GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS
(RAILWAY BOARD)

No.2014/Proj./DBR/BNC/2/10 New Delhi, dated:01.05.2015

Director (Project & Planning)
Bangalore Metro Rail Corporation Ltd.,
3rd floor, BMTC Complex K.H. Road,
Shanthinagar, Bangalore-560 027

Sub: Approval on Design Basis Report of Bangalore Metro Phase-II.

Ref: RDSO's letter No.UTHS/24/BMRCL dated 28.4.2015.

In supersession to this office letter of even number dated 24.02.2015, the Design Basis Report (DBR) – (Version April, 2015) of Bangalore Metro Rail Corporation Ltd. received through RDSO vide letter under reference above has been examined and approval of Railway Board is hereby conveyed.

Accordingly, approved copy of DBR (Version April, 2015) is enclosed.

DA: As above

01.05.15

(Ruth Changsan)
Director/Woks (Plg.)
Railway Board

Copy to:-

Executive Director/UTHS, RDSO, Manak Nagar, Lucknow

BANGALORE METRO RAIL CORPORATION LIMITED

BMR PROJECT – PHASE II

VIADUCT AND ELEVATED STATIONS

DESIGN BASIS REPORT

11/5/2015

April' 2015

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06/04/2015
Chief Engineer
(Planning & Design)
BMRCL

VIADUCT AND ELEVATED STATIONS

DESIGN BASIS REPORT

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IN

ion of project

ted in the meridians of 12° N latitude and 77°3' E Longitude, spread over an area c
ed at an altitude of 900m.

Bangalore Metro Rail Project comprises of the 6 sections & the civil contract is divide
/ lines as follows.

- R1 Extension Viaduct & Stations: Baiyappanahalli Depot to Whitefield station (15.
isting of 13 stations.
– R2 Extension Viaduct & Stations: Mysore Road Station to Kengeri Terminal statio
) consisting of 6 stations.
– R3 Viaduct & Stations: Hesaraghatta cross Station to BIEC (3.77 Km) consisting of

– R4 Extension Viaduct & Stations: Puttenahalli to Anjanapura Township (6.3 Km
g of 5 stations.
– R5 Extension: RV Road Station to Bommasandra Station (18.71 Km) consisting of 1

– R6 Elevated Viaduct & Stations: Gottigere Station to Nagavara Station
Elevated stretch: Viaduct- 6.98 Km, Station – 6nos

rical Design Feature:

ge adopted is Standard Gauge (1435 mm)
ient of superstructure = variable (level to 4 %) [loads and forces on structures shall b
ked out based on the actual gradient at the particular pier under consideration]
rizontal alignment of superstructure comprises Straight, Transition and Curved stretche
Minimum design radius of curvature in plan is 120 m.
Centre to centre of track should be as per approved SOD (In Phase-I, c/c of tracks = 4.2
throughout. This is adequate to take the extra clearances required in curves.).
Loading corresponding to Modern Rolling Stock (MRS).

pe of DBR

is design basis note is prepared to standardize the design methodology for BMRCL Phase
l structures & Station Bridge structures made of RCC, PSC and steel for the project. Statio
structures are structures on which Metro Rail will ply. It consists of frame work of columns an
supporting Station Concourse and Station platform. The station bridge structure shall be designe
elevant IRS Codes.

POSED STRUCTURAL SYSTEM OF VIADUCT

Superstructure system:

- **Viaduct**:-Precast PSC segmental Single Box girder or Cast-in-situ prestressed box girder f
supporting 2 tracks with incline webs. Provisions for fixing parapet with emergency walkway a
also provided.
- **Station** Concourse: - Pre-cast RC beam or Pre-cast Prestressed I-Beam or U or T beam for flo
support.
- **Station** Platform:- Pre-cast Prestressed I-Beam or U or T beam or cast in situ beams f
supporting 2 tracks and Pre-cast Prestressed I-Beam or U or T beam for platform.
- **Ballast** less track. (Rebar provision for track concrete plinth integral with deck slab.)
- **The** standard spans (c/c of pier) will be 16 m, 19 m, 22 m, 25 m, 28 m & 31 m. Subtracting
adding usual standard 3m each from the centre of span shall make these spans. Fig 2 gives t
salient features of the standard box girder segment superstructure.

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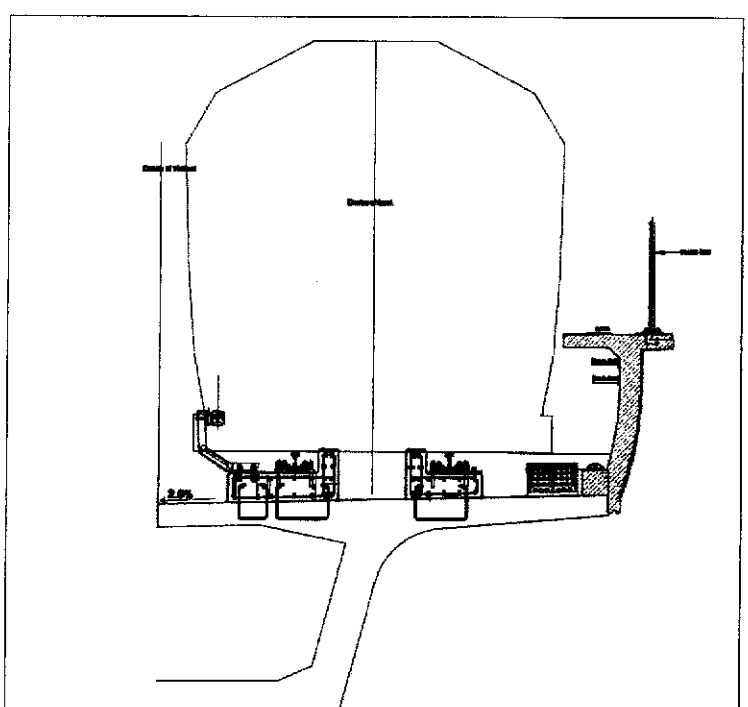
2.2. Emergency Walkway:

Walkway on the viaduct shall be provided for evacuation of passengers in safe condition

Emergency Walkway on Viaducts



Minimum emergency walkway width 550mm.

Minimum internal width of cable trough at bottom = 600 mm. The bottom of cable trough fl have a cross-fall of 2 % towards the track side and weep hole (50 mm dia.) at interval of 2 m.

The above widths are in conformity with approved SOD of BMRCL.

2.3. Bearing :

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

a. Elastomeric Bearing
b. Pot cum PTFE Bearing

Design details are explained in subsequent paras.

2.4. Substructure system:

Substructure shall consists Pier column- Rectangular, circular and Double D shape columns finishes until the start of flare for pier cap.

2.5. Foundation system:

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

2.6. Parapets:

Precast parapet as per the approved SOD of BMRCL shall be used in viaduct and cast in situ shall be used in station areas.

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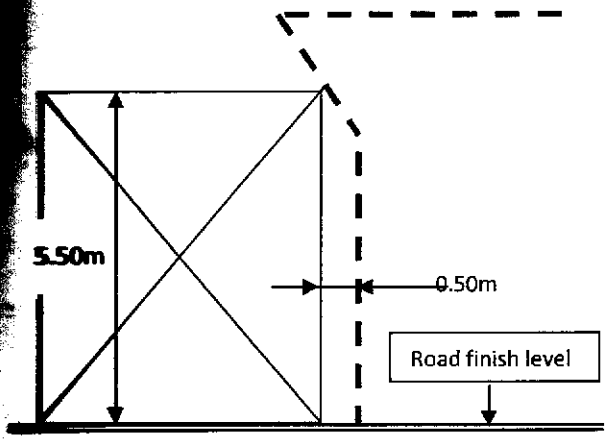
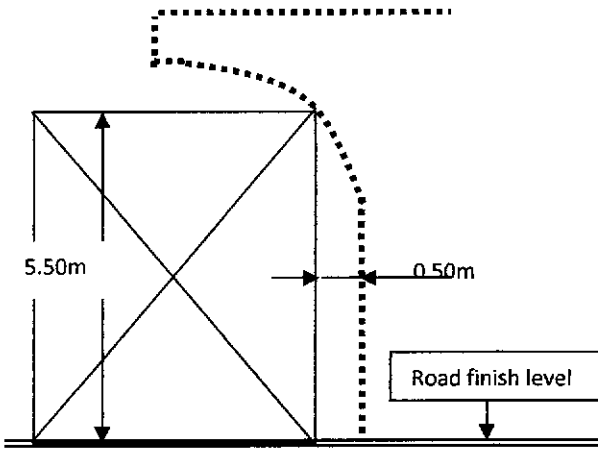
CLEARANCES FOR STRUCTURES

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 at 0.5m (0.45m (width of the 1m-high Jersey-type crash barrier) + 0.05 m (clearance between crash barrier and pier shaft)) from pier shaft outer line.





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 AND 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/m3 for PSC and RCC based on reinforcement percentage, 23kN/m3 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 of IRS CBC. All properties of HSD/TMT bar shall conform to IS: 1786 with elongation requirements as per Clause 5.3 of IS: 13920.

4.4. Prestressing Hardware

4.4.1.Prestressing steel for tendons

Prestressing 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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4.5. Pre stressing Units:

4.5.1.Jacking Force: Jacking force (maximum initial pre-stressing force) shall be as per 16.8.1of IRS CBC: 1997.

4.5.2.Relaxation properties: For long term relaxation losses in pre stressing steel, 3 times t hours value given in IRS CBC (Clause 16.8.2.2).

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 (or IS: 8500 as applicable).

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 provisions and Submerg Welding (SAW) shall be done. Field welding shall not be done.

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.

5. LOADS

5.1. Dead load (DL):

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

5.2. Super Imposed Dead Load (SIDL):

Superimposed dead loads include all the weights of materials on the structure that are not s elements but are permanent. It includes weight of track form plinth/ rails/ fasteners/ cables/ hand-rail/OHE mast /cable trough/signaling equipment etc. and will be considered in the d per the site conditions.

5.2.1 SIDL1 (Fixed SIDL or Non variable SIDL) :

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

5.2.2 SIDL2 (Variable SIDL) :

The following items shall be considered as variable SIDL

Rails + pads

Third rail & fixtures

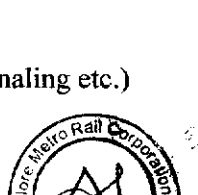
Hand rail

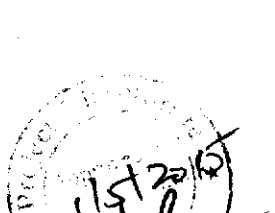
Cables

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.

5.4. Live Load (LL):

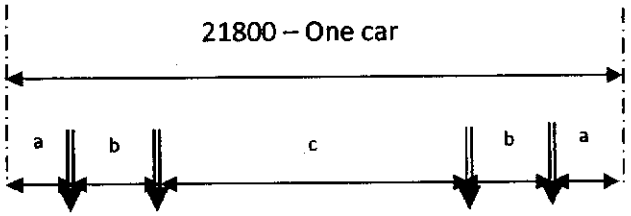
The simply supported structures shall be designed for light Metro loading Envelop tabulated at Annexure III. Loads other than standard trains like track machines, cranes, any new rolling stock etc. which may come on this structure should be within the loading envelope initially decided by the metro.

The loading envelope to be chosen for phase-II reaches except Reach 5 and 6 will be as given in para 5.4.1, which will be based on the Rolling Stock planned to be used on the Metro system. Separate EUDL chart for reach 5 and 6 shall be worked out and included as an addendum to DBR subsequently.

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

5.4.1. Vertical Train Live Load

The Train Live Load will be the "Modern Rolling Stock" type, with the following axle configurations:



All axle loads = 15 tons/axle for all reach extensions except reach 5 and 6.

Note: The axle load for Reach 5 and 6 (New lines) to be considered as 16.0t.

Maximum number of successive cars: 6

Configuration:

a = 2.4m

b = 2.30m

c = 12.40m

(2a+2b+c=21.8m)

Maximum number of axles will be loaded on the superstructure to arrive at maximum longitudinal force, max **shear and max BM.** Since both the tracks will be supported by single box girder, hence superstructure, bearing **and substructure will be** checked for the live load combinations given in para 5.4.2.

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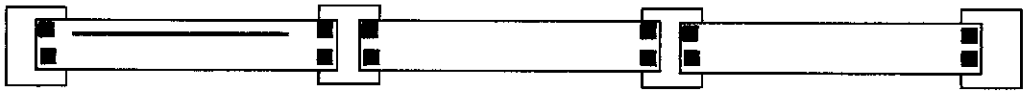
It shall be ensured that live load coming on structure is within loading envelope decided by BMI also be ensured that loads other than passenger trains like track machines, cranes, new rolling stoc may come on this structure should be within loading envelope decided by BMRCL.

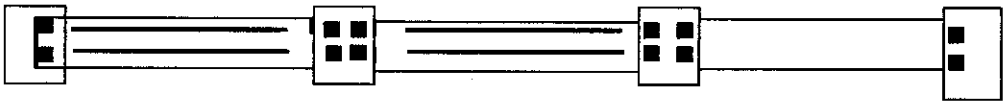
In case of maximum shear force, bending moment and longitudinal forces critical load c combinations shall be considered.

Equivalent uniformly distributed load & longitudinal force chart for BMRCL metro loading Annexure III. For new lines in Reach 5 and 6, similar EUDL charts will be prepared and used fo purposes.

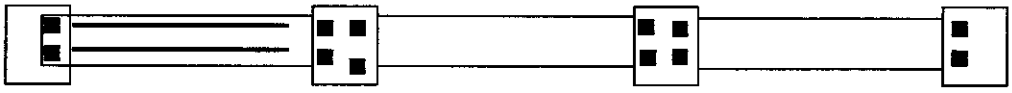
5.4.2.Live Load Combinations



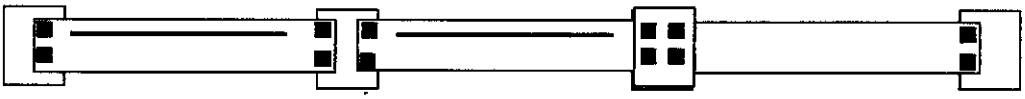
LL0: used for Deck Torsion, Bearing Compression, Uplift, Shaft check, Foundation check



LL1: used for shaft check, Foundation check, Shear Key check



LL2 : Used for Deck check, Bearing Compression check, Shaft check, Foundation check;



LL3 : Used for Shaft check, Foundation check

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

5.6. Footpath Live Load:

Footpath live load shall be adopted as 490 kg/m2 as per cl.2.3.2.1 of IRS: Bridge Rule-2008(42). As per BMRCL Metro Railway (general) rules, 2013 clause 50(10), whenever footpath/ walkway is under use by passengers during evacuations or by maintenance personnel for main third rail will be switched off resulting in no movement of trains on both tracks.

5.7. Braking and Traction (BR/TR):

The value of braking and traction forces are as given below:

Braking load is taken as 18 % of the unfactored axle load of MRS Coach.

Traction load is taken as 20 % of the unfactored axle load of MRS Coach.

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 in design as per site condition.

5.10. Wind Load (WL): As per clause 2.11 of IRS bridge Rules.

5.11. Seismic Load (EQ): RDSO Guidelines on Seismic design of Railway Bridges (January – 2015) shall be followed (These guidelines also cover 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) : For PSC box section Temperature Gradient shall be 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:

- **12 mm** for Long Term Settlement; (based on Cl.6.1.5 of IS 2911 –Part 4).
- **6 mm** for Short Term Settlement (50% of Long term)

5.14. Vehicle collision load on piers: As per Clause 222 of IRC: 6.

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 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. Rail Structure Interaction (LWR Forces):

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.

5.16.1. Rail Structure interaction studies shall be done as per provisions of UIC 774-3 R with the following parameters specified in consultation with track design engineers:

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i) Track resistance in loaded and unloaded conditions.
ii) Maximum additional stresses in rail in tension as well as compression on account Structure interaction.
iii) Maximum vertical deflection of the girder ends.

5.16.2. Software and general methodology to be used for carrying out Rail-Structure in analysis must be validated before adopting the same.

5.16.3. Representative stretches must be chosen for carrying out Rail-Structure interaction.

5.16.4. Checks must be performed for break in rail continuity due to unusual conditions like or for maintenance purposes.

5.16.5. RDSO Guidelines for carrying out RSI studies shall be referred.

5.16.6. LWR forces shall be considered in appropriate load combination as per IRS-CBC.

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 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 XXVIII of IRS Bridge Rules with Gauge in place of Broad Gauge. For ULS and Stability check, loading shall be proportion maximum axle load.

Sacramento derailment criteria may be used for U-girders. This criterion correspond application of 40% of one coach weight applied horizontally as a 3m long uniform impac the appropriate flange of the girder. This derailment load corresponds to an ULS load. 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 IRS Concrete Bridge Code shall be followed. The partial loa and load combinations shall be as per clause 11 and Table-12 of IRS CBC. However, combination 2, "RDSO guidelines on Seismic Design of Railway Bridges (Jan-2015) followed".

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

6.3. Design of viaduct shall be done in accordance with the construction methodology/ cor 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

The provisions IRS – CBC- Reprint 2014 (with A & C 1) vide cl .16.4.2.2, 16.4.2.3, 16. 17.3.3 shall be applicable for Prestressed cast in situ and segmental construction. For Gen construction (Beams, columns and slabs), cl 10.2 shall govern the design

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7.3. SLS check:

7.3.1.SLS check:

. The provisions IRS – CBC – Reprint 2014 (with A & C 1) shall be applicable

7.3.2.Crack Width:

Crack width in reinforced concrete members will be checked for SLS combination-1. Crac width will be as per Clause 15.9.8.2 of IRS CBC. Crack width shall not exceed the admissibl 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 tha actual axial load will be considered to act simultaneously.

Clause no.10.4.1, 11.3.4 and 13.3 of IRS CBC shall be kept in view while calculating vertica 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

The Clause 3.6 of IRS steel Bridge code-2003 (with correction slip 18) shall govern. If λ value are required to be used, the train closest to the actual train formation proposed to be run on th 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 suitabl **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.

8. DESIGN METHODOLGY

8.1. Bearing System

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

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

8.1.3.Clause 15.9.11.3 & 15.9.11.4 of IRS CBC should be followed for considering replacement o **bearings.**

8.1.4.If elastomeric 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.

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8.3. Foundation

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

8.3.1.Pile Foundation:

For piles and pile caps, load combinations shall be considered as per IRS CBC, Table various specific assumptions made for the pile and pile cap design including pile load testi be as per IS: 2911 and IRS Bridge Substructure and Foundation Code.

8.3.2.Soil structure analysis:

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

9. PROJECT SPECIFIC ADDITIONAL INFORMATION/DETAILS

1. Axle loads of Modern Rolling Stock of BMRCL is shown in Annexure I
2. Structural gauge details for elevated stretches of BMRCL along with the box girder det parapet are shown in Annexure II

10. DESIGN CODES AND STANDARDS

The IRS Codes shall be followed in principle. Although main clauses have been mentione DBR, the other relevant clauses as available in the IRS codes shall also be followed. If provis not available in IRS, the order of preference shall be as follows, unless specifically m 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:

iv. IRC
v. IS
vi. Euro Code
vii. Other national codes.

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

11. DESIGN SOFTWARE:

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

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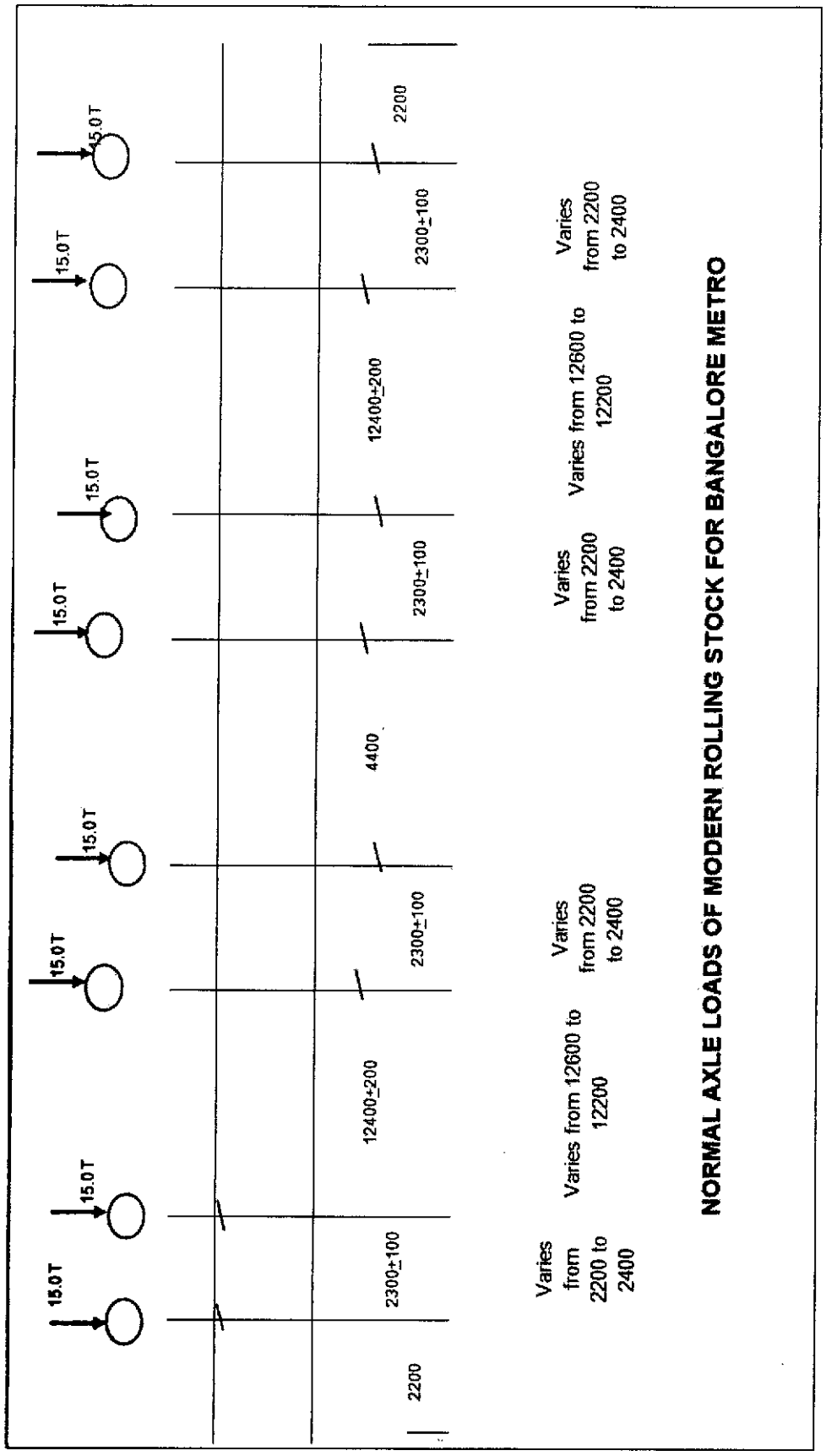
ANNEXURE-I



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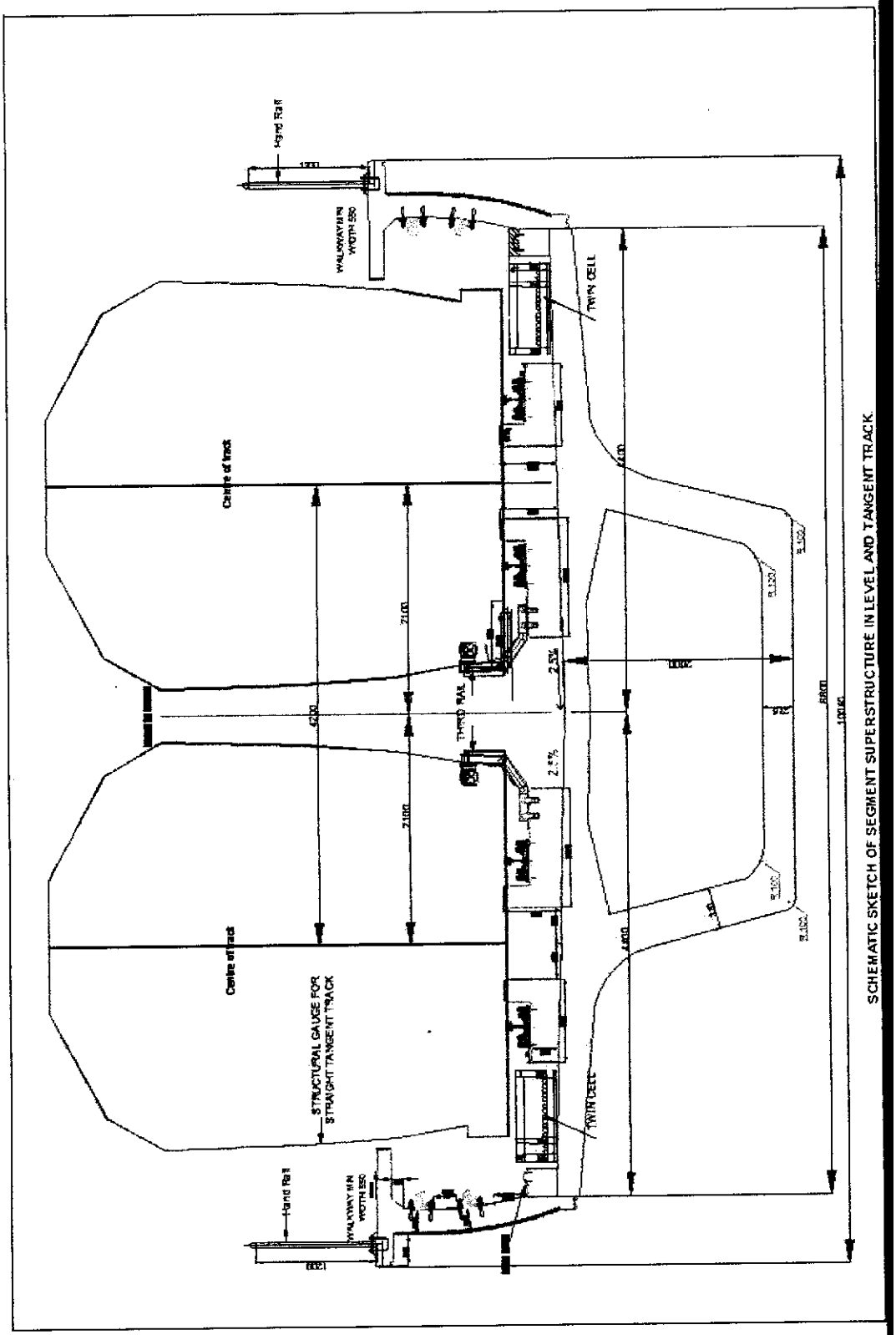

SCHEMATIC SKETCH OF SEGMENT SUPERSTRUCTURE IN LEVEL AND TANGENT TRACK

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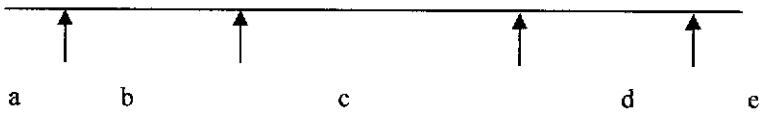
ANNEXURE III

EQUIVALENT UNIFORMLY DISTRIBUTED LOAD& LONGITUDINAL FORCE CHART FOR LIGHT METRO LOADING for all reach extensions.

Standard Train Formation Considered: 2DMC+1TC+2DMC+1TC+2DMC.

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-1 =21.8m (BMRCL).



Standard Maximum Height of Centre of Gravity from Rail Level: 1525 mm for 1435mm Gauge.

Maximum Axle Load: 15.0t for All reaches extensions.

Note: The axle load for Reach 5 and 6 (New lines) to be considered 16.0t.

Tractive Effort (TE): 20% of Vertical Axle Load for DMC/MC.

Braking Force (BF): 18% of Vertical Axle Load for DMC/MC/TC.

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.

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.

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

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L (M)	EUDL(Tonne)		LF(Tonne)	
	SF	BM	TE	BF
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

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L (M)	EUDL(Tonne)		LF(Tonne)	
	SF	BM	TE	BF
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
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

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IS 1732:	1989	Dimensions for round and square steel bars for structural and general engineering purposes
IS 1786:	1985	High strength deformed steel bars and wires for concrete reinforcement.
IS 1791:	1985	Batch type concrete mixers
IS 1834:	1984	Hot applied sealing compound for joint in concrete
IS 1888:	1982	Method of load tests on soils
IS 1892:	1979	Code of practice for sub surface investigations for foundations
IS 1893:Part I	2001	Criteria for earthquake resistant design of structures
IS 2062:	2011	Steel for general structural purposes
IS 2090:	1983	High tensile steel bars used in prestressed concrete
IS 2386:	1963	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:	1969	Methods of sampling of aggregate for concrete
IS 2502:	1963	Code of practice for bending and fixing of bars for concrete reinforcement
IS 2751:	1979	Recommended practice for welding of mild steel plain and deformed bars used for reinforced construction
IS 2911:	1979	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:	1996	Recommendations on stacking and storage of construction materials at site
IS 4326:	1993	Earthquake resistant design and construction of buildings – code of practice
IS 4656:	1968	Form vibrators for concrete
IS 4736:	1986	Hot-dip zinc coatings on mild steel tubes
IS 4826:	1979	Hot-dipped galvanised coatings on round steel wires
IS 4925:	1968	Concrete batching and mixing plant
IS 4926:	1976	Ready mixed concrete
IS 5525:	1969	Recommendations for detailing of reinforcement in reinforced concrete works
IS 5529:	1985	Code of practice for in-situ permeability tests
IS 5640:	1970	Method of test for determining aggregate impact value of soft coarse aggregate
IS 5816:	1970	Method of test for splitting tensile strength of concrete cylinders
IS 5892:	1970	Concrete transit mixers and agitators
IS 7205:	1974	Safety code for erection of structural steel work
IS 7293:	1974	Safety code for working with construction machinery
IS 7320:	1974	Concrete slump test apparatus
IS 7969:	1975	Safety code for handling and storage of building materials
IS 8112:	1989	43 grade ordinary Portland cement
IS 8142:	1994	Method of test for determining setting time of concrete by penetration resistance

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IS 8500:	1991	Structural steel-micro alloyed (medium and high strength qualities) (Superseded by IS 2062-2006)
IS 9013:	1978	Method of making, curing and determining compressive strength of accelerated cured concrete test specimens
IS 9103:	1979	Admixtures for concrete
IS 9284:	1979	Method of test for abrasion resistance of concrete
IS 9417:	1989	Recommendations for welding cold worked bars for reinforced concrete construction
IS 9595:	1996	Recommendations for metal arc welding of carbon and carbon manganese steels
IS 10262:	1982	Recommended guidelines for concrete mix design
IS 12269:	1987	53 grade ordinary Portland cement
IS 13920:	1993	Ductile detailing of Reinforced Concrete Structures subjected to Seismic Forces
IS 14268	1995	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

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.
- UIC 772 – 2 R The International Union of Railways Publication.
- UIC 774 – 3R Rail Structure interaction.

The design relating to fire safety and escape shall be in accordance with the requirements of NFPA 130 Standard for Fixed Guide way Systems.

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