GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS
(RAILWAY BOARD)

2023/Proj./SURAT-METRO/DBR/30/36 New Delhi, dated 10.05.2023

Managing Director,
Gujarat Metro Rail Corporation Limited,
Block No.1, 01st Floor, Karmayogi Bhavan,
Behind Nirman Bhavan, Sector 10/A,
Gandhinagar, Gujarat - 382010

Sub: Approval of Design Basis Reports (DBR)'s (April, 2023-R1) for Viaduct, Elevated Stations and Bored Tunnel of Surat Metro Rail Project of Gujarat Metro Rail Corporation Limited (GMRCL).

Ref: DBR's uploaded on RDSO's online portal by GMRCL on 15.04.2023

The Design Basis Reports (DBR)'s (April, 2023-R1) for Viaduct, Elevated Stations and Bored Tunnel of Surat Metro Rail Project of Gujarat Metro Rail Corporation Limited (GMRCL) has been examined in consultation with RDSO and approval of Railway Board is hereby conveyed for the same.

Accordingly, approved copies of DBR's are enclosed.

Encl: As above

10.05.23
(F.A. Ahmad)
Director/Gati Shakti (Civil)-IV
Railway Board
Ph. 011-47845480

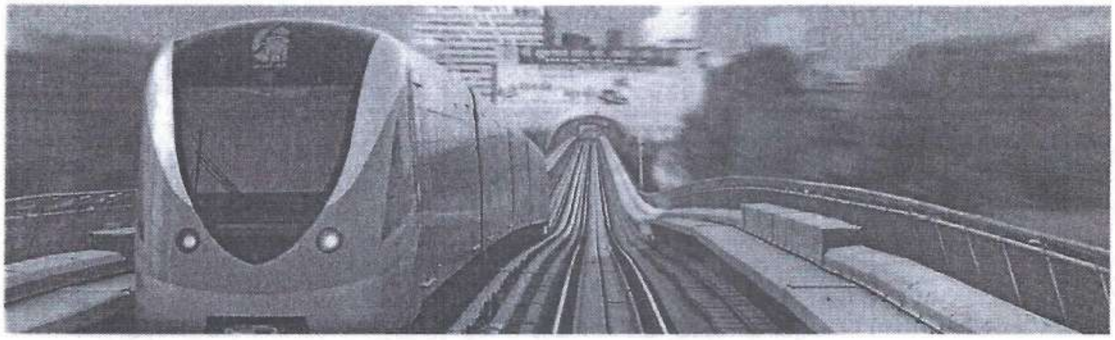
Copy to:

1. **PED/(R&T)/UTHS,** RDSO, Manak Nagar, Lucknow-226011 w.r.t RDSO's letter No. UTHS/129/GMRC/SMCL/CIVIL dated 20.04.2023
2. **OSD/UT & Ex-Officio Joint Secretary**, Ministry of Housing & Urban Affairs (MoHUA), Nirman Bhawan, New Delhi-110011

DESIGN BASIS REPORT (DBR) FOR DESIGN OF VIADUCT

APRIL 2023-R1

2023/Proj./SURAT-METRO/DBR/30/36 (Computer No. 3428264)



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GUJARAT METRO RAIL CORPORATION (GMRC) LIMITED.

(A SPV of Government of India and Government of Gujarat)

SURAT METRO RAIL PROJECT, PHASE – I

Examined and found in order

DEEPAK DWIVEDI

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Date: 2023.04.20
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Directorate Approved on 10/5/2023 Railway Board

DGM/ Design

CGM (P&D)

Director (Project & Plg)

2023/Proj./SURAT-METRO/DBR/30/36 (Computer No. 3428264)

Contents

Project Directorate Approved on 10/8/2023 Railway Board

Project Directorate Approved on 10/5/2023 Railway Board

1. INTRODUCTION

1.1. Brief Description of Project

Surat Metro Rail Project, Phase-I comprises of two Corridors. The details of the two corridors are given below:

Corridor 1: Sarthana to Dream City

Corridor 2: Bhesan to Saroli

Sarthana to Dream City Corridor is 21.61 km long with Standard Gauge (SG), having 15.14 km elevated section and 6.47 km underground section. It comprises of 20 stations out of which 14 are elevated stations and 6 are underground stations. One depot-cum-workshop is proposed near Dream City station.

Bhesan to Saroli Corridor is 18.74 km long elevated corridor with Standard Gauge (SG), and it comprises of 18 elevated stations. One depot-cum-workshop is proposed near Bhesan station.

This Design Basis Report pertains to Viaduct Portion of Surat Metro Rail Project, Phase-I from Sarthana to Dream City and Bhesan to Saroli.

1.2. Geometrical Design Feature

Gradient, Maximum Degree of Curve, Spacing of track should be as per the approved SOD of GMRC.

1.3. Scope of DBR

This Design Basis Report provides design criteria for the Metro viaduct tracked sections. All civil design works shall be performed taking into consideration this Design Basis Report.

2. PROPOSED STRUCTURAL SYSTEM OF VIADUCT

2.1. Superstructure System

The superstructure shall be simply supported single cell Box girder constructed by precast segmental construction technique with internal pre-stressing and with epoxy gluing and temporary pre-stressing of segments. At a few locations nonstandard/special spans are envisaged e.g. precast post-tensioned I girders with cast-in-situ deck slab. In general, super structure (Box Girder) will be accommodating two tracks as per approved SOD of GMRC.

However at crossovers / turnouts / railway crossings/ highway crossings, precast pre-stressed I-girder (pre/post-tensioned) / steel girder with cast-in-situ concrete deck slab is to be provided.

Minimum clearance in case of PSC Superstructure and minimum dimensions shall be considered as per Clause 16.9.6 of IRS CBC.

Design of superstructure should be done in accordance with construction methodology/construction sequence to be adopted during execution by GMRC.

2.2. Emergency Walkway

Walkway on the viaduct shall be provided for evacuation of passengers in safe conditions. The walkway dimension shall conform to the approved SOD of Metro system.

2.3. Bearing

Bearing will be either Elastomeric, POT-PTFE or Spherical.

2.4. Substructure System

The substructure design shall consist of Pile, Pile Cap, Shear Key, Crash Barrier, Piers and Pier Caps.

2.5. Foundation System

In general, Pile foundations shall be adopted, but open foundations may be considered provided the soil parameters permit.

2.6. Parapets

Parapets are to be either monolithic with the precast deck, or precast reinforced concrete stitched to the precast deck. Minimum clear height of Parapets shall be 1.2m.

3. CLEARANCE FOR STRUCTURES

3.1. Clearances for Road Traffic

As per relevant IRC specifications and Road Authority requirements.

3.2. Clearances for Railway Traffic

Indian Railways Schedule of Dimensions (SOD) shall be applicable.

3.3. Clearances for Metro Traffic

As per approved SOD of specific Metro system.

4. STRUCTURAL MATERIALS AND PROPERTIES

4.1. Cement

Clause 4.1 of IRS CBC.

4.2. Concrete

4.2.1. Density

24/25 kN/m^3 for PSC and RCC based on reinforcement percentage, 23kN/m^3 for plain cement concrete (IS: 875 part 1).

4.2.2. Young's Modulus

Clause 5.2.2.1 of IRS CBC

4.2.3. Modular ratio

Clause 5.2.6 of IRS CBC

4.2.4. Minimum grade of concrete for structural elements

Clause 5.4.4 of IRS CBC.

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4.2.5. Thermal Expansion Coefficient

$\varepsilon = 1.17 \times 10^{-5}$ /°C (Clause 2.6.2 of IRS Bridge Rules).

4.2.6. Poisson's ratio

0.15 for all concretes.

4.3. Reinforcing steel

As per Clause 4.5 & 7.1.5 of IRS CBC.

4.4. Pre-stressing Hardware

4.4.1. Pre-stressing steel for tendons

4.4.1.1. As per Clause 4.6 of IRS-CBC.

4.4.1.2. Characteristic Strength: As per Clause 16.2.4.3 of IRS-CBC.

4.5. Pre-stressing Units

4.5.1. Jacking Force:

Jacking force (maximum initial pre-stressing force) shall be as per Clause: 16.8.1 of IRS CBC.

4.5.2. Pre-stress Losses:

As per Clause 16.8.2 and 16.8.3 of IRS CBC.

4.5.3. Sheathing:

As per Clause 7.2.6.4.2 of IRS CBC.

4.5.4. Anchorages:

As per Clause 7.2.6.4.3 and Clause 16.8.3.4 of IRS CBC

4.6. Structural steel for steel and composite bridges

4.6.1. Steel shall conform to IS: 2062.

4.6.2. Fabrication shall be done as per provisions of IRS B1 (Fabrication Code).

4.6.3. Design of steel structures shall be done as per IRS Steel Bridge Code.

4.6.4. IS codes may be referred for steel-RCC composite construction.

4.6.5. Welding shall be done following IRS Steel Bridge Code, IRS Welded Bridge Code or relevant IS code for welding.

4.7. Structural Steel for Miscellaneous Use

4.7.1. Design shall be done as per IS: 800 and related provisions.

4.7.2. Hollow steel sections for structural use shall be as per IS: 4923.

4.7.3. Steel tubes for structural purpose shall be as per IS: 1161.

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DGM(PROJ)

4.7.4. Steel for General Structural Purposes shall be as per IS: 2062.

4.7.5. Relevant code may be adopted for Stainless Steel as per requirement.

5. LOADS

5.1. Dead load (DL)

Dead load shall be based on the actual cross section area and unit weights of materials and shall include the weight of the material that are structural components of viaduct and permanent in nature.

5.2. Super Imposed Dead Load (SIDL)

Superimposed dead loads include all the weights of materials on the structure that are not structural elements but are permanent. It includes weight of track form plinth/rails/fasteners/cables/parapet/hand-rail/cable trough/signaling equipment/Third Rail for providing electric traction power to train etc. and will be considered in design as per site conditions.

Note: The SIDL can be of two types: Fixed or non-variable, and variable. In case Metro certifies that a portion of SIDL is of fixed or non-variable type and is not likely to vary significantly during the life of the structure and a special clause for ensuring the same is incorporated in the Metro's maintenance manual, the load factors applicable for dead load may be considered for this component of SIDL.

5.3. Shrinkage and Creep

Shrinkage and creep effects will be calculated as per IRS-CBC.

5.4. Live Load (LL)

The simply supported structures shall be designed for one of the loading envelopes (Light, Medium or Heavy) tabulated in the Annexure-I. The loading envelope chosen shall be as per the Rolling Stock planned to be used on the Metro system (i.e 16t).

Loads other than standard trains like track machines, cranes, any new rolling stock etc. which may come on this structure should be within the loading envelope initially decided by the metro as above.

For special structures like continuous structures, cable stayed bridges, etc. the actual train loads may be used for design.

5.5. Coefficient of Dynamic Augment (CDA)

CDA shall be adopted as per IRS Bridge Rules.

5.6. Footpath Live Load

As per Clause 2.3.2 of IRS Bridge Rules.

5.7. Braking and Traction (BR/TR)

The value of braking and traction forces will be taken as per rolling stock used. For twin tracked decks carrying traffic in opposite directions, consideration should be given to braking forces from

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one train and traction forces from another, acting simultaneously which will be maximum longitudinal loading on a deck. For more than 2 tracks, Clause 2.8.4 of IRS Bridge Rules shall be considered.

As per Clause 2.8.5 of IRS Bridge Rules, when considering seismic forces, in transverse/longitudinal seismic condition, only 50% of gross tractive effort /braking force will be considered.

Dispersion of longitudinal forces is not allowed as per Clause 2.8.3.4 of IRS Bridge Rules.

5.8. Centrifugal Force (CF)

On curved track, the centrifugal forces shall be determined in accordance with Clause 2.5 of IRS Bridge Rules.

5.9. Gradient Effect

Shall be considered as per site condition.

5.10. Wind Load (WL)

As per Clause 2.11 of IRS Bridge Rules.

5.11. Seismic Load (EQ)

'"Seismic Code for Earthquake Resistant Design of Railway Bridges" shall be followed. This code also covers load combination and ductile detailing aspects.

5.12. Temperature Effect

Clause 2.6 of IRS Bridges Rules.

5.12.1. Overall Temperature (OT)

As per Clause 215.2 of IRC: 6.

5.12.2. Differential Temperature (DT)

As per IRC: 6.

5.12.3. Temperature Gradient

As per Clause 215 of IRC: 6.

5.13. Differential Settlement

Considered only in the design of continuous structures. Differential settlement between two adjacent viaduct piers will be:

- 12mm for Long Term Settlement.
- 6mm for Short Term Settlement (50% of Long Term).

5.14. Vehicle Collision Loads on Piers (VCL)

(a) Vehicle Collision load in piers: As per Clause 222 of IRC: 6.
(b) Rules specifying the loads for design of super-structure and sub-structure of bridges and for assessment of the strength of existing bridges should be done as per IRS: Bridge Rules.

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5.15. Buffer Load

Provision of Buffers is contemplated at the end of temporary terminal stations during stage opening of the Corridors, at Pocket track ends and at terminal stations of the corridors (at the end of turn back/stabling lines). Such buffers will be of friction type. These buffers will be designed to have stopping performance based on mass of fully loaded train and its deceleration to avoid damage to the train or buffer.

Viaduct elements need to be designed for such buffer load. The exact buffer loads need to be interfaced and ascertained during the detailed design.

5.16. Long Welded Rail (LWR) Forces

Guidelines vide BS Report No.119 "RDSO Guidelines for carrying out Rail-Structure Interaction studies on Metro System (Version-2)" shall be followed.

5.17. Racking Forces

As per Clause 2.9 of IRS Bridge Rules.

5.18. Vibration Effect

Effect of vibration due to the movement of metro train on station bridge structure will be taken into consideration.

5.19. Forces on Parapets

As per Clause 2.10 of IRS Bridge Rules.

5.20. Derailment Load

Derailment loads shall be considered as per Appendix XXV of IRS Bridge Rules with relevant gauge. For ULS and Stability check, loading shall be proportioned as per the maximum axle load.

Sacramento derailment criteria may be used for U-girders. This criterion corresponds to the application of 40% of one coach weight applied horizontally as a 3m long uniform impact load on the U-girder top flange. This derailment load corresponds to a ULS load. For the SLS combination 5 of IRS-CBC a 1/1.75 co-efficient shall be applied to the derailment load.

5.21. Erection Forces

As per Clause 2.13 of IRS Bridge Rules.

6. LOAD COMBINATIONS

6.1. Methodology

Provisions of Bridge Rules/IRS Concrete Bridge Code shall be followed for load combinations.

6.2. Loading Condition

The superstructure/bearings, sub-structure and foundation will be checked for the one track loaded condition as well as the both track loaded condition, for single span and both span loaded conditions, as the case may be.

Project Directorate Received on 10/5/2023 Railway Board

6.3. Design as per Construction methodology and Construction Sequence

Design of the viaduct shall be in accordance with the construction methodology/construction sequence to be adopted during execution.

7. DESIGN PARAMETERS

7.1. Unit of Design

[t], [m], [mm], [kN], [kN/m²], [MPa], [°C], [rad].

7.2. ULS Check

As per IRS Concrete Bridge Code.

7.3. SLS Check

As per IRS Concrete Bridge Code.

7.3.1. Crack Width

Crack width in reinforced concrete members will be checked for SLS Combination-1. Crack width will be as per Clause 15.9.8.2 of IRS CBC. Crack width shall not exceed the admissible value based on the exposure conditions given in Clause 10.2.1 of IRS CBC.

For crack control in columns, Clause 15.6.7 of IRS CBC will be modified to the extent that actual axial load will be considered to act simultaneously.

7.3.2. Clause 10.4.1, 11.3.4 and 13.3 of IRS CBC shall be kept in view while calculating vertical deflection at mid span.

7.4. Fatigue Check

7.4.1. RCC and PSC structures

Clause 13.4 of IRS CBC shall govern.

7.4.2. Steel structures

Clause 3.6 of IRS Steel Bridge Code shall govern. If λ values are required to be used, the train closest to the actual train formation proposed to be run on metro system shall be used. Otherwise, detailed counting of cycles shall be done.

7.5. Durability

7.5.1. Provisions of clause 5.4 of IRS CBC shall be followed to meet durability requirements.

7.5.2. Cover to reinforcement shall be in accordance with Clause 15.9.2 of IRS CBC.

7.6. Design Life

As per Clause 15.1.3 and 16.1.3 of IRS CBC.

7.7. Drainage

The drainage of deck shall be designed to cater the maximum envisaged rainfall intensity and suitable longitudinal and transverse slope should be provided. Moreover, the provisions of Clause 10.4.1.1 and 15.2.2 of IRS CBC shall be followed.

8. DESIGN METHODOLOGY

8.1. Bearing System

8.1.1. Elastomeric bearings shall be designed in accordance with EN 1337 Part-1 and Part-3.

8.1.2. Design of POT-PTFE Bearings shall be as per IRC: 83 Part-III.

8.1.3. Deign of Spherical and Cylindrical Bearing shall be as per IRC: 83 Part-IV.

8.1.4. Clause 15.9.11.3 & 15.9.11.4 of IRS CBC should be followed for considering replacement of bearings.

8.1.5. If bearings cannot accommodate the seismic forces, concrete shear keys/seismic restrainer shall be provided.

8.2. Pier Cap and Pier

8.2.1. For designing the pier cap as corbel, the provisions of Clause 17.2.3 of IRS CBC should be followed.

8.2.2. In case of shear, span of effective depth ratio being more than 0.6, pier cap will be designed as flexural member.

8.2.3. The effective length of a cantilever pier for the purpose of slenderness ratio calculation will be taken as per IRS CBC.

8.3. Foundation

8.3.1. Foundation shall be designed as per IRS Bridge Substructure and Foundation Code, IRS Concrete Bridge Code, Manual on the design and construction of well and pile foundation, IS-2911 and IRC-45.

8.3.2. Soil Structure analysis

When designing elements forces or estimating displacements, the soil stiffness shall be assessed based on the actual ground data.

9. PROJECT SPECIFIC ADDITIONAL INFORMATION/DETAILS

Nil

10. DESIGN CODES AND STANDARDS

The IRS codes shall be followed in-principle. Although main clauses have been mentioned in the DBR, the other relevant clauses as available in the IRS codes shall also be followed. If provisions are not available in IRS, the order of preference shall be as follows, unless specifically mentioned otherwise in the relevant clause of DBR:

For Railway loading related issues:

i. UIC Codes
ii. Euro Codes
iii. Any other code, which covers railway loading.

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For other Design/detailing related issues:

i. IRC
ii. IS
iii. Euro Code
iv. Other national codes.

These codes with latest revisions including all addendums/notifications and correction slips only shall be used.

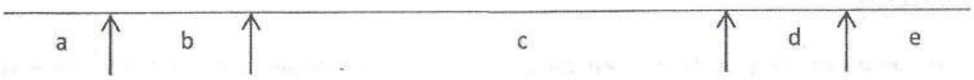
11. DESIGN SOFTWARE

Any commercial or proprietary software can be used for analysis/design provided the same is validated with manual computations or other standard software in multiple scenarios.

ANNEXURE-I

Following Parameters have been taken for preparation of EUDL & LF Chart.

1. Train Formation — 2DMC+1TC+2DMC+1TC+2DMC
2. Axle Distances: — a=2.4m, b= 2.2m, c=12.8m, d=2.2m, e= 2.4m, overall length of DMC/MC for Combination-1 =22.0m



3. Standard Maximum Height of Centre of Gravity from Rail Level: 1830mm for 1676mm Gauge and 1700mm for 1435mm Gauge.
4. Maximum Axle Load — 16.0t
5. Tractive Effort (TE) — 20% of Vertical Axle Load for DMC/MC.
6. Braking Force (BF) — 18% of Vertical Axle Load for DMC/MC/TC.
7. Loaded Length — For Bending Moment. L is equal to the effective span in meters. For Shear, L is the loaded length in meters to give the maximum Shear in the Member under consideration.
8. EUDL (BM) — The Equivalent Uniformly Distributed load (EUDL) for Bending Moment (BM), for spans upto 10m, is that uniformly distributed load which produces the BM at the center of the span equal to the absolute maximum BM developed under the standard loads. For spans above 10m, the EUDL for BM, is that uniformly distributed load which produces the BM at one-sixth of the span equal to the BM developed at that section under the standard train loads considered.
9. EUDL (SF) — EUDL for Shear Force (SF) is that uniformly distributed load which produces SF at the end of the span equal to the maximum SF developed under the standard train loads considered.

L (M)	EUDL (T)		LF (T)	
	SF	BM	TE	BF
0.5	32.00	32.00	03.20	02.92
1.0	32.00	32.00	03.20	02.92
1.5	32.00	32.00	03.20	02.92
2.0	32.00	32.00	03.20	02.92
2.5	33.73	32.00	06.40	05.74
3.0	38.15	32.00	06.40	05.74
3.5	41.31	32.00	06.40	05.74
4.0	44.00	32.00	06.40	05.74
4.5	46.22	34.39	06.40	05.74
5.0	48.00	36.65	06.40	05.74
5.5	52.28	38.55	06.40	05.74

6.0	50.66	40.17	06.40	05.74
6.5	52.48	41.75	09.60	08.66
7.0	56.10	43.18	09.60	08.66
7.5	58.29	44.44	09.60	08.66
8.0	60.64	45.58	09.60	08.66
8.5	62.72	48.53	09.60	08.66
9.0	65.14	51.15	12.80	11.48
9.5	68.44	53.50	12.80	11.48
10.0	71.43	55.62	12.80	11.48
11.0	76.56	66.28	12.80	11.48
12.0	80.86	71.42	12.80	11.48
13.0	84.48	75.78	12.80	11.48
14.0	87.59	79.51	12.80	11.48
15.0	90.29	82.74	12.80	11.48
16.0	92.64	85.57	12.80	11.48
17.0	94.72	88.06	12.80	11.48
18.0	96.56	90.28	12.80	11.48
19.0	98.22	92.27	12.80	11.48
20.0	99.71	94.05	12.80	11.48
21.0	101.06	95.67	15.06	13.55
22.0	103.25	97.14	16.00	14.40
23.0	105.71	98.48	18.07	16.28
24.0	108.19	99.71	19.20	17.32
25.0	111.54	100.84	19.20	17.32
26.0	114.64	102.37	19.20	17.32
27.0	117.50	104.50	19.20	17.32
28.0	120.53	106.49	19.20	20.14
29.0	124.09	108.76	19.20	20.14
30.0	127.43	111.54	19.20	21.65

Notes:

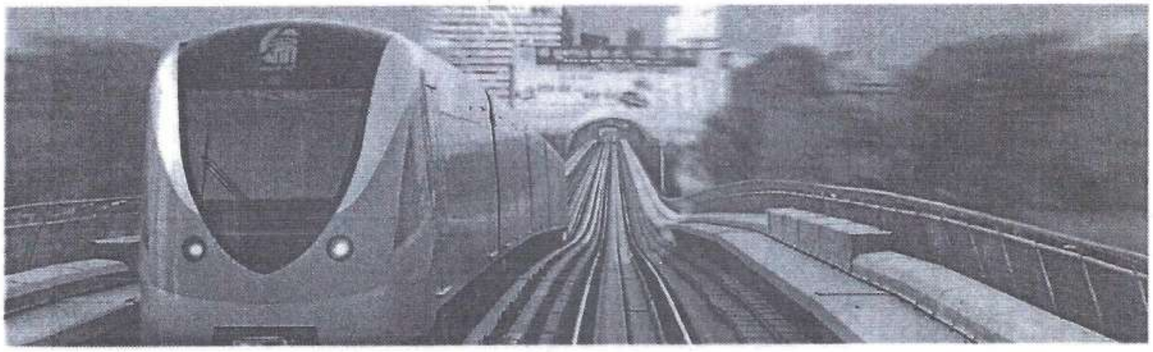
1. The above values are corresponding to 16t axle configuration which has been calculated from the EUDL chart in Model DBR corresponding to 17t axle load.
2. For any other combination/vehicle to be permitted to run on the metro system, its EUDL for vertical load as well as longitudinal force(LF) shall be worked out and compared with design EUDL & LF given in table above.
3. When loaded length lies between the values given in the table above, the EUDL for Bending Moment and Shear can be interpolated.
4. Where loaded length lies between the values given in the Table, the tractive effort or braking force shall be assumed as that for the longer loaded length.
5. Impact Load to be considered separately.
6. Effects of Coefficient of Dynamic Augmentation needs to considered separately.

Project Directorate Approved on 10/5/2023 Railway Board

DESIGN BASIS REPORT (DBR) FOR DESIGN OF ELEVATED STATIONS

APRIL 2023-R1

2023/Proj./SURAT-METRO/DBR/30/36 (Computer No. 3428264)



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GUJARAT METRO RAIL CORPORATION (GMRC) LIMITED.

(A SPV of Government of India and Government of Gujarat)

SURAT METRO RAIL PROJECT, PHASE – I

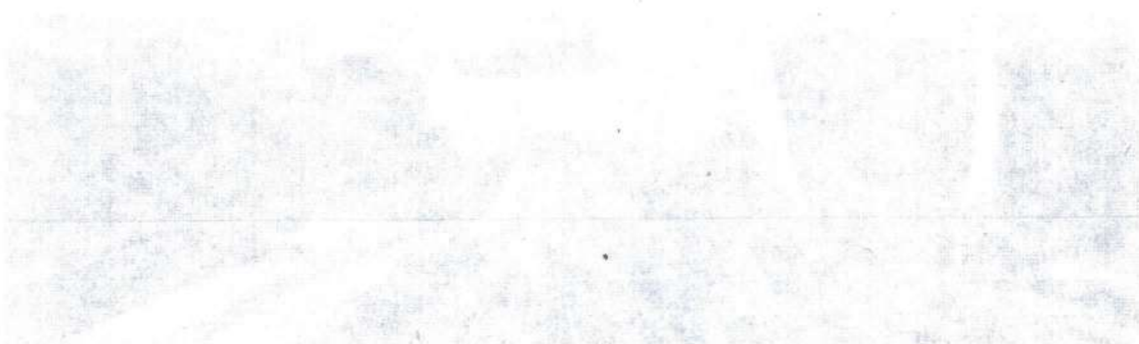
Examined and found in order

CGM (P&D)

DGM/ Design

Director (Project & Plg)

2023/Proj./SURAT-METRO/DBR/30/36 (Computer No. 3428264)



Contents

DGM (PRD)

Project Directorate
Approved on
10/3/2023
Railway Board

1.0 INTRODUCTION

1.1 Brief Description of the Project

Surat Metro Rail Project, Phase-I comprises of two Corridors. The details of the two corridors are given below:

Corridor 1: Sarthana to Dream City

Corridor 2: Bhesan to Saroli

Sarthana to Dream City Corridor is 21.61 km long with Standard Gauge (SG), having 15.14 km elevated section and 6.47 km underground section. It comprises of 20 stations out of which 14 are elevated stations and 6 are underground stations. One depot-cum-workshop is proposed near Dream City station.

Bhesan to Saroli Corridor is 18.74 km long elevated corridor with Standard Gauge (SG), and it comprises of 18 elevated stations. One depot-cum-workshop is proposed near Bhesan station.

This design basis report pertains to elevated stations of Sarthana to Dream City and Bhesan to Saroli corridors of Surat Metro Rail Project, Phase-I.

The entire route will be elevated except 6.47 km which is underground section. The proposed list of stations is shown below:

S.No.	Station Name	Elevated/Underground	Remarks
Sarthana to Dream City Corridor			
1	Sarthana	Elevated	
2	Nature Park	Elevated	
3	Varachha Chopati Garden	Elevated	
4	Shri Swaminarayan Mandir Kalakunj	Elevated	
5	Kapodra	Underground	
6	Labheshwar Chowk	Underground	
7	Central Warehouse	Underground	
8	Surat Railway Station	Underground	
9	Maskati Hospital	Underground	
10	Chowk Bazar	Underground	
11	Kadarsha Ni Nal	Elevated	
12	Majura Gate	Elevated	Interchange
13	Rupali Canal	Elevated	
14	Althan Tenament	Elevated	
15	Althan Gam	Elevated	
16	VIP Road	Elevated	
17	Surat Women ITI	Elevated	
18	Bhimrad	Elevated	
19	Convention Centre	Elevated	
20	Dream City	Elevated	

Project Directorate Approved on 10/5/2023 Railway Board

S.No.	Station Name	Elevated/Underground	Remarks
Bhesan to Saroli Corridor			
1	Bhesan	Elevated	
2	Botanical Garden	Elevated	
3	Ugat Vaarigruh	Elevated	
4	Palanpur Road	Elevated	
5	L.P.Savani school	Elevated	
6	Performing Art Centre	Elevated	
7	Adajan Gam	Elevated	
8	Aquerium	Elevated	
9	Badri Narayan Temple	Elevated	
10	Athawa Chaupati	Elevated	
11	Majura Gate	Elevated	Interchange
12	Udhana Darwaja	Elevated	
13	Kamela Darwaja	Elevated	
14	Anjana Farm	Elevated	
15	Model Town	Elevated	
16	Magob	Elevated	
17	Bharat Cancer Hospital	Elevated	
18	Saroli	Elevated	

1.2 Scope

The objective of this Design Basis Report is to establish a procedure for the design of "Elevated Stations for Gujarat Metro Rail Corporation (GMRC) Limited Surat Metro Rail Project, Phase-I". This is meant to serve as guide to the designer but compliance with the rules there in does not relieve them in any way of their responsibility for the stability and soundness of the structure designed. The design of Elevated Stations require an extensive and thorough knowledge and entrusted only to specially qualified engineers with adequate practical experience in structure designs.

The DBR is only for structural design of Elevated Stations. Extended platform portion which is generally on single column or portal type structure shall be designed as part of viaduct.

The structural elements connected to the member on which metro live loads are supported may also be designed with taking loads applicable as specified in "Model Design Basis Report (DBR) for Viaduct of Metro System". LWR forces shall be specified by Metro, if RSI analysis is not a practicable. Load combination as per "Model Design Basis Report (DBR) for Viaduct of Metro System" shall also be considered. Other structural elements such as secondary beams, stub columns etc., may be designed as per IS: 456 2000.

Structures, where Metro Live loads are not applicable, the design of Plain and Reinforced Concrete Structures will generally be governed by IS:456-2000, Pre-stressed Concrete structures shall generally be governed by IS:1343, Steel structures design shall generally be governed by IS:800 & Seismic design shall be governed by IS: 1893.

1.3 Units

The main units used for design will be: [t], [m], [mm], [kN], [kN/m^2], [MPa], [^{0}C], [rad].

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2.0 DESIGN SPECIFICATION FOR STATION BUILDING

2.1 Materials

2.1.1 Cement

For plain and reinforced concrete structures, cement shall be used as per clause 5.1 of IS: 456 and in case of pre-stressed concrete structures, as per clause 5.1 of IS: 1343.

2.1.2 Concrete

As per clause 6, 7, 8, 9 and 10 of IS:456 in case of Plain and Reinforced Concrete Structures and Clause 6, 7, 8, 9 and 10 of IS:1343 for Pre-stressed Concrete Structures.

Short-term modulus of elasticity (E_c) shall be taken as per cl. 6.2.3.1 of IS: 456 for Plain and Reinforced Concrete structures and IS: 1343 for Pre-stressed concrete structures.

The modular ratio for concrete grades shall be taken as per Annex B of IS: 456.

The Density of concrete shall be as per IS: 456.

2.1.3 Pre-stressing Steel for Tendons

As per clause 5.6.1 of IS: 1343.

2.1.3.1 Young's Modulus

As per pre-stressing steel used in accordance with Para 2.1.3 above.

2.1.3.2 Pre-stressing Units

As per clause 13 of IS: 1343.

2.1.3.3 Maximum Initial Pre-stress

As per clause 19.5.1 of IS: 1343.

2.1.3.4 Density

Weight of strands shall be as per relevant clauses of IS codes as per material being used as indicated in para 2.1.3 above.

2.1.3.5 Sheathing

As per clause 12.2 of IS: 1343.

2.1.4 Structural Steel

Structural steel used shall confirm to

a) Hollow steel sections as per IS: 4923 – 1997.

b) Steel for General structural purposes as per IS: 2062.

c) Steel tubes for structural purpose shall be as per IS: 1161.

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Note:

(i) Grade of steel to be used shall be indicated, shall not be less than minimum grade as applicable, based on whether structure is taking moving loads or not and relevant code as indicated in note (ii) and (iii) below.

(ii) Design of steel structure will be governed by IRS Steel Bridge Code in case structure is taking moving loads of Metro, otherwise will be governed by IS: 800. In case of composite (steel-concrete) structures, it will be governed by IS: 11384 & IS: 3935.

(iii) Fabrication shall be done in accordance with IRS B1 (Fabrication Code), in case structure is taking moving loads of Metro, otherwise shall be done as per IS: 800.

2.1.5 Reinforcement

As per clause 5.6 of IS: 456 for Plain and Reinforced concrete structures and as per clause 5.6.2 of IS: 1343 for Pre-stressed concrete structures.

Note: For Seismic zone III, IV & V, HYSD steel bars having minimum elongation of 14.5 percent and conforming to requirements of IS:1786 shall be used.

2.1.5.1 Reinforcement Detailing

All reinforcement shall be detailed in accordance with clause 12 and 26 of IS: 456 for Plain and Reinforced concrete structures, as per clause 12.3 and 19.6.3 of IS: 1343 for Pre-stressed Concrete structures. Ductile detailing of seismic resisting RC elements, shall comply with ductile requirements of IS: 13920.

2.2 Durability

Durability of Concrete shall be as per clause 8.0 of IS: 456 for Plain and Reinforced Concrete structures, as per clause 8.0 of IS: 1343 for Pre-stressed Concrete structures and Section 15 of IS: 800 for Steel Structures.

2.2.1 Concrete Grades

The minimum grade of concrete for all structural elements including piles, blinding layer and levelling course shall be as under:

Sr. No.	Structural Components	Minimum grade of concrete
A	Pre-tensioned girders	M50
B	Superstructure-deck slab, beams, piers and pier arms Portal beams Pedestal Shear key and seismic stoppers	M40
C	Crash barrier, pier protection	M40
D	Slabs, Beams, Walls, Columns	M35
E	Pile, Pile cap, Open foundation, Basement slab, Ancillary building foundation slab, Retaining wall	M35
F	Solid slab	M40
G	Blinding concrete or levelling course	M15

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2.2.2 Cover to Reinforcement

As per clause 26.4 of IS: 456 for Plain and Reinforced Concrete Structures and clause 12.3.2 of IS: 1343 for pre-stressed concrete structures. Cover to pre-stressing steel shall be in accordance with clause 12.1.6 of IS: 1343.

2.2.3 Fire Resistance period

All the structural elements in the station building shall be designed for a minimum fire resistance period of 2 hours. The minimum element thickness for this fire resistance shall be as per clause 21 of IS: 456 for Concrete structures and as per Section 16 of IS: 800 for Steel structures.

2.2.4 Crack Width Check

All structural concrete elements shall be designed to prevent excessive cracking due to flexure, early age thermal effects and shrinkage. Flexural crack width shall be checked in accordance with clause 35.3.2 and 43 of IS: 456 for Plain and Reinforced Concrete Structures and clause 20.3.2 and 24.2 of IS: 1343 for Pre-stressed Concrete structures.

2.3 Clearances

i. **Clearance for Road Traffic:** As per relevant IRC specifications and Road Authority requirements.
ii. **Clearance for Railway Traffic:** Indian Railways Schedule of Dimensions (SOD) shall be applicable.
iii. **Clearances for Metro Traffic:** As per approved SOD of GMRC.
iv. **For utility services:** The clearances to utilities, drainage etc. shall be as mandated by the utility owner/department.

2.4 Design Loads

Elementary loads to be considered for design are:

Dead Loads	DL
Super Imposed Loads	SIDL
Imposed (Crowd Live) Loads	LL
Earthquake Loads	EQ
Wind Loads	WL
Collision/Impact Loads/Derailment Loads	CL*
Construction & Erection Loads	EL
Temperature Loads	OT
Shrinkage	S
Creep	C
Earth & water pressure	EP
Surcharge Loads (Traffic, building etc.)	SR
Pre-stress Force	PR
Long Welded Rail Force	LWR
Differential Settlement	DS

*Load as applicable shall be taken.

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2.4.1 Dead loads

Dead load shall be based on the actual cross section area and unit weights of materials and shall include the weight of the materials that are structural components of Elevated Station and permanent in nature.

2.4.2 Superimposed Dead Loads (SIDL)

Superimposed dead loads include all the weights of materials on the structure that are not structural elements but are permanent.

Note: The SIDL can be of two types: Fixed or non-variable, and variable. In case Metro certifies that a portion of SIDL is of fixed or non-variable type and is not likely to vary significantly during the life of the structure and a special clause for ensuring the same is incorporated in the Metro's maintenance manual, the load factors applicable for dead load may be considered for this component of SIDL.

The minimum distributed and concentrated loads shall be in accordance to IS: 875, wherever SIDL values are not available in relevant codes, the following values shall be adopted:

Stations

For platform slab, the following assumptions will be taken:

- Suspension load - 2.0 kN/m^2 uniform loads.

  (Suspension load will be considered as load of false ceiling, plumbing & electrical equipments, Escalator Pits etc. This load is applicable wherever necessary.)

- PSD - As per contractor's specifications.

For the concourse area, the following assumption will be taken:

- Suspension load - 2.0 kN/m^2 uniform loads.

  (Suspension load will be considered as load of false ceiling, plumbing & electrical equipments.)

- Lift and Escalator support shall be designed as per manufacturer's details.

Note: The wall loads will be taken based on actual location shown in architectural drawings. External wall load/glazing load will be taken as per details provided in architectural drawings.

SIDL for two tracks

Details of SIDL for two tracks:

Cables	0.7 kN/m
Cable troughs with cover	7.4 kN/m
Cable trays	0.1 kN/m
Concrete plinths for rails	28.0 kN/m
Rails + Pads	3.0 kN/m
Miscellaneous (OCS, signaling)	4.0 kN/m
Hand Rail	0.8 kN/m

2.4.3 Imposed (Crowd Live) Load

Imposed loads on station buildings are those arising from occupancy and the values include, normal use by persons, furniture and moveable objects, vehicles, rare events such as concentrations of people and furniture, or the moving or stacking of objects during times of re-organization and refurbishment, this shall be as per clause 19.3 of IS:456.

2.4.4 Earthquake Loads

Earthquake design shall follow the seismic requirements of IS: 1893 (Part 1). The provision as per Design Basis Report for Viaduct Metro System shall be followed where structures are taking moving loads of metro.

2.4.4.1 Drift Limitation

The storey drift in the building shall satisfy the drift limitation specified in clause 7.11.1 in IS: 1893.

2.4.4.2 Seismic Detailing

i. For reinforced concrete structures as per IS: 13920.
ii. For other structures as per IS: 4326.

2.4.5 Wind Loads

The wind load shall be calculated as per IS: 875 (Part 3).

2.4.6 Collision/Impact Loads/Derailment Loads

I. For road traffic as per IRC: 6.
II. For metro as per IRS Bridge Rule.
III. Clause 6.1.2 of IS: 875 (Part 5).

2.4.7 Construction and erection loads

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

2.4.8 Temperature

As per clause 19.5 of IS: 456. Temperature gradient shall be considered as per Clause 215 of IRC: 6, if applicable.

2.4.9 Shrinkage

The shrinkage strains shall be evaluated as per clause 6.2.4 of IS: 456 for Plain and Reinforced Concrete Structures and clause 6.2.4 of IS: 1343 for Pre-stressed Concrete structures.

For structure supporting Metro loading, the effects of shrinkage as per Cl. 5.2.3 of IRS-CBC shall be considered.

2.4.10 Creep

The creep strains shall be evaluated as per clause 6.2.5 of IS: 456 for Plain and Reinforced Concrete Structures and clause 6.2.5 of IS: 1343 for Pre-stressed Concrete structures.

For structure supporting Metro loading, the effects of creep as per Cl. 5.2.4 of IRS-CBC shall be considered.

2.4.11 Earth & Water Pressure

In the design of structures or parts of structures below ground level, such as retaining walls and underground pump room/water tank etc., the pressure exerted by soil or water or both shall be duly accounted for. When a portion or whole of the soil is below the free water surface, the lateral earth pressure shall be evaluated for weight of soil diminished by buoyancy and the full hydrostatic pressure (As per IS: 875 Part 5).

All foundation slabs/footings subjected to water pressure shall be designed to resist a uniformly distributed uplift equal to the full hydrostatic pressure. Checking of overturning of foundation under submerged condition shall be done considering buoyant weight of foundation.

If any of the structure supporting Metro loading is subjected to earth pressure, the loads and effects shall be calculated in accordance with Cl. 5.7 of IRS-Bridge Sub-structure & Foundation Code.

2.4.12 Surcharge Load

In the design of structures or parts of structures below ground level, such as retaining wall and underground pump room/water tank etc., the pressure exerted by surcharge from stationary or moving load, shall be duly accounted for.

2.4.13 Pre-stressing Force (PR)

The Pre-stressing Force should be as per IS: 1343.

2.4.14 Long welded Rail Force

A Rail Structure Interaction [RSI] analysis is required because the continuously welded running rails are continuous over the deck expansion joints. The interaction occurs because the rails are directly connected to the decks by fastening system.

1) Rail structure interaction studies shall be done as per provisions of UIC 774-3R with the following parameters specified in consultation with track design engineers:
   i. Track resistance in loaded and unloaded conditions.
   ii. Maximum additional stresses in rail in tension as well as compression on account of rail-structure interaction.
   iii. Maximum vertical deflection of the girder at ends.
2) Software and general methodology to be used for carrying out Rail-Structure Interaction analysis must be validated before adopting the same.
3) Representative stretches must be chosen for carrying out Rail-Structure Interaction.
4) Checks must be performed for break in rail continuity due to unusual conditions fractures or for maintenance purposes.
5) RDSO Guidelines for carrying out RSI studies shall be preferred.
6) LWR forces shall be considered in appropriate load combination as per IRS Concrete Bridge Code.

2.4.15 Settlement

Maximum and differential settlement shall not exceed, as provided in Table 1 of IS: 1904.

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2.4.16 Other Forces and Effects

As per clause 19.6 of IS: 456.

2.5 Design Load Combinations

2.5.1 Ultimate Load Combinations

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

(i) Load combinations and factors as per Table 18 of IS: 456 for Plain and Reinforced Concrete Structures.
(ii) Load combination and factors as per Table 7 of IS: 1343 for Pre-stressed Concrete structures.
(iii) Load combination as per Section 3 and factors as per Section 5 of IS: 800 for Steel structures.
(iv) Load combination as per clause 6.3 of IS: 1893 (Part 1).
(v) Load combinations as per IRS CBC and RDSO guidelines for Seismic design of Railway Bridges where Metro live loads are applicable.

Note: (i) Load combination for construction load case shall be decided by Metro as per methodology of construction.

(ii) Reference of IRC: 6 or IS: 875 (Part 5) be taken for collision case if collision of road vehicles are involved as applicable.

2.5.2 Serviceability Load Combinations

The following load combinations and load factors shall be used for design for serviceability limit state:

I. Load combinations and factors as per Table 18 of IS: 456 for Plain and Reinforced Concrete Structures.
II. Load combination and factors as per Table 7 of IS: 1343 for Pre-stressed Concrete structures.
III. Load combination as per Section 3 and factors as per Section 5 of IS: 800 for Steel structures.
IV. Load combinations as per IRS CBC where Metro live loads are applicable.

2.6. Deflection Criteria

The deflection limitations as per clause 23.2 of IS: 456 for Plain and Reinforced Concrete Structures, Clause 20.3.1 of IS: 1343 for Pre-stressed Concrete structures and Clause 5.6.1 of IS: 800 for Structural Steel members shall be followed.

2.6.1. Lateral Sway

The lateral sway at the top of the building due to Wind loads should not exceed H/500, where H is the height of the building.

2.7. Fatigue Check

Fatigue phenomenon needs to be analyzed only for those structural elements that are subjected to repetition of significant stress variation (under traffic load). Fatigue check for

(i) **RCC and PSC structures** -As per clause 13.4 of IRS CBC.

(ii) **Steel Structures –**

a) In case of Metro live loads, as per clause 3.6 of IRS Steel Bridge Code shall govern. If λ* values are required to be used, the train closest to the actual train formation proposed to be run on the metro system shall be used, otherwise detailed counting of cycles shall be done.

b) For other cases as per Section 13 of IS: 800.

*Damage equivalence factors (As per IRS Steel Bridge Code).

2.8. Foundations

2.8.1. Types of Foundation

Considering the nature of ground, type of proposed structures, expected loads on foundations, the following type of foundations are considered practical.

a) Spread or pad footing
b) Raft foundation
c) Pile foundation

No matter the type of foundation to be adopted, the following performance criteria shall be satisfied:

1) Foundation must not fail in shear.
2) Foundation must not settle by more than the settlements permitted as per Table-1 of IS: 1904.

2.8.2. Design of Pile

IS: 2911 shall be followed for design of pile, load capacity etc.

Pile Settlement

Methods of estimating the settlement of deep foundation depend upon the type of deep foundation and the manner of transfer of loads from the structure to the soil. Theoretical estimation of settlement shall be done in accordance with IS: 8009 (Part II) by integrating the vertical strain for the entire depth of soil and rock formation. The settlement of each pile and/or pile group should be determined and it should be demonstrated that such total and/or differential settlement can be tolerated by the structure.

2.8.3. Foundations

IS: 1904 shall be followed for design of foundations in soil. The safe bearing capacity for shallow foundations shall be calculated in accordance with IS: 6403.

Computation of Settlements of Foundations

The calculation for settlement of foundations shall be done as per:

- IS: 8009 (Part I) for shallow foundations.
- IS: 8009 (Part II) for deep foundations.

2.9 Design of Water Retaining Structure

It should be designed as per IS: 3370.

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3.0 LIST OF DESIGN CODES AND STANDARDS

The designs of station buildings shall be carried out as per provisions of this Design Specifications. Reference shall be made to following codes for any additional information.

Order of preferences of codes shall be as follows: -

I. IS
II. IRS
III. IRC
IV. BS or Euro Code
V. AASHTO

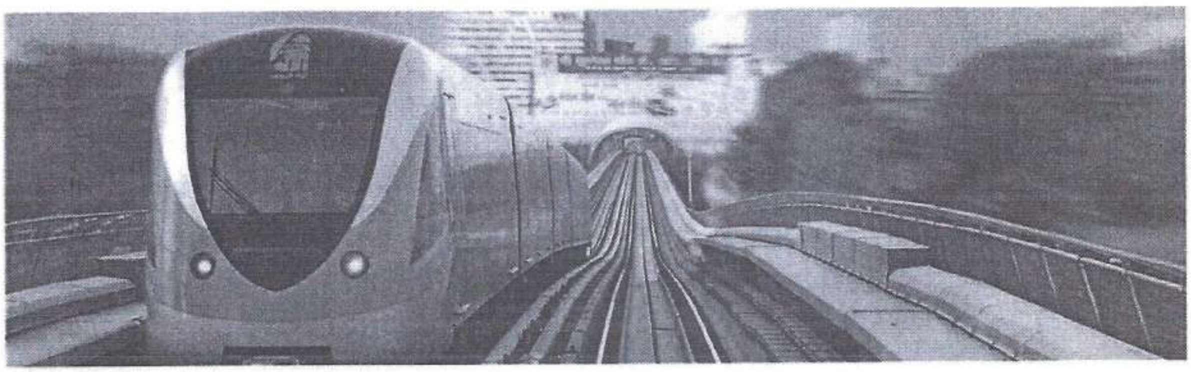
Project Directorate
Approved on 10/5/2023
Railway Board

Signature Not Verified
Digitally Signed,
Name: ANAND SINGH BISHT
Date: 15-Apr-2023 18:24:44

DESIGN BASIS REPORT (DBR) FOR DESIGN OF BORED TUNNEL

APRIL 2023-R1

2023/Proj./SURAT-METRO/DBR/30/36 (Computer No. 3428264)



Project Directorate
Approved on
10/5/2023
Railway Board

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GUJARAT METRO RAIL CORPORATION (GMRC) LIMITED.

(A SPV of Government of India and Government of Gujarat)

SURAT METRO RAIL PROJECT, PHASE – I

Examined and found in order

DEEPAK DWIVEDI Digitally signed by DEEPAK DWIVEDI Date: 2023.04.20 17:49:51 +05'30'

CGM (P&D)

Director (Project & Plg)

ROJECT, Project Directorate on 10/05/2023 12:02 pm

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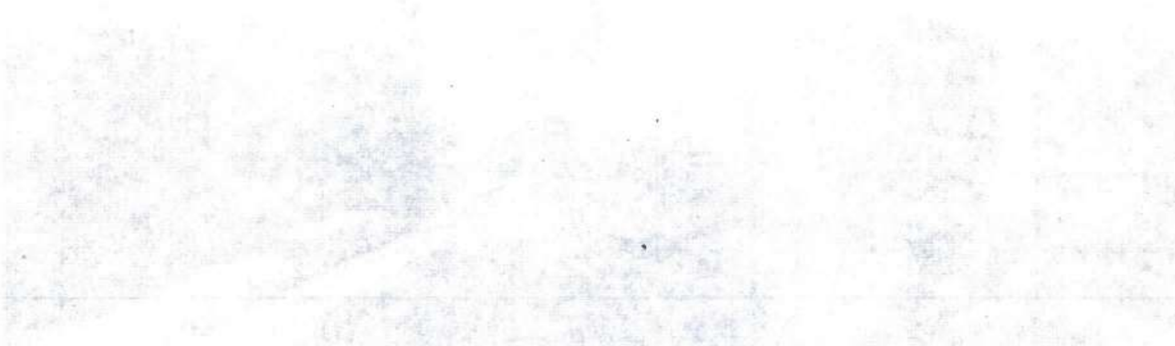

Contents

1 GENERAL

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

1.1 Brief Description of the Project

Surat Metro Rail Project, Phase-I comprises of two Corridors. The details of the two corridors are given below:

Corridor 1: Sarthana to Dream City

Corridor 2: Bhesan to Saroli

Sarthana to Dream City Corridor is 21.61 km long with Standard Gauge (SG), having 15.14 km elevated section and 6.47 km underground section. It comprises of 20 stations out of which 14 are elevated stations and 6 are underground stations. One depot-cum-workshop is proposed near Dream City station.

Bhesan to Saroli Corridor is 18.74 km long elevated corridor with Standard Gauge (SG), and it comprises of 18 elevated stations. One depot-cum-workshop is proposed near Bhesan station.

This Design Basis Report pertains to Viaduct Portion of Surat Metro Rail Project, Phase-I from Sarthana to Dream City and Bhesan to Saroli.

The portions of Corridor-1 from Kapodra to Chowk Bazar will be underground and the remainder will be elevated.

Project Details:

Details	Corridor 1 Sarthana to Dream City	Corridor 2 Bhesan to Saroli	Total
Underground Length (km)	.6.47	NIL	6.47
Elevated Length (km)	15.14	18.74	33.88
Total Length (km)	21.61	18.74	40.35
Underground Station (nos)	06	NIL	06
Elevated Station (nos)	14	18	32
Total Station (nos)	20	18	38

Underground Station Details:

Details	Corridor 1 Sarthana to Dream City
1	Kapodra
2	Labheshwar Chowk
3	Central Warehouse
4	Surat Railway Station
5	Maskati Hospital
6	Chowk Bazar

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1.2 Geometric Design Criteria

Sr. No.	Criteria	Dimension
1	Gauge	1435mm
2	Max. Operating speed	80km/h
3	Max. Axle load, loaded condition	16 tonne
4	Max. Gradient running track Max. Gradient depot connecting track	4% 4%
5	Minimum vertical curve radius Minimum horizontal curve radius	1500m 120m (main line track)
6	Traction power collection	750 Volt DC Traction system
7	Inclination of rail	1 in 20
8	Wheel tread profile	UIC 510-2 (S1002)
9	Rail profile	UIC 60 E1
10	Maximum cant	125mm
11	Maximum cant deficiency	100mm

2 SCOPE OF DBR

The design basis report hereto provides minimum standards that are to govern the design of the bored tunnel by Tunnel Boring Machine (TBM). The purpose is to establish the minimum requirements for the investigation, design, instrumentation and monitoring for bored tunnel works. 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 relative utility authorities shall be followed and specified.

3 MATERIALS

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.

(5) In all cases the cement shall meet the 28 day strength requirement of IS 8112-1989 or IS 12269-1987.

3.2 Concrete

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

a. 24 kN/m³ for pre-stressed concrete (IS: 875 part-1 table-1 item 21 value rationalized).

b. 24 kN/ m³ for reinforced concrete with 2% or less reinforcement (IS: 875 part-1 table-1 item 22 values rationalized).

c. 25 kN/ m³ for reinforced concrete with above 2% reinforcement (IS: 875 part-1 table-1 item 22 values rationalized).

d. 23 kN/ m³ for plain concrete (IS: 875 part-1 table-1 item 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: 1.17×10^{-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 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.

(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	310 MPa	78.5 kN/m³	0.30	1.2×10^{-5} per °C
Structural Steel (Conforming to IS:2062)		410 MPa	250MPa (for t<20mm), 240MPa (for 20mm < t < 40mm), 230MPa (for t > 40mm)			

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4 TUNNEL PROFILE, CONSTRUCTION METHODS AND SHAPE

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.

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 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 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 including 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 456:2000.

(6) The design method shall take into to 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,

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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. Seismic Loads:

Surat falls in seismic zone III as per IS1893:2016: The zone factor (Z) related to Zone III is 0.16 (Table 2 and Annex E in IS1893:2016).

The importance factor (I) chosen is 1.5 to meet the seismic design requirements (Table 6 in IS1893:2016).

d. Appropriate ground loads, water pressure.

e. Railway loads, where applicable.

f. Structural requirements for resisting buckling.

g. Long- and short-term ground yield or squeeze.

h. Unequal grouting pressures.

i. Adjacent bored tunnelling or excavation.

j. Openings in, or extensions to, the lining.

k. Long-or short-term loads induced by construction.

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l. Temperature and shrinkage.

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

n. Jacking forces, where applicable.

o. 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 of 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 are 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 Flotation

For flotation 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 Annex 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.

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6.5.1 Load Cases

The following load cases will be considered:

(i) Load case-1: Ground water table at the ground surface with uniform surcharge of 60 KN/m²

(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-part1-1997 and Hong Kong DSM-Section 4-2009.

Load Case	Dead Load	Hydro Static Pressure	Earth Pressure	Surcharge Load
Case1	1.4	1.4	1.4	1.4/1.5/1.6#
Case2	1.4	1.4	1.4	-
Case3	1.4	1.4	1.4	1.4/1.5/1.6#
Case4	1.4	1.4	1.4	
Case5	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 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 will be adopted.

*- Load factor for extreme water table (flooding case) will 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 ground pretreatment (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.

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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 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 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 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.

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 (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 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 shaft to the surface shall be 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 adjacent cross-passages in 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 1.2 metres.

(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. Walkways 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 safety standards. The TBM procured for this project must be capable of efficient excavation and installation of support within the expected site and ground conditions. This includes soil, rock, soil/rock mixture and existing EBS (notably wells), 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 RUNING 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 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

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(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 reputed 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 of preferences of codes will be as follows:-

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

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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