GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS
(RAILWAY BOARD)

2021/Proj/BMRCL/BDR/30/54 New Delhi, dated 27.10.2021

Managing Director,
Bangalore Metro Rail Corporation Limited,
Head office 3rd BMTC Complex,
KH Road, Shanti Nagar,
Bengaluru- 560027
(Karnataka)

Sub:- Design Basis Reports (DBRs) for Viaduct and Elevated Stations (September, 2021) for ORR and Airport Line Phase 2A and 2B of Reach-6 of Bangalore Metro Rail Project of Bangalore Metro Rail Corporation Limited(BMRCL-NAMMA Metro).

Ref: DBR uploaded on RDSO's online portal by BMRCL-NAMMA Metro on 08.10.2021

The Design Basis Reports (DBRs) for Viaduct and Elevated Stations (September, 2021) for ORR and Airport Line Phase 2A and 2B of Reach-6 of Bangalore Metro Rail Project of Bangalore Metro Rail Corporation Limited (BMRCL-NAMMA Metro) have been examined in consultation with RDSO and approval of Railway Board is hereby conveyed for the same, except the minor changes made in the DBRs as under:-

SN	DBR for	Corrections made in para No
1	Viaduct	2.2, Figure -1 and Para 4.3
2	Elevated Stations	1.2.2, 2.1.3.1 and 2.1.3.4

Accordingly, approved copy of DBRs is enclosed.

Encl: As above

27/10/2021
(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/BMRCL/NAMMA/P02/082021dated 19.10.2021

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

DESIGN BASIS REPORT FOR VIADUCT

BANGALORE METRO RAIL PROJECT

(ORR AND AIRPORT LINE PHASE 2A AND 2B OF BMRCL)

Examined & found in order except Para no. 2.2, Fig.1 and Para 4.3 for which corrections have been made in the document.

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SEPTEMBER 2021

DESIGN BASIS REPORT FOR VIADUCT

ORR AND AIRPORT LINE PHASE 2A AND 2B OF BMRCL

Examined & found in order

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REV.	DATE	DESCRIPTIONOF REVISION	PREPAREDBY	CHECKEDBY	APPROVEDBY
01	06/09/2021	As per Comments received from RDSO dated 01-07-2020.	Renganayagi. B AEE.BMRCL.	G. C. Shivakumar CE (P&D), BMRCL.	A.K.JHA Advisor(P&D), BMRCL.

DESIGN BASIS REPORT - VIADUCT
CONTENTS

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Chief Engineer (Planning & Design) BMRCL

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Project Directorate
Approved on
27/10/2021
Railway Board

1. INTRODUCTION

1.1. Brief description of project:

Bangalore is located in the meridians of 12° N latitude and 77°3' E Longitude. spread over an area of 531sq. km. located at an altitude of 900m.

Phase IIA of the Bangalore Metro Rail Project comprises of the ORR Line from Central Silk Board Junction to Krishnarajapuram (17.175km).

Phase II B comprises of Airport Link Line from Krishnarajapuram to Airport (28km).

1.2. Geometrical Design Feature:

- Gauge adopted is Standard Gauge (1435 mm)
- Gradient of superstructure = variable (level to 4.0 %) (Loads and forces on structures shall be worked out based on the actual gradient at the particular pier under consideration)
- Horizontal alignment of superstructure comprises Straight, Transition and Curved stretches. Minimum design radius of curvature in plan is 120 m.
- Centre to Centre of track should be as per approved SOD (proposed c/c of tracks = 4.0m at grade and UG & 4.85m/5.03m on Elevated. Extra clearances required on curves shall be as per SOD requirements.
- Loading corresponding to Modern Rolling Stock (MRS).

1.3. Scope of DBR:

This design basis note is prepared to standardize the design methodology for BMRCL Phase II A & B Viaduct bridge structure made of RCC, PSC and Steel for the Project.

2. PROPOSED STRUCTURAL SYSTEM OF VIADUCT

2.1. Superstructure system

- **Viaduct:** Precast U-Girder, Box Girder, Pre/Post tensioned I Girders with cast-in-situ deck slab are proposed for viaduct including transition span. However, at major crossings steel girders with concrete deck composite unit will be provided.
- The standard spans (c/c of pier) will be 20m to 28m. Modified Annexure -II gives the salient features of standard U-Girder superstructure.
- Take off location: Precast U girder, Pre/post tensioned I girders
- Ballast less track: Rebar dowels are provided from deck slab for casting of Rail Plinth.
- Provisions for fixing parapet with emergency walkway are also provided

2.2. Emergency Walkway:

Walkway on the viaduct shall be provided for evacuation of passengers in safe conditions. As shown in Fig-1,

Railway Board vide letter dt 11.03.2016 has approved SOD of BMRCL. According to para 1.8 of approved SOD, Minimum width of walk way is 550 mm with note (ii) i.e. " walkway should be used by Metro inspection group only in non - operation periods.

It is now proposed by BMRCL that this walk way is also to be used for emergency evacuation of passengers and the width is proposed as per earlier approved SOD(550 mm). However, as per the latest standards, for emergency evacuation of the passengers, the unobstructed clear width of walk ways must be 610 mm or more as per para 6.2.1.11 of NFPA 130 (Standard for fixed guide way transit and passenger rail system).

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(610 mm unobstructed clear width is to be made available as per NFPA 130 Standard for fixed guide way transit and passenger rail system).

~~550~~ mm

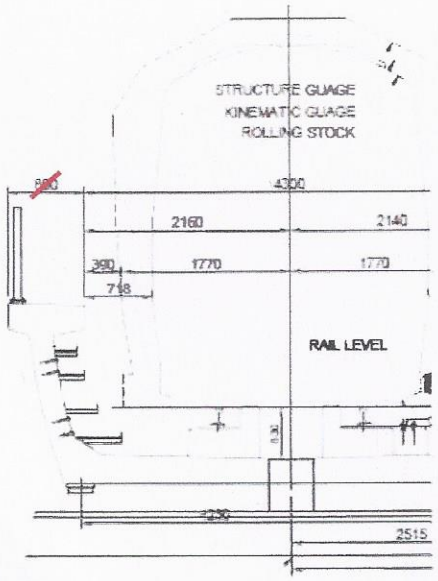

Fig.1

~~Minimum emergency walkway width is 550 mm.~~

~~The above width is in conformity with approved SOD of BMRCL.~~

The minimum emergency walk way width to be adopted as 610 mm. This needs fresh proposal for revised SOD for approval of Railway Board.

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2.3. Bearing:

Three types of bearings are proposed to be used on BMRCL as shown below depending upon the structural requirement of viaduct geometry.

a. Elastomeric Bearing
b. Pot cum PTFE Bearing
c. Spherical Bearing

Design details are explained in subsequent para.

2.4. Substructure system

Substructure shall consist of Cast in situ pier. For pier caps precast or cast in situ is proposed. Pier columns are normally with Circular/ Rectangular.

2.5. Foundation system

Predominantly pile foundations shall be adopted with 1.0/1.2/1.5m diameter. Open foundations will be adopted in rocky strata at few locations.

2.6. Parapets

Steel parapets are provided for a height of 1.10m above walkways (Fig-1)

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3. CLEARANCES FOR STRUCTURES

3.1. Clearance for Road Traffic: As per relevant IRC specifications and Road Authority requirements.

As per relevant IRC, Minimum Vertical Clearance of 5.50m is provided as shown in fig.2

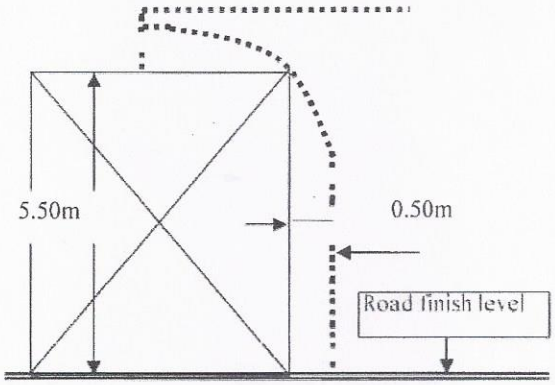

Fig.2

3.2. Clearance 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 AS PROPERTIES

4.1. Cement: Type of Cement to be used shall be as per 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, 23 kN/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.

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

Reinforcing steel to be used shall be as per Clause 4.5 and 7.1.5 of IRS CBC. All properties of HSD/TMT bars shall conform to IS: 1786 ~~with elongation requirements as per Clause 5.3 of IS: 13920.~~

4.4. Pre-stressing Hardware

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4.4.1. Pre-stressing steel for tendons
Pre-stressing steel for tendons to be used shall be as per clause 4.6 of IRS-CBC.

4.4.2. Characteristic Strength: It shall be as per clause 16.2.4.3 of IRS-CBC.

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27/10/2021

4.5. Pre-stressing Units:

4.5.1. Jacking Force: Jacking force (maximum initial pre-stressing force) shall be as per clause: 16.8.1of 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 Clause16.8.3.4 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 Codes 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.

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

4.7.5. Relevant code shall 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 materials 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 from plinth/ rails/ fasteners/ cables/ parapet/ hand-rail/Third rail & fixing /cable trough/signaling equipment etc. and will be considered in the design as per the site conditions.

5.2.1. SIDL1 (Fixed SIDL or Non-variable SIDL):

Rail Plinth, Precast Parapet and roof structure will be considered as Dead Load for the purpose of analysis of structures. The weight of the rail plinth and parapet will remain same throughout the life of the structure. This is incorporated in the maintenance manual of BMRCL.

5.2.2. SIDL2 (Variable SIDL):

The following items shell be considered as variable SIDL

- Rails + Pads
- Third rail & fixtures
- Hand rail
- Cables
- Cable trough cell
- Cable trays
- Miscellaneous (OFC, Signaling etc.)

5.3. Shrinkage and creep:

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

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5.4. **Live Load (LL):**

The simply supported structures shall be designed for Metro loading envelop given in Annexure-I. The EUDL chart for BMRCL metro loading is given in Annexure III.
Loads other than standard trains like track machines, cranes, any new rolling stock etc. Which may come on this structure should be within this loading envelope.
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 Rule.

5.7. **Braking and Traction (BR/TR):**

The value of braking and traction forces will be taken as per rolling stock used, to be decided by Metro. For twin tracked decks carrying traffic in opposite directions, consideration should be given to braking forces from 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, 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 covers load combination and ductile detailing aspects.

5.12. **Temperature effect:** Clause 2.6 of IRS Bridge 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

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5.13. **Differential settlement:**

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

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

5.14. **Vehicle collision load on piers:**

a. 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.

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 the 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

Chief Engineer
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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 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 Standard Gauge in place of Broad Gauge. For ULS and Stability check, loading shall be proportioned as per 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 an ULS load. For 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 rule/IRS Concrete Bridge Code shall be followed for load combinations.

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

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

7. DESIGN PARAMETERS

7.1. **Units for design:** [t], [m], [mm], [kN]. [kN/m^2], [MPa]. [°C]. [rad]

7.2. **ULS Check:** As per IRS Concrete Bridge code.

7.3. **SLS check:** The provisions IRS – CBC shall be applicable.

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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.

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7.3.2. Clause no.10.4.1, 11.3.4 and 13.3 of IRS CBC shall be kept in view while calculating vertical deflection at mid span.

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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 the 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 & 15.2.2 of IRS: CBC 1997 shall be followed.

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8. DESIGN METHODOLOGY

8.1. Bearing System:

8.1.1. Elastomeric bearings shall be designed in accordance with EN 1337 Part 1 & Part 3.
8.1.2. Design of Pot - PTFE Bearings shall be as per IRC: 83 Part-III.
8.1.3. Spherical Bearings shall be designed in accordance with IRS 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:

For designing the pier cap as corbel, the provisions of Clause 17.2.3 of IRS CBC should be followed.
In case of shear span to effective depth ratio being more than 0.6 pier cap will be designed as flexural member.
The effective length of a cantilever pier for the purpose of slenderness ratio calculation will be taken as per IRS CBC.
For straight standard spans and curved spans up to 200m Radius precast pier caps have been proposed the designs of the same shall be as per IRS CBC.

8.3. Foundation:

IRS Bridge Substructure and Foundation Code should be followed for design of foundations.

8.3.1. Pile Foundation: 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, IS2911 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 (IF ANY)

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

Chief Engineer

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.

For other Design/ detailing related issues:

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

List of various design codes and standards to be used at various stages of works is appended as Annexure IV. 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.

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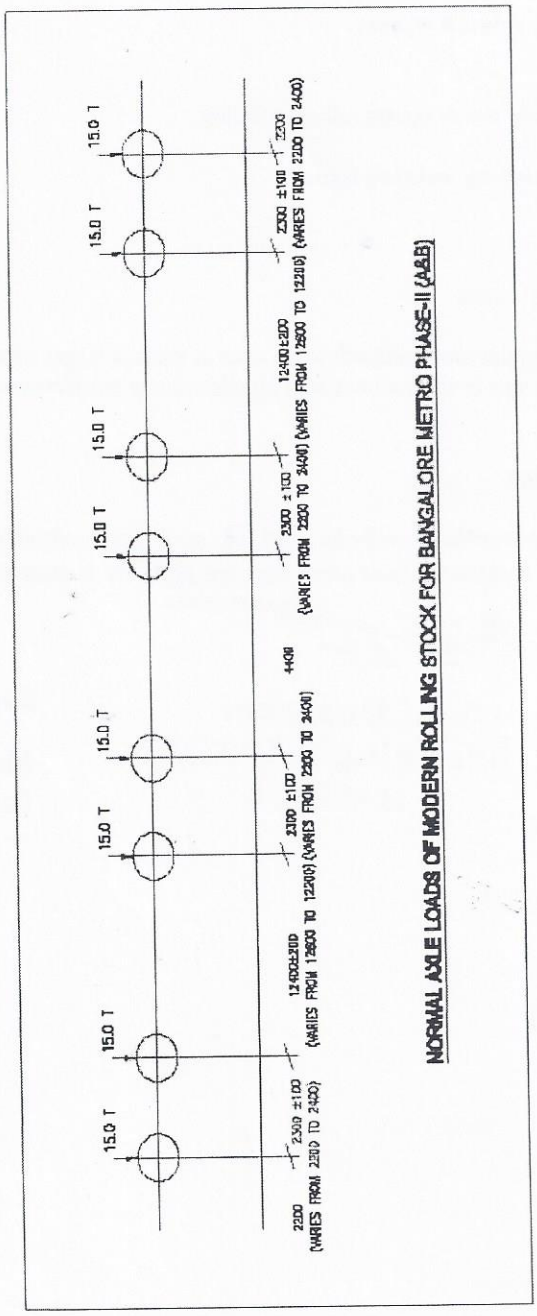
ANNEXURE- I



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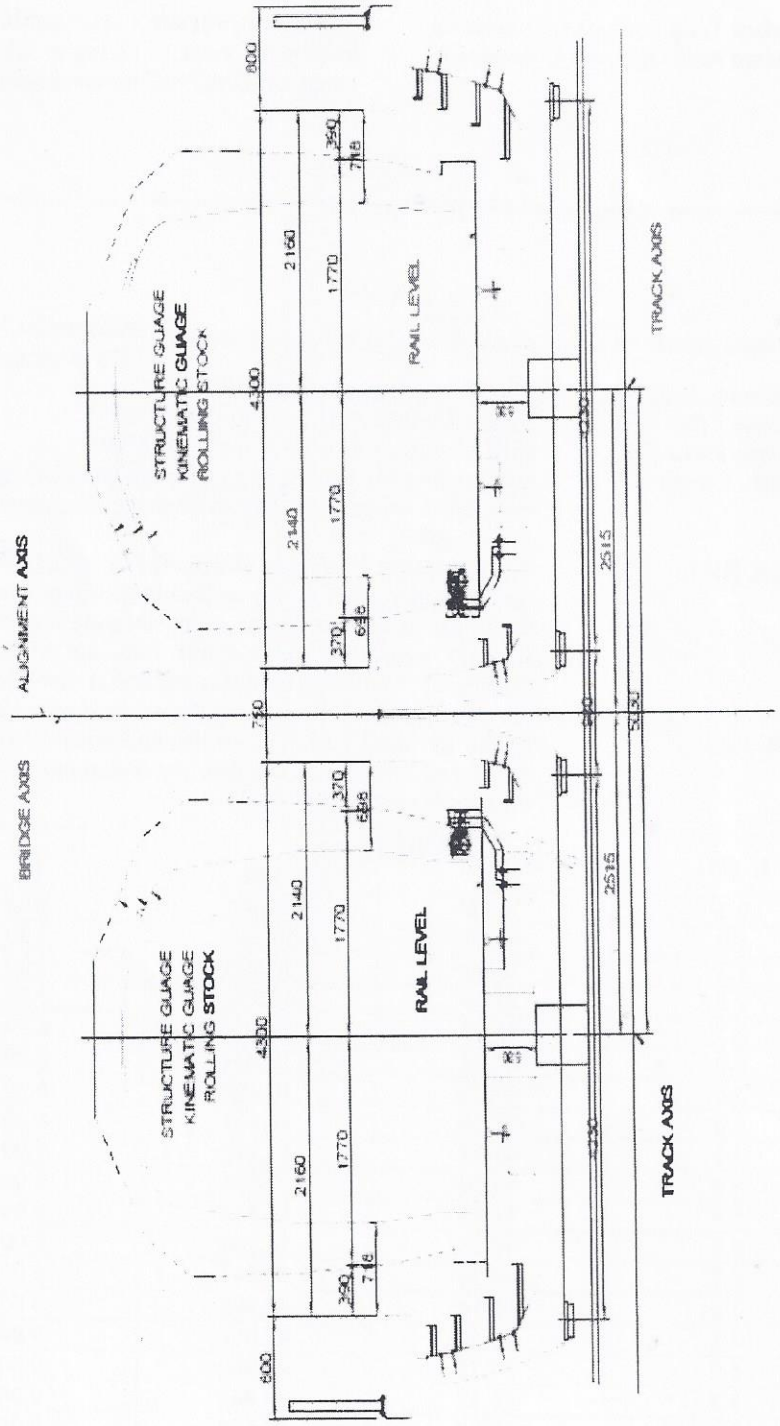
ANNEXURE-II



SCHEMATIC SKETCH OF SUPERSTRUCTURE IN LEVEL AND TANGENT TRACK

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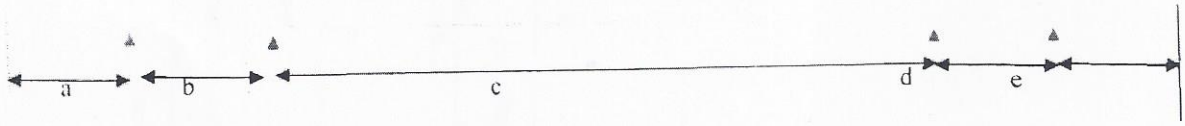
ANNEXURE III

EQUIVALENT UNIFORMLY DISTRIBUTED LOAD& LONGITUDINAL FORCE CHART FOR LIGHT METRO LOADING

1. Standard Train Formation Considered: 2DMC+1TC+2DMC+1TC+2DMC.
2. Standard Axle Distances Considered: a=2.4m, b= 2.3m, c=12.4m, d=2.3m, e= 2.4m, overall Length of DMC/MC for combination-I =21.8m (BMRCL).



3 Standard maximum height of centre of gravity from rail level: 1830 mm for 1676mm gauge and 1700 mm for 1435 m gauge

4 Maximum Axle Load: 15.0t for all reaches extensions.

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 (Tonne)		LF (Tonne)	
	SF	BM	TE	BF
0.5	30.00	30.000	3.00	2.70
1.0	30.00	30.000	3.00	2.70
1.5	30.00	30.000	3.00	2.70
2.0	30.00	30.000	3.00	2.70
2.5	32.40	30.000	6.00	5.40
3.0	37.00	30.000	6.00	5.40
3.5	40.29	30.000	6.00	5.40
4.0	42.75	30.459	6.00	5.40
4.5	44.67	33.252	6.00	5.40
5.0	46.20	35.574	6.00	5.40
5.5	47.45	37.532	6.00	5.40
6.0	48.55	39.204	6.00	5.40
6.5	49.38	40.647	6.00	5.40
7.0	50.14	41.905	6.00	5.40
7.5	52.40	43.011	9.00	8.10
8.0	54.75	43.990	9.00	8.10
8.5	56.82	44.863	9.00	8.10
9.0	58.67	45.646	9.00	8.10
9.5	60.63	46.535	12.00	10.80
10.0	63.60	48.025	12.00	10.80
11.0	68.73	59.236	12.00	10.80
12.0	73.00	63.600	12.00	10.80
13.0	76.62	67.938	12.00	10.80
14.0	79.71	71.657	12.00	10.80
15.0	82.40	74.880	12.00	10.80
16.0	84.75	77.700	12.00	10.80
17.0	86.82	80.188	12.00	10.80

18.0	88.67	82.400	12.00	10.80
19.0	90.32	84.379	12.00	10.80
20.0	91.80	86.160	15.00	13.50
21.0	93.80	87.771	15.00	13.50
22.0	96.35	89.236	15.00	13.50
23.0	99.63	90.574	18.00	16.20
24.0	102.98	91.800	18.00	16.20
25.0	106.06	93.350	18.00	16.20
26.0	108.90	95.529	18.00	16.20
27.0	111.53	97.840	18.00	16.20
28.0	114.66	100.774	18.00	18.90
29.0	117.95	103.506	18.00	18.90
30.0	121.36	106.056	18.00	21.60
31.0	125.19	109.339	18.00	21.60
32.0	128.78	112.485	18.00	21.60
33.0	132.15	115.593	21.00	21.60
34.0	135.32	119.252	21.00	21.60
35.0	138.31	122.702	24.00	21.60
36.0	141.13	125.960	24.00	21.60
37.0	143.81	129.042	24.00	21.60
38.0	146.34	131.962	24.00	21.60
39.0	148.74	134.732	24.00	21.60
40.0	151.06	137.364	24.00	24.30
41.0	153.95	139.867	24.00	24.30
42.0	156.71	142.251	24.00	24.30
43.0	159.87	144.525	24.00	27.00
44.0	163.05	146.695	24.00	27.00
45.0	166.09	148.768	24.00	27.00
46.0	169.00	151.278	24.00	27.00
47.0	171.79	153.804	24.00	27.00
48.0	174.88	156.255	24.00	29.70
49.0	178.04	159.189	24.00	29.70
50.0	181.30	162.005	24.00	32.40
51.0	174.12	164.711	24.00	32.40
52.0	188.17	167.312	24.00	32.40
53.0	191.41	169.816	24.00	32.40
54.0	194.53	172.227	24.00	32.40
55.0	197.54	175.069	24.00	32.40
56.0	200.44	177.836	24.00	32.40
57.0	203.24	180.606	24.00	32.40
58.0	205.94	183.699	24.00	32.40
59.0	208.56	186.687	24.00	32.40
60.0	211.11	189.576	27.00	35.10
61.0	214.04	192.370	27.00	35.10
62.0	216.88	195.074	27.00	35.10
63.0	219.99	197.691	30.00	37.80
64.0	223.12	200.663	30.00	37.80
65.0	226.14	203.575	30.00	37.80
66.0	229.08	206.476	30.00	37.80
67.0	231.93	209.663	30.00	37.80
68.0	235.00	212.756	33.00	40.50
69.0	238.11	215.760	33.00	40.50
70.0	241.30	218.678	36.00	43.20
71.0	244.66	221.513	36.00	43.20
72.0	247.93	224.300	36.00	43.20
73.0	251.10	227.392	36.00	43.20
74.0	254.21	230.400	36.00	43.20
75.0	257.22	233.453	36.00	43.20
76.0	260.15	236.697	36.00	43.20
77.0	263.00	239.857	36.00	43.20
78.0	265.78	242.935	36.00	43.20

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79.0	268.50	245.936	36.00	43.20
80.0	271.17	248.862	39.00	45.90
81.0	274.12	251.716	39.00	45.90
82.0	277.00	254.500	39.00	45.90
83.0	280.08	257.216	42.00	48.60
84.0	283.18	259.869	42.00	48.60
85.0	286.20	262.458	42.00	48.60
86.0	289.15	264.988	42.00	48.60
87.0	292.03	267.459	42.00	48.60
88.0	295.09	270.199	42.00	51.30
89.0	298.18	272.893	42.00	51.30
90.0	301.33	275.593	42.00	54.00
91.0	304.52	278.498	42.00	54.00
92.0	307.83	281.340	42.00	54.00
93.0	310.97	284.121	45.00	54.00
94.0	314.04	287.117	45.00	54.00
95.0	317.05	290.094	48.00	54.00
96.0	320.00	293.040	48.00	54.00
97.0	322.89	296.205	48.00	54.00
98.0	325.70	299.304	48.00	54.00
99.0	328.48	302.342	48.00	54.00
100.0	331.23	305.518	48.00	56.70
101.0	334.19	308.236	48.00	56.70
102.0	337.09	311.096	48.00	56.70
103.0	340.17	313.901	48.00	59.40
104.0	343.24	316.652	48.00	59.40
105.0	346.26	319.351	48.00	59.40
106.0	349.22	321.998	48.00	59.40
107.0	352.12	324.597	48.00	59.40
108.0	355.17	327.147	48.00	62.10
109.0	358.24	329.852	48.00	62.10
110.0	361.37	332.581	48.00	64.80
111.0	364.61	335.261	48.00	64.80
112.0	367.78	338.154	48.00	64.80
113.0	370.90	340.002	48.00	64.80
114.0	373.96	343.800	48.00	64.80
115.0	376.97	346.550	48.00	64.80
116.0	379.92	349.252	48.00	64.80
117.0	382.83	351.908	48.00	64.80
118.0	385.69	354.742	48.00	64.80
119.0	388.50	357.560	48.00	64.80
120.0	391.29	360.390	51.00	67.50
121.0	394.25	363.610	51.00	67.50
122.0	397.17	366.777	51.00	67.50
123.0	400.24	369.980	54.00	70.20
124.0	403.30	373.287	54.00	70.20
125.0	406.32	376.541	54.00	70.20
26.0	409.28	379.743	54.00	70.20
127.0	412.20	382.898	54.00	70.20
128.0	415.25	385.997	57.00	72.90
129.0	418.31	389.113	57.00	72.90
130.0	421.42	392.350	60.00	75.60

Note: (1) 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.

(2) When loaded length lies between the values given in the table above, the EUDL for Bending Moment and Shear can be interpolated.

27/10/2021

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(3) 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.

(4) Impact Load to be considered separately.

****

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BMRCL

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Approved as per Approval Directorate

27/10/2021

ANNEXURE-IV

INDIAN RAILWAY STANDARDS (IRS) (Latest Revision)

IRS CONCRETE BRIDGE CODE
IRS BRIDGE RULES
IRS STEEL BRIDGE CODE
IRS BRIDGE SUBSTRUCTURE & FOUNDATION CODE IRS
FABRICATION CODE (B1)
IRS WELDED BRIDGE CODE

INDIAN ROAD CONGRESS (IRC) STANDARDS (Latest Revision)

IRC 5	Standard Specifications and Code of Practice for Road Bridges, Section I- General Features of Design
IRC 6	Standard Specifications and Code of Practice for Road Bridges, Section II – Loads and Stresses
IRC 22	Standard Specifications and Code of Practice for Road Bridges, Section VI – Composite Construction for Road Bridges
IRC 24	Standard Specifications and Code of practice for Road Bridges, Section V – Steel Road Bridges
IRC 78	Standard Specifications and Code of practice for Road Bridges, Section VII- Foundation & Substructure
IRC 83	Standard Specifications and code of practice for Road Bridges, Section IX - Bearings Part I, II &III: Bearings (Metallic, Elastomeric and POT & PTFE Bearings)
IRC 87	Guidelines for the Design and Erection of False Work for Road Bridges
IRC: SP-65	Guidelines for Design and Construction of Segmental Bridges
IRC: 112	Code of Practice for Concrete Road Bridges

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INDIAN STANDARD (IS) Codes

National Building Code

SP 7		Bureau of Indian Standards.
IS 226		Structural steel (standard quality)
IS 269		33 grade Ordinary Portland Cement.
IS 383		Coarse and fine aggregates from natural Sources for concrete
IS 432		Mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement
	(Part 1)	Mild steel and medium tensile steel bars
	(Part 2)	Hard-drawn steel wire
IS 455		Portland slag cement
IS 456		Code of practice for plain and reinforced concrete
IS 460		Test sieves
IS 516		Method of test for strength of concrete
IS 650		Standard sand for testing cement
IS 800		Code of practice for general construction in steel
IS 814		Covered electrodes for manual metal arc welding of carbon and carbon manganese steel
IS 815		Classification coding of covered electrodes for metal are welding of structural steel
IS 823		Code of procedure for manual metal arc welding of mild steel
IS 875		Code of practice for design loads (other than earthquake) for buildings and structures
IS 1161		Steel tubes for structural purposes
IS 1239		Mild steel tubes, tubulars and other wrought steel fittings
	(Part 1)	Mild steel tubes

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Chief Engineer

	(Part 2)	Mild steel tubulars and other wrought steel pipe fittings
IS 1343		Code of practice for Pre-stressed Concrete
IS 1732		Dimensions for round and square steel bars for structural and general engineering purposes
IS 1786		High strength deformed steel bars and wires for concrete reinforcement.
IS 1791		Batch type concrete mixers
IS 1834		Hot applied sealing compound for joint in concrete
IS 1888		Method of load tests on soils
IS 1892		Code of practice for sub surface investigations for foundations
IS 1893:Part I		Criteria for earthquake resistant design of structures
IS 2062		Steel for general structural purposes
IS 2090		High tensile steel bars used in prestressed concrete
IS 2386		Methods of test for aggregate for concrete
	(Part 1)	Particle size and shape
	(Part 2)	Estimation of deleterious materials and organic impurities
	(Part 3)	Specific gravity, density, voids, absorption and bulking
	(Part 4)	Mechanical properties
	(Part 5)	Soundness
	(Part 6)	Measuring mortar making properties of fine aggregates
	(Part 7)	Alkali – aggregate reactivity
	(Part 8)	Spectrographic examination
IS 2430		Methods of sampling of aggregate for concrete
IS 2502		Code of practice for bending and fixing of bars for concrete reinforcement
IS 2751		Recommended practice for welding of mild steel plain and deformed bars used for reinforced construction
IS 2911		Code of practice for design and construction of pile foundations
	(Part 1)	Concrete piles3
	Section 2	Bored cast-in-situ concrete piles
	(Part 4)	Load test on piles
IS 4082		Recommendations on stacking and storage of construction materials at site
IS 4326		Earthquake resistant design and construction of buildings – code of practice
IS 4656		Form vibrators for concrete
IS 4736		Hot-dip zinc coatings on mild steel tubes
IS 4826		Hot-dipped galvanised coatings on round steel wires
IS 4925		Concrete batching and mixing plant
IS 4926		Ready mixed concrete
IS 5525		Recommendations for detailing of reinforcement in reinforced concrete works
IS 5529		Code of practice for in-situ permeability tests
IS 5640		Method of test for determining aggregate impact value of soft coarse aggregate
IS 5816		Method of test for splitting tensile strength of concrete cylinders
IS 5892		Concrete transit mixers and agitators
IS 7205		Safety code for erection of structural steel work
IS 7293		Safety code for working with construction machinery
IS 7320		Concrete slump test apparatus
IS 7969		Safety code for handling and storage of building materials
IS 8112		43 grade ordinary Portland cement
IS 8142		Method of test for determining setting time of concrete by penetration resistance
IS 8500		Structural steel-micro alloyed (medium and high strength qualities) (Superseded by IS 2062-2006)
IS 9013		Method of making, curing and determining compressive strength of accelerated cured concrete test specimens
IS 9103		Admixtures for concrete
IS 9284		Method of test for abrasion resistance of concrete

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IS 9417	Recommendations for welding cold worked bars for reinforced concrete construction
IS 9595	Recommendations for metal arc welding of carbon and carbon manganese steels
IS 10262	Recommended guidelines for concrete mix design
IS 12269	53 grade ordinary Portland cement
IS 13920	Ductile detailing of Reinforced Concrete Structures subjected to Seismic Forces
IS 14268	Uncoated stress relieved low relaxation seven-ply strands for Pre stressed Concrete

FOREIGN STANDARDS

ASTM D-297	Methods for Rubber Product Chemical Analysis
ASTM D-395	Compression set of vulcanised rubber
ASTM D-412	Tension testing of vulcanised rubber
ASTM D-429	Adhesion of vulcanised rubber to metal
ASTM D-573	Accelerated ageing of vulcanised rubber by the oven method
ASTM D-624	Tear resistance of vulcanised rubber
ASTM D-797	Young's Modulus in flexure of elastomer at normal and subnormal temperature
ASTM D-1149	Accelerated Ozone cracking of vulcanised rubber
ASTM D-1559	Test for resistance to plastic flow of bituminous mixtures using Marshall apparatus
UIC 774-3R	Rail Structure interaction.
EN 1337-3	Structural bearings - Part 3: Elastomeric bearings

Note: - The above list is not exhaustive and shall be augmented during detailed design and construction of the viaduct

OTHER PUBLICATIONS

Updated version of following publications shall be followed.

- Indian Standard Hand Book on Steel Sections Part I
- Indian Railways Manual on Design and Construction of well and pile foundations.
- Seismic code for Earthquake Resistant Design of Railway Bridges
- RDSO Guidelines for RSI ANALYSIS.

The design relating to fire safety and escape shall be in accordance with the requirements of NBC.

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Examined & found in order

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27/10/2021

HIRENDRA KUMAR RAGHU
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DESIGN BASIS REPORT FOR STATIONS

BANGALORE METRO RAIL PROJECT

(ORR AND AIRPORT LINE PH 2A AND 2B OF BMRCL)

Examined & found in order except para no. 1.2.2, 2.1.3.1 and 2.1.3.4 where corrections have been made in the document

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SEPTEMBER 2021

DESIGN BASIS REPORT FOR STATIONS

ORR AND AIRPORT LINE PHASE 2A AND 2B OF BMRCL

Examined & found in order

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Date: 2021.10.18 20:38:51 +05'30'

REV.	DATE	DESCRIPTION OF REVISION	PREPARED BY	CHECKED BY	APPROVED BY
01	06/09/2021	As per Comments received from RDSO dated 01-07-2020.	Renganayagi. B AEE.BMRCL.	G.C. Shivakumar CE (P&D), BMRCL.	A.K.JHA Advisor(P&D), BMRCL.

Project Directorate
Approved on
27/10/2021

TABLE OF CONTENTS

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Project Directorate
Received on
27/10/2021
Railway Board

Chief Engineer
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BMRCL

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Project Directorate
Approved
27/10/2021
Railway Board

1. INTRODUCTION

1.1. Brief description of project:

Bangalore is located in the meridians of 12° N latitude and 77°3' E Longitude, spread over an area of 531sq. km. located at an altitude of 900m.

Phase II A of the Bangalore Metro Rail Project comprises of the ORR Line from Central Silk Board Junction to Krishnarajapuram (17.175km).

Phase II B comprises of Airport Link Line from Krishnarajapuram to Airport (28km).

1.1.1 Geometrical Design Feature

- Gauge adopted is Standard Gauge (1435 mm)
- Centre to Centre of track should be as per approved SOD (proposed c/c of tracks = 4.2m/4.85m/5.03m on Elevated. Extra clearances required on curves shall be as per SOD requirements.
- Loading corresponding to Modern Rolling Stock (MRS).

1.2. Proposed Structural System of Station

1.2.1. Superstructure system

- Precast U-Girder, Pre/Post tensioned I Girders with cast-in-situ deck slab are proposed for track supporting Girders inside stations
- Take off location: Pre/Post-tensioned I Girders
- Station Concourse & Platform and Entry structures: Cast-in-situ, Pre-cast RC beam or Pre-cast Prestressed pre-tensioned I-Beam or U or T beam for floor support.
- Ballast-less track: Rebar dowels are provided from deck slab for casting of Rail Plinth.
- Provisions for fixing parapet with emergency walkway are also provided.

1.2.2. Emergency Walkway

Walkway on the Loop lines merging with stations shall be As shown in Fig-1. "Walkway should be used by Metro inspection groups only in non operation periods".

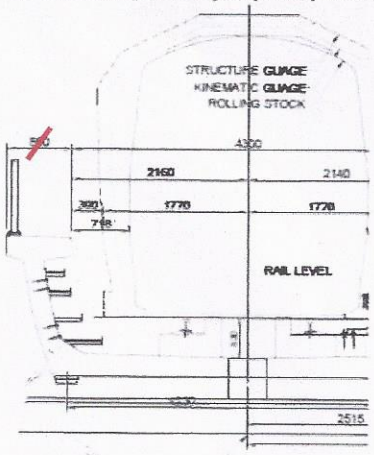

Fig.1

~~Minimum emergency walkway width is 550 mm.~~

~~The above width is in conformity with approved SOD of BMRCL.~~

(610 mm unobstructed clear width is to be made available as per NFPA 130 Standard for fixed guide way transit and passenger rail system).

~~550~~ mm

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1.2.3. Bearing

Elastomeric bearings shall be used for station girders.

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1.2.4. Substructure system

Substructure shall consist of Cast in situ pier/ Cast in situ Pier/Column. For pier caps /beams precast or cast in-situ is proposed. Pier columns are normally with Circular/Rectangular.

1.2.5. Foundation system

Predominantly pile foundations shall be adopted with 1.0/1.2/1.5m diameter. Open foundations will be adopted in rocky strata at few locations.

1.2.6. Parapets

Steel parapets are provided for a height of 1.10m above walkways (Fig-1).

1.3. Scope of DBR

This design basis note is prepared to standardize the design methodology for BMRCL Phase II A&B station bridge structure made of RCC, PSC and Steel for the Project.

The DBR is only for structural design of Elevated Stations. Extended platform portion which is generally on single column or portal type of 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 Metro System". LWR forces shall be specified by Metro, if RSI analysis is not practicable. Load combination as per "Model Design Basis Report (DBR) for Viaduct Metro System" shall also be considered. Other structural elements such as secondary beams, stub columns etc, Entry/Exit Structures etc., may be designed as per IS: 456.

Structures, where Metro live loads are not applicable, the design of Plain and Reinforcement Concrete structures will generally be governed by IS:456. 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.

1.4. Units:

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

2. 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 (Ec) 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.

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2.1.3. Prestressing Steel for Tendons

As per clause 5.6.1 of IS:1343.

2.1.3.1. Young's Modulus

As per prestressing steel used in accordance with Para ~~4.5~~ 2.1.3 above.

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2.1.3.2. Prestressing Units
As per clause 13 of IS:1343.

2.1.3.3. Maximum Initial Prestress
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 ~~4.3 above.~~ 2.1.3 above.

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2.1.3.5. Sheathing
As per clause 12.2 of IS:1343.

2.1.4. Structural Steel
Structural steel used shall confirm to

- Hollow steel sections as per IS:4923
- Steel for General Structural Purposes as per IS:2062
- Steel tubes for structural purpose shall be as per IS:1161

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 as per clause 5.6.2 of IS:1343 for Prestressed 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 prestressed 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 & Reinforced concrete structure as per clause 8.0 of IS:1343 for Prestressed concrete structures and section 15 of IS:800 for Steel Structures.

2.2.1. Concrete Grades

The minimum grade of concrete shall be depending upon the environment to which the structure is likely to be exposed during its service life and shall be as per clause 5.4.4 of IRS CBC for the structures supporting metro loading.

And for the remaining structures minimum grade to be followed as per Table 1 of IS 456 and IS 1343. The following are the minimum grade to be followed for the various members.

Minimum Grade of Concrete

Structural Member	Moderate Exposure
PCC Member	M25
RCC Member	M30
PSC Member	M35

Approved Drawings
4/12/2021

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The minimum grades of concrete to be used for various structural elements in this project are mentioned below:

- Beams : M35
- Slabs : M35
- RCC Walls : M35
- Columns : M35
- Pile and Pile caps : M35
- Prestressed members : M40

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 prestressed concrete structures. Cover to prestressing 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 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 Prestressed 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 specific Metro system.

(iv) **Clearances for utility services:** The clearances to utilities, drainage etc. shall be 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
Train Live load	LL
Coefficient of Dynamic Augment	CDA
Braking/Traction Load	BR
Imposed (Crowd Live) Loads	IL
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, buildings etc.)	SR
Prestressing Force	PR
Long Welded Rail Force	LWR
Differential Settlement	DS
Racking Forces	
Vibration Effect	

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2.4.1 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 materials that are structural components of Elevated Station and permanent in nature.

2.4.2. 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 from plinth/ rails/ fasteners/ cables/ parapet/ hand-rail/ Third rail &fixing/ cable trough/ signaling equipment etc. and will be considered in the design as per the site conditions.

The minimum distributed and concentrated loads shall be in accordance to IS:875, wherever available for remaining Metro railway shall specify the loads.

2.4.2.1 SIDL1 (Fixed SIDL or Non-variable SIDL)

Rail Plinth, Precast Parapet, Floor finishes and roof structure will be considered as Fixed SIDL for the purpose of analysis of structures. The weight of the rail plinth and parapet will remain same throughout the life of the structure. This is incorporated in the maintenance manual of BMRCL.

2.4.2.2. SIDL2 (Variable SIDL)

The following items shell be considered as variable SIDL

- Rails + Pads
- Third rail & fixtures
- Hand rail
- Cables
- Cable trough cell
- Cable trays
- Miscellaneous (OFC, Signaling etc.)

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2.4.3. Train Live Load (LL)

Track carrying/connected structures shall be designed for Metro loading envelop given in Annexure-I of viaduct DBR.

Loads other than standard trains like track machines, cranes, any new rolling stock etc. Which may come on this structure should be within this loading envelope.

2.4.4. Coefficient of Dynamic Augment (CDA): CDA shall be adopted as per IRS Bridge Rules.

2.4.5. Braking and Traction (BR/TR)

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

2.4.6. Imposed (Crowd Live) Load (IL)

Imposed loads on station buildings are those arising from occupancy and the values includes, normal use by persons, furniture and movable 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.

31

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2.4.7 Earthquake Load (EQ)

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

2.4.7.1 Drift Limitation

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

2.4.7.2 Seismic Detailing

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

2.4.8. Wind Load (WL)

The wind load shall be calculated as per IS: 875 part 3

2.4.9. Collision / Impact Load / Derailment Load(CL)

(i) For road traffic as per IRC: 6.
(ii) For metro as per IRS Bridge Rule.

2.4.10. Construction and erection load (EL)

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.

2.4.11. Temperature (OT)

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

2.4.12. Shrinkage (S)

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 prestressed concrete structures.

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

2.4.13. Creep (C)

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 prestressed concrete structures.

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

2.4.14. Earth & Water Pressure (EP)

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 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/footing 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.

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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-Substructure Code.

2.4.15. Surcharge Load (SR)
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 surcharge from stationary or moving load, shall be duly accounted for.

2.4.16 Prestressing Force (PR)
The pre-stressing force should be as per IS: 1343.

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

2.4.18. Differential Settlement (DS)
Maximum and differential settlement shall not exceed, as provided in table 1 of IS: 1904.

2.4.19. Racking forces: As per Clause 2.9 of IRS Bridge Rules.

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

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2.4.21. Erection Forces: As per Clause 2.13 of IRS Bridge Rules.

2.4.22. 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 prestressed concrete structures.
iii. Load combination as per Section 3 and factors as per Section 5 of IS:800 for Steel structures.
iv. Load combination of per clause 6.3 of IS:1893 (Part-I)
v. Load combinations as per IRS CBC and Seismic code for Earthquake Resistant Design of Railway Bridges where Metro Live load is applicable.

Note:
i. Load combination for construction load case shall be accounted by BMRCL as per methodology of construction
ii. Reference of IRC:6 be taken for collision case if collision of road vehicles are involved.

2.5.2 Serviceability Load Combinations

The following load combinations and load factors shall be used for design of 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 prestressed 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 and Seismic code for Earthquake Resistant Design of Railway Bridges where Metro Live load is applicable.

2.6. Deflection Criteria
The deflection limitation as per clause 23.2 of IS: 456 for Plain and Reinforced Concrete Structures and clause 20.3.1 of IS:1343 for prestressed Concrete structures shall be followed.

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Clause no.10.4.1, 11.3.4 and 13.3 of IRS CBC shall be kept in view while calculating vertical deflection at mid span for track carrying girders.

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 Type of Foundations

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

- Spread or Pad footing
- Raft Foundation
- Pile Foundation

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

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

2.8.2 Design of Pile

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.

Pile Settlement

Methods of estimating the settlement of deep foundations 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 Design of 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.

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Computation of Settlements of Foundations

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

- IS:8009 Part-1 for shallow foundations
- IS:8009 Part-2 for deep foundations

27/10/2021

Soil structure analysis: While designing elements forces or estimating displacements the soil stiffness shall be assessed based on the actual ground data.

34

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2.9 **Design of Water Retaining Structures:** It should be designed as per IS 3370.

3. PROJECT SPECIFIC ADDITIONAL INFORMATION / DETAILS (IF ANY)

NIL

4. DESIGN CODES AND STANDARDS

The designs of station buildings shall be carried out as per provisions of these 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

List of various design codes and standards to be used at various stages of works is appended as Annexure I. These codes with latest revisions including all addendums/notifications and correction slips only shall be used.

5. 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.

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ANNEXURE-I

LIST OF CODES

INDIAN STANDARD (IS) Codes

National Building Code		
SP 7		Bureau of Indian Standards.
IS 226		Structural steel (standard quality)
IS 269		33 grade Ordinary Portland Cement.
IS 383		Coarse and fine aggregates from natural Sources for concrete
IS 432		Mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement
	(Part 1)	Mild steel and medium tensile steel bars
	(Part 2)	Hard-drawn steel wire
IS 455		Portland slag cement
IS 456		Code of practice for plain and reinforced concrete
IS 460		Test sieves
IS 516		Method of test for strength of concrete
IS 650		Standard sand for testing cement
IS 800		Code of practice for general construction in steel
IS 814		Covered electrodes for manual metal arc welding of carbon and carbon manganese steel
IS 815		Classification coding of covered electrodes for metal are welding of structural steel
IS 823		Code of procedure for manual metal arc welding of mild steel
IS 875		Code of practice for design loads (other than earthquake) for buildings and structures
IS 1161		Steel tubes for structural purposes
IS 1239		Mild steel tubes, tubulars and other wrought steel fittings
	(Part 1)	Mild steel tubes
	(Part 2)	Mild steel tubulars and other wrought steel pipe fittings
IS 1343		Code of practice for Pre-stressed Concrete
IS 1732		Dimensions for round and square steel bars for structural and general engineering purposes
IS 1786		High strength deformed steel bars and wires for concrete reinforcement.
IS 1791		Batch type concrete mixers
IS 1834		Hot applied sealing compound for joint in concrete
IS 1888		Method of load tests on soils
IS 1892		Code of practice for sub surface investigations for foundations
IS 1893:Part I		Criteria for earthquake resistant design of structures
IS 2062		Steel for general structural purposes
IS 2090		High tensile steel bars used in prestressed concrete
IS 2386		Methods of test for aggregate for concrete
	(Part 1)	Particle size and shape
	(Part 2)	Estimation of deleterious materials and organic impurities
	(Part 3)	Specific gravity, density, voids, absorption and bulking
	(Part 4)	Mechanical properties
	(Part 5)	Soundness
	(Part 6)	Measuring mortar making properties of fine aggregates
	(Part 7)	Alkali – aggregate reactivity
	(Part 8)	Spectrographic examination
IS 2430		Methods of sampling of aggregate for concrete
IS 2502		Code of practice for bending and fixing of bars for concrete reinforcement
IS 2751		Recommended practice for welding of mild steel plain and deformed bars used for reinforced construction.
IS 2911		Code of practice for design and construction of pile foundations
	(Part 1)	Concrete piles3
	Section 2	Bored cast-in-situ concrete piles
	(Part 4)	Load test on piles

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IS 4082	Recommendations on stacking and storage of construction materials at site
IS 4326	Earthquake resistant design and construction of buildings – code of practice
IS 4656	Form vibrators for concrete
IS 4736	Hot-dip zinc coatings on mild steel tubes
IS 4826	Hot-dipped galvanised coatings on round steel wires
IS 4925	Concrete batching and mixing plant
IS 4926	Ready mixed concrete
IS 5525	Recommendations for detailing of reinforcement in reinforced concrete works
IS 5529	Code of practice for in-situ permeability tests
IS 5640	Method of test for determining aggregate impact value of soft coarse aggregate
IS 5816	Method of test for splitting tensile strength of concrete cylinders
IS 5892	Concrete transit mixers and agitators
IS 7205	Safety code for erection of structural steel work
IS 7293	Safety code for working with construction machinery
IS 7320	Concrete slump test apparatus
IS 7969	Safety code for handling and storage of building materials
IS 8112	43 grade ordinary Portland cement
IS 8142	Method of test for determining setting time of concrete by penetration resistance
IS 8500	Structural steel-micro alloyed (medium and high strength qualities) (Superseded by IS 2062-2006)
IS 9013	Method of making, curing and determining compressive strength of accelerated cured concrete test specimens
IS 9103	Admixtures for concrete
IS 9284	Method of test for abrasion resistance of concrete
IS 9417	Recommendations for welding cold worked bars for reinforced concrete construction
IS 9595	Recommendations for metal arc welding of carbon and carbon manganese steels
IS 10262	Recommended guidelines for concrete mix design
IS 12269	53 grade ordinary Portland cement
IS 13920	Ductile detailing of Reinforced Concrete Structures subjected to Seismic Forces
IS 14268	Uncoated stress relieved low relaxation seven-ply strands for Pre stressed Concrete

INDIAN RAILWAY STANDARDS(IRS)(Latest Revision)

IRS CONCRETE BRIDGE CODE
IRS BRIDGERULES
IRS STEEL BRIDGE CODE
IRS BRIDGESUBSTRUCTURE & FOUNDATION CODE IRS FABRICATION CODE(B1)
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INDIAN ROAD CONGRESS(IRC)STANDARDS(LatestRevision)

IRC5	Standard Specifications and Code of Practice for Road Bridges, Section I- General Features of Design
IRC6	Standard Specifications and Code of Practicefor Road Bridges,Section II– Loads and Stresses
IRC22	Standard Specifications and Code of Practice forRoad Bridges, SectionVI– Composite Construction for Road Bridges
IRC24	Standard Specifications and Code of practice for Road Bridges, SectionV– Steel Road Bridges

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IRC78	Standard Specifications andCodeofpractice forRoad Bridges, SectionVII- Foundation& Substructure
IRC 83	Standard Specifications and code of practice for Road Bridges, Section IX - Bearings Part I, II &III: Bearings (Metallic, Elastomeric and POT & PTFE Bearings)
IRC 87	Guidelines for the Design and Erection of False Work for Road Bridges
IRC: SP-65	Guidelines for Design and Construction of Segmental Bridges
IRC: 112	Code of Practice for Concrete Road Bridges

FOREIGN STANDARDS

ASTM D-297	Methods for Rubber Product Chemical Analysis
ASTM D-395	Compression set of vulcanised rubber
ASTM D-412	Tension testing of vulcanised rubber
ASTM D-429	Adhesion of vulcanised rubber to metal
ASTM D-573	Accelerated ageing of vulcanised rubber by the oven method
ASTM D-624	Tear resistance of vulcanised rubber
ASTM D-797	Young's Modulus in flexure of elastomer at normal and subnormal temperature
ASTM D-1149	Accelerated Ozone cracking of vulcanised rubber
ASTM D-1559	Test for resistance to plastic flow of bituminous mixtures using Marshall apparatus
UIC 774-3R	Rail Structureinteraction.
EN1337-3	Structural bearings -Part 3:Elastomeric bearings

Note:-The above list is not exhaustive and shall be augmented during detailed design and construction of the station.

OTHERPUBLICATIONS

Updated version of following publications shall be followed.

- Indian Standard Hand Book on Steel Sections Part I
- Indian Railways Manual on Design and Construction of well and pile foundations.
- Seismic code for Earthquake Resistant Design of Railway Bridges
- RDSO Guidelines for RSI ANALYSIS.

The design relating to fire safety and escape shall be in accordance with the requirements of NBC.

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