GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS
(RAILWAY BOARD)

2015/Proj./MMRC/DBR/2/7 New Delhi, dated 05.10.2021

Managing Director,
Mumbai Metro Rail Corporation Limited,
(MMRCL), E Block BKC, Bandra Kurla Complex,
Bandra East (Mumbai),
Maharashtra- 400051

Sub: Approval of Design Basis Report for Underground Bored Tunnel (September, 2021) for Mumbai Metro Rail Line-3 (Colaba-Bandra-SEEPZ) Project of Mumbai Metro Rail Corporation Limited (MMRCL).

Ref: DBR uploaded on RDSO's online portal by MMRCL on 14.09.2021

The Design Basis Report for Underground Bored Tunnel (September, 2021) for Mumbai Metro Rail Line-3 (Colaba-Bandra-SEEPZ) Project of Mumbai Metro Rail Corporation Limited (MMRCL) has been examined in consultation with RDSO and approval of Railway Board is hereby conveyed for the same.

Accordingly, approved copy of DBR is enclosed.

Encl: As above

05/10/2021
(D.K Mishra)
Director/MTP
Railway Board
☎ 011-23097061

Copy to:

1. **Executive Director/UTHS**, RDSO, Manak Nagar, Lucknow-226011 w.r.t RDSO's letter No. UTHS/MMRCL/MMRCL/P01/032021 dated 28.09.2021

2. **OSD/UT & Ex-Officio Joint Secretary**, Ministry of Housing & Urban Affairs (MoHUA), Nirman Bhawan, New Delhi-110011

MMRC

DESIGN BASIS REPORT (DBR)

UNDERGROUND WORKS FOR BORED TUNNELS

September 2021

MUMBAI METRO RAIL CORPORATION

MMRC

Quality Information

Document	General Consultancy for Mumbai Metro Rail Line-3 (Colaba-Bandra-SEEPZ) Design Basis Report
Ref	
Date	August 2016
Prepared by	Harshavardhan S Deshpande
Reviewed by	Gordon Torp Petersen

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
00	August 2016	RDSO Design Basis Report	Ron Mickell (PM)	
01	July 2019	RDSO Design Basis Report	Ron Mickell (PM)	
02	August 2019	RDSO Design Basis Report	Ron Mickell (PM)	
03	Jan 2020	RDSO Design Basis Report	Ron Mickell (PM)	
04	Mar 2020	RDSO Design Basis Report	Ron Mickell (PM)	
05	Dec 2020	RDSO Design Basis Report	Ron Mickell (PM)	
06	Sept 2021	RDSO Design Basis Report	Ron Mickell (PM)	

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Mumbai Rail Corporation Ltd.

MMRC

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1. GENERAL

Wherever applicable provisions of approved model DBR of Viaduct shall be followed.

Geometric Design Criteria:

Sr. No	CRITERIA	DIMENSIONS
1	Gauge	1435 mm
2	Maximum operating Speed	85 km/h
3	Design Speed	95 km/h
4	Max. Axle load, loaded condition	17 MT (Metric Ton) or 170 kN
5	Max. Gradient running track	4%
6	Gradient depot connecting track	4%
7	Minimum vertical curve radius	1500m
8	Minimum horizontal curve radius	200 m (main line track)
9	Traction power collection	Overhead catenary system (OCS) at 25kV (AC). Rails shall be used for traction return current
10	Inclination of rail	1 in 20
11	Wheel Thread Profile	UIC 510-2 (S1002)
12	Rail profile	UIC 60 (861-3)
13	Maximum cant	125 mm
14	Maximum cant deficiency	100 mm

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1.1 Brief Description of Project

Mumbai is a fast-growing Metropolis of the country and is expected to continue to grow in the future. Mumbai Metropolitan Region (MMR) comprises of 7 municipal corporations, 13 municipal councils and 996 villages and extends over an area of 4,355 sq.km. The existing transport facilities are overcrowded, and the road network is congested and there is a large gap between the demand and supply. To decongest the public transport and to increase the mobility across the city Under Ground Rapid Transit System under the aegis of MMRC is planned, which is called MML-3. Line -3 covers the total length of 33.508 kMs traversing from Colaba in the south via Bandra to SEEPZ. This line consists of 26 under ground stations.

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This Design Basis report deals in the Bored tunnel for the Mumbai Metro Line-3 (MML3).

There are total 26 underground stations in Mumbai Metro Line-3 of total length 33.508 kms, the name of the stations is given in table below.

Sr.no	Station Name
1.	Cuffe Parade Station
2.	Vidhan Bhavan
3.	Church-gate
4.	Hutatma Chowk
5.	CST Metro
6.	Kalbadevi
7.	Girgaon
8.	Grant Road
9.	Mumbai Central
10.	Mahalaxmi
11.	Science Museum
12.	Acharya Atreya Chowk
13.	Worli

Sr.no	Station Name
1.	Siddhivinayak
2.	Dadar Station
3.	Shitladevi Temple
4.	Dharavi Station
5.	BKC station
6.	Vidhya Nagari Station
7.	Santacruz Station
8.	CSIA-Domestic Station
9.	Sahar Road Station
10.	CSIA- International Station
11.	Marol Naka Station
12.	MIDC station
13.	SEEPZ station

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 relevant utility authorities shall be followed and specified.

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3. MATERIALS

3.1 Cement

1. Ordinary Portland cement (OPC) of 53 grade conforming to IS 12269-1987 and OPC of 43 Grade conforming to IS-8112-1989, 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. In all cases, the cement shall meet the 28 days strength requirement.

5. For foundation and substructure, the Engineer may direct the OPC substitution by Blast furnace slag cement conforming to IS:455.

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3.2 Concrete

1. The density of concrete adopted shall be as below –
   a. 24kN/m^3 for reinforced concrete with 2% or less reinforcement (IS: 875 part-1 Table-1 item 22 value rationalized)
   b. 25 kN/m^3 for reinforced concrete with above 2% reinforcement (IS: 875 part-1 Table-1 item 22 value rationalized).
   c. 24 kN/m^3 for plain cement concrete (PCC) (IS875: part-1 table-1 item 20)
   d. 24 kN/m^3 for pre-stressed concrete (IS 875: part-1 table-1 item 21 value rationalized)
2. Short term modulus of elasticity 'Ec' and Modular Ratio 'm' shall be as per clause no. 6.2.3.1 & B-1.3 (d) of IS-456-2000 respectively.
3. The minimum Grade of concrete for segmental lining Shall be M45.
4. Thermal expansion coefficient: 1.17 X 10^{-5} / ^{0} C (cl 2.6.2 IRS Bridge Rule).
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 150mm cube at 28 days.
8. Minimum concrete cover shall be as per IS: 456 & as per durability criteria conforming to ODS.

3.3 Reinforcement

Only thermo-mechanically treated (TMT) reinforcement bars of grade Fe 500-D with minimum Yield Stress of 500 MPa and minimum total elongation of 14.5% (for seismic zone III, IV, V) conforming to IS 1786 shall be adopted.

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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: 4923-1997 "Hollow steel sections for structural use with Yst 310"
   b. IS: 2062-2006 "Steel for General Structural Purposes (Grade B- Designation 410-B)"
3. Hollow steel sections shall be square (SHS) or rectangular (RHS). Other traditional rolled sections like plates, angles, channels, joists can also be used where required.
4. The connection with concrete shall be effected by internally threaded bolt sleeves (hot dipped galvanized @ 300 grams per square meters) 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 connection within the steel structure shall be designed as direct welded members with or without gusset plates. The minimum thickness of metal for SHS/RHS section for main chord members as well as bracing shall be 4mm as applicable for steel tubes in clause 6.3 of IS-806.

3.4.1 Material Properties

Material Properties: Material Properties shall be as follows:

Steel Type	Young's Modulus	Tensile Strength	Yield Strength	Density	Poisson's Ratio	Coeff. Of Thermal Expansion
Hollow Steel Sections (IS-4923)	200,000 MPa	450 MPa	310 MPa	78.5 kN/m3	0.3	1.2×10^{-5}/ ° C
Structural Steel (IS-2062)		410 MPa	•250 MPa (t<20) •240 MPa (20<t<40) •230 MPa (t>40) t= thickness in mm			

4. TUNNEL PROFILE, CONSTRUCTION METHODS

The bored tunnel comprises of twin single-track tunnels. The spacing between the tunnels shall be based on the soil strata and determined by numerical analysis and as per other planning requirements. The minimum internal diameter for bored tunnel shall meet all services and SOD (Schedule of Dimension) requirements. Bored tunnel in rock and soil will be excavated mainly using tunnel boring machines, other method, if required, based on geology and hydrology 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.

5. DESIGN LIFE/ DESIGN SPECIFICATION/ REQUIREMENT/ PRINCIPLES - BORED TUNNEL

5.1 Design Life

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Design life shall be minimum 120 years.

5.2 Tunnel Design

1. The design of the bored tunnel lining 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 as prescribed in load section 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

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within prescribed limits determined by the authority for that EBS, the Employers Representative or the owner.

5. The designer shall ensure that ground movement 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 minimize 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 tunneling, Designer to constantly review the ground conditions based on what was expected and what conditions were actually encountered to allow excavation to be carried out in the safest and most efficient manner. This review shall be fully integrated into the construction risk control and management systems and should typically include:
   a. Probing ahead of and around the bored tunnel face in rock conditions.
   b. Interpretation of fresh data and correlation with previous information.
   c. Prediction of ground conditions likely to be encountered.
   d. Investigation on the surface for the presence of water wells / bore wells for domestic use in residential areas that intersect the alignment.

8. Ground information from all construction activities shall be collated and interpreted, if required appropriate action shall be taken.

5.3 Tunnel Lining Segments

1. The design of the segments shall be adequate for all stresses induced during stacking, lifting, transport, erection jacking and impact, including in-service 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 and the rock loading (which shall be as worked out from the geotechnical/rock-mechanics engineering principles).

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 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 4 hours fire rating as per IS: 456-2000.

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, electrical resistivity, Alkali Silica Reactivity resistance and chloride/sulfate resistance as per the latest and relevant International Standards.
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.

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9. The design shall allow for the expected variation in ground conditions and the size, proximity, timing and method of construction of adjacent excavations/ tunneling. 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 permanent lining should be such that the deflections are within permissible limits as per BS 8110 – Part 1 and IS: 456-2000.

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 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 dimension. The elastomeric gasket shall be suited to the condition under which it is required to operate for the design life. The gasket groove 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

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a. Ring Configurations,
b. Segment Size and Form,
c. Fixing details including,
   - Ring to ring fixing
   - Segment to segment fixings;
   - Fixing for all equipment's to be installed
   - Handling, stacking and installation of segments;
   - Holes, recess and fixtures for other system component.
d. Tolerances in production and installation of segment 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.

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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 support shall be designed to fulfil the following requirements and to resist the following loads.

1. Dead Load
2. Superimposed surface loads from traffic, existing structures over and adjacent to the bored tunnel, and any specified future loads.
3. Appropriate ground loads, water pressure, and seismic loads.
4. Railway loads where appropriate
5. Long- and short-term ground yield or squeeze.
6. Unequal grouting pressures.
7. Adjacent bored tunneling or excavation.
8. Long or short-term loads induced by construction.
9. Temperature and shrinkage.
10. Handling loads, including impact especially on segments.
11. Jacking forces, where appropriate.
12. Accidental loading such as fire and derailment.

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6.2 Loading Condition

1. Dead load comprises the self-weight of the basic structure and secondary elements supported and the ground load. The depth of cover shall be the actual depth or a minimum 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 that supports that structure.
4. Additional support, ground treatment 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.

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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 the design.
7. 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.

8. The grouting pressure will not exceed the hydrostatic pressure more than 1 bar, however the actual pressure shall be decided by Designer based on the geological conditions.

9. Structural requirements for resting buckling are to be checked since tunnel is being designed as compression member.

10. Additional loads/stresses in adjacent rings due to openings at cross-passages location 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 floatation 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

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

6.5.1 Load cases

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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/m2

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.

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.

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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

7. GENERAL CONSTRUCTION METHODS

1. Initial ground support for the bored tunnels is expected to comprise of ground pre-treatment (where necessary) and/or precast concrete segments.

2. Method 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 method 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.

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

2. Spiles shall be steel rods or tubes of outside diameter not less than 32 millimeters.

3. Pipe piles shall be steel tubes of outside diameter not less than 100 millimeters.

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 fiber reinforced resin rods.

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5. Rock bolts shall be tensioned bar manufactured out as one of the following types - solid steel bar, slit or deformed steel tube, glass fiber 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. Exception to these permanent linings may be at cross-passages (links between tunnels), enlargements of the bored tunnel and at the junction between cut-and-cover and bored tunnel sections. In such locations permanent cast-in-place concrete linings shall be used, or alternative types of permanent lining may be proposed subject to the noticed Employer's Requirement.

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 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 currents. The bonding shall be part of the corrosion control system designed and installed by the contractor to the notice of the Employer's requirement. 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.

7.1.3 Gasket Grooves

Gasket grooves shall be provided around all joint faces of each segment and key in accordance with the dimension as approved by the engineer in charge. The design shall incorporate sealing gasket in the segment design.

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7.1.4 Grout Holes

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

7.1.5 Waterproofing

Suitable water proofing materials and methods shall be used to meet the water tightness requirements and the proposed system shall be approved by the Engineer. The water proofing membrane and methods shall comply with the relevant BS/ATM codes and Contract.

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.

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8. CROSS-PASSAGES

1. Where tunneling 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 deemed necessary for the expected ground conditions.

2. Passenger emergency evacuation design for cross-passages between running tunnels shall be in accordance with the requirements of NFPA-130-2010 standard for fixed guideway transit and passenger Rail system as follows.

   a. In single-track tunnels the distance from a station (platform end) to a mid-tunnel escape shaft (to the surface) or to the next station (platform end) shall not exceed 762 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 (like divided by a minimum 2 hours rated walls or where train ways are in twin bores).

   b. The distance between adjacent cross-passages in the tunnel shall be provided as per clause NFPA 130-2010, clause 6.2.2.3.2

   c. Track cross over shall not be considered as cross passages

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

4. The cross-passage floor screed shall be laid to fall and drain into the running tunnel drainage system. Floor level shall correspondence 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, clause 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.

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9. TUNNEL MAINTENANCE WALKWAYS

a. Walkway to be designed as per approved SOD.

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 the 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 requirements of TBM –

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

2. TBM design shall make adequate provision for the safety of the workmen and the application of safe methods of tunneling.

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

4. 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 synchronized 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 shall not be permitted.

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

11. DRAINAGE ARRANGEMENT IN RUNNING TUNNELS

1. The Designer shall coordinate with the adjacent station plumbing design before finalizing the design for drainage arrangement and sump location.

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.
VR = A * v * t * F.O.S. $*10^{-3}$ Where,
VR = Volume of reserve, m^3
A = lining/wall area, m^2
v = Maximum leakage rate, $l/m^2/day$
t = Maximum response time, (day)

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F.O.S. = Factor of Safety

3. For running tunnel/underground structures', 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 design basis report and Contract documents, all design work shall comply with the appropriate current standards issued by the Bureau of Indian Standards (BIS), or if such a standard does not exist, then the appropriate current standard issued by the British Standard Institute (BSI) or European code shall be referred. If appropriate standard from BIS, BSI or EN does not exist, then subject to Notice by the Engineer, an appropriate current standard form a reputable institution may be used. The designer shall follow updated codes with latest correction slips.

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

The order Preferences of codes will be as follows: -

1. BIS (Bureau of Indian Standards)

2. BSI / EN (British or Euro codes)

3. IRC (Indian Road Congress)

4.IRS (Indian Railway Standards

5.AASHTO (American Association of State Highway and Transportation Officials)

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.

HIRENDRA KUMAR RAGHU
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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 conformed to best International standards NFPA130, NFPA101 etc. and to the best international practices. These sub-systems shall obtain Notice of No Objection from concerned STATE Authorities.

Project Directorate Approved Railway Board 05/10/2021

Examined & found in order

Mohammad Faiz Ansari
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