GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS
(RAILWAY BOARD)

No. 2015/Proj./Model DBR/2/2 New Delhi, dated 03.03.2017

To,

Managing Directors,
(As per list attached)

Sub: Model Design Basis Report (DBR) for Bored Tunnel sections of Metro Systems in India.

The Model Design Basis Report (February, 2017), for Bored Tunnel sections of Metro Systems prepared by RDSO in consultation with technical representatives of various Metros has been examined and approval of Railway Board is hereby conveyed.

Accordingly, approved copy of DBR is enclosed.

DA: As above

03.03.17

(Ruth Changsan)
Director/Works (Plg.)
Railway Board
☎ 011-23097061

Copy to : (i) **Secretary**, Ministry of Urban Development, Nirman Bhavan , New Delhi for Information

(ii) **Executive Director/UTHS,** RDSO, Manak Nagar, Lucknow w.r.t their letter No. UTHS/51 dated 21.02.2017 for information and uploading on RDSO's website please.

1. **The General Manager,** Metro Railway, Kolkata.
2. **Managing Director, Delhi Metro Rail Corporation Ltd.**, Fire Brigade Lane, Barakhambha Road, New Delhi-110001.
3. **Managing Director, Chennai Metro Rail Ltd.,** CMRL Depot, Admin Building, Poonamalee High Road, Koyambedu, Chennai-600086.
4. **Managing Director, Hyderabad Metro Rail Ltd.,** Metro Rail Bhawan, Saifabad, Hyderabad-500 004.
5. **Managing Director, Bangalore Metro Rail Corporation Ltd.,** 3rd Floor, BMTC Complex, K.H. Road, Shanthinagar, Bangalore-560 027.
6. **Managing Director, Rapid Metrorail Gurgaon Ltd.**, 2nd Floor, Ambience Corporate Towers, Ambience Island, NH-8, Gurgaon-122001.
7. **Managing Director, Jaipur Metro Rail Corporation Ltd.,** Khanij Bhavan, Behind Udyog Bhavan, C-Scheme, Jaipur- 302005.
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9. **Managing Director, Kolkata Metro Rail Corporation Ltd.**, Munsi Premchand Sarani, Kolkata-700021.
10. **Managing Director, Mumbai Metro One Private Ltd.,** Mumbai Metro One Depot, D N Nagar, J.P. Road, 4 Bungalows, Andheri (West), Mumbai 400053.
11. **Chairman & Managing Director, MEGA Company Limited,**5th Floor, Nirman Bhawan, Opp. Gate No.4, Sachivalaya,Sector-10A, Gandhinagar,Gujarat-382010.
12. **Managing Director, Lucknow Metro Rail Corporation Ltd.**, 1st Floor, Janpath Market, Hazratganj, Lucknow-226001.
13. **Managing Director,** Pune Metro Rail Corporation, Nucleus Jeejeebhoy Tower, 3rd Floor, Office No. T-1, T-2 T Road, Opp. Commissioner Office, Gawaliwada, Pune, Maharashtra - 411001
14. **Managing Director,** Nagpur Metro Rail Corporation Limited, Metro House, 28/2, C.K Naidu Marg, Anand Nagar, Civil Lines, Nagpur, Maharashtra -440001
15. **Managing Director, Mumbai Metro Rail Corporation Limited,** Namttri Building, Plot No.13, E Block, Bandra-Kurla Complex, Bandra (East), Mumbai-400051.
16. **Chief Commissioner of Railway Safety,** N.E Railway, DRM office Campus 16, Ashok Marg, Lucknow -226001

Model Design Basis Report (DBR) for Underground Bored Tunnels for Metro Systems in India

Feb'2017

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1. General:

Where ever applicable provisions of approved model DBR of viaduct to be followed.

1.1 Brief description of Project:

2. SCOPE OF 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. The 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

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3.1 Cement

(1) Ordinary Portland cement (OPC) of 33 grade, 43 grade and 53 grade conforming to IS: 269, IS: 8112-1989 and IS: 12269-1987, respectively, shall be used.

(2) Portland pozzolana cement (PPC) conforming to IS:1489 may also be used.

(3) The Employer's Representative may give notice for the usage of sulphate-resistant Portland cement conforming to IS:12330 for structural elements exposed to soil.

(4) For foundation and substructure, the Engineer may direct the OPC substitution by Blast Furnace Slag Cement confirming to IS:455.

3.2 Concrete

(1) The Density of concrete adopted shall be as below:

a. 24 kN/m^3 for prestressed concrete (IS:875 part-I table-1 item 21 value rationalized).

b. 24 kN/m^3 for reinforced concrete with 2% or less reinforcement (IS: 875 part-I table-1 item 22 value rationalized).

c. 25 kN/m^3 for reinforced concrete with above 2% reinforcement (IS: 875 part-I table-1 item 22 value rationalized).

d. 23 kN/m^3 for plain concrete (IS:875 part-I table-1item 20).

(2) Short term modulus of elasticity 'E_c', & Modular Ratio 'm' shall be as per clause no. 6.2.3.1 & B-1.3 (d) of IS: 456 respectively.

(3) Minimum grade of concrete shall be M35.

(4) Thermal Expansion Coefficient : 1.17 x 10^{-5} / °C (Cl.2.6.2 IRS Bridge Rules).

(5) Poisson's Ratio : 0.15 for all concretes.

(6) Minimum cement content and Maximum Water -Cement ratio as per Table 5 of IS: 456.

(7) Strength of concrete is the specified characteristic compressive strength of 150 mm cube at 28 days.

(8) Minimum concrete cover as per IS: 456.

3.3 Reinforcement

Only thermo-mechanically treated reinforcement bars conforming to IS:1786 shall be adopted. (For seismic zone III, IV & V with minimum total elongation of 14.5%).

3.4 Structural Steel: General

(1) Design of Structural steelwork shall comply with IS: 800.

(2) Two types of structural steel to be used and shall comply with the following standards:

a) IS: 4923 "Hollow steel sections for structural use with Y_{st} 310".

b) IS: 2062 "Steel for General Structural Purposes (Grade B-Designation 410-B)".

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

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

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(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 4 millimetres as applicable for steel tubes in cl. 6.3 of IS: 806.

3.4.1 Material Properties

Material properties shall be as follows:

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

4 TUNNEL PROFILE, CONSTRUCTION METHODS

The bored tunnels 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 services 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 to be decided. Initial tunnel support will generally include precast concrete segments, shotcrete/wire mesh, rock bolts, lattice girders, steel sets, or forepoles wherever necessary.

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5 DESIGN LIFE/ DESIGN SPECIFICATIONS / REQUIREMENTS / PRINCIPLES

5.1 Design Life

Design life is to be kept minimum 100 years.

5.2 Tunnel Design

(1) The design of the bored tunnel shall be fully compatible with the construction methodology and shall be carried out using suitable software.

(2) The design shall also take into account all expected loads prescribed in item no.6.

(3) The design shall take into account all additional loads, stresses and strains

imposed by or on adjacent Existing Building Structures (EBS) and 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 Employer's Representative, 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 regime, and similarly the influence of the groundwater on the bored tunnels.

(7) During tunnelling, Designer to constantly review the ground conditions based on envisaged and actual condition encountered, to allow excavation to be carried out in the safest and most efficient manner. This review shall be fully integrated into the construction risk control and should typically include:

a) Probing ahead of and around the bored tunnel face in rock conditions.

b) Interpretation of fresh data and correlation with previous information.

c) Prediction of ground conditions likely to be encountered.

d) Investigation on the surface for the presence of water wells / bore wells for domestic use in residential areas that intersect the alignment.

(8) Ground Information from all 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, transport, erection jacking and impact, including in-service stress & 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 strata surrounding the tunnel.

(3) The design of the bored tunnel linings shall take into account the proximity of the bored tunnels one to another, the sequence and timing of construction and

the proximity of adjacent EBS.

(4) The design shall also consider the relative rates of loading / unloading due to TBM jacking force in both the lateral and vertical directions, and the resultant induced tunnel deformations whether temporary or permanent.

(5) The segment has to be designed for 4hr fire rating as per IS:456.

(6) The design method shall take into account the interaction between the lining and the ground, the deflection of the lining and the redistribution of the loading dependent upon the relative flexibility of the lining, the variability and compressibility of the ground.

(7) The designer shall consider and 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 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 should be such that the deflections are within permissible limits as per BS: 8110-part1 and IS:456.

(12) The thickness of segments shall suit the method of construction and shall not be so large that part 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 and for the planned reinforcement and required 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 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 accurate mating of the gaskets of adjacent segments.

(15) A groove for post-construction grouting/caulking as necessary shall be provided on the intrados for each segment joint.

(16) The lengths of segments shall be chosen with regard to bending stresses during handling, storage and erection and the long term stresses due to ground loading and the resultant deflections.

(17) The design of linings shall include tapered rings in order to negotiate the alignment curvature and to correct for line and level during construction with the minimum use of circumferential joint packers consistent with attaining the required degree of water-tightness of the bored tunnels in accordance with the contract.

(18) The design for segment lining shall address aspects including the following, as appropriate

a) Ring configurations,
b) Segment size and form,
c) Fixing details including for:
ring to ring fixings;
segment to segment fixings;
fixings for all equipment to be installed
handling, stacking and installation of segments;
holes, recesses and fixtures for other system components.
d) tolerances in production and installation of segments shall be accounted in the design.
e) Installation of Other components, such as:
grout hole valves;
gaskets;
bedding and packing materials.
f) Cavity grout, between lining and ground.
g) Instrumentation and monitoring to demonstrate performance of the installed linings.
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

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

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 minimum one diameter of tunnel. The depth of cover shall be measured from the ground surface to the tunnel crown.

b) Traffic surcharge shall be as per the loading of IRC/IRS as applicable.

c) Loads from existing or known future adjacent structures above or within the area of influence, which will remain in place above the bored tunnels, or any specified future loading. The applicable foundation load and its influence shall be computed based on the type and use, and the foundation type which supports that structure.

d) Additional support, 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.

e) 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.

f) Hydrostatic pressure, ignoring pore pressure relief arising from any seepage into the tunnel. Water at ground level to be considered for design.

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

h)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.

i) Structural requirements for resisting buckling is to be checked since tunnel is being designed as compression member.

j) Additional loads / stresses in adjacent rings due to openings at cross passages locations to be considered.

6.3 Floatation

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 flotation 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:

(i) Load case-1: Ground water table at the ground surface with uniform surcharge of 60 KN/m^2.

(ii) Load case-2: Ground water table at the ground surface with no surcharge.

(iii) Load case-3: Ground water table at 3m below existing ground water level with uniform surcharge of 60 KN/m^2.

(iv) Load case-4: Ground water table at 3m below existing ground water level with no surcharge.

(v) Load case-5: Ground water table at extreme water level with no surcharge.

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6.5.2 Load factors and Combinations

The design forces will be derived based on the following load factors Based on 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	1	1	1

\# - If Surcharge load is taken as per British standards then load factor should be 1.6

- If Surcharge load is taken as per Indian standards then load factor should be 1.5
- 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) can be reduced to 1.0

** - Water level for serviceability is to be at ground level.

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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 the permanent lining construction to be prepared.

(3) Excavation shall be carried out in a uniform and controlled manner, over-cutting shall be kept to a minimum..

(4) Appropriate methods and necessary steps to be taken to control flows and movement into, and to maintain the stability of the excavation.

(5) Instrumentation and monitoring arrangements for ground and existing building structures (EBS) movement and distortion and changes to the groundwater table(s) and the trigger (Alert, Action & Alarm) levels for each and every identified EBS to be performed. Designer has to specify the required instrumentation and monitoring arrangement to maintain the safety of the EBS.

7.1 Tunnel Lining – General

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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 opening. The Contractor shall provide dimensional details of the steel sets or lattice arches girders and lagging which include all calculations regarding imposed loads before and after any ground pretreatment.

(2) Spiles shall be steel rods or tubes of outside diameter not less than 25 millimetres.

(3) Pipe piles shall be steel tubes of outside diameter not less than 100 millimetres.

(4) Rock dowels shall be untensioned steel bars threaded at one end and provided with a face plate, shim plates and a conical seated washer and nut, or split or deformed steel tubes, or glass fibre reinforced resin rods.

(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 the notice 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 the notice of The Employer's Representative.

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

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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 segment as per design excluding the key.

7.1.5 Waterproofing

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

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 would necessitate 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 (ie, 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 deemed necessary for the expected ground conditions

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(2) Passenger emergency evacuation design for cross-passages between running tunnels which are constructed by either cut-and-cover or bored method shall generally be in accordance with the requirements of NFPA-130-2010 standard 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

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shaft to the surface shall not exceed 762 metres. 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 be provided as per clause NFPA 130 2010 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 width of 1.2 metres and a height of 2.1 metres. Throughout the cross-passage the minimum headroom of 2.1 metres shall be maintained over a width of 1.2m.

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

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

(6) The cross-passage permanent lining shall comprise concrete lining designed generally in accordance with the requirements of these documents with the following exception that the maximum allowable deflection on radius shall be as per IS:456 clause 23.2(b).

(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 lining such that on completion of the openings and removal of the temporary supports the total deflection of the linings in either the opening, junction or running tunnel and water ingress do not exceed the limits.

9 TUNNEL WALKWAYS

a. Walk ways to be designed as per approved SOD.

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deep

b. The Escape Walkway shall provide continuous access from the trains to the cross-passages and/or station platforms.

10 TUNNEL BORING MACHINES

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 design requirement of TBM.

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 tailskin. 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 plumbing design before finalising the design for drainage arrangement and sump location.

(2) The reserve capacity of a groundwater seepage sump shall be calculated on the

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basis of the area of bored 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	=	Bored tunnel lining area, m^2
v	=	Maximum leakage rate, $l/m^2/day$
t	=	Maximum response time, (day)
F.O.S	=	Factor of Safety

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

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

(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 standard from BIS and BSI does not exist, then subject to approval by engineer, an appropriate current standard from a reputable institution may be used. The designer shall follow updated codes with latest correction slips

(***Note:*** the years of the codes mentioned below are notional, hence each time the designer shall adopt latest code with the latest correction slip)

The Order Preferences of codes will be as follows:-

i. BIS
ii. BSI or Euro Code
iii. IRC
iv. IRS
v. AASHTO

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13 UNDERGROUND STATION BUILDING

For design of Underground station building load factors, and other provisions in IS:456 shall be adopted as in case of Elevated stations.

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. should be designed and commissioned as per best International Standards like NFPA130, NFPA101 etc. and the best international practices. These sub-systems should be got approved from the concerned STATE Authorities.

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