GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS
(RAILWAY BOARD)

No. 2014/Proj./DBR/BNC/2/10 New Delhi, date 28.08.2015

The Managing Director,
MEGA Company Limited,
5th floor, Nirman Bhawan,
Opp. Sachivalaya Gate No. 4,
Sector-10-A,
Gandhinagar-382010,
Gujarat

Sub: **Approval of Design Basis Report (Version-5), Ahmedabad Metro Rail Project Phase-I.**

Ref: MEGA's letter No. MEGA/MD/Design/DBR/Structure/June-15 dated 22.07.2015

The Design Basis Report (DBR) for viaduct, Version -5 of Metro Link Express for Gandhinagar and Ahmedabad (MEGA) Co. Ltd. has been examined in consultation with RDSO and approval of Railway Board is hereby conveyed.

Accordingly, approved copy of DBR (Version-5) is enclosed.

DA/As above.

28.08.15

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

Copy to: Executive Director/UTHS, RDSO, Manak Nagar, Lucknow.

METRO-LINK EXPRESS FOR GANDHINAGAR AND AHMEDABAD

STRUCTURAL DESIGN BASIS REPORT FOR VIADUCT

Version - 5

5427
OUTWARD
DATE : 24/07/15

Metro-Link Express for Gandhinagar& Ahmedabad (MEGA) Company Ltd.

(A Govt. of Gujarat Undertaking)
5th Floor, NirmanBhavan, Opp. Sachivalaya Gate No. 4
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1.0 INTRODUCTION

This Design Basis Report pertains to Viaduct Portion of Ahmedabad Metro Project from Motera stadium to APMC and Vastral Gam to Thaltej providing North-South and East-West connectivity respectively.

1.1 SCOPE OF THE PROJECT

The Viaduct for Ahmedabad Metro project comprises of Precast PSC segmental single box girder or cast-in-situ box girder with inclined webs supporting two tracks with RCC substructure and Bored Cast in situ pile foundation. The standard gauge of 1435mm shall be followed. The centre to centre distance between the two tracks shall be as per SOD of MEGA.

1.2 AIM OF DESIGN BASIS REPORT

This Design Basis Report provides Design Criteria for Viaduct of Ahmedabad Metro

2.0 UNITS

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

3.0 TRACK GEOMETRY, TRACK STRUCTURE AND ROLLING STOCK

Track Geometry, Track Structure & Rolling Stock should be as per the approved SOD of MEGA.

4.0 ROADWAY AND RAILWAY CLEARANCES

The viaduct runs along and crosses several existing roadways and existing railways. The following sections outline the general clearance requirements for these crossings.

4.1 CLEARANCES FOR ROAD TRAFFIC

Clearance for road traffic shall be as per Road Authority of IRC requirement.

4.2 CLEARANCES FOR EXISTING RAILWAY CROSSINGS

Clearance for Railway Traffic should be as per Schedule of Dimensions of Indian Railways. General Arrangement Drawing of railway crossing shall be approved by the relevant Railway Authority.

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4.3 CLEARANCES FOR ROLLINGSTOCK OF AHMEDABAD METRO

Clearances for Rolling Stock should be as per the approved Schedule of Dimensions of MEGA.

5.0 DESIGN LIFE & SERVICEABILITY

The life of main Structural systems should be as per clause 15.1.3 of IRS: CBC. The design life of PSC structure shall be as per clause 16.1.3 of IRS: CBC.

6.0 MATERIALS PARAMETERS

6.1 CONCRETE

I. Young's Modulus & Modular ratio

A. Young's Modulus

Clause no. 5.2.2.1 of IRS: CBC should be followed.

B. Modular Ratio

Modular Ratio including long term effects such as creep shall be taken as follows (§ 5.2.6 of IRS: CBC).

For tensile reinforcement, $m_t = 280/ f_{ck}$

For compressive reinforcement, $m_c = 420/ f_{ck}$

II. Minimum Grade of Concrete & Cover

Minimum grade of concrete should be as per clause no 5.4.4 of IRS: CBC for exposure condition defined in Clause 5.4.1 of IRS: CBC.

The cover should be as per clause 15.9.2 of IRS: CBC

III. Cement

The type of cement shall be as per clause 4.1 of IRS: CBC.

The minimum cementitious material content shall be as per clause 5.4.5 & table 4 (c) of IRS: CBC.

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The maximum water-cement ratio shall be as per clause 5.4.3 & table 4(a) of IRS: CBC.

The total chloride content by weight of cement shall be as per clause 5.4.6 of IRS: CBC.

IV. Density

Density of concrete shall be as per Table 1 of IS: 875 (part-I).

V Poisson's Ratio

Poisson's ratio for all concrete: 0.15.

VI. Thermal Expansion Coefficient

Coefficient of thermal expansion (α) has been considered as per § 2.6.2 of IRS: Bridge Rules.

VII. Time-Dependent Characteristics of Materials

I. Long term losses should be calculated in accordance with clause 16.8.2 of IRS: CBC.
II. The design shall be done according to construction sequence to be adopted in site.
III. Validation of software should be done by MEGA.

6.2 PRESTRESSING STEEL FOR TENDONS

Prestressing steel shall be conforming to IS: 14268, Low Relaxation stress relieved strands as per clause 4.6 of IRS: CBC.

6.2.1 Young's Modulus

Young's Modulus of Prestressing steel shall be as per clause 4.6.2 of IRS: CBC.

6.2.2 Prestressing Units

Prestressing Units: 7K13, 12K13,19K13,7K15, 12K15, 19K15
For Anchorage: refer clause 7.2.6.4.3 and 16.8.3.4 of IRS: CBC.
Jacking Force shall be as per Clause 16.8.1 of IRS: CBC.
Transmission length of Pre-tensioned steel shall be as per §16.8.4.1 of IRS: CBC.

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Other Parameters

Sheathing: Corrugated HDPE Duct shall be used as per clause 7.2.6.4.2 of IRS: CBC.

Wobble /Curvature shall be as per clause 16.8.3 of IRS: CBC.

Maximum Slip at anchorage = 6mm (to be decided based on pre-stressing anchorage system adopted).

6.3 REINFORCEMENT STEEL (REBARS)

Reinforcement as per clause 4.5 of IRS: CBC shall be adopted.

6.4 STRUCTURAL STEEL FOR STEEL &COMPOSITE BRIDGES

Structural steel shall conform to IS: 2062.
Fabrication shall be done as per provisions of IRS B1 (Fabrication Code).
Design of Steel Structures shall be done as per IRS: Steel Bridge Codes.
IS codes shall be referred for steel RCC composite construction.
Welding shall be done following IRS: Steel Bridge Codes Provisions and submerged Arc welding (SAW) shall be done. Field welding shall not be done.

6.5 STRUCTURAL STEEL FOR MISCLLANEOUS USE

Design shall be done as per IS: 800 and related provisions.
Hollow steel sections for structural use shall be as per IS: 4923.
Steel tubes for structural purposes shall be as per IS: 1161.
Steel for general structural purposes shall be as per IS: 2062.

7.0 LOADS TO BE CONSIDERED FOR DESIGN

Followings are the various loads to be taken into consideration for analysis and design of structures as prescribed in IRS: Bridge Rules up to latest up-to-date correction slip.

7.1 DEAD LOAD

7.1.1 Self weight of structure (DL)

Dead load includes weight of structural component of bridge superstructure.

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7.1.2 Super Imposed Dead Load (SIDL)

The following items shall be considered as SIDL:

I. Rails + pads
II. Cable trough cell
III. Cable trays
IV. Hand Rail
V. Third Rail
VI. Miscellaneous (OCS, signaling)
VII. Cables
VIII. Parapet
IX. Plinths

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

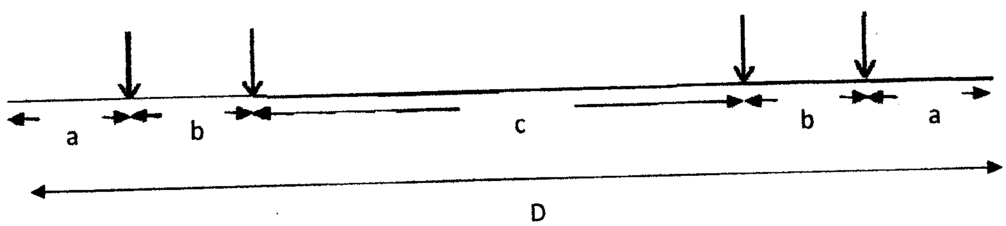
7.2 PRE-STRESS FORCE (PR)

The pre-stressing force calculation will be as per § 16.8 of IRS: CBC. The loss of pre-stress due to friction will be calculated as per § 16.8.3 of IRS: CBC. The loss of pre-stress, other than friction losses will be calculated as per § 16.8.2 of IRS: CBC.

7.3 LIVE LOAD (LL)

7.3.1 Railway Vehicular Load

Each component of the structure shall be designed / checked for all possible combinations of these loads and forces. They shall resist the effect of the worst combination of following coach dimension:



Maximum Axle load = 16 t

Maximum number of successive cars = 6

Where,
D = 22600 mm (Length of a car over coupler)

a = (balance)
b = 2200mm to 2400mm (Length of rigid wheel base for single bogie)
b + c = 14800 +/- 250 mm (Distance between bogie centres)

Based on these four combinations are done

Comb 1: b = 2200 mm and b + c = 14550 mm
Comb 2: b = 2200 mm and b + c = 15050 mm
Comb 3: b = 2400 mm and b + c = 14550 mm
Comb 4: b = 2400 mm and b + c = 15050 mm

Moving load analysis is done for all four combinations of axle spacing as mentioned above and envelope of forces viz., Bending moment and shear forces are found out. From this envelop, equivalent UDL for bending moment and shear forces is found out and tabulated below.

Where,
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 for bending moment for spans above 10m such that the bending moment due to EUDL at 1/6 of the span is equal to bending moment developed at the same section due to load train as defined above
EUDL (SF): The equivalent uniformly distributed load for shear force for spans such that the shear force due to EUDL at the support is equal to shear force developed at the same section due to load train defined above

EUDL for the Rolling Stock of MEGA is as under:

L (M)	EUDL (T)		LF (T)	
	SF	BM	TE	BF
11.5	75.337	71.28	12.8	11.52
13	83.522	73.818	12.8	11.52
14.5	89.719	81.078	12.8	11.52

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16	94.210	86.593	12.8	11.52
17.5	97.911	91.032	12.8	11.52
19	100.821	94.522	12.8	11.52
20.5	103.372	97.4	12.8	11.52
22	105.340	99.893	12.8	11.52
23.5	106.289	101.944	16.0	14.4
25	109.442	103.711	19.2	17.28
26.5	112.839	105.312	19.2	17.28
28	117.749	105.545	19.2	17.28
29.5	121.820	108.740	19.2	17.28
31	125.693	111.065	22.4	20.16
32.5	129.789	115.234	22.4	20.16
34	134.526	118.994	25.6	23.04
35.5	140.109	122.581	25.6	23.04
37	145.275	127.051	25.6	23.04
38.5	150.024	131.713	25.6	23.04
40	154.360	136.938	25.6	23.04

Notes

1. Effect of Dynamic augmentation needs to be considered separately.
2. Longitudinal forces need to be worked out considering LWR-RSI analysis as per clause 5.16 of model DBR.

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

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

7.3.2 Dynamic Augmentation

CDA for longitudinal and transverse analysis shall be as per IRS: Bridge Rules.

7.3.3 Braking and Traction (BR / TR)

The value of braking and traction forces will be taken as per rolling stock used, to be decided by MEGA. For twin tracked decks carrying traffic in opposite directions, considerations should be given to braking forces from one train and traction forces from another, acting simultaneously which will be maximum longitudinal loading on deck. For more than two tracks, Clause 2.8.4 of IRS: Bridge Rules shall be considered.

As per Clause 2.8.5 of IRS: Bride Rules, when considering seismic forces, in

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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.

7.3.4 Centrifugal Forces Due to Curvature of Superstructure

The horizontal centrifugal force due to moving load in curved superstructure is to be considered as per § 2.5 of IRS: Bridge Rules.

$$C = Wv^2/127R$$

Where W is axle load in kN, v is maximum design speed in km/h and R is radius of curvature in m. This force is assumed to act at a height of 1.80 m above rail top level.

7.3.5 Racking Force

The horizontal transverse loading due to racking specified in IRS: Bridge Rules § 2.9 is applicable to design of lateral bracing.

7.4 TEMPERATURE EFFECTS (TL)

7.4.1 General:

As per Clause 2.6 of IRS: Bridge Rules.

1). Overall Temperature (OT): As per Clause 215.2 of IRC: 6.

2). Differential Temperature (DT): As per IRC: 6.

3). Temperature gradient: As per Clause 215 of IRC: 6.

7.4.2 Resistance to movement of elastomeric bearings (BS)

Elastomeric bearing will resist movement/deformation of superstructure other than applied load i.e. due to variation of temperature/creep strain/shrinkage strain etc. The bearing resistance shall be calculated as per Clause 211.5.1.3 of IRC: 6-2014 duly ensuring provisions given in IRS: Bridge Rules.

7.4.3 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.

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

2. Software and general methodology to be used for carrying out Rail-Structure interaction analysis must be validated before adopting the same.
3. Representative stretches must be chosen for carrying out Rail-Structure interaction.
4. Checks must be performed for break in rail continuity due to unusual conditions like fractures or for maintenance purposes.
5. RDSO Guidelines for carrying out RSI studies shall be referred.
6. LWR forces shall be considered in appropriate load combination as per IRS: CBC.

7.5 EMERGENCY WALKWAY (LFP)

The layout of walkway shall be as per approved SOD of MEGA.

7.6 WIND LOAD (WL)

The wind load shall be calculated as per § 2.11 of IRS: Bridge Rules and IS: 875 (Part 3).

7.7 SEISMIC FORCE (EQ)

Seismic analysis of viaducts will be conducted as per "RDSO Guidelines on Seismic Design of Railway Bridges-Jan 2015" (These guidelines also cover load combinations and ductile detailing aspects).

7.8 ERECTION TEMPORARY LOADS (ETL)

Erection forces and effects shall be considered as per clause 2.13 of IRS: Bridge Rules. The weight of all permanent and temporary material together with all other forces and effects which can operate on any part of during erection shall be taken into account

7.9 DERAILMENT LOADS (DR)

The derailment load shall be as per Appendix-XXV of IRS: Bridge Rules with

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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.

7.10 FORCES ON PARAPET

The parapets shall be designed to resist lateral horizontal force & a vertical force of 1.50kN/m applied simultaneously at the top of the parapet as per § 2.10 of IRS: Bridge Rules. Additional noise barrier In addition to above aerodynamic actions from passing of train shall be taken into account based on the design speed of the train, aerodynamic shape of the train, the shape of parapet structure and the position of parapet structure.

7.11 DIFFERENTIAL SETTLEMENT (DS)

Differential Settlement between two adjacent viaduct piers shall be as follows

- 12 mm for Long Term Settlement;
- 6 mm for Short Term Settlement

The allowable settlement for pile group is 25mm (as per IS:2911-Part 4), hence differential settlement between two foundations is considered as half of 25mm i.e. 12mm as long term settlement. The short term settlement of 6mm is considered to cater for bearing replacement condition.

Differential settlement shall be considered only in the design of continuous structures, if any.

7.12 BUOYANCY LOADS

Clause 5.10 of IRS: substructure and foundation shall be considered for evaluating effect of buoyancy for submerged part of structure under water.

7.13 VEHICLE COLLISION LOAD (VCL)

The vehicle collision load shall be considered as per clause 222 of IRC: 6-2014.

7.14 GRADIENT EFFECT

The load due to longitudinal gradient effect shall be considered as applicable.

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7.15 BUFFER LOAD

The buffer load shall be considered as applicable.

7.16 VIBRATION EFFECT

The vibration effect shall also be considered as applicable.

7.17 SHRINKAGE AND CREEP

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

7.18 FOOTPATH LIVE LOAD

As per clause 2.3.2 of IRS Bridge Rule.

8.0 LOAD COMBINATIONS

8.1 ELEMENTARY LOADS DEFINITION

Elementary loads taken into account are:

Elementary load			
Dead Load			DL
Super Imposed Loads			SIDL
Shrinkage & Creep			SC
Prestress			PS
Live load	LL	Train Weight	TW
		Dynamic Impact	I
		Force due to curvature or Transverse eccentricity	CF
		Longitudinal Force (tractive, Braking)	LF
	Live Load on Foot Path* When Live load on Foot path is considered then No CDA shall be applied on Train Live Load to account for Stationary train under emergency condition.		LFP
Overall temperature effect			OT
Differential Temperature			DT
Long welded rail forces			LR
Racking forces			RF
Forces on parapets			PP
Wind pressure effect :	WL	Longitudinal Direction	WL x
		Transverse Direction	WL z

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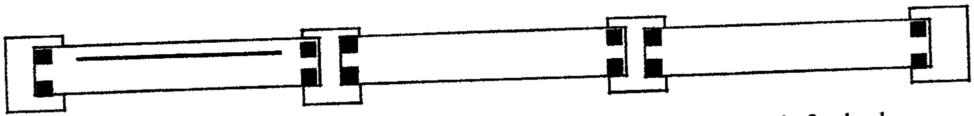
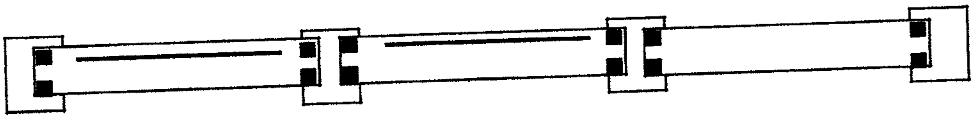
Earthquake	EQ	Longitudinal direction	EQ X
		Transverse direction	EQ z
		Vertical direction	EQ Y
Buoyancy			B
Differential settlement			DS
Derailment Load			DR
Frictional Restraint			FR

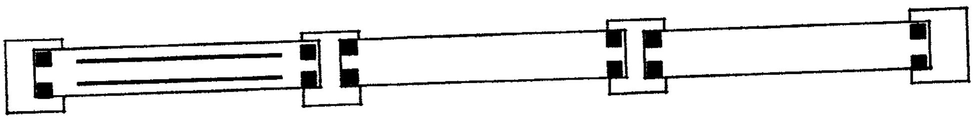
The analysis and design will be carried out for all possible cases of rolling train loads. All the supporting structures, such as superstructure, bearings, substructure and foundations shall be checked for the most onerous cases.



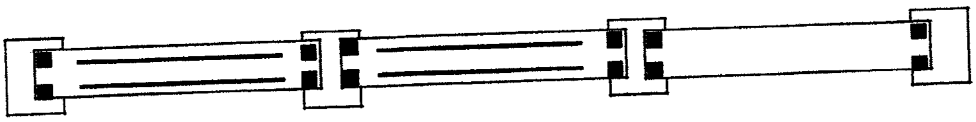
LL1: Used for Deck Torsion, Bearing Compression, Uplift check, Shaft check, Foundation check



LL2: Used for Shaft check, Foundation check



LL3: Used for Deck check, Bearing Compression check, Shaft check, Foundation check



LL4: Used for shaft check, Foundation check, Shear Key check

8.2 LOAD COMBINATIONS METHODOLOGY

The ULS and SLS load combinations and partial safety factors for loads should be followed as per clause 11.2, clause 11.3 and Table 12 of IRS: CBC.

In lieu of combinations-2 of clause 11.0 and Table-12 of IRS:CBC, All structural

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elements shall be checked for Ultimate limit state and Serviceability limit state load Combinations as defined in clause 6.7 of "RDSO Guidelines on Seismic Design of Railway Bridges-Jan 2015".

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.

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

9.0 DESIGN CHECK FOR CONCRETE STRUCTURE

9.1 ALLOWABLE STRESSES FOR CONCRETE AT SERVICEABILITY LIMIT STATE

The stresses at transfer, construction stage and during service for prestressed cast in situ and segmental construction shall be as per clause 16.4.2.2 (Concrete Compressive stress Limitations), 16.4.2.3 (Steel stress Limitations), 16.4.2.4(Cracking), 17.3.3(Other types of Connections) and 17.4 (Composite Concrete Constructions) of IRS: CBC. However for precast segmental construction, no tensile stress shall be permitted at transfer and during construction.

Clause 10.2(Serviceability Limit States) of IRS: CBC shall be used for RCC construction (Beams, columns and slabs).

9.2 ULS CHECK FOR PRESTRESSED CAST-IN SITU CONCRETE/COMPOSITE CONSTRUCTION

Clause 16.4.3 (Ultimate Limit State: Flexure) to clause 16.4.6 (Longitudinal shear) of IRS: CBC shall be applicable for cast-in situ Prestressed construction whereas for composite construction clause 17.4 (Composite Concrete Constructions) shall be used.

9.3 ULS CHECK FOR RCC STRUCTURE

As per IRS: CBC.

10.0 DURABILITY & CRACK WIDTH

10.1 DURABILITY

Provision of clause 5.4 of IRS: CBC shall be followed.

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10.2 CONCRETE COVER

The cover should be as per clause 15.9.2 of IRS: CBC.

10.3 CRACK WIDTH CHECK

For SLS Combination GI, crack width in reinforced concrete members shall be calculated as per clause 15.9.8.2.1 of IRS: CBC.

The allowable crack width should be as per clause 10.2.1(a) based on the exposure condition defined in clause 5.4.1 of IRS: CBC and table-10 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. 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.

11.0 FATIGUE

11.1 GENERAL

Fatigue phenomenon shall be analyzed only for those structural elements that are subjected to repetition of significant stress variation (under traffic load). Thus generally the fatigue shall be regarded only for deck structural part supporting the tracks.

11.2 PRESTRESSED CONCRETE STRUCTURES

The fatigue shall be checked as per clause 13.4 of IRS: CBC.

11.3 REINFORCED CONCRETE STRUCTURES

The fatigue shall be checked as per clause 13.4 of IRS: CBC.

11.4 STEEL STRUCTURES

Clause 3.6 of IRS: Steel Bridge Code / clause 13.2 of IRS: welded 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.

12.0 FOUNDATIONS

(i) IRS: Bridge substructures and foundation code shall be followed for design of Foundations.

(ii) Pile Foundation

For Piles and pile caps, load combinations shall be considered as per IRS: CBC, Table 12. The various specific assumptions made for the pile and pile cap design including pile load testing shall be as per IS: 2911 and IRS: Bridge substructures and Foundation codes.

(iii) Soil structure Analysis

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

13.0 PILE CAP

It is incorporated in clause 12.0.

14.0 PIER CAP & PIER

For designing the pier cap as corbel the provisions of clause 17.2.3 of IRS: CBC shall be followed. In case of shear span to effective depth ratio being more than 0.6, pier cap will be designed as flexural members.

The effective length of a cantilever pier for the purpose of slenderness ratio calculations shall be done as per IRS: CBC.

15.0 PIER CAP

It is incorporated in clause 14.0.

16.0 BEARING SYSTEM AND ITS DESIGN METHODOLOGY

16.1 BEARING SYSTEM

Considering the span configuration and safety aspects of the structural system (in normal and seismic condition), it is proposed to adopt laminated elastomeric bearings placed underneath the Box-girder/ PSC-girders for transfer of vertical forces and a reaction block (protruding above the pier head) for transfer of in-plane forces. The elastomeric bearing shall be designed as per EN 1337 Part 1 and Part-3 along with IRC: 83 Part-II. Wherever EN code is not clear UIC 772 – 2R and along with IRC: 83 Part-II shall be followed.

POT cum PTFE or Spherical bearings may be provided if elastomeric bearings are not possible to design for special spans. POT-PTFE and spherical bearing shall be designed as per IRC: 83 Part-III 2002 and IRC: 83 Part-IV 2014 respectively.

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16.2 REPLACEABILITY OF BEARINGS

While finalizing the proposed bearing system, it shall be kept in mind that accessibility and replacement of each part of bearing are of paramount importance as the design life of bearings is shorter than that of the structure. Keeping in view the above cited criteria, all the bearings and pier caps will be detailed for replacement of bearings in the future.

Special Low Height jacks shall be employed to replace bearings, if minimum vertical clearance is less than 400mm as stipulated in clause 15.9.11.3 and 15.9.11.4 of IRS: CBC.

16.3 UPLIFT

If required, a holding-down device connecting the deck and the pier head shall be placed in order to prevent the deck from overturning. The holding-down device may be integrated in the pot-bearing system or be a separate system constituted of bars embedded in pier cap and viaduct with appropriate details, permitting translation/rotation. Other systems can also be foreseen.

Due to the lack of appropriate guidelines in Indian codes, the design criteria for holding down device (upward force limit requiring holding down device, design formulas) will be taken from the latest international practice (AASHTO, MOTC codes).

17.0 SUPERSTRUCTURE SYSTEM OF VIADUCT

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

However at crossovers / turnouts / railway crossings/ highway crossings, precast prestressed I-girder (pre/post tensioned) / steel girder with cast in situ slab concrete deck composite superstructure / voided slab units have been proposed.

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

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

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18.0 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 Clauses 10.4.1.1 & 15.2.2 of IRS: CBC shall be followed.

Solid Pier

The drain pipe of double wall HDPE corrugated pipes with water collection box at top which will be located within the solid pier to avoid unpleasant aesthetics.

Deck

The top of soffit slab will be profiled so as to collect the run-off water at multiple points by providing a cross slope of 2.5%. Drainage pipes will be provided to collect the runoff.

19.0 LIST OF DESIGN CODES AND STANDARDS, APPLICABILITY

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, wherever, applicable. If provisions are not available in IRS, the order of preference shall be as follows, unless specified otherwise:

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. AASHTO

19.1 IRS CODES (WITH LATEST VERSIONS)

IRS Bridge Rules

IRS Concrete Bridge Code

IRS Bridge substructure & Foundation Code

IRC Steel Bridge Code

IRS Fabrication Code (B1) IRS Welded Bridge Code

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RDSO Guidelines on Seismic Design of Railway Bridges-

January 2015

19.2 IRC CODES (WITH LATEST VERSIONS)

IRC: 5 Standard Specification & Code of Practice for Road Bridges – General Features of Designs

IRC: 6 Standard Specification & Code of Practice for Road Bridges – Loads and Stresses

IRC: 18 Design Criteria for Pre-stressed Concrete Road Bridges (Post Tensioned Concrete)

IRC: 21Standard Specification & Code Of Practice For Road Bridges -Cement Concrete (Plain &Reinforcement.)

IRC: 22 Standard Specification & Code of Practice for Road Bridges, Section VI – Composite Construction for Road Bridges --Cement Concrete (Plain &Reinforcement.)

IRC: 24 Standard Specification & Code of Practice for Road Bridges, Section V –Steel Road Bridges

IRC:78Standard Specification & Code of Practice for Road Bridges – Section Foundations & Sub-structure

IRC: 83(I)Standard Specification & Code of Practice for Road Bridges, Part-I Metallic Bearings

IRC: 83(II) Standard Specification & Code of Practice for Road Bridges, Part-II Elastomeric Bearings

IRC: 83(III) Standard Specification & Code of Practice for Road Bridges, Part-III POT, POT-cum-PTFE, Pin and Metallic Guide Bearings

IRC 83(IV) Standard Specification and Code for practice of road bridges, Part IV: Spherical and Cylindrical Bearings.

IRC: 112Code of Practice for Concrete Bridges

IRC- Sp-71 Guidelines for Design and Construction of Pre-cast Pre-Tensioned Girders for bridges

19.3 IS CODES (WITH LATEST VERSIONS)

IS:269	Specs for Ordinary and Low Heat Portland Cement
IS:383	Specs for coarse and fine aggregate from natural sources for concrete
IS:432	Specs for Mild steel & medium tensile steel-bars (Part 1)
IS:456	Plain and reinforced concrete - code of practice

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IS:800	Code of Practice for General construction in steel
IS:875	Code of Practice for Design Loads Parts 1, 2, 3, 4 & 5 (Other than Earthquake) for Building and structures
IS:1080	Design and Construction of shallow foundations in soils (Other than Raft, Ring & Shell)
IS:1343	Code of Practice for Pre-stressed Concrete -based essentially on CP-110
IS:1364	Hexagon Head Bolts, screws & nuts of product grades A & B Part 1 (Part 1 Hexagon Head Bolts (size range M1:6 to M64)
IS: 13920	Ductile Detailing of Reinforced concrete structures subjected to seismic structures code of practice
IS:1489	Specifications for Portland Pozzolana Cement (Fly ash based)
IS:1786	High Strength Deformed steel bars and wires for concrete reinforcement
IS:1893	Criteria for Earthquake Resistant Design of structures
IS:1904	Design and Construction of Foundation in soils General Requirements
IS:1905	Code of Practice for Structural Use of Un-reinforced Masonry
IS:2062	Specifications for Weldable structural steel
IS:2502	Code of Practice for Bending and Fixing of Bars for Concrete Reinforcement
IS:2911	Code of Practice for Design & Constr. of Pile Foundations Part 1
(Part 1/Sec2)	Concrete Piles Section 2 Bored Cast-in-situ Piles (with amendments)
IS:2911	Code of Practice for Design & Constr. of Pile Foundations Part 4 Load test on Piles
IS:2950	Designs and Construction of Raft Foundations
IS:3935	Code of Practice for Composite Construction
IS:4326	Code of Practice for Earthquake Resistant Design and construction of Buildings
IS:4923	Hollow steel sections for structural use -specification
IS:8009	Calculation of settlement of shallow foundations
IS:8112	Specifications for 43 Grade Ordinary Portland cement
IS:8500	Structural Steel -Micro alloyed (Medium and high strength quantities)
IS:9103	Specifications for 53 Grade Ordinary Portland cement
IS:11384	Code of Practice for Composite Construction in Structural Steel and Concrete
IS:12070	Code of Practice for Design and Construction of Shallow Foundations on Rocks
IS:12269	Specifications for 53 Grade Ordinary Portland cement
IS:14268	Uncoated Stress Relieved Low relaxation Seven-ply Strands for pre

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	stressed Concrete
IS:14593	Design and Construction of Bored Cast-in-Situ Piles Founded on Rocks

19.4 BS Codes (WITH LATEST VERSIONS)

BS: 4447	Specifications for the performance of prestressing anchorage for post-tensioned concrete.
BS: 4486	Specifications for high tensile bars used for prestressing.
BS: 5400	Code of Practice for Design of Concrete Bridges Part 4-1990.
BS: 5400	Code of Practice for Fatigue Part 10-1990.
BS: 8006	Code of Practice for strengthened reinforced soils and other fills - 1995.
BS: 8007	Design of concrete structures for retaining liquids.

19.5 OTHERS (WITH LATEST VERSIONS)

UIC 776-1R Loads to Consider In Railway Bridge Design

UIC 776-3R Deformation of Bridges

UIC 772- 2R The International Union of Railway Publication

UIC 774 – 3R Rail Structure Interaction

CEB-FIB Model Code 1990 for concrete structures.

The design relating to Fire safety and escape shall be in accordance with the requirements of NFPA 130 standard for fixed guide way system.

FIP Recommendations for the Acceptance of Post-Tensioning Systems

M.O.R.T & Highway Specifications

Eurocode 0 Basis of Structural Design

Eurocode 1 Actions on Structures-Part2: Traffic Loads On bridges

Eurocode 2 Design of Concrete Structures – Part1-1 General Rules and Rules for Building

Eurocode 2 Design of Concrete Structures-Part 2 Concrete Bridges- Design and Detailing Rules

ACI 358.1R-92 (American Concrete Institute) for assessment of dynamic impact for transit Guide ways.
RDSO guidelines for carrying out RSI (Version 2.0) issued in January 2015
BS – 111 version-3 issued in January 2015

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