GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS
(RAILWAY BOARD)

E-File No. 2020/Proj/MPMRCL/DBR/30/4 New Delhi, dated 29.09.2020

Managing Director,
Madhya Pradesh Metro Rail Corporation Limited, (MPMRCL),
2nd Floor, Bhopal Smart City Development Corporation Limited,
Sector-A, Berkheda, Bhopal-462022, Madhya Pradesh

Sub: Approval of Design Basis Reports (DBR)'s for Viaducts, Elevated Stations and Bored Tunnel Sections (May, 2020) for Bhopal and Indore Metro Rail Projects of Madhya Pradesh Metro Rail Corporation Limited (MPMRCL).

Ref: MPMRCL's letter No. 3640/MPMRCL/2020 dated 02.06.2020

The Design Basis Reports (DBR)'s for Viaducts, Elevated Stations and Bored Tunnel Sections (May, 2020) for Bhopal and Indore Metro Rail Projects of Madhya Pradesh Metro Rail Corporation Limited (MPMRCL) has been examined in consultation with RDSO and approval of Railway Board is hereby conveyed.

Accordingly, approved copies of DBRs are enclosed.

Encls: As above

29/09/2020
(D.K Mishra)
Director/MTP
Railway Board
☎ 011-47845480

Copy to: (i) **Executive Director/UTHS**, RDSO, Manak Nagar, Lucknow w.r.t RDSO's letter No. UTHS/120/MPMRCL/Civil dated 12.06.2020

(ii) **OSD/UT & Ex-Officio Joint Secretary**, Ministry of Housing & Urban Affairs (MoHUA), Nirman Bhavan, New Delhi-110001

716537/2020/O/o DD(Project)

MADHYA PRADESH METRO RAIL CORPORATION LIMITED

Madhya Pradesh Metro Rail Co. Ltd.

BHOPAL AND INDORE METRO RAIL PROJECT

DESIGN BASIS REPORT (DBR)
for BORED TUNNEL SECTION

May 2020

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Date

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1 INTRODUCTION

1.1 Brief Description of Project

A. Bhopal Metro Rail Project

- Bhopal Metro Rail Project is a rail-based Metro system on standard gauge tracks (1435 mm).
- Bhopal Metro Rail Project has two lines, Purple line and Red line and 1 Depot area serving both the lines.
- Purple Line has a total of 16 stations, of which 14 are elevated and 2 are underground.
- Red Line has a total of 14 stations, and all are elevated including a passenger interchange with Purple Line.
- Traction Power will be based on 750V DC system using third rail as contact line.

B. Indore Metro Rail Project

- Indore Metro Rail Project is a rail-based Metro system on standard gauge tracks (1435 mm).
- Indore Metro Rail Project consists of Yellow Line (Ring Line) and 1 Depot area.
- Yellow Line has a total of 23 elevated stations and 6 underground stations.
- Traction Power will be based on 750V DC system using third rail as contact line.

1.2 General:

Where ever applicable the provisions of the Project Viaduct Design Basis Report (DBR) shall be followed.

2 SCOPE OF THE DBR

The scope of this DBR is for Bored Tunnels by TBM. The design basis report hereto provides minimum standards that are to govern the design.

This design basis report shall be read in conjunction with the Outline Construction Specifications where appropriate.

The design of the permanent and temporary supporting works shall comply with code of practice and standards at the time of submission of Tender Documents, Regulations made and requirements issued by the Indian Government and by related utility authorities shall be followed and specified.

3 MATERIALS

3.1 Cement

1. Ordinary Portland Cement (OPC) of Grades 33, 43 and 53 shall conform to IS: 269-2015 (Note; Codes IS:8112-1989 and IS:12269-1987 have been superseded

by IS:269-2015).

2. Portland Pozzolana Cement (PPC) conforming to IS: 1489 may be used.
3. The Employer's Representative may permit on request the use of Sulphate Resistant Portland Cement conforming to IS: 12330 for structural elements that are exposed to soil.
4. For Foundation and Substructure designs the Engineer may direct the substitution of OPC by Blast Furnace Slag Cement which shall conform to IS: 455.

3.2 Concrete

1. Concrete density shall be as follows;
   a) 24kN/m^3 for Pre-stressed Concrete (IS: 875 Part-1 Table-1 item 21 value rationalised).
   b) 24kN/m^3 for Reinforced Concrete with 2% or less reinforcement (IS: 875 Part-1 Table-1 item 22 value rationalised).
   c) 25kN/m^3 for Reinforced Concrete with above 2% reinforcement (IS: 875 Part-1 Table-1 item 22 value rationalised).
   d) Plain Concrete 23kN/m^3 (IS: 875 Part-1 Table-1 item 20).
2. Short term modulus of elasticity 'Ec' & Modular Ratio 'm' shall comply with IS: 456 Clauses no. 6.2.3.1 & B-1.3(d).
3. The minimum grade of concrete shall be M35.
4. The Thermal Expansion Coefficient shall be 1.17x10^{-5} / °C and in compliance with IRS Bridge Rules Clause 2.6.2.
5. The Poisson's Ratio for all concretes shall be 0.15.
6. The minimum cement content and maximum Water-Cement ratio shall comply with IS: 456 Table 5.
7. The strength of concrete shall be the specified characteristic compressive strength of a 150mm cube at 28 days.
8. The minimum concrete cover shall comply with IS: 456.

3.3 Reinforcement

Only Thermo-Mechanically Treated (TMT) reinforcement bars conforming to IS: 1786 shall be adopted. (For seismic zones III, IV & V the minimum total elongation shall be 14.5%).

3.4 Structural Steel: General

1. Design of all Structural steelwork shall comply with IS: 800.
2. Two types of structural steel to be used and shall comply with the following standards:
   a) IS: 4923 "Hollow steel sections for structural use with Y_{st} 310".
   b) IS: 2062 "Steel for General Structural Purposes (Grade B-Designation 410-B)".

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3. Hollow steel sections shall be Square (SHS) or Rectangular (RHS). Other traditional rolled sections like plates, angles, channels, joists can also be used where required.

4. The connection with concrete shall be provided by internally threaded bolt sleeves (hot dipped galvanized @ 300g/m²) manufactured from IS: 2062 Grade B mild steel. The sleeve shall receive a hexagon-head bolt M20 Class 8.8 as per IS: 1364 (Part 1) with a galvanized spring washer.

5. The connections within the steel structure shall be designed as direct welded members, with or without gusset plates. The minimum thickness of metal for SHS/RHS sections for main chord members as well as bracings shall be 4mm as applicable for Steel tubes confirmed by IS: 806 Clause 6.3.

3.4.1 Material Properties

Material properties shall be as follows:

Steel Type	Young's modulus	Tensile Strength	Yield Strength	Density	Poisson's ratio	Coefficient of Thermal Expansion
For Hollow Steel sections (Conforming to IS: 4923)	200,000 MPa	450 MPa	310MPa	78.5 kN/m^3	0.30	1.2×10^{-5} per °C
Structural Steel (Conforming to IS: 2062)		410 MPa	250MPa (for t<20mm), 240MPa (for 20mm<t<40 mm), 230MPa (for t>40mm)			

4 TUNNEL PROFILE, CONSTRUCTION METHODS

The bored tunnels shall comprise twin single-track tunnels. The spacing between the tunnels shall be based on the soil strata and determined by numerical analysis. The minimum internal diameter for bored tunnel shall meet all the service requirements (kinematic and structural envelopes) and SOD (Schedule of Dimensions) requirements.

Bored tunnels in rock and soil will be excavated mainly using tunnel boring machines. Other methods if required based on geological and hydrological condition may be considered but shall require the Engineer's approval.

Initial tunnel support will generally include precast concrete segments, shotcrete/wire mesh, rock bolts, lattice girders, steel sets, or fore poles wherever necessary.

5 DESIGN LIFE / DESIGN SPECIFCATIONS / REQUIREMENTS / PRINCIPLES

5.1 Design Life

The design life shall be a minimum 100 years.

5.2 Tunnel Design

1. The design of the bored tunnels shall be fully compatible with the construction methodology and shall be carried out using suitable design software.
2. The design shall take into account all the expected loads prescribed in Clause 6 (Design Loads and Loading Conditions) of this document.
3. The design shall take into account all additional loads, stresses and strains imposed by or on to adjacent Existing Building Structures (EBS) and any assumed distortions and loads by or on the proposed bored tunnels.
4. Where bored tunnels are adjacent to or beneath EBS, the design shall demonstrate that these EBS shall not be subjected to unacceptable movement, distortion or loss of support which endangers the stability of the EBS and that any resulting movements and distortions will be within prescribed limits determined by the authority for that EBS, the Engineer, or the Owner.
5. The Designer shall ensure that ground movements and distortions, and changes to the loads and piezometric pressures, which may affect adjacent EBS either at surface or underground are within the allowable tolerances for each of those EBS.
6. The design shall consider and minimise the short and long-term influence of the bored tunnels on the groundwater regimes, and similarly the influence of the groundwater on the bored tunnels.
7. During tunnelling, the Designer shall review the ground conditions based on envisaged and actual conditions encountered, to allow excavation to be carried out in the safest and most efficient manner. This review shall be fully integrated into the construction risk management and shall typically include:
   a) Probing ahead of and around the bored tunnel face in rock conditions.
   b) Interpretation of fresh data and correlation with previous information.
   c) Prediction of ground conditions likely to be encountered.
   d) Investigations on the surface for the presence of water wells / bore wells for domestic use in residential areas that intersect the alignment.
8. Ground information from surrounding construction activities shall be collated and interpreted.

5.3 Tunnel Lining segment

1. The design of the segments shall be adequate for all stresses induced during stacking, lifting, transportation, erection, jacking and impact. This design shall include in-service stress and impact.
2. The design shall consider in-situ ground stresses and shall provide evidence and/or measurements in support of the parameters adopted in the design as part of the calculations. The ground load on the tunnel shall be based on the actual height of overburden above the tunnel lining and the coefficient of earth pressure at rest of the soil/rock strata surrounding the tunnel.
3. The design of the bored tunnel linings shall take into account the proximity of

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bored tunnels one to another, the sequence and timing of construction and the proximity of adjacent EBS.

4. The design shall also consider the relative rates of loading/unloading due to Bored Tunnel Machine (TBM) jacking forces in both the lateral and vertical directions, and the resultant induced tunnel deformations whether temporary or permanent.
5. The segmental lining shall to be designed for 4-hour fire rating in compliance with IS: 456.
6. The design method shall take into account;
   i. the interaction between the lining and the ground,
   ii. the deflection of the lining and the redistribution of the loading dependent upon the relative flexibility of the lining and
   iii. the variability and compressibility of the ground.
7. The design shall conform to all durability aspects of the permanent bored tunnel lining including permeability/transmissivity and electrical resistivity.
8. The design shall take into account the proximity of the lining to the tunnel face at the time of installation and the potential for additional ground loads as the face advances.
9. The design shall allow for the expected variation in ground conditions and the size, proximity, timing and method of construction of adjacent excavations. The lining flexibility shall make due allowance for likely deflection of the lining during construction and operation.
10. Where a permanent or secondary lining is to be installed inside a temporary or primary lining, the ground loads used in the permanent lining design shall consider all loads as described in the Contract and any additional ground loads that may arise from time-dependent ground strains.
11. The stiffness of the permanent lining shall be designed so that the deflections are within permissible limits of IS: 456 and BS: 8110 Part-1.
12. The thickness of segments shall suit the method of construction and shall not be so large that part of shoving of the shield becomes a general necessity.
13. The thickness of the segments shall be consistent with the capacity of the circle bolting arrangements to withstand the shear forces induced in linings built with staggered joints, for the designed reinforcement and specified concrete cover.
14. A groove for a single elastomeric gasket shall be provided on all joint faces of each segment and key in accordance with the gasket manufacturers directed dimensions. The elastomeric gasket shall be suited to the conditions under which it is required to operate for the design life. The gasket grooves shall allow for the accurate mating of the gaskets of adjacent segments.
15. A groove for post-construction grouting/caulking, as necessary, shall be provided on the intrados of each segment joint.
16. The length of tunnel segments shall be designed and adopted with regard to the

alignment, bending stresses during handling, storage and erection and the long-term stresses due to ground loading and resultant deflections.

17. The design of linings shall include tapered rings in order to negotiate the horizontal and vertical alignment curvature, and to correct for line and level adjustment during construction. The use of circumferential joint packers shall be minimised to reduce the risk of attaining the required degree of water-tightness of the bored tunnels, which shall be in accordance with the Contract {see Material and Workmanship Specifications}.

18. The tunnel segment lining design shall confirm;

    a) Ring configurations,

    b) Segment size and shape,

    c) Fixing details including for;

        i. Ring to ring fixings

        ii. Segment to segment fixings

        iii. Fixings for all equipment to be installed

        iv. Handling, stacking and installation of segments

        v. Holes, recesses and fixtures for other system components,

    d) Tolerances for segment production and installation.

    e) Installation of other components, such as:

        i. Grout hole valves

        ii. Gaskets

        iii. Bedding and packing materials.

    f) Cavity grout, between lining and ground.

    g) Instrumentation and monitoring to demonstrate the performance of the installed tunnel lining.

    h) Short-term (during construction) intermediate (immediately after construction) and long-term (full design life) loading conditions.

    i) Stresses induced by grouting and ground pre-treatment, where applicable.

6 DESIGN LOADS AND LOADING CONDITIONS

6.1 Loads

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

a) Dead Load

b) Superimposed surface loads from traffic, existing structures over and adjacent to the bored tunnel, and any specified future loads.

c) Appropriate ground loads, water pressure and seismic loads.

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d) Railway loads where appropriate.

e) Long and short-term ground yield or squeeze.

f) Unequal grouting pressures.

g) Adjacent bored tunnelling or excavation.

h) Long or short-term loads induced by construction.

i) Temperature and shrinkage.

j) Handling loads, including impact, especially in the case of unreinforced segments.

k) Jacking forces, where appropriate.

l) Accidental loading such as fire and derailment.

6.2 Loading Conditions

1. Dead Load comprises the self-weight of the basic structure and secondary elements supported and the weight of earth covers. The depth of cover shall be the actual depth or minimum one diameter of tunnel. The depth of cover shall be measured from the ground surface to the tunnel crown.
2. Traffic surcharge shall be as per the loading of IRC/IRS as applicable.
3. Loads from existing or known future adjacent structures above or within the area of influence, which will remain in place above the bored tunnels, or any specified future loading. The applicable foundation load and its influence shall be computed based on the type and use, and the foundation type which supports that structure.
4. Additional support, ground treatment or additional lining thickening shall be provided unless it can be shown that adequate provision already exists. Any structure surrounding tunnel should be supported by grouting and shotcreting techniques, should not be supported from tunnel lining.
5. Where provision for a specific future structure is not made a minimum uniformly distributed surcharge of 60 kilo-Pascal at the design finished ground level shall be assumed.
6. Hydrostatic pressure, ignoring pore pressure relief arising from any seepage into the tunnel. Water at ground level to be considered for design.
7. Loads and load changes due to known construction activity to the vicinity of the bored tunnel, such as the excavation and the formation of underpasses, basements, pile groups, bridges, diaphragm walls and cable ground anchors.
8. The grouting pressure will not exceed the hydrostatic pressure by more than 1 bar however the actual pressure will be decided by in-charge chief Engineer based on the geological conditions.
9. Structural requirements for resisting buckling is to be checked since tunnel is being designed as compression member.
10. Additional loads / stresses in adjacent rings due to openings at cross passages locations to be considered.

6.3 Floatation

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For floatation check, the water table is assumed to coincide with the ground level. Where the bored tunnels are relatively shallow they shall be checked for the possibility of flotation due to differential water pressure at representative typical locations. Uplift due to displaced water to be considered in the design. The overall factor of safety against floatation shall not be less than 1.1 for any of the condition.

6.4 Crack Width

All structural concrete elements shall be designed to prevent excessive cracking due to flexure, early & long term age thermal shrinkage. Flexural crack width shall be checked in accordance with Appendix F of IS: 456. The limits specified in cl. 35.3.2 of IS:456 has to be followed.

6.5 Load Cases, Load Factors and Combinations

All analysis shall clearly show the designs achieve the design factors of safety.

6.5.1 Load Cases

The following load cases will be considered at each design section:

1. Load Case – 1: Ground water table at the ground surface with uniform surcharge of 60kN/m^2.
2. Load Case - 2: Ground water table at the ground surface with no surcharge.
3. Load Case – 3: Ground water table at 3m below existing ground water level with uniform surcharge of 60kN/m^2.
4. Load Case – 4: Ground water table at 3m below existing ground water level with no surcharge.
5. Load Case -5: Ground water table at extreme water level with no surcharge.

6.5.2 Load factors and Combinations

The design forces will be derived based on the following load factors as per IS: 456-2000, BS 8110- Part 1-1997 and Hong Kong DSM - Section 4 – 2009.

Load Case	Dead Load	Hydro Static Pressure	Earth Pressure	Surcharge Load
Case 1	1.4	1.4	1.4	1.4/1.5/1.6#
Case 2	1.4	1.4	1.4	-
Case 3	1.4	1.4	1.4	1.4/1.5/1.6#
Case 4	1.4	1.4	1.4	
Case 5	1.4	1.4*	1.4	
Serviceability**	1.0	1.0	1.0	1.0

If Surcharge load is taken as per British Standards then the load factor shall be 1.6

If Surcharge load is taken as per Indian Standards then the load factor shall be 1.5

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For special cases of conservative surcharge load (such as future flyover construction etc.) load factor of 1.4 can be adopted.

* Load factor for extreme water table (flooding case) may be reduced to 1.0.

** Water level for serviceability shall be ground level.

7 GENERAL CONSTRUCTION METHODS

1. Initial ground support for the bored tunnels is expected to comprise ground pre-treatment (where necessary) and or precast concrete segments.
2. Methods for excavation spoil removal, ground treatment, installation of initial support and permanent lining construction shall be confirmed.
3. Excavation shall be carried out in a uniform and controlled manner and over-excavation shall be kept to a minimum.
4. Appropriate methods and necessary steps shall be taken to control ground and water inflows to maintain the stability of the tunnel excavation.
5. Instrumentation and monitoring installations for Ground and Existing Building Structures (EBS) movement and distortion and changes to the ground water table(s) and the trigger (Alert, Action and Alarm) levels shall be confirmed in the design. Designer has to specify the required instrumentation and monitoring arrangement to maintain the safety of the EBS.

7.1 Tunnel Lining - General

7.1.1 Tunnel Lining – Temporary Support

1. Steel sets and lattice arch girders shall be rolled to suit the dimensional requirements of the designed tunnel opening and/or profile. The Contractor shall provide dimensional details of the steel sets or lattice arch girders and lagging, and this shall include all calculations regarding imposed loads before and after any ground pre-treatment.
2. Spiles shall be steel rods or tubes of outside diameter not less than 25 millimetres.
3. Pipe piles shall be steel tubes of outer diameter not less than 100 millimetres.
4. 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.
5. Rock bolts shall be tensioned bar manufactured out as one of the following types; solid steel bar, slit or deformed steel tube, glass fibre reinforced resin rods.
6. Alternative materials shall be subject to approval of the Employer's Representative.

7.1.2 Tunnel Lining - Permanent Support

1. The permanent bored tunnel support or lining shall generally comprise segmental Spheroidal Graphite Iron (SGI) or Precast concrete (plain or reinforced) rings that are held securely in place, and the same will remain so for all known possible

future conditions.

2. Exceptions to these permanent linings may be at cross-passages (links between tunnels), enlargements of the bored tunnel and at the junction between cut-and-cover and bored tunnel sections. In such locations cast-in-place linings shall be used, or alternative types of permanent lining may be proposed subject to approval of The Employer's Representative / The Engineer.

3. The reinforcement for segmental concrete lining shall be detailed such that there is no electrical continuity across the circle joints. To prevent stray current effects and to inhibit the corrosion, suitable property enhancers shall be added into concrete. Such concrete shall be tested in accordance with ASTM C 1202 and DIN 1048. SGI lining segments and all concrete reinforcement shall be bonded to mitigate stray current. The bonding shall be part of the corrosion control system designed and installed by the Contractor to the notice of The Employer's Representative / The Engineer. The corrosion control system shall be tested and proven to satisfaction of the Designer that the corrosion control system functions as designed at all locations.

7.1.3 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 Engineer in charge. The design shall incorporate sealing gaskets in the segmental design.

7.1.4 Grout holes

Grout holes shall be provided in each segment as per design, excluding the key.

7.1.5 Waterproofing

Suitable waterproofing materials and methods shall be used to meet the Employers requirements.

7.1.6 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.

7.2 Underpinning of Existing Structures

Where the construction of tunnels or other underground works necessitate the removal of existing support or foundations to existing structures, the Designer shall carry out investigations of the extent of the existing works, their design and loading conditions and propose a suitable supporting/underpinning arrangement where ever is applicable.

8 CROSS-PASSAGES

1. Where tunnelling is carried out not using TBM (i.e., by hand or face excavator) temporary support using pipe piles, Spiles, structural steel sets, lattice-arch girders, base-plates, ties and connections and lagging sprayed concrete (shotcrete) or cast-in-place concrete all of which comply with the relevant standards may be used together with appropriate ground pre-treatment as

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deemed necessary for the expected ground conditions.

2. Passenger emergency evacuation design for cross-passages between running tunnels, which are constructed by either cut-and-cover or bored tunnel, shall comply with NFPA -130 – 2010 for fixing guide-way transit and passenger Rail system as follows;

   a) In single-track tunnels, the distance from the end of a station to a tunnel shaft to the surface shall not exceed 762 meters. Cross-passages shall be permitted to be used in lieu of emergency exit stairways to the surface where train ways are located within separate structures.

   b) The distance between cross-passages in the tunnel shall comply with NFPA 130 -2010 clause 6.2.2.3.2.

   c) Track cross-overs shall not be considered as cross-passages.

3. The openings into the running tunnels shall have a minimum width of 1.2 metres and a minimum height of 2.1 metres. Throughout cross-passages a minimum headroom of 2.1 metres shall be maintained over a minimum width of 1.2 metres.

4. The cross-passage floor screed shall be laid to fall and drain into the running tunnel drainage system. Floor levels shall correspond with the level of the bored tunnel escape route.

5. A concrete bulkhead fitted with a steel door and frame shall be constructed to isolate the cross-passage from each running tunnel. This door shall be self-latching, have a fire resistance of 2 hours minimum and shall be capable of withstanding the maximum differential pressures on either side created by the passage of trains. The maximum force to open the door shall comply with NFPA 130 2010 clause 6.2.2.4.2.

6. The cross-passage permanent lining shall comprise of a concrete lining designed to comply with the requirements of this documents, with the following exception that the maximum allowable deflection on the radius shall comply with IS: 456 Clause 23.2(b).

7. The junctions with the running bored tunnels shall be steel-framed and encased with concrete. The junctions shall be designed to fully support the running tunnel linings at the openings together with the ground and groundwater loads on the junction itself.

8. The cross-passages and junctions shall comply with same water-tightness criteria as the bored tunnels.

9. Where openings for cross-passages and the like are to be formed in running tunnels with segmental concrete or SGI linings, temporary internal supports to the running tunnel lining shall be provided. These supports shall adequately restrain the ground and the tunnel lining such that on completion of the openings and the removal of the temporary supports the total deflection of the linings in either the opening, junction or running tunnel and water ingress does not exceed the limits.

9 TUNNEL WALKWAYS

1. Walkway design shall comply with the Project Schedule of Dimensions (SOD).
2. The Escape Walkway shall provide continuous access from the trains to the cross-passages and/or station platforms.

10 TUNNEL BORING MACHINES (TBM)

The TBM shall be robust with adequate safety margins for the anticipated duty, designed and manufactured to comply with all safety standards. The TBM procured must be capable of efficient excavation and installation of support within the expected site and ground conditions. This includes soil, rock, soil/rock mixture and existing EBS (notably wells) all mainly below the groundwater table.

General TBM design requirements include;

a) TBM design shall ensure that the cutter-head can be retracted back from the unexcavated ground to minimise the risk of the TBM jamming and to facilitate maintenance.

b) TBM design shall make adequate provision for the safety of the workmen and the application of safe methods of tunnelling.

c) TBM shall be designed for and equipped with a supplemental ground stabilisation system. This system shall comprise regularly spaced grout ports built into the shield for drilling into and grouting the ground ahead of the tunnel face. The location and number of ports shall be adequate for implementation of face stabilisation measures needed for access to the face in all ground conditions. All ports shall be readily accessible and fitted with valves.

d) TBM shall be designed to enable the void between the segment lining and the ground (tunnel extrados) to be grouted continuously from the shield as the shield is propelled forward by synchronised operation. TBM design shall allow control of the grouting volume, pressure and pipes to be cleaned in the event of a blockage. Grout pipes shall be integral within the thickness of the TBM tail skin. A minimum of four (4) separate grout pipes shall be provided. External grout pipes will not be permitted.

e) The TBM shall be designed to maintain a pressure on the excavated ground at all times. This pressure shall at-least balance the in-place soil and hydraulic pressures making up the total overburden pressure and shall be capable of varying the face pressure as the overburden pressure changes. The design shall also take into account the soil type, density, gradation, strength and abrasion.

11 DRAINAGE ARRANGEMENT IN RUNNING TUNNELS

1. The Designer shall coordinate with the adjacent station drainage design before finalising the design for the tunnel drainage arrangement and sump locations.
2. The reserve capacity of a groundwater seepage sump shall be calculated on the basis of the area of bored tunnel lining applicable to the sump in accordance with the following formula;

$$V_R = A \times v \times t \times FOS \times 10^{-3}$$

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Where;

V_R	=	Volume of reserve, m^3
A	=	Bored tunnel lining area, m^2
v	=	Maximum leakage rate, $l/m^2/day$
t	=	Maximum response time, (day)
FOS	=	Factor of Safety

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

4. The tunnel sump design shall include outlets for the longitudinal drain pipe and discharge mains, pumps of suitable capacity and power connection. Sumps shall be fitted with steel covers and provided with step irons or access ladder. Permanent discharge mains shall be installed as well as embedment of conduits for permanent electric power cables to the pumps.

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

12 LIST OF DESIGN CODES AND STANDARDS

Subject to the requirements of this specification and other control documents, all design work shall comply with the appropriate current standards issued by the Bureau of Indian Standards (BIS), or if such a standard does not exist, then the appropriate current standard issued by the British Standard Institute (BSI). If appropriate standards from BIS and BSI do not exist, then subject to approval by the Engineer an appropriate current standard from a reputable Institution may be used.

Note: The years of codes mentioned are notional and the Designer shall adopt latest standard or code with the latest correction slip(s).

1. The Order Preferences of codes will be as follows:

i.	Bureau of Indian Standards	IS
ii.	British Standards Institute	Euro code
iii.	Indian Roads Congress	IRC
iv.	Indian Railway Standards	IRS
v.	American Codes	AASHTO

13 UNDERGROUND STATION BUILDING

Load factors for the design of Underground station buildings shall comply with IS:456 shall and in compliance with the Project Elevated Stations DBR.

14 MECHANICAL & ELECTRICAL SYSTEMS

The items like Fire Detection System, Fire Suppression System, Fire Alarm PA System, Emergency Lighting, Power Supply System, Tunnel Ventilation etc. shall be designed and commissioned as per best International Standards like NFPA130, NFPA101 etc. and best International practices. These sub-systems shall be

approved by the concerned State Authorities and the Owner.

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