tunnel wall shall be considered to maintain the long term tunnel deep sink temperature below the design criterion.

The fans at both ends of a station shall be activated in the same mode (supply or exhaust) to avoid air to be recirculated via station trackway.

The push- pull ventilation shall be activated in one direction for half of the night and reversed during the other half to increase the tunnel cooling efficiency.

In practical, the ventilation system shall be automatically controlled by the reading of temperature sensors installed in the concrete and in the surrounding soil. The Contractor shall propose a ventilation algorithm that optimizes the tunnel cooling effect and the energy consumptions

In order to save energy, the following ventilation strategy shall be investigated for cooling the tunnel at night. It consists in activating only the fans that supplying fresh air into the ventilation network. The exhaust of the warm air is done by opening the draught relief shafts at the opposite end of the tunnels. In order to balance properly the flow rates in the first tunnel sections, tunnel booster fans shall be installed at tunnel portals.

The expected number of tunnel booster fans is around 4 jet fans per bore and per ramp with a nominal thrust of 2300 N per fan. Those values are given for reference only and are not contractual. The final number of fans and nominal thrust shall be provided without any cost revision as per the results of the study carried out by the contractor during the detailed design

4.5.3. Congested Operations

The congested mode shall be activated in a tunnel when a high temperature is reported by the linear heat detection system, which is provided by the E&M in the tunnel. Once high temperature detected, the congested operation mode shall be activated

automatically. Nevertheless, it shall be previously confirmed that the vehicle blocked in the tunnel is not in fire before activating the ventilation scenario by TCC operator.

4.5.4. Emergency Conditions

In case of fire in tunnel, the TVS shall generate longitudinal air flow that can prevent back layering of smoke and create a smoke free path in the upstream of fire for egress

For train fire in tunnel, the tunnel air velocity in the annular of train shall exceed the critical velocity. The direction of the ventilation flow shall be selected to maximize the safety of tunnel users.

The TVS emergency control system shall be equipped if required with a regulation process that consists of using TVF of adjacent stations that are not used in the process in order to balance properly air flow in tunnel sections. Indeed, many phenomena can affect the longitudinal air velocity in the tunnel over the time such as smoke buoyancy effect, effective fire heat release rate, location of fire, location of other vehicles in the corridor. For that reason, it is generally not possible to have a predefined ventilation rate allowing the respect of critical velocity as per SEDH for any situation. The ventilation rates of adjacent TVF have to be modified over the time according to the evolution of the situation (fans represented with green arrow in the following figure). The automatic regulation process shall be based on air velocity measurement in the tunnels for which dedicated velocity sensors shall be installed and monitored by the tunnel ventilation control system. TVF shall be equipped with inverters. The need of regulation process shall be determined for each interstation with 1D ventilation simulations. This will consist at least

In case of tunnel fire, the non-incident tunnel shall be pressurized to prevent smoke getting into the non-incident tunnel through the opening of the cross-passage doors. In doing so, the Contractor shall verify that the designed ventilation strategy will not cause any smoke recirculation into the non-incident tunnel due to the closeness of shafts for smoke exhaust and air intake or adverse wind condition.

The Ventilation control system shall be controlled and monitored by the TVE SCADA provided at the control room outside the tunnel on both sides.

4.5.5. Control & Monitoring

The TVS SCADA shall be capable of processing a large quantity of TVS control data in real time.

The system shall work 24 /7 continuously in the TCC, the Control Room (CR) and in the technical rooms.

The TVS SCADA system includes the operators' workstations, the PLCs, the I/O modules, cabling allowing the data's transfer until the communication switch in the CER, cabling allowing feed the power supply of all the TVS SCADAs equipment, the software and the development associated to the data's management (PLC, supervisory…) and everything needed to make the system correctly working.

The TVS SCADA allows carrying out the following functions:

a. Acquire data
b. Data monitoring
c. Control equipment
d. Data analysis, trending, etc.
e. Help operator staff and maintenance staff to operate and maintain the TVS system properly.

Controls shall be arranged to provide fans and dampers operation. Tunnel ventilation system shall be operable from a dedicated HMI at the operation control centre and Integrated Backup panels at station control rooms and shall also be provided with an overriding manual control at the ventilation control panels in TVS technical rooms.

The TVS SCADA shall enable monitoring the TVS and ECS equipment in the TCC and the CR by the workstations. One workstation shall be located at the TCC. This workstation shall be able to control and monitor the full ventilation system in both places. The TVE contractor will provide the workstations in Control Room that will be shared between ECS and TVS systems. Each workstation will only be able to monitor the tunnel ventilation equipment. Human Machine Interface (HMI) in the TCC and in the Control Room shall be provided to allow:

a. TCC operator to monitor and control the TVS systems equipment at TCC
b. operators to monitor the TVS equipment at CR.
c. Integrated Backup Panels (IBP) shall be provided at:
    i. TCC in case of failure of TCC workstation. This IBP shall enable the activation of all ventilation scenarios.
    ii. At CRs to enable local control of the TVS system by operators as a secondary priority control in case of failure of TVS SCADA system at TCC.

d. Moreover, Ventilation Control Panel (VCP) shall be able to operate the ventilation plant monitoring and control the closer as possible from the PLC which manage ventilation's plant. The VCP shall be installed on the PLC's cabinets or at a distance less than 2 meters.
e. Redundant PLC shall provide for IBP.
f. Traditional push button with mimic panel is recommended instead of LCD to achieve the required safety level for VCP and IBP.
g. SIL 2 is required for TVS SCADA including PLCs, VCP and IBP.
h. The Contractor shall provide TCP/IP protocol for communication.

The contractor shall provide suitable adjustment at the TCC and the CR to integrate the necessary equipment for achieving the requisite control and monitoring. The equipment choice shall be submitted to the Employer or his representatives before purchase.

The completion of SCADA system at TCC will be in 2 Phases (based on project program). Therefore, the testing and commissioning shall be provided at each phase to ensure services are fully functioning. Precautions shall be taken and necessary planning shall be done for testing and commissioning of Phase 2 on a live system. Additional commissioning plan and methodology shall be submitted for approval before the work is implemented on a live system.

4.5.6. Functioning Mode

4.5.6.1. Normal, Congestion, Fire Emergency Mode

The TCC shall be provided to achieve desired operation of the controlled TVS equipment normally automatically but with provision for manual intervention. The automatic operation shall conform to the operational, functional and overall system needs described in the ventilation strategies.

Three operations mode shall be foreseen:

a. The normal mode
b. The congested mode
c. The emergency mode

In normal, congestion, or emergency mode, the ventilation SCADA shall clearly indicate the functioning mode to the ventilation operator. In normal operating (normal,

congestion, or emergency mode), the TCC workstation shall have the master privilege. With this workstation the operator will have the global vision of the TVS. He will be the only one operator able to drive the TVS. The Integrated Backup Panels in SCRs will only have the right to visualize the status of their ventilation plants.

The normal, congestion and emergency operation modes shall be able to be activated at the TCC workstation. The operation modes, which can be activated at the TCC workstation, shall also be possible on the IBP at TCC. It shall also be possible to activate the different operation modes locally at inside tunnel TVS equipment. Each VCP shall only be able to activate the ventilation system of its own TVS room at different supply and exhaust rate in each bore. Thus, four management levels are available in order to compensate the failure of one of them.

Operation mode is mainly determined by the operating status of the TVS equipment and automatic dampers. Status shall be monitored by the PLC and compared with the pre-set stored program. An alarm shall be sent from the PLC to TCC, VCP and CR if the correct sequence is not achieved within a pre-set time interval.

The functioning mode will have to study the different modes, the priority organization between the different management levels, possible degraded mode, and the switching modes.

In case of fire, or in fire mode, the TVS SCADA shall display the appropriate view on the operator workstation. In the TCC, the ventilation operator will be able to choose a scenario among a pre-established list.

a. If the operator knows the right scenario to start, he will have to validate the appropriate one.
b. If the operator does not know the appropriate scenario, he will have to launch a limited serial of questions, where is fire, to help him in his choice. Note that the location of the fire will be provided by the linear heat detection system installed along the tunnels.

   This high-level alarm will be received by the E&M and data shall be transferred to TVS SCADA. TVS SCADA shall get the information through the interface link between ECS -E&M BMS & LHDS Controller at TCC.

In emergency mode, TCC shall have the capability of overriding tunnel ventilation system as below:

a. Capability of operating the tunnel ventilation fans in a push-pull mode shall be provided for tunnel ventilation systems. Controls shall be arranged to produce airflow either in the direction of travel or in the reverse direction.
b. Capability of operating track dampers independently of the tunnel ventilation fans shall be provided.
c. Tunnel ventilation fans and bypass dampers shall be interlocked such that the fan dampers open and the bypass dampers close upon fan start up.

4.5.6.2. Degraded Mode

Three different ways to monitor the TVS are foreseen (TCC/, CR, VCP).

In order to prevent the different solution's failure, degraded mode for the data monitoring shall foresee:

a. In normal operation, the ventilation operator is able to monitor the TVS in the operation control centre (status equipment, send commands on equipment, receive alarms).
b. The degraded mode when the TCC workstation is down: IBP at TCC shall be able to take over monitor and control of the TVS. In that case, the IBP at TCC will have the right to operate the TVS. A procedure implemented in the main redundant PLC shall be established in order to give the privilege to the IBP located at TCC.
c. The degraded mode when the PLC at TCC is down: an alarm shall immediately (< 5second) warn operators that the communication with the TCC is down. Each IBP in CRs shall be able to take over the control of the TVS system in the station and adjacent stations. A protocol shall be implemented in the station PLCs to give automatically the right and the privilege for a local control of the local ventilation systems when the main PLC at TCC does not respond. The first operator who takes the right will inhibit automatically the right allowed to control the system in adjacent IBPs. In normal and congested mode, the priority control shall automatically be given back to the TCC as soon as the main PLC has recovered its functionalities..
d. The degraded mode when one or several IBP in the CR are down: the ventilation workstation or IBP in the TCC shall be able to monitor and control of tunnel ventilation system. As the TCC is the priority manager, a CR's IBP failure would not have any influence on the TVS operating. However, an alarm shall immediately (< 5 second) warn station and TCC operators that the communication with the IBP is down.

e. The degraded mode when TCC and one or several IBP in the CR are down: the adjacent tunnel IBP or the VCP shall be able to monitor and control locally the TVS if needed (see c. for the specific requirements).
f. The degraded mode when one or several VCP are down: the ventilation workstation in the TCC shall be able to monitor and control of tunnel ventilation system. As the TCC is the priority manager, a VCP's failure would not have any influence on the TVS operating. However, an alarm shall immediately (< 5second) warn ventilation's operators that the communication with a VCP is down.
g. In the worst case, when there is no monitor and control system available for the TVS, an emergency operating procedure will have to be put in action, for example, operation will not be allowed because the passengers' safety is not ensured.

4.5.6.3. Switching Mode

The switch of mode is compulsorily a human action; there are no possibilities to automatically switch a mode. The switching modes are:

a. From normal to congestion or fire mode
b. From congestion to normal and fire mode
c. From fire to normal or congestion mode

The TVE contractor shall study the different conditions which allow the switching modes.

4.6. Inspection, Testing and Commissioning

4.6.1. General Requirements

The Contractor shall put in place a full testing program to demonstrate that all the requirements of the Specification are met.

Tests shall comply with GS defined in Section 6-Aiii chapter 9.

Dynamic tests shall be carried out by the Contractor as an essential part of the TVS Completion Tests. As given in GS, the Contractor shall develop an Integrated Testing & Commissioning plan to verify the system in all modes of operation and with all necessary interfacing requirements. Test programs, methods and results shall be documented and submitted to the Engineer In charge.

The Contractor shall supply documentation showing how system safety and reliability are ensured. It shall include as a minimum; failure modes, system failures and how equipment thresholds have been adjusted in order to keep them above worst-case

interference levels and what equipment tolerances and parameters have been allowed in designing the system. This information shall be presented in one coherent document.

Possession requirements for installation, testing & commissioning of new sections and their integration with commissioned section(s) will be furnished to the Engineer In charge for notice of no objection.

The contractor shall include in the Integrated Testing & Commissioning plan, methodology of ensuring safety during integrated testing and commissioning and service trials.

The Engineer In-charge may conduct independent safety audits and will therefore require access to all the relevant design and product information. The contractor shall provide all necessary assistance for this to the Engineer Incharge.

All the tests shall be carried out by the Contractor and will be witnessed by the Engineer Incharge. The Engineer Incharge reserves the right to carry out any additional tests they consider necessary to satisfy themselves that the System meets the requirements of the Specification.

The Contractor shall support the Engineer Incharge additional tests as necessary. The Contractor's support shall include, but not be limited to:

a. Provision of test equipment;
b. Attendance of competent staff;
c. Provision of test procedures.

Engineer In-charge may request that repeat tests be carried out to simulate the failure mode of any critical hardware/ software component that is deemed to have a significant effect on the safety or reliability of the system.

The Contractor shall provide any simulation equipment, required for testing or commissioning.

The Contractor shall provide details of the testing activities as specified in the Specification in the Testing and Commissioning program.

All alterations to equipment, systems and designs shall be carried out within the scheduled time prior to installation & commissioning.

Access shall be granted to the Engineer Incharge to any facilities where installation, cutover work, or other tests are in progress and to all inspection and test and commissioning records.

The Contractor shall support any testing required by any statutory organizations in order to obtain approval for Revenue operation.

The Engineer In-charge reserves the right to access at any time the records of all pre and post installation inspection and testing of equipment. In the absence of adequate documentation, the Engineer In charge shall have the right to request the Contractor to repeat these tests to avoid problems being accumulated at subsequent phases. Testing and commissioning will not be allowed to start until the Post Installation Inspection and Testing phases are completed.

4.6.2. Sequence of Tests

The sequence of tests shall be as follows:

a. Type Tests;
b. Factory acceptance tests shall be carried out at least for fans, dampers and TVS SCADA (platform tests)
c. Installation Tests and Inspection
d. Partial Acceptance Tests (PAT)
e. System Acceptance Tests (SAT)
f. Integrated Testing And Commissioning;
g. Service Trials

4.6.3. Type Tests

Type Tests shall be performed prior to full production and before FAT.

Type Tests shall be used to confirm that the proposed equipment is fit for purpose in the environmental conditions specified and meets the requirements of the Specification including the EMI/EMC.

The Contractor shall provide a schedule of type tests required for the various components such as Fans, dampers equipment, Electrical equipment, Cables, etc. All Sub-systems, components, modules etc. requiring type testing shall be listed and submitted to the Engineer Incharge for notice of no objection.

The Contractor shall provide detailed Type test specifications in respect of tests to be performed for individual sub-systems, components, modules etc., as listed out by the contractor in the above clause.

Type tests shall include but not limited to the following tests:

a. Mechanical tests based on the function to be performed. For the fans, those tests include balance and vibration tests, measurement of clearance between impeller and casing, flow rates and pressure measurements for each type of fan…)
b. Electrical tests to demonstrate compliance with design electrical characteristics in
c. interference with power supply (Voltage, electrical current, power factor)
d. Fatigue tests to demonstrate the reliability or longevity of the equipment.

4.6.4. Factory Acceptance Tests

a. The Factory Test Plan shall be submitted the Engineer Incharge for notice of no objection as per the GS. The plan shall adopt a top-down approach and describe the FAT strategy as regards to methodology, procedures to be followed and records to be submitted. Contractor shall submit the comprehensive list of specifications to be followed.
b. The FAT plan/submission shall include the appropriate testing and inspection items for approval.
c. The FAT shall demonstrate that each subsystem meets its performance and maintainability specification in accordance with the contractor design based on quality, performance and functional requirements.
d. No equipment should be delivered to the Site until the Contractor has demonstrated to the satisfaction of the Project Manage/Employer that the equipment conforms to the Specification by carrying out the FAT.
e. The Engineer In-charge/Employer will witness the FAT.

4.6.5. Installations Tests and Inspection

1) Pre-Power up checking, power up, customization and configuration of equipment: The contractor shall submit a plan for Pre-Power up checking, power up, customization and configuration of equipment for notice of no objection to the Engineer Incharge. The necessary test shall be carried out by the contractor based on the no objection plan and shall be witnessed by the Engineer Incharge.
2) Installation tests shall be carried out by the Contractor for each subsystem following Installation but before Functional Tests to demonstrate that the installation has been carried out correctly.
3) The Contractor shall submit an Installation inspection and Testing Plan prior to the commencement of the Installation inspection and testing.

4) The inspection shall verify that equipment has been installed according to the procedures and designs that have been submitted with Notice of no objection by the Engineer Incharge, and that equipment is correctly located and labelled.
5) The inspection shall verify that any false feed, temporary wiring and redundant items have been removed and that equipment is correctly protected against interference, damage and deterioration.
6) The Contractor shall maintain inspection records to demonstrate that each item of equipment has been inspected and found to be satisfactory and attach to this record a detailed list of any discrepancies found and remedial work carried out. Inspection records shall be kept for all installed equipment and a detailed list attached of any discrepancies.
7) As the discrepancies are rectified, the record sheets shall be amended to record the corrections.
8) The Contractor shall provide detailed Installation test specifications for each category of tests, these shall include, but not be limited to the following for notice of no objection by the Engineer Incharge:

a. Equipment Check.
b. Layout and equipment profile check.
c. Electrical measurements.
d. Continuity test as per the wiring diagrams.
e. Cable insulation tests.
f. Power Cubicle function tests.
g. Wire continuity tests.
h. Earthing and Surge protection system tests.
i. Software is correctly installed with the correct version and checksum.
j. Circuit board is of correct version and is correctly installed.
k. Control tables test.
l. Interfaces tests with other equipment.

4.6.6. Partial Acceptance Tests (PAT)

4.6.6.1.General

a. Installation work shall be completed and inspection records submitted to the Engineer Incharge for notice of no objection before the commencement of each PAT.
b. The PAT Plan shall be submitted to the Engineer Incharge for notice of no objection at least 60 days before the commencement of each PAT.

c. All tests shall be documented; tests results recorded and submit to the Engineer Incharge for Notice of no objection.
d. Test certificates with completed test records, which demonstrate equipment and components meet the performance requirements of the specification, shall be submitted for information.
e. The Engineer In-charge will witness the PAT at his discretion.

4.6.6.2.Local Functional Tests

a. Local functional tests of the PAT shall be carried out on installed equipment including local TVS SCADA equipment before System Acceptance Tests (SAT) to demonstrate that the Section of the Works operates correctly in accordance with the Specification.
b. Local functional tests shall be performed in sequence through all required operations to prove that the System performs in accordance with the Specification and that the local configuration data (for example, control tables) is correct.
c. Where necessary, input conditions shall be simulated.
d. The Contractor shall provide detailed Functional specifications program for notice of no objection by the Engineer Incharge and shall be carried out by Contractor's personnel, who should be independent of design and installation.
e. The functional tests to be performed shall contain as a minimum, but not be limited to the following:
    i. Function tests: Equipment shall be tested individually to verify that it responds properly to control command from dedicated local PLC.
    ii. Calibration of sensors: velocity sensors in tunnel shall be calibrated to determine the correlation between the measured velocity and the average longitudinal velocity.
    iii. Measurement of volume flow rate delivered by TVF, OTEF and UPSAF on site meet performance requirements for which they have been designed. Measurement of flow rate technique shall be in accordance with ISO 5802 or equivalent.
    iv. Local ventilation scenarios implemented in local PLC shall be tested for each TV technical room to verify that the system responds properly. Those tests shall include normal and degraded push and pull modes at various flow rates in both tubes. Those tests shall be activated both from VCP and from ventilation workstation in CR. As the network backbone may not be available for these tests, the push-pull scenarios shall be activated from both adjacent stations VCP and CR of the tested tunnel. Velocity measurements in tunnels shall be recorded during those tests.

4.6.7. System Acceptance Tests

4.6.7.1.General

a. System Acceptance Tests shall comprise comprehensive testing of the completely assembled installation to ensure that every item has been installed, adjusted, and that all systems operate in every respect in accordance with the requirements of the Specification and are available for integrated testing & commissioning.
b. Prior to System Acceptance Testing, the Contractor shall submit a System Acceptance Test Plan to the Engineer Incharge for notice of no objection. The plan shall adopt a top-down approach and describe the System Acceptance strategies and processes.
c. The System Acceptance Plan shall identify a comprehensive list of specifications, standards, method statements, procedures, drawings and records to be submitted to the Engineer Incharge for notice of no objection. The Plan shall also include a program, which identifies the dates for system acceptance submission and tests.
d. Any tests carried out which are deemed as System Acceptance Tests shall be identified. If these tests have been carried out earlier or form the part of earlier carried tests, the same need not be repeated unless desired by the Engineer Incharge. However, these tests should be identified and included in the System Acceptance Test Plan.
e. These tests shall be conducted in the presence of the Engineer Incharge and/or Employer.
f. Any defects which become apparent in the course of these tests shall be made good and modifications as approved shall be implemented and recorded. All affected equipment shall be retested and certified before the system is accepted.

4.6.7.2.Prerequisites for SAT

a. All documentation for the Safety Report shall be submitted to the Engineer Incharge for notice of no objection.
b. All PAT shall be completed and test records submitted to the Engineer Incharge for notice of no objection.
c. Facilities for the maintenance of the System shall be in place.
d. The SAT Plan shall be submitted to the Engineer Incharge for notice of no objection at least 90 days before the commencement of the SAT.

4.6.7.3.System Acceptance Test Requirements

It shall be the Contractor's responsibility to conduct all tests and record data, and restore the TVS to full operational use following the SAT.

During the SAT, all interfaces with external systems other than those pertaining to the designated contractors to TVS shall be tested.

System Acceptance Tests shall include but not be limited to the following:

a. Functional test of each remote-control link and system in respect of both controls and indications
b. Functional test for all tunnel ventilation scenarios including degraded mode. Those tests shall include:
    i. ventilation scenarios that are activated and managed from TCC via main PLC and TCC workstation including regulation process
    ii. ventilation scenarios that are activated and managed locally via PLC and workstation.
    iii. Velocity measurements shall be performed during those tests to check the performance of ventilation algorithms.
c. Check of system voltages and loads and a system check under low voltage conditions. Test of system response to the loss of one incoming power feed and to the transfer from normal to standby supply. Additional system tests shall be conducted for all equipment, including changeover and redundant equipment under high voltage conditions to ensure that no function, subsystem, system remains in an unsafe state due to the high voltage settings of the power supply equipment.
d. Demonstrate that the system shall automatically re-initialize upon restoration of power following a complete power failure or reboot of any sub-system or system.

4.6.8. Integrated Testing and Commissioning

4.6.8.1.General

a. On completion of testing and commissioning of the Contractor’s own system to the satisfaction of the Engineer Incharge, the Contractor shall carry out all tests necessary to integrate the TVS with all other systems of the Employer such as Communication, Power supply etc. and demonstrate correct operation of all internal and external interfaces.
b. Integrated testing & commissioning plan containing the schedule of integrated tests in coordination with the other designated contractors and test procedures shall be

submitted to the Engineer In charge for notice of no objection in accordance with the GS. The tests shall be carried out in coordination with the relevant Designated Contractors.

c. The Contractor shall be required to lead in certain Integrated Testing and Commissioning where such tests are required to prove the performance of system provided by the Contractor
d. All the defects and shortfalls in the contractor's system discovered in the course of Integrated Testing and Commissioning shall be made good and retested to the satisfaction of the Engineer Incharge before the dates fixed for service trials.
e. Integrated testing and commissioning shall include the integration of the section under integrated testing and commissioning with all earlier commissioned sections including TCC without disturbing the safety & revenue operation of the earlier sections.
f. The Engineer In-charge may instruct additional test if needed.
g. All Integrated Testing and commissioning tests shall be completed and test records submitted to the Engineer Incharge for notice of no objection.

4.6.8.2. Integrated Testing & Commissioning of TVS equipment

a. The Contractor shall be responsible for integrated testing & commissioning of the TVS equipment in co-operation with the Telecom Contractors.
b. Tests with the Telecom contractor shall include the following tests, but not be limited to the following:
    i. Transmission system work properly
    ii. Data transmission time from site to site.

4.6.9. Service Trials

4.6.9.1. General

a. Service trials shall include TVS tests including vehicles inside the tunnels.
b. Prior to Service trial tests, the Contractor shall submit a Service trials Plan to the Engineer Incharge for notice of no objection. The plan shall adopt a top down approach and describe the Service trials strategies and processes.
c. Any tests carried out which are deemed as Service trials Tests shall be identified.
d. These tests shall be conducted in the presence of the Engineer Incharge and/or Employer.
e. Any defects which become apparent in the course of these tests shall be made good and modifications as approved shall be implemented and recorded. All affected equipment shall be retested and certified before the system is accepted.

4.6.9.2.Pre requisites for Service Trials

All SAT shall be completed and test records submitted to the Engineer Incharge for notice of no objection.

The Service trials Plan shall be submitted to the Engineer Incharge for notice of no objection at least 120 days before the commencement of the Service Trials.

4.6.9.3.Service Trials Requirements

It shall be the Contractor's responsibility to conduct all tests and record data and restore the TVS to full operational use following the Service trials.

Service trials shall include but not be limited to the following functional tests:

a. **Normal mode:** Evaluation of ventilation flow rates and pressure levels induced by vehicle piston effects in draught relief shafts
b. **Congested mode:** Evaluation of the performance of TVS congested scenarios included vehicles blocked in the tunnel
c. **Emergency mode:** Evaluation of the performance of TVS Fire scenarios included vehicles blocked in the tunnel

Velocity measurements from sensors installed in tunnels shall be recorded during those tests to check the performance of ventilation algorithms.

4.7. Installation

4.7.1. Construction & Installation Plan

1. The Contractor shall attend a weekly planning meeting with the Engineer Incharge to finalise the work detail, commencing 4-weeks prior to the start of Installation on Site.
2. The Contractor shall submit a Construction and Installation Plan for notice of no objection to the Engineer Incharge 90 days prior to the start of Installation on Site.
3. The contractor shall provide their installation Specification, which shall ensure that installation work and quality conform to the best-accepted practices. This installation Specification shall be submitted to the Engineer Incharge for notice of no objection.
4. Special attention shall also be paid to all equipment whose correct functioning is essential to the safe and efficient operation of the tunnel. In particular, the contractor shall comply with the following requirements:
   a. Tail cables running to the trackside equipment shall not have any jointing.
   b. All equipment shall be installed sufficiently clear of the high voltage and heavy current equipment so that maintenance risk is reduced to a minimum.
   c. All equipment shall be installed clear of any stair or door access.

d. All equipment shall be installed not to cause any infringement to the schedule of fixed and moving dimensions.
e. Appropriate fixed means of access shall be provided for easy and safe maintenance of equipment such as TBF and velocity sensors.

5. Design and Installation specifications of trackside equipment shall comply with the requirements of Schedule of Dimensions not only for the fixed structures but also for movable parts like doors etc., as far as possible.

4.7.2. Method Statement

The Method Statements, as described in the GS, shall be submitted to the Engineer Incharge for notice of no objection at least 30 days prior to the installation activity commencing On-Site.

4.7.3. Temporary Works

1) The design of the Temporary Works shall be submitted to the Engineer Incharge for notice of no objection
2) All Temporary Works shall be removed prior to Engineer Incharge taking over of the works or section, or as directed by the Engineer Incharge.
3) All Temporary Works shall be clearly distinguishable from the Permanent Works. Work on Safety Critical Subsystems
4) The Contractor shall ensure that all safety critical activities are identified prior to the commencement of the Installation.
5) Procedures for safety critical activities shall be submitted to the Engineer Incharge for notice of no objection.

4.7.4. Health and Safety

1) All Site personnel shall be required to undertake an induction safety-training course as detailed in the GS and in the Employer's Requirements on Safety, Health & Environment.
2) Staff Safety
3) The Contractor shall ensure that all areas of work are sufficiently illuminated, ventilated and fire protected for the Works to be undertaken safely and that a safe system of work is employed for all activities.

a. Identification of Staff:

The control of persons entering or working upon the site shall be managed by the civil contractors.

b. Access and Egress Arrangements:

i. The Contractor shall co-operate, at all times, with the Engineer Incharge and Project Contractors to ensure that the Site is protected from unauthorized admission, either wilfully or otherwise.

ii. The Contractor shall make due provision for the safe access and egress to the Site of Works for its staff and subcontractors. This access shall be maintained such that it is free of all hazards and is in a safe condition throughout the duration of the Works.

4.7.5. Installation Work

The Contractor shall undertake installation work in stages as shown in the General Conditions of Contract. Installation, testing, and commissioning of later stages shall not impact revenue operation of earlier stages.

1) Site Supervision

In accordance with the safety aspects of the Specification, the Contractor shall ensure that the Works are adequately supervised by properly trained and competent supervisory staff.

2) Resident Engineer

The Contractor shall ensure that a Resident Engineer is available on-Site for the duration of the On-Site Works during normal working hours and on-call to arrive on Site within 30 minutes at all other times.

3) The Resident Engineer shall have sufficient authority to progress the Contractor's work on Site.

4) The Resident Engineer shall be competent and qualified to act on behalf of the Contractor, and provide upon request information which may include:

a. Current progress of the Works;
b. Planned work for the next 5 weeks;
c. Audit and inspection reports;
d. Health and safety information; and
e. Documents and records pertaining to the Works etc.

1) Transportation of Equipment and Materials The transportation of materials, plant or equipment by the Contractor shall be undertaken in accordance with the requirements of the GS.

2) Competence of Personnel

The Contractor shall propose a Site organisation chart and manpower plan for notice of no objection by the Engineer Incharge, 4 weeks prior to the commencement of work on Site. The Site organization chart and manpower plan shall detail the staff competency and levels of authority.

The Contractor shall ensure that all its staff and subcontractors are trained and competent in the tasks that they are required to undertake. Such persons shall have their generic competence established and recognized through the holding of an appropriate licence, and must demonstrate their specific competence and knowledge in the particular systems, environment and procedures.

In addition to the generic form of licence, the Contractor shall provide evidence of specific competence and knowledge, which shall include:

a. Assessment and certified training in particular systems.
b. Recording of competence and work in the licence holder's logbook, and
c. Receiving or in receipt of sufficient and current exposure to the area of work that the holder is licensed for.

On no account shall the Contractor's staff undertake work for which they are not competent for and for which a current valid licence is not held

The Engineer In-charge reserves the right to undertake, at any time, checks on the proficiency of the Contractor's staff, licensing and all associated documentation.

Should any of the Contractors staff be found incompetent or unlicensed, he will be removed from the Site until their competency has been established.

Equipment Locations :

All equipment shall be located and positioned such that the environmental, maintenance and operational requirements are met. These shall include as a minimum:

a. Safety.
b. Impact on Project Contractors.
c. Access and egress.

4.8. Drawings and Records

4.8.1. General

The Contractor shall provide 6 copies of all as built drawings in 3 sets in A1 & 3 sets in A3 size, bound into circuit books. All drawings for use in trackside environment shall be durable and weatherproof.

The Contractor shall ensure that, at each equipment location, an as-built copy of the Site documentation is provided. This documentation shall include as a minimum:

a. Circuit diagrams
b. Ventilation schematic diagram
c. Arrangement of tunnel ventilation equipment
d. Installation Drawings; and
e. Operation and maintenance manuals.

4.8.2. Circuit Diagrams

The circuit wiring books containing the circuit diagrams shall include as a minimum the following information:

a. Control & monitoring circuits.
b. Cubicle and rack profiles.
c. Room layout.
d. Power supply arrangement.
e. Earthing & bonding arrangement.
f. Cable circuit information.
g. Circuits of interface of TVS with Telecom

4.8.3. Cable Records

The Contractor shall ensure that the as-built cabling infrastructure is fully documented and accurate at the time of Employer's taking over of the works or section. The documentation shall include:

a. Schematic of the cable routes along with GPS mapping.
b. Location of cable joints.
c. Cable types.
d. Installed dates.
e. Test data.
f. Core plan indicating the circuit and function of each core.

The Contractor shall be responsible for adding to all of the Combined Services Drawings with the cable installation details and the timely supply of these marked up drawings to the Engineer Incharge for overall co-ordination.

4.8.4. Earthing

The Contractor shall provide at each TVS equipment room earth bars that shall be connected to the earthing system (see Section 6-A – Appendix 16).

4.9. Asset Identification

1) The Contractor shall submit an asset database for notice of no objection by the Engineer Incharge. The database shall contain the complete asset listing for the TVS.
2) The database shall be designed with a minimum of the following information:

a. Asset details;
b. Failure history;
c. Date installed;
d. Date(s) tested.

3) All equipment and software, down to the line replaceable unit, shall have a unique identification number that is capable of being identified electronically and manually.
4) All TVS assets such as Fans, Dampers, Inverters PLC and workstation equipment shall be identified.

5. Plumbing

5.1. General Requirement

5.1.1. Scope of Work

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

1) Water Supply for fire fighting
2) Drainage (Waste & vent)
3) Rain Water Drainage (Surface water)
4) Seepage Water Drainage (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, Mumbai 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.

5.1.2. Responsibilities

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

1) 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.
2) 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.
3) Testing, Commissioning, Verification & Validation of the Systems and getting the Notice of no Objection by the Employer / Engineer.
4) Selection of Plant to meet performance criteria and specification with supporting calculations
5) Capacity of Seepage Water Sump
6) 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.
7) Capacity of Seepage Water Pump Sets
8) Sizing of Seepage Water Pipes both Gravity and Pumped mains running in the and Tunnels.
9) 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
10) Arrangements to handle expansion / contraction
11) Acoustic and vibration isolation
12) Co-ordination with all the other services for the interface requirements
13) Liaison with the Local Authority & getting approval
14) All legal fees & statutory requirements

5.1.3. Additional Standards, Codes and Regulations for Plumbing

In addition to the standards listed in "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 plusnickel 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 3Product 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 roofdrainage
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, priorto 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 mediumsand 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 suppliesand fire fighting
IS: 9842	Preformed fibrous pipe insulation
IS: 9912	Coal tar based coating materials and suitable primers for protectingiron and steel pipe lines
IS: 10221	Code of practice for coating and wrapping of underground mild steelpipelines
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		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 Generaltechnical 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 andsewage
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 2Tolerances
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 engineeringpurposes
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 waterworks purposes
IS: 780	Specification for sluice valves for water works purposes (50 mm to300 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 to1200mm size)
IS: 3950	Specification for surface boxes for sluice valves
IS: 5312 (Part 1)	Specification for swing check type reflux (non-return) valves: Part 2 Multi door pattern
IS: 5312 (Part 2)	Specification for swing check type reflux (non-return) valves: Part 2 Multi door pattern
IS:12992 (Part 1)	Safety relief valves, spring loaded: Design
IS: 13095	butterfly valves for general purposes
Sanitary Fittings	
IS:771 (Part 1 to 3)	Specification for glazed fire clay sanitary appliances
IS: 774	Specification for flushing cistern for water closets and urinals (other than plastic cistern)
IS: 775	Specification for cast iron brackets and supports for wash basins and sinks
IS: 781	Specification for cast copper alloy screw down bib taps and stopvalves for water services

IS: 1700	Specification for drinking fountains
IS: 2548 (Part 2)	Specification for plastic seats and covers for water closets: Part 1Seats 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 ceramicmetal systems
IS: 2963		Specification for waste plug and its accessories for sinks and washbasin
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 resinbath 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 freshwater
IS2002:		Steel plates for pressure vessels for intermediate and hightemperature 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.

5.2. Drainage

5.2.1. General Requirements

The contractor shall design the system based on 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 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 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 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 structure.

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 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 peak 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 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.

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 Contractor shall liaise with the local authorities for the following:

1. Final connection point with the existing Municipal (or the relevant agency) 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 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 sets shall be selected based on the following minimum requirements,

i. Head loss
ii. Discharge based on 4Hrs of operation to empty the sump.
iii. Pump efficiency to be not less than 95% of the maximum possible for the particular type of pump chosen
iv. Pump shall be selected considering maximum life span based on corrosion analysis of the water or content of solid to be pumped
v. The motors shall be rated a minimum of 25% more than its rated KW or as per the applicable standards
vi. The pump should be maintenance free with liquid level controlled automatic operation and capable of remote interface & monitoring
vii. 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
viii. The pump shall be noise and vibration free
ix. The pump shall be of centrifugal and self-priming type
x. The pump shall be generally rated for 2900rpm or 3000rpm
xi. The duty and standby pumps shall be identical
xii. The Net Positive Suction Head (NPSH) of the pump shall always be lower than the atmospheric NPSH to avoid cavitation due to evaporization M. Capacitor banks shall be provided for power factor improvements
xiii. 100% stand-by shall be provided for each installation
xiv. The pump shall be rated for continuous operation under all conditions
xv. The motor shall have DOL starters for ratings less than 3.75KW and suitable star delta starters for higher ratings.
xvi. Starter shall incorporate systems for protecting the motor from overload, short circuit, earth fault, under voltage and single phasing
xvii. 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
xviii. Pump shall be provided with in-built protection against dry running, reverse rotation pump failure
xix. The sump capacity must take into account the dead storage of water and the free space required at the top of the sump
xx. Automatic changeover switch shall be provided to change the duty, standby operation cyclically
xxi. The status of the pump operation and any trip or faulty operation shall raise an alarm and indicate the same in the CR and TCC

xxii. Enough clearance shall be provided between the pump & wall and between the pumps and between the pumps and floor

xxiii. 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 gate valves / 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 CR and TCC 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.

5.2.2. 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 Network.

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

5.2.2.1. 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 vehicles. The surface water from the pavement areas 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.

5.2.2.2. Ground Water Seepage

The Contractor shall design and install a drainage system for the seepage water. 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.

5.2.2.3. Seepage Water Drainage;

a) Drains shall be provided in the cavity wall every 10 metres

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 tunnel 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 tunnel is routed horizontally to the waste water collection pit.

f) The slope for the drain shall follow the slope of the tunnel 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.

5.2.2.4. 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

5.2.2.5. Sump Pits and Sump Pumps (Seepage Water)

The Seepage Water Sump and Pump sets shall be provided the tunnel. The Sump and Pump sets shall be provided at appropriate locations.

1. Sump Pits

   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 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. 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.

5.3. Fire Detection & Alarm System

5.3.1. General Requirement

5.3.1.1. 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 automatic 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.

5.3.1.2.Responsibilities

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

1. Detailed Design of the systems / packages listed in the scope of works.
2. 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.
3. Cable sizes, cable containment, voltage drop and electrical protective devices in accordance with the co-ordinated cable routing and the actual rating of Plant.
4. 24V DC battery sizing calculations.
5. Fault level discrimination
6. EMC analysis and EMI control measures for the Works
7. Acoustic and vibration isolation
8. All software design
9. Liaison with the Local Authority & getting approval
10. All legal fees (or as chargeable by Authorities/Agencies) & statutory requirements
11. 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 BSEN standards & VALIDATED as a complete system by the Contractor:
12. Fire Detection & Alarm System including VESDA
13. Emergency Lighting System
14. 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
15. G. Fire Fighting Systems (Fire Pumps / Sprinkler Valves etc.)
16. H. Clean Agent Fire Suppression System (Total Flooding & Panel Flooding)
17. Automatic Doors /Access control
18. HV Power Supply SCADA
19. M&E SCADA
20. TVS SCADA
21. 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.