GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS
(RAILWAY BOARD)

2019/JV Cell/K-RIDE/BSTP/EBR/07(Part) New Delhi, dated 25.08.2021

Managing Director,
Rail Infrastructure Development Company (Karnataka) Limited,
(K-RIDE), MSIL house, 7th Floor,
#36, Cunningham Road,
Bangalore-560052

Sub: Approval of Design Basis Reports (DBRs) for 'Bengaluru Sub-Urban Rail Project' (BSRP) of Rail Infrastructure Development Company (Karnataka) Limited (K-RIDE).
Ref:- K-RIDE's DBR uploaded on RDSO's Online Portal on 30/07/2021

The Design Basis Reports (DBRs) for Elevated Stations and Viaduct (July, 2021) for 'Bengaluru Sub-Urban Rail Project' (BSRP) of Rail Infrastructure Development Company (Karnataka) Limited (K-RIDE) has been examined in consultation with RDSO and approval of Railway Board is hereby conveyed for the same.

Accordingly, approved copies of DBRs are enclosed.

Encl: As above

25/08/2021
(D.K Mishra)
Director/MTP
Railway Board
☎ 011-23097061

Copy to: **Executive Director/UTHS**, RDSO, Manak Nagar, Lucknow w.r.t RDSO's letter No. UTHS/BSRC/K-RIDE/P01/052021 dated 03.08.2021

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K RIDE

RAIL INFRASTRUCTURE DEVELOPMENT COMPANY (KARNATAKA) LIMITED

(K-RIDE)

BENGALURU SUB-URBAN RAIL PROJECT

(BSRP)

DESIGN BASIS REPORT

For

ELEVATED STATION

(July – 2021)

Examined & found in order

BSRP-DBR – ELEVATED STATIONS

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1. INTRODUCTION

1.1. Brief description of Stations and salient features.

S. NO	ITEM DESCRIPTION	CORRIDOR 1	CORRIDOR 2	CORRIDOR 3		CORRIDOR 4
		KSR Bengaluru City to Devanahalli	Baiyyappanahalli Terminal to Chikkabanavara	Kengeri to Cantonment	Cantonment to Whitefield	Heelalige to Rajankunte
1.	No. of Elevated stations	8 (including one future station)	6	4	-	4
2.	No. of At-Grade stations	7	8 (including one future station)	5 (including one future station)	5	15 (including two future stations)
3.	No. of stations repeated	1 (with corridor 3)	2 (with corridor 1)	0	-	1 (with corridor 1)
3.	No. of Interchange stations	3	2	1	-	1

1.1.1. The stations are divided into public and non-public areas (those areas where access is restricted). The public areas are further subdivided into paid and unpaid areas.

1.1.2. The platform level has adequate assembly space for passengers for both normal operating conditions and a recognized abnormal scenario.

1.1.3. The concourse contains automatic fare collection system in a manner that divides the concourse into distinct areas. The 'unpaid area' is where passengers gain access to the system, obtain travel information and purchase tickets. On passing through the ticket gates, the passenger enters the 'paid area', which includes access to the platforms.

1.1.4. The arrangement of the concourse is assessed on a station-by-station basis and is determined by site constraints and passenger access requirements. However, it is planned in such a way that maximum surveillance can be achieved by the ticket hall supervisor over ticket machines, automatic fare collection (AFC) gates, stairs and escalators. Ticket machines and AFC gates are positioned to minimize cross flows of passengers and provide adequate circulation space.

1.1.5. Sufficient space for queuing and passenger flow has been allowed at the ticketing gates.

1.1.6. Station entrances are located with particular reference to passenger catchment points and physical site constraints.

1.1.7. The DG set, bore well pump houses and ground tank would be located generally in one area on ground.

1.2. Scope of DBR

The object of this Design Basis Document is to establish a common procedure for the design of "Elevated Metro Stations of BSRP". This is meant to serve as a guide to the designer but compliance with the rules there-in does not relieve them in any way of their responsibility for the stability and soundness of the structure designed. The design of Elevated Metro Stations requires an extensive and thorough knowledge and entrusted to only to specially qualified engineers with adequate practical experience in structure designs.

Design basis report (DBR) of viaduct shall be followed for following structures/elements of station:

- For single pier station.
- Structural elements which support metro live loads.

This design basis report is applicable for following structures/structural elements:

- Structural elements of station which do not support metro live loads.
- Ancillary structures

Prestressed concrete structures shall be designed as per IS: 1343. RCC Structures shall be designed by IS: 456. Steel structure design shall be designed by IS: 800. Seismic design shall generally be governed by IS: 1893.

1.3. Units:

The main units used for design will be: [m], [mm], [t], [kN], [kN/m2], [MPa], [°C], [rad].

2. PROPOSED DESIGN SPECIFICATIONF OR 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. For PSC structures Cl. 5.1 of IS: 1343 shall be used.

2.1.2. Concrete

As per Cl. 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.*

Density of concrete

- Density of concrete is as per IS : 456
- 25 kN/m3 for Reinforced concrete & Prestressed concrete
- 24 kN/m3 for Plain concrete
- 26 kN/m3 for wet concrete

2.1.3. Prestressing steel for tendons

As per Cl. 5.6.1 of IS: 1343.

I. Young's Modulus

As per Cl. 5.6 of IS: 1343.

II. Prestressing Units

As per Cl. 13 of IS: 1343.

III. Maximum initial Prestress

As per Cl. 19.5.1 of IS: 1343.

IV. Density:

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For density of strands and all other materials, the densities shall be considered as per relevant IS Codes as indicated in para 2.1.3 above.

V. Sheathing

As per Cl. 12.2 of IS: 1343.

2.1.4. **Structural Steel**

Structural steel used shall confirm to following:

a) Hollow steel sections as per IS: 4923

b) Steel for general Structural Purpose as per IS: 2062

c) Steel tubes for structural purpose 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 (II) and (III) below.

II. Design of steel structure will be governed by IRS steel bridge rule in case of structure is taking loads of Metro, otherwise, by IS 800. In case of composite (steel concrete) structure it will be governed by IS: 11384 & IS: 3935.

III. Fabrication shall be done in accordance with IS: 800.

Tensile Strength / Yield Strength

Structural steel conforming to IS: 2062 shall be adopted.

Welding shall be done as relevant IS codes for welding.

Grade#	Tensile Strength (Mpa)	Yield Stress (Mpa)		
		t<20	t=20-40	t>40
E250 B0	410	250	240	230
E350 B0	490	350	330	320
E450 B0	570	450	430	420

Where, t = thickness of steel members

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- Young's Modulus shall be taken as 20,000kg/mm^2 as per Clause 2.2.4 of IS: 800
- Density: 7850 kg/m^3 as per clause 2.2.4 of IS: 800
- Poisson's Ratio: 0.30 as per clause 2.2.4 of IS: 800
- Thermal Expansion Coefficient: 12x10-6 as per clause 2.2.4 of IS: 800

2.1.5. Reinforcement Steel (Rebars)

As per Cl. 5.6 of IS: 456 for Plain and Reinforced concreter structures and as per Cl.5.6.2 of IS: 1343 for prestressed concrete structures.

Note: HYSD steel bars having minimum elongation of 14.5% and confirming to requirements of IS: 1786 shall be used.

2.1.6. Reinforcement Detailing

All reinforcement shall be detailed in accordance with Cl. 12 & 26 of IS: 456 & SP: 34 for plain and reinforced concrete structures and as per Cl. 12.3 & 19.6.3 of IS: 1343 for PSC structures.

The 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 Cl. 8 of IS: 456 for Plain & RCC, as per Cl. 8 of IS: 1343 for PSC elements and as per "section 15 " of IS: 800 for steel structures.

For foundation & pier design, the exposure condition is Moderate. And in case of Nallah crossing, the exposure condition may be treated as "Severe".

2.2.1. Concrete Grades:

The minimum grade of concrete shall be as per IS: 456 for Plain and RCC structures and IS: 1343 for PSC structures.

2.2.2. Cover to Reinforcement:

As per Cl. 26.4 of IS: 456 for Plain and RCC structures and Cl. 12.3.2 of IS: 1343 for PSC structures. Cover to Prestressing steel shall be in accordance with Cl. 12.1.6 of IS: 1343.For the Pile foundations, cover shall be taken as 75mm for all exposure conditions

2.2.3. Fire Resistance Period

All the structural elements shall be designed for minimum period of fire resistant of 2 hours. The minimum element thickness for fire resistance shall be as per Cl. 21of 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 Cl. 35.3.2 and 43 of IS: 456 for Plain and RCC structures and Cl. 20.3.2 & 24.2 of IS: 1343 for PSC 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. **Clearance for Metro Traffic:** The clearances to railway traffic shall comply with the BSRP Schedule of Dimensions (SOD).

IV. **For Utility Services**: The clearances to utilities, drainage etc. shall be as mandated by the utility owner/department.

2.4. DESIGN LOAD

Load	Abbreviations
Dead load	DL
Super imposed dead load (Fixed)	SIDL
Live Load	LL
Earthquake Load	EQ
Wind Load	WL
Collision/Impact loads/ Derailment load	CL
Construction and Erection loads	EL
Temperature Load	TL
Shrinkage	S

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Creep	C
Earth Pressure & Water pressure	EP & WP
Water Pressure	WP
Surcharge Load	SL
Pre-stressing force.	PS
Long Welded rail Force	LWR
Differential settlement	DS

2.4.1. Dead Load (DL)

Dead load shall be based on the actual cross-sectional area and unit weights of materials and shall include the weight of structural members of the station building.

2.4.2. Super Imposed Dead Load For Non-Track Area (SIDL)

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

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

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

FIXED SIDL (SIDL)

For platform slabs, the following loads in SIDL will be taken

1. Floor finishes is assumed to be a 3.6 kN/m2 uniform load as per architectural requirement.
2. Suspension load is assumed to be 2.0 kN/m2 uniform load (Suspension load will be considered as the load of false ceiling and services. This load will be considered

3. where ever is applicable.
4. Light partition wall load is assumed to be 1.0 kN/m2 uniform load.

For concourse area, the following loads in SIDL will be considered.

1. Floor finishes is assumed to be a 3.6 kN/m2 uniform load as per architectural requirement.
2. Load due to additional fill in the toilets (brick bat) shall be considered as per architectural drawing.
3. Suspension load is assumed to be 2.0 kN/m2 uniform load (Suspension load will be
4. considered as the load of false ceiling and services. This load will be considered where ever is applicable.
5. Loads due to escalator / lift will be considered as per manufacturer's detail.
6. Light partition wall load should be taken as minimum 1.0 kN/m2 at concourse.
7. Loads due to Platform screen door (PSD) shall be considered as per actual.
8. Loads due to solar panel shall be considered as 30 kg/m2.
9. SIDL for Technical Room shall be as follows:
   a) UPS Room* : 25** kN/m^2
   b) ASS room* : 15** kN/m^2
   c) Other Technical Room* : 10** kN/m^2

*This should be verified with actual load and its location.

** Values are minimum load to be considered in design. Actual loads will be calculated on the basis of equipment & machinery which have to be installed at detail design stage. The concentrated load of 40kN for ASS/UPS room and 20kN for other technical room shall also be considered in design.

Note:

The walls loading will be taken based on actual location shown in architectural drawings. External wall load/glazing load will be taken as per details provided in architectural drawings. It is proposed to take 230 mm thick brick wall with 20 mm thick plaster on either side. However, the same shall not be taken less than 2.4 kN/m^2.

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Above loads intensities are minimum loads to be considered in design, Actual load may be higher as per detailed architectural drawings.

2.4.3. Imposed (Crowd Live) loads (LL)

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

Location	Distributed load (kN/m^2)	Concentrated load (kN)
Public/Staff Room		
Concourse Floor	5	4.5
Staircase area	5	4.5
Platform	5	4.5
Office Accommodation	5	4.5
Shop	5	4.5
Foot over Bridge (FOB)	5	4.5

2.4.4. Earthquake Loads (EQ)

- Earthquake design shall follow the seismic requirement of IS: 1893 (Part1)
- The provisions of DBR for viaduct of Metro system shall be followed where structures are taking moving loads of Metro.

Horizontal Seismic Coefficient- The horizontal seismic design coefficient shall be calculated as per following expression

$$A_h = (Z/2) * (I/R) * (Sa/g)$$

Where,

A_h = horizontal seismic coefficient to be considered in design

Z = peak ground acceleration or zone factor = 0.24

I = importance factor = 1.5

R = response modification factor = 5

Sa/g = normalized pseudo spectral acceleration for corresponding

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to relevant damping of load resisting elements (pier/columns) depending upon the fundamental period of vibration T

Damping factor = 5% for RCC structures

Damping factor = 2% for steel structures

I. Drift Limitations

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

II. Seismic detailing

a) For RCC structures as per IS: 13920
b) For other structures as per IS: 4326

2.4.5. Wind Loads (WL)

Calculation of Wind load is based on IS-875 (part 3) -2015 or Latest.

The design wind speed at height z is considered as follow:

Vz = Vb. K1. K2. K3

Vb (m/s): Regional basic wind speed, taken 33 m/s for Bengaluru.

K1: Probability factor, considered 1.07

K2: Terrain height and structure size factor, considered 0.84

K3: Topography factor, considered 1.00

Thus **Vz = 33* 1.07*0.84*1 = 29.66 m/s**.

The design wind pressure is calculated as below:

Pz = 0.6*(Vz) 2 = 0.527kN/m2

For unloaded structures (no Live Load on deck), an amplification factor of 1.5 is applied on wind load s per Bridge Rule.

Design wind pressure, $P_d = P_z * K_d * K_a * K_c$ = wind directionality factor, pg.9 / 10

K_d = wind directionality factor, page 9 / 10 of IS: 875-3-2015 = 0.9 for buildings

K_a = area averaging factor, pg.9/10 = 0.8 Table 4 (for contributory area > 100 m^2)

Kc =combination factor, pg. 9/10 = 0.9 Cl. 7.3.3.13 of IS: 875-2015, Page 16

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2.4.6. **Collision and impact loads/ derailment loads.**

I. For road traffic as per IRC 6.

II. For Metro as per IRS bridge rule.

2.4.7. **Construction and Erection Loads (ER)**

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

2.4.8. **Temperature Load (TL)**

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

2.4.9. **Shrinkage**

Shrinkage strain shall be evaluated as Cl. 6.2.4 of IS: 456 for plain and RCC structures and Cl. 6.2.4 of IS: 1343 for prestressed concrete structures.

For structure supporting metro loadings the effects of creep is as per Cl 5.2.3of IRS CBC shall be considered.

2.4.10. **Creep**

Creep strain shall be evaluated as per Cl. 6.2.5 of IS: 456 for plain and RCC structures and Cl. 6.2.5 of IS: 1343 for prestressed concrete structures.

2.4.11. **Earth Pressure (EP) & Water pressure (WP)**

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

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

If any of the structure supporting metro building is subjected to earth pressure, the loads and effects shall be calculated accordance with 5.7 of IRS substructure code.

2.4.12. **Surcharge Load (SL)**

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

2.4.13. **Prestressing force (PS)**

The prestressing force should be as per IS: 1343.

2.4.14. **Long welded rail force**

Long welded rail force shall be specified by metro duly supported by either codal provision or calculation, if RSI analysis is not practicable.

2.4.15. **Settlement (DS)**

Maximum and differential settlement shall not exceed, as provided in Table 1 of IS: 1904. The allowable settlement for pile group is 25mm (as per IS 2911-part 4);

2.4.16. **Other Forces and Effects**

As per Cl. 19.6 of IS: 456

2.5. LOAD COMBINATIONS

2.5.1. Ultimate load combinations.

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

Following shall be considered.

I. For plain and RCC structures / elements, shall be as per Table 18 of IS: 456

II. For PSC elements, the load combinations shall be as per table 7 of IS: 1343.

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III. For steel structures, the load combinations shall be as per IS: 800.

IV. Load combinations as per 6.3 of IS: 1893-1

V. Load combination as per IRS CBC and RDSO guidelines for seismic design of railway bridges where Metro live loads are applicable.

Note:

1. Load combination for construction loads case shall be decided by metro as per methodology of construction.
2. Reference of IRC: 6 be taken for collision case if collision of road vehicles are involved.
3.

Table 18: values of partial factor for loads						
Load combination	Limit state of collapse			Limit state of serviceability		
	DL	LL	WL	DL	LL	WL
DL+LL	1.5	1.5	1.0	1.0	1.0	
DL+WL	1.5		1.5	1.0		1.0
DL+LL+WL	1.2	1.2	1.2	1.0	0.8	0.8
1. While considering earthquake effects, substitute EL for WL						
2. For the limit states of serviceability, the values of factor given in this table are applicable for short term effects. While ascertaining long term effects due to creep the dead load and part of live load likely to be permanent may be considered						
3. This value is to be considered when suitability against overturning or stress reversal is critical						
4. DL- dead load, LL live load, WL- wind load, EL earthquake load.						

2.5.2. Serviceability load combination:

The following load combination and load factor shall be used for design for serviceability limit stage

i. For plain and RCC structures / elements, shall be as per Table 18 of IS: 456

ii. For PSC elements, the load combinations shall be as per table 7 of IS: 1343.

iii. For steel structures, the load combinations shall be as per section 3 and section 5 of IS: 800.

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iv. Load combinations as per IRS CBC where metro live loads are applicable.

2.6. DEFLECTION CRITERIA

The deflection limitations as per Cl. 23.2 of IS: 456 for Plain and RCC Structures and Cl. 20.3.1 if IS: 1343 for PSC structures shall be followed.

2.6.1. Lateral Sway

The lateral sway at the top of the building due to wind loads should not exceeds 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 checks for:

I. R CC 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 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. FOUNDATION SYSTEM

2.8.1. Type of foundation:

Considering the nature of ground, type of proposed structure, expected loads on foundation, the following type of foundations are considered practical:

a. Spread or pad footing
b. Raft Foundation
c. Pile foundation

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

1. Foundation must not fail in shear

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2. Foundation must not settle by more than the settlements permitted as per table-1 of IS: 1904.

2.8.2. Design of Pile Foundation

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

Theoretical estimation of settlement for deep foundation shall be done in accordance with **IS: 8009-Part-2.**

Pile settlement

Method of estimating the settlement of deep foundations depends upon the type of deep foundation and 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 section 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 foundation.

2.8.3. Shallow foundation:

IS 1904 shall be followed for design of foundation in soil.

The safe bearing capacity for Shallow foundation shall be calculated in accordance with IS: 6403.

Calculation of settlements shall be done as per **IS: 8009-Part-1.**

2.9. DESIGN OF WATER RETAINING STRUCTURES

The underground tank in a station shall be designed as a water retaining structure based on IS: 3370. Various types of loadings shall be considered in the design of the underground tank. The side walls shall be subjected to earth pressure. The water table being high in the area, horizontal pressure due to it shall also be considered. Stability of water tank shall be checked against buoyancy and foundation raft shall be designed for the worst of buoyant force and soil pressure. The tank shall also be designed for surcharge loading if any. Water proofing treatment shall be done on the external surface as well as in the internal surface.

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2.9.1. Masonry walls

All Masonry walls shall be treated as non-structural infill panels and shall be treated as one way / two-way slab panels spanning between adjoining beams and columns to check structural safety. Masonry walls shall be designed as un-reinforced masonry as per IS: 1905 and IS: 4326. Shear connector reinforcement between walls & upper beams and walls & sides of columns shall be provided for external walls, while the internal partition walls shall be connected with roof slabs/beams using dry packing mortar between top of walls and soffit of slab / beam.

2.9.2. Design ground water table

The Ground water table (Base value) shall be considered as maximum (in terms of RL) of Ground water table data published by

- Central Ground water board (CGWB)/ State authority,
- Ground water table reported in Geotechnical report provided by BSRP in tender documents,
- Ground water table reported in Geotechnical report provided by Design & Build contractor.

The design Ground water table shall be taken as 2.0m higher than the Base value for evaluation of effects for design purposes.

2.9.3. Liquefaction

Liquefaction shall be considered as per IS 1893-Part-1. The design Ground water table shall be used for liquefaction potential calculation. The Moment Magnitude Mw to be taken in design shall be 7.0. The factor of safety shall be more than 1.0 to ascertain that the strata are not liquefiable.

2.9.4. Soil parameters

The values of soil strength parameters (c, ϕ. etc.) to be used for design purposes shall be lesser of the following:

1. As per soil investigation report in the tender document.
2. As per soil investigation done by contractor.

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The soil investigation report of Bore hole done by contractor shall be compared by soil investigation report of the nearest Bore hole given in the tender document.

3. LIST OF DESIGN CODES AND STANDARDS

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

Order of preferences of codes shall be as follows: -

I. IS

II. IRS

III. IRC

IV. Euro Code

V. AASTHTO:

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

4. 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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Date: 30-Jul-2021 15:08:24

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K RIDE

RAIL INFRASTRUCTURE DEVELOPMENT COMPANY (KARNATAKA) LIMITED

(K-RIDE)

BENGALURU SUB-URBAN RAIL PROJECT (BSRP)

DESIGN BASIS REPORT

for

VIADUCT

July - 2021

Examined & found in order

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Project Directorate
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Railway Board

BSRP-DBR- VIADUCT and AT-GRADE

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1. INTRODUCTION

1.1. Brief description of project

Bengaluru is the fifth largest metropolis in India and is one of the fastest growing cities in Asia. It is also the capital of Karnataka. It is globally recognized as IT capital of India and also as a well-developed industrial city. The city which was originally developed as a Garden City over the years, slowly transformed into an industrial and software hub of India. Emergence of IT sector has overshadowed other areas of development and has metamorphosed the city into a global hub. The establishment of the IT hubs on the outskirts has converted the city and its surroundings into Silicon Valley of India. It has also caused an urban sprawl around, to some extent lop sided towards south and east.

Bengaluru population has been growing faster. There has been a phenomenal growth in the population of vehicles as well, especially the two and four wheelers in this period due to rising household incomes. In the absence of adequate public transport system, people are using the personalized modes which is not only leading to congestion on limited road network but also increasing environmental pollution. An average citizen of Bengaluru spends more than 240 hours stuck in traffic every year. Such delays result in loss of productivity, reduced air quality, reduced quality of life, and increased costs for services and goods.

The Ministry of Railways and Govt. of Karnataka have jointly approved the Feasibility report for Bengaluru Suburban Rail Project for running dedicated sub-urban rail services. The report was prepared by M/s.RITES and the project will be implemented by K-RIDE.

CORRIDORS	SECTION	LENGTH IN KM		
		ELEVATED	ATGRADE	TOTAL
1	Bengaluru - Devanahalli	18.98	22.42	41.40
2	Baiyyappanahalli – Chikkabanavara	12.91	12.10	25.01
3	Kengeri – Whitefield	10.40	25.12	35.52
4	Heelalige - Rajankunte	13.29	32.95	46.24
	TOTAL			

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1.2. Geometrical Design Feature:

1.2.1	Maximum Gradient,		3%
1.2.2	Maximum Degree of Curve,	Main line	200 m
		Other than main line	175 m
1.2.3	Spacing of Track	Elevated and at grade	3900 mm
		Underground	3900 mm
		Stations	4100
1.2.4	Axle Load		17 T

1.3. Scope of DBR

The present scope of work includes viaduct portion from Bengaluru – Devanahalli, Baiyyappanahalli – Chikkabanavara, Kengeri – Whitefield and Heelalige – Rajankunte total 4 number corridors of 148.17 km

This Design Basis Report is intended to fully satisfy the statutory requirements of Indian Railways for design of proposed elevated Viaduct. This design basis report covers design basis with design parameters and assumptions to be adopted in design of foundations & substructures and superstructure of the Viaduct/Bridge based on Model DBR issued by RDSO.

2. PROPOSED STRUCTURAL SYSTEM OF VIADUCT

2.1. Superstructure system:

The superstructure shall be precast Simply supported PSC Segmental Box girder/Single U-Girder/I-girder with cast in situ deck.

However, Balanced Cantilever /Steel girder/ Steel through type truss /Steel Composite Girders shall be proposed at sharp curves /special spans / crossover / turnout /railway crossing/ highway crossing of variable span as per site requirement.

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2.2. Emergency Walkway;

Walkway on the viaduct shall not be provided. For safe evacuation of passengers during emergency, end evacuation from driver and rear cabin is designed, and passenger evacuated to nearest station on affected track.

2.3. Bearing:

2.3.1. Considering the span configuration and safety aspects of the structural system (in normal and seismic condition), it is proposed to adopt elastomeric bearing placed underneath girder for transfer of vertical forces and for transfer of in-plane forces.

2.3.2. The shear key at both end of span would also take the transverse loads (transverse seismic). The shear key would anyway be also designed at each pier head to prevent any large movements of deck in both longitudinal and transverse directions. They will act as a second line of resistance against large seismic forces and consequent displacements.

2.3.3. Elastomeric bearing shall be designed as per EN1337 part 1 and 3.

2.3.4. In case-loads / movements are high and elastomeric bearings cannot be designed, only then pot bearings shall be used. All the pot bearings, if any, will be designed as per IRC: 83 Part-III.

2.3.5. While finalizing the proposed bearing system, it will be ensured that the bearings are replaceable and adequate accessibility for the same is available.

2.4. Substructure system:

2.4.1. Generally, viaduct superstructure is supported on single cast-in-place RC pier with cast in situ/precast prestressed pier cap made integral with the pier with cast in situ concrete over the pier.

2.4.2. Post tensioning shall be accomplished partially in casting yard and partly in-situ depending on design requirements. The pier cap shall be wide enough to support all the bearings for the four girders and also provide space for placing lifting jacks for replacement of bearings.

2.4.3. However, if pretensioned/ steel I Beam with Cast in situ slab superstructure is provided cast in situ stepped pedestal shall be provided.

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2.4.4. Slenderness effect in Piers shall be duly considered as stipulated in IRS-CBC or alternatively P-δ analysis shall be carried out.

2.4.5. To prevent the direct collision of vehicle to pier, a crash barrier of 1.0m height above existing road level may be provided all around the pier with a gap of 25mm between the crash barrier and outer face of pier.

2.4.6. Size of the pier may be required to be increased to control the stresses / deformations based on case-to-case basis. As far as possible, pier shall be elongated along longitudinal direction. Only in special cases pier elongation along transversal direction shall be adopted depending on structural requirement.

2.4.7. The space between the elastomeric bearings shall be utilized for placing the shear key (seismic restrainer). An outward slope of 1:200 shall be provided at pier top for the drainage due to spilling of rainwater, if any.

2.4.8. Where ever plan alignment of the elevated guide-way is not matching with central median, cantilever pier shaped (reinforced / prestressed) pier or portal beam with piers resting on central median / footpath shall be provided. Such portal shaped beams shall generally be monolithic with piers at its both ends.

2.5. Foundation system:

2.5.1. Major stretch comprises of soil strata up to 25 m to 35m below N.G.L. Pile foundations shall be adopted.

2.5.2. Major part of alignment, comprises of soil, up to 30 m deep. The soil generally consists of compact silty sand to sandy silt with small pebbles. For typical piers, a large diameter bored monopile of size 2.4 m is foreseen. In places where piers are tall or they are eccentric or on sharp curvature foundation consisting of group of four (4) piles is foreseen. Where weak soil is encountered multi-pile solution will be adopted.

2.5.3. Initial pile load tests at required locations shall be conducted. The intended methodology and equipment for pile installation shall be employed while carrying out the initial pile load tests.

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2.6. Parapets:

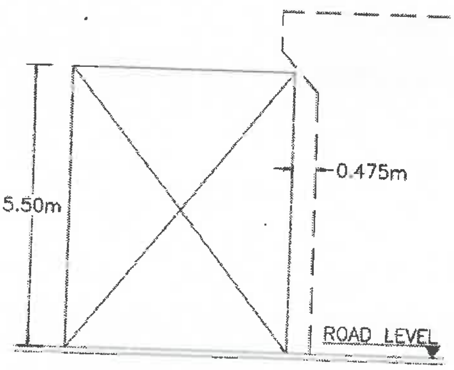
2.6.1. Precast RCC/Steel parapets will be provided for the superstructure other than U-girder. They are fitted with deck slab/girder, either through bolting or stitching with concrete. Parapet shall be non-structural member. In case of PSC Box/I Girder precast concrete parapet shall be provided on both side of guideway.

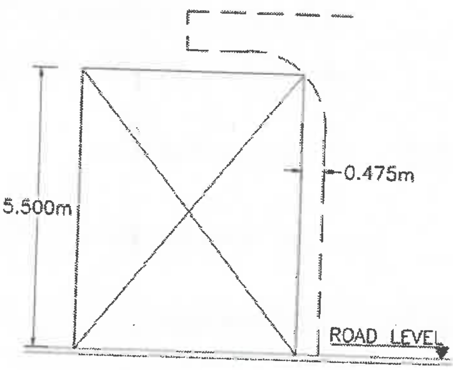
2.6.2. Because of the use of U girders separate parapets are not required. However, these shall be treated for aesthetics and shall be provided with sound barrier on both side of elevated guide way where necessary. Since frontal evacuation is planned in case of emergency, parapet need not to have any provision of walkway at top. However, parapet shall have provision that in case additional sound absorber materials are required at specific location to limit noise within allowable limit, the same can be mounted at its top. Structure provided for parapet shall also be able to carry the cables along the guide way.

2.6.3. At cross over locations where precast concrete/Steel I Beam with Cast in situ slab superstructure is provided, a precast concrete parapet (connected to deck by in-situ connection) shall be provided on both sides.

3. CLEARANCES FOR STRUCTURES

3.1. Clearance for Road Traffic:





- *As per relevant IRC specifications and Road Authority requirements.*
- The shape of pier cap / hammer head pier cap shall be so dimensioned that a required clearance of 5.5 m is always available on roadside beyond

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vertical plane drawn on outer face of crash barrier i.e., 0.475m (0.45m (width of the 1m-high Jersey-type crash barrier) + 0.025m (clearance between crash barrier and pier shaft)) from pier shaft outer line.

3.2. Clearance for Railway Traffic:

When the KRIDE Rail viaduct crosses the Indian Railway track, minimum horizontal and vertical clearances as per IRS Schedule of Dimensions shall be followed.

3.3. Clearances for Metro Traffic:

As per approved SOD of BSRP

4. STRUCTURAL MATERIALS AND PROPERTIES

4.1. Cement: Clause 4.1 of IRS CBC

4.2. Concrete

4.2.1. Density:

Following density of various types of concrete shall be adopted for calculation of self-weight of concrete members (as per IS:875 part 1).

4.2.1.1. 25 kN/m3 for prestressed concrete.

4.2.1.2. 25 kN/m3 for reinforced concrete.

4.2.1.3. 24 kN/m3 for plain cement concrete.

4.2.2. Young's Modulus:

As per Clause 5.2.2.1 of IRS CBC.

4.2.3. Modular ratio:

Modular ratio for all concrete grades shall be taken as per cl.5.2.6 in of IRS-CBC.

4.2.4. Minimum grade of concrete for structural elements:

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4.2.4.1. Minimum grade of concrete should be as per clause-5.4.4 of IRS-CBC. For exposure condition defined in Clause-5.4.1 of IRS-CBC.

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

4.2.4.3. Concrete characteristics as detailed above might need to be improved for foundation if the structure environment is found to be particularly aggressive (soil or water). This shall be assessed on case-by-case basis.

4.2.5. Thermal Expansion Coefficient:

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

4.2.6. Poisson's ratio:

0.15 for all concretes.

4.3. Reinforcing steel:

4.3.1. As per clause 4.5 and 7.1.5 of IRS CBC

4.3.2. Only Thermo-mechanically treated reinforcement bars of grade 500 conforming to IS: 1786 will be adopted

4.3.3. Elongation requirements as per Clause 5. 3 of IS:13920.

4.4. Prestressing Hardware:

4.4.1. Prestressing steel for tendons:

4.4.1.1. As per clause 4.6 of IRS CBC

4.4.1.2. Characteristic Strength: As per clause 16.2.4.3 of IRS CBC

4.5. Pre stressing Units:

4.5.1. Jacking Force: Jacking force: Jacking force (Maximum initial prestressing force) shall be as per clause 16.8.1 of IRS CBC: Reprint 2014 or latest.

4.5.2. Prestress Losses:

4.5.2.1. As per clause 16.8.2 and 16.8.3 of IRS CBC

4.5.2.2. For Long term, relaxation losses in prestressing steel, 3 times the

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1000 hours value given in IRC: 18-2000 or latest shall be used.

4.5.2.3. For short term loss calculations of pre stress following coefficient shall be taken

1. Friction (wobble) 0.002 m-1
2. Friction (curvature) 0.17 rad^{-1}

4.5.3. Sheathing:

As per Cl 7.2.6.4.2 of IRS CBC

4.5.4. Anchorages:

Cl 7.2.6.4.3 and Cl 16.8.3.4 of IRS CBC

4.6. Structural steel for steel and composite bridges

4.6.1. Structural steel sections conforming to Grade Fe 490 (E350) as per IS: 2062 shall be adopted in case high strength steel is required.

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 2003 or latest, IRS welded Bridge code 1989 or latest 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. Three types of structural steel are proposed as per the following standards:

4.7.2.1. IS: 4923 "Hollow steel sections for structural use with Yst 310"

4.7.2.2. IS: 1161 "Steel tubes for structural purpose

4.7.2.3. IS: 2062 "Steel for General Structural Purposes (Grade B-Designation 410B)"

4.7.3. The hollow steel sections would be square (SHS) or rectangular (RHS). Other traditional rolled sections like plates, angles, channels, joists would also be used where necessary.

4.7.4. The base connections and connection with concrete shall be effected by internally threaded bolt sleeves (hot dipped galvanized @ 300 gm/ sqm)

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4.7.5. IS: 2062 Grade B mild steel. The sleeve shall receive hexagon-head bolt M20 Class 8.8 as per IS: 1364 (Part 1) with galvanized spring washer.

4.7.6. The connections within the steel structure would be effected essentially by direct welding of members with/ without gusset plates. The minimum thickness of metal for SHS/RHS sections for main chord members as well bracings shall be 4mm as applicable for steel tubes in clause 6.3 of IS: 806.

4.8. Time Dependent Characteristics of Materials

Long term losses in pre stressing (pre tensioning and post tensioning) and evolution of material characteristics are calculated using:

- Formulae and parameters given in IRS CBC
- Or using CEB-FIP model

Humidity ratio=70%

5. LOADS

Following elementary loads shall be taken into account for design of structural component of viaduct:

Elementary load			
Dead loads	DL	Self-Weight maxi	D_{max}
		Self-Weight mini	D_{min}
		Overhead Line Equipment	OLE
	Shrinkage & Creep		SC
	Prestress		PR
Super Imposed Loads			SIDL
Live load	LL	Train Weight	TW
		Dynamic Impact	I
		Force due to curvature or Transverse eccentricity	CF
		Longitudinal Force (traction, braking)	LF
	Live Load on Foot Path		LFP
Derailment Load			DER
Overall temperature effect			OT
Differential Temperature			DT
Long welded rail forces			LWR
Racking forces			RF
Forces on parapets			PP

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Wind pressure effect:	WL	Longitudinal Direction	WL_X
		Transverse Direction	WL_Z
Earthquake	EQ	Longitudinal direction	EQ_X
		Transverse direction	EQ_Z
		Vertical direction	EQ_Y
Differential settlement (Applicable for continuous units only)			DS
Vehicle Collision load on Piers			VCL
Buffer Load			BL

5.1. Dead load (DL):

Self-weight of all structural elements shall be worked out based on the actual cross-section area and unit weight as defined in the previous section of this report. And includes the weight of the materials that are structural components of viaduct and permanent in nature.

5.2. Super Imposed Dead Load (SIDL):

This includes all the weights of the materials on the structure that are not structural elements but are permanent. In case of U girder parapet is part of structural element, hence it is taken in to account separately.

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

5.2.1. For calculation of Superimposed dead load, following assumptions shall be taken:

5.2.2. Variable type (The following assumptions)

		Double track	Single track
1	rails + pads	0.30	0.15
2	Cables	0.07	0.04
3	cable trough cell	0.74	0.35
4	cable trays	0.01	0.01

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5	hand-rail	0.08	0.08
6	plinth (slab track)	3.44	1.72
7	Lightweight deck drainage concrete	0.24	0.12
8	OHE mast signaling etc.	0.40	0.20
9	miscellaneous (OCS, signaling, fasteners)	0.40	0.20
	Total (Tones/meter)	6.05	3.05

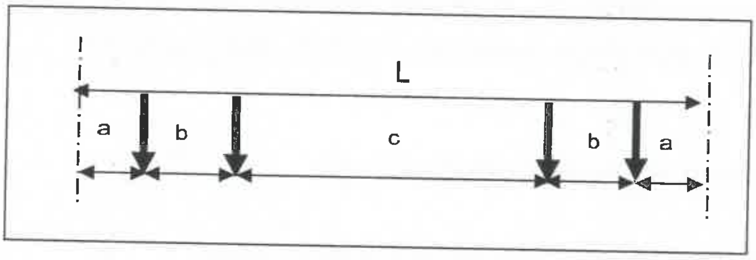
Parapet load will be taken as per 5.19.

5.3. Shrinkage and creep

For calculation of shrinkage & creep, IRS: CBC shall be used but other codes could also be used depending on humidity ratio and notional thickness of the member. In such case, shrinkage calculation shall be done assuming average relative humidity of 70%.

5.4. Vertical Train Live Load (TW)

5.4.1. 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:



Axle loads = 17 tons

Maximum number of successive cars in a train = 6 (extendable to 9)

Wheel Configuration

5.4.1.1. a = (balance)
5.4.1.2. b = 2300 mm to 2500 mm (Wheel base in a bogie)
5.4.1.3. c = 11700 mm to 12700 mm (Distance between Axle-2 and Axle-3 in the car)

Total Length of one car L = 2a +2b +c = 21740 mm (Length of a car)

5.4.2. Moving load analysis shall be carried out in order to estimate maximum

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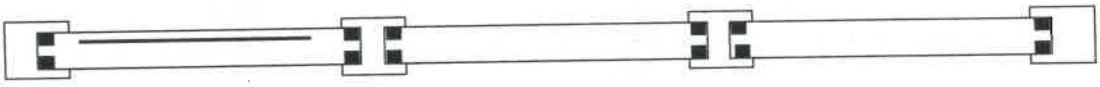
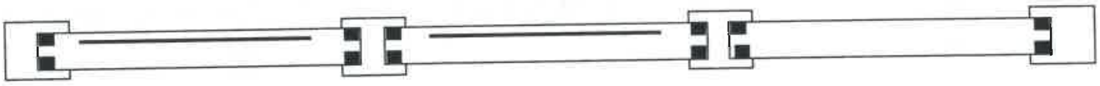
longitudinal force. max shear and max BM

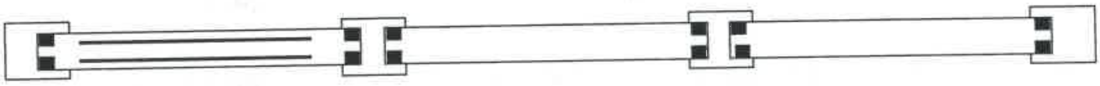
5.4.3. Maximum number of axles shall be loaded on the superstructure to arrive at maximum longitudinal force, max shear and max BM. Substructure shall be checked for one track loaded condition as well as both tracks loaded condition. Where both the tracks are supported by single box superstructure, the bearings shall also be checked for one track loaded condition as well as both tracks loaded condition. Live load envelope cases shall be based on all possible configuration of train such as one car, two cars, three cars, four cars



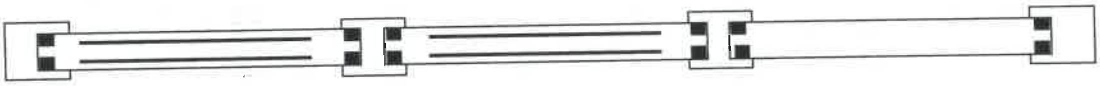
LL1: used for deck torsion, bearing compression, uplift, shaft check, foundation check



LL2: used for shaft check, foundation check



LL3: used for deck check, bearing compression check, uplift, shaft check, foundation check



LL4: used for shaft check, foundation check & shear key check.

5.5. Coefficient of Dynamic Augment (I)

CDA shall be adopted as per IRS bridge rules.

5.6. Footpath Live Load (LFP)

Footpath live load shall be adopted as 490 kg/m2 as per cl 2.3.2 of IRS Bridge rules. As there is no walkway, footpath live load shall not to be considered with carriageway live load.

5.7. Braking and Traction (LF) (horizontal train load)

5.7.1. Braking load shall be taken as 18% of the un-factored vertical Axle loads.

5.7.2. Traction load shall be taken as 20% of the un-factored vertical Axle loads.

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5.7.3. Tractive force of one track and braking force of another track shall be taken in the same direction to produce worst condition of loading. Where both tracks are supporting by single structure

5.7.4. As per IRS Bridge Rules Cl 2.8.5, when considering seismic forces, only 50% of gross tractive effort / braking force shall be considered. However, IRS Bridge Rules Cl 2.8.3.4 specifies that dispersion and distribution of longitudinal forces are not allowed for new bridges.

5.7.5. The provision of UIC-774-3 in relation to rail-structure interaction is well known and is being used in many rail-based structures. Rail-structure interaction studies show that several piers of the guide way participate in resisting the braking and traction forces. Hence after distribution and dispersion of longitudinal forces through rail, bearing forces in a given span is less than braking/tractive forces transferred from wheels located in the same span. Hence it is recommended to adopt the international practice of distributing

5.8. **Centrifugal Force (CF)**

5.8.1. Centrifugal Force shall be as per Cl 2.5 of IRS Bridge Rules.

5.8.2. Maximum Designing speed of 110km/hr. will be considered for computation of centrifugal force. In sharp radius, following speed shall be considered as per rolling stock characteristics and Schedule of Dimensions. Please note that values given below are for radius of centerline of track and not the centre line of alignment.

Plan Radius of Track (m)	Maximum Designing speed (km/hr)
R=600	105
R=500	95
R= 400	85
R=300	75
R=250	65
R=200	60
R=175	55

5.9. **Gradient effect**: Shall be considered as per site condition.

5.10. **Wind Force (WL)**

Calculation of Wind load is based on 2.11 of IRS Bridge Rules.

The design wind speed at height z is considered as follow:

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Vz = Vb. K1. K2. K3

Vb (m/s): Regional basic wind speed, taken 33 m/s for Bengaluru.

K1: Probability factor, considered 1.07

K2: Terrain height and structure size factor, considered 0.84

K3: Topography factor, considered 1.00

Thus **Vz = 33* 1.07*0.84*1 = 29.66 m/s**.

The design wind pressure is calculated as below:

Pz = 0.6*(Vz) 2 = 0.527kN/m2

For unloaded structures (no Live Load on deck), an amplification factor of 1.5 is applied on wind load s per Bridge Rule.

5.11. Seismic Force (EQ)

Seismic analysis of viaducts will be conducted as per: Seismic code for Earthquake Resistant Design of Railway Bridge" shall be followed. This code also covers load combination and ductile detailing aspects.

5.11.1. General Principle

5.11.1.1. Seismic analysis of viaducts shall be conducted according to the proposed modifications in Indian standard IRC 6:2010, clause 219.

5.11.1.2. Therefore, the seismic actions are calculated by a 2-steps process:

5.11.1.3. Single mode analysis to obtain the fundamental vibration period of the viaduct

5.11.1.4. Estimation of seismic forces using the spectrum response, defined hereafter.

5.11.2. Fundamental Vibration Period Calculation

5.11.2.1. The fundamental period calculation is performed according to the table C-3.3.1 of IRC 6:2010. Each pier is considered as a single degree of freedom oscillator with mass placed at the Centre of Gravity (COG) of the deck.

5.11.2.2. Expression given in Appendix A of the clause 22 of IRC 6:2010 can be also used for period computation. This is: T

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$$2.0 \times \sqrt{\frac{D}{1000F}}$$

5.11.2.3. D = Appropriate dead load and live load in KN as defined is "Mass" section

5.11.2.4. F = Horizontal force in kN required to be applied at the centre of mass of the superstructure for one mm horizontal deflection at the top of the pier along the considered direction of horizontal force.

a) **Masses**

- Permanent masses (Self Weights, SIDL) of:
  - i. Full span longitudinally attached with shear keys, at each side of the pier (For Longitudinal seismic)
  - ii. Half of spans on either side of pier (For Transverse seismic)
- Mass of the pier cap (neglecting Shear-Key)
- Mass of the top half of the pier

25% of Train mass shall be considered while evaluating time period / forces due to seismic in transverse direction. This percentage is only for working out the magnitude of seismic force. Train mass shall not be considered when acting in the direction of traffic i.e. longitudinal direction. In both the seismic conditions (longitudinal as well as transverse), for calculating the stresses due to vertical effect of live load, 50% of the design live load shall be considered at the time of earthquake.

As per IRS Bridge Rules, correction slip no.22 dated 17 / 1 / 1994, in transverse/ longitudinal seismic condition, only 50% of gross attractive effort / braking force shall be considered.

b) **Stiffness**

- Stiffness shall be calculated with the un cracked section characteristics

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and with the concrete instantaneous modulus of elasticity, for all structural elements.

- Wherever pile foundations are provided, effect of the foundation system (pile-cap + piles + soil) in the flexibility of the substructure is considered by a set of equivalent springs added simulating pile-soil interaction (for details refer to pile stiffness calculation).

5.11.3. Response Spectrum Definition

5.11.3.1. All numerical values mentioned in this chapter are based on a 5% damping ratio, which will be used for the design.

a) Basic Design Response Spectrum

Response spectrum used for seismic calculation shall be as per IRS seismic code.

b) Seismic Acceleration

Sa/g being computed by the relevant IRC:6 seismic acceleration can then be calculated by:

Ah = (Z/2) * (I/R) * (Sa/g), where:

Ah = horizontal seismic coefficient to be considered in design (Seismic acceleration = Ah*g)

Z = Zone factor = 0.16 (Bengaluru region = zone II)

I = Importance factor = 1.5

Since a tie connection is provided between seismic arrestor and superstructure, following response reduction factor will be adopted for different structural component.

ComponentResponse	Reduction Factor, R
Elastomeric Bearings	Same as per Pier

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Portal Beam	1.0
Piers & Portal Pier	3.3
Cantilever Piers	2.5
Foundations (i.e., Pile cap etc.)	2
Seismic Restrainers	1.0

Above factor is based on the assumption that ductile detailing shall be followed for all structural component.

5.11.4. Vertical Seismic Coefficient

The vertical seismic coefficient shall be taken as two third of the horizontal seismic coefficient (Ah).

$$Av = 2/3 * Ah$$

Since Bengaluru is in zone-III, vertical seismic to be considered only for prestressed superstructure. Vertical seismic is not to be considered for substructure & foundation.

5.11.5. Seismic Combinations

As per IRC 6: 2010, the following seismic combinations shall be considered:

a) $\pm r_1 \pm 0.3 r_2 \pm 0.3 r_3$

b) $\pm 0.3 r_1 \pm r_2 \pm 0.3 r_3$

c) $\pm 0.3 r_1 \pm 0.3 r_2 \pm r_3$

r1: Seismic force calculated by Ah in X direction (x, axis of the project)

r2: seismic force calculated by Ah in Z direction (Z , transverse direction)

r3: Vertical seismic calculated by Av

5.11.6. For design of foundation, the seismic loads shall be taken as 1.25 times the

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forces transmitted to it by substructure, so as to provide sufficient margin to cover the possible higher forces transmitted by substructure arising out of its over strength.

5.11.7. For calculation of displacement of any element of bridge or bridge as a whole due to seismic, response reduction factor of 1.0 shall be taken.

5.12. **Temperature effect:**

As per Clause 2.6 of IRS bridge rules

5.12.1. Overall Temperature (OT)

5.12.1.1. Following guidelines given in IRC: 6: cl 215.2, For Bengaluru city

5.12.1.2. Highest Maximum Bridge Temperature = 47.5°C (as per Fig.8)

5.12.1.3. Lowest Minimum Bridge Temperature = 0°C (as per Fig.9)

5.12.1.4. Total Variation of Temperature = 47.5 = 47.5°C

5.12.1.5. Mean Variation of temperature = 47.5 / 2= 23.75°C

5.12.1.6. Bridge temperature to be assumed when the structure is effectively retrained (as per cl 215.2 of IRC-6:2010). For Concrete Structure:

= ± (Mean variation of temperature + 10°C)

= ± (23.75°C + 10°C)

= ± 33.75°Ca

5.12.1.7. Hence an overall differential temperature of ±35°C (taking account of difference between construction temperature and maximum/minimum coming temperature) shall be considered.

5.12.2. Differential Temperature (DT)

5.12.2.1. For closed sections differential temperature shall be considered as defined in IRC: 6-, Clause 215 with a modification that average thickness of 150mm wearing coat shall be assumed as the deck top is covered by track plinth, cable trough. To take account of such effect, temp gradient shall be modified as given in BD 37/01. Thermal stresses in superstructure shall be evaluated based on the half of the elastic instantaneous modulus of elasticity of concrete.

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5.12.2.2. Above-mentioned check shall be also performed for beam slab superstructure system also.

5.12.2.3. For U section structures, no temperature gradient is necessary to be taken. Indeed, the U shape section will be a fully opened section, gradient-wise similar to a slab, and gradients are not considered for slabs less than 605mm deep.

5.12.3. Temperature gradient: As per Clause 215 of IRC-6

5.13. Differential settlement

Differential settlement between two adjacent viaduct piers shall be:

5.13.1.1. 12 mm for Long Term Settlement (based on Cl.6.1.5 of IS 2911 -Part 4).

5.13.1.2. 6 mm for Short Term Settlement (50% of long term) Or

5.13.1.3. Where piles are supported on end bearing (socketed in rock), a differential settlement of 2 mm shall be considered.

5.13.1.4. Differential settlement is to be considered only in the design of continuous structures, if any.

5.13.1.5. While deriving the effect of differential settlement, long term modulus of concrete of superstructure (half the instantaneous modulus of concrete) shall be taken.

5.14. Vehicle Collision Loads on Piers (VCL)

5.14.1. The vehicle collision load on piers: As per Clause-222 of IRC: 6.

5.14.2. 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

5.14.3. While checking for vehicle collision load, the principal live loads on the guideway, seismic or wind need not to be considered.

5.14.4. Vehicle collision load to be checked for 1.0 x VCL in SLS (stress check) only and 1.25 x VCL in ULS.

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5.15. Buffer Load (BL)

5.15.1. 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 the stopping performance based on mass of fully loaded train and its deceleration to avoid damage to the train or buffer:

5.15.2. 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 Forces (LWR)

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 (RF)

Such load is applicable for steel bridges with lateral bracing. Racking Forces as given in IRS: Bridge Rules Cl 2.9.1 shall be used for such purposes.

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 (PP)

As per Clause 2. I of IRS bridge Rules. In addition to self-wt., parapets shall be designed to resist a lateral horizontal and vertical force of 150kg/m applied simultaneously at the top of the railing or parapet. 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.

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5.20. Derailment Load (DER)

5.20.1. Derailment loads shall be considered as per Appendix XXV of IRS Bridge Rules

5.20.2. Check for derailment loads shall be made as per IRS Bridge rule. For ULS & stability check loading shall be proportioned as per maximum axle load

5.20.3. Sacramento derailment criteria may be used for U-girder. The criteria correspond to applicable 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. Construction loads (CL)

5.21.1. The erection forces should be as per clause 2.13 of IRS Bridge Rules.

5.21.2. For superstructure constructed span by span, distributed construction live load of (1.0kN/m2) shall be taken in addition to any other equipment loads (such as temporary prestressing frames and bars) at the top of superstructure to be erected. Any reaction at top of erected structure from the LG girder during erection of span segments or self-hauling of launching girder shall also be considered.

5.21.3. For superstructure constructed by balance cantilever construction, following construction loads shall be considered in conformity with EN 1991-1-6.

5.21.4. Construction live load (qc):- A distributed load (qca) of 1.0kN/m2 shall be taken as a construction live load (workers on top of erected superstructure). In addition to above a distributed load (qcb) of 0.2kN/m2 shall be also to be taken into account for the allowance of miscellaneous small sized machinery and light equipment. To take account of storage of any material or construction equipment at tip of cantilever a load (Fcb) of 100kN shall be also taken into account.

5.21.5. Form Traveler / Lifter Gantry (Qcc):- Actual load of form traveler / Lifter Gantry shall be taken into account. Such load shall be lowered or enhanced by a factor of 0.96 or 1.06 depending on whether the load effect is favorable or unfavorable.

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5.21.6. Movable heavy machinery and equipment Loads (Qcd):- Loads from any construction equipment moving over the part / fully erected structure such as movement of launching girder, beam and winches , trucks delivering the segments

5.21.7. Accidental Release of Form Traveller/ Lifter Gantry (Ac) :- In case of accidental release of any empty form traveller during erection / casting of segment, dynamic response of the same shall also be taken in addition to removal of form traveller. Such dynamic response shall be 100% of form traveller weight. It means upward force equivalent to twice the form traveller weight shall be applied for the accidental release of form traveller.

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 PARAMETER

7.1. **Units for design**: The main units used for design shall be: [t], [m], [mm], [kN], [kN/m2], [MPa], [°C], [rad]

7.2. ULS checks

7.2.1. Requirements for Ultimate Limit State check for Superstructure with internal prestressing as given below: -

7.2.1.1. 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

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shall be used

7.2.1.2. Section Capacity check for RC beams (ULS) for the superstructure should be conforming to Clause-15.4 of IRS-CBC. The design of RCC slabs shall conform to Clause 15.5 of IRS-CBC. The design of column should conform to Clause-15.6 of IRS-CBC.

7.3. SLS checks

7.3.1. As per IRS concert Bridge Code.

7.3.2. Crack Width

7.3.2.1. Crack width in reinforced concrete members shall be checked for SLS combination 1. Crack width shall be as per cl 15.9.8.2 of IRS CBC. Crack width shall not exceed the admissible value based on the exposure conditions defined in section 10.2.1. of IRS CBC

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

7.3.3. Vertical Deflection at Mid Span

1. 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.

7.4. Fatigue Check

General

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

7.4.1. PSC Structures and RC Structures

The fatigue shall be as per Clause 13.4 of IRS CBC.

7.4.2. Steel Structures

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1. Clause 3.6 of IRS Steel Bridge/ Clause 13.2 of IRS Welded bridge code shall govern.
2. Requirements of the IRS-CBC, 13.4 shall be followed for reinforcement bar welding.
3. Lap welding & welding in part of deck slab subjected to concentrated loads shall not be allowed.
4. 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.

7.4.3. Composite Structures

7.4.3.1. The stresses in steel shall be as per relevant clauses of IRS codes.

7.4.3.2. The stresses for shear studs and concrete shall be as per IRC codal provisions.

7.4.3.3. Modular ratio for slow loads shall be 3 times the modular ratio of instantaneous loads

7.5. Durability

7.5.1. Following specifications are intended to meet the durability requirements per IRS CBC-1997 (up to A&C-13):

1. Complete and adequate drainage;
2. Sufficient concrete cover;
3. Limiting crack width
4. Appropriate concrete mixture design and good pouring, acceptable permeability and surface finishing **(IRS-CBC 5.4)**

7.5.2. Cover to reinforcement

1. Cover to reinforcement shall be in accordance with clause 15.9.2 of IRS CBC.
2. Considering moderate condition of exposure for exposed structure i.e., superstructure, pier & foundation, following values of concrete cover to outermost

- Precast segmental Superstructure 35mm

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- Cast-in-situ superstructure 40mm
- For Pier/ Pier Cap 50mm
- For Open foundation 75mm
- For Pile cap 75mm
- For Pile 75mm
- Concrete cover to prestressing duct 75mm

7.6. Design life

All components of viaduct structures shall be designed for a design life of 100 years. Following below-mentioned parameters as given in IRS: CBC, 100 years design life can be ensured (refer cl 16.1.3 of IRS: CBC) in non-coastal /non-sea areas.

7.7. Drainage

7.7.1. Solid pier

The drain pipe will be located within the solid pier to avoid aesthetics problems. A manhole shall be provided in the superstructure at each pier location to inspect the pipes and clear blockage, if any. Provision shall be made for examination and cleaning drain pipe.

7.7.2. Deck

1. The drainage of deck is designed to cater the maximum envisaged rainfall intensity and suitable longitudinal and transverse slope is provided. Moreover, the provisions of clause 10.4.1.1 & 15.2.2 of IRS CBC is followed
2. The top of deck slab of box girder shall be profiled so as collect the run-off water at one points (in the centre of deck) by providing a cross inward slope of 2.5%. Runner pipe shall be provided (hung from deck slab) inside the girder to collect run off through the drain chamber (to be provided in every alternate segment) which shall pass through opening of girder at one end and then drain off in the water collecting box provided at pier top.

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8. DESIGN METHODOLOGY

8.1. Bearing System

8.1.1. Elastomeric bearing shall be designed as per EN 1337 part-1 and 3

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

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

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

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

8.1.6. In case-loads / movements are high and elastomeric bearings cannot be designed, only then pot bearings shall be used. All the pot bearings, if any, will be designed as per IRC: 83 Part-III.

8.2. Pier cap and pier

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

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

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

8.3. Foundation

8.3.1. Foundations shall be designed as per IRS Bridge Substructure & Foundation Code, IRS Concrete Bridge Code, Manual on the design and construction of well and Pile foundation, IS-2911 and IRC-45 should be followed for design of foundations.

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. EARTH WORKS FOR FORMATION

9.1. As per Comprehensive guidelines and specifications for railway formation,

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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 be followed. If provisions are not available in IRS, the order of preference shall be as follows, unless specifically mentioned otherwise in the relevant clause of DBR.

For Railway loading related issues:

I. UIC Codes

II. Euro Codes

III. Any other code which covers railway loading

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 given in para 10.1 to 10.10.5. These codes with latest revisions including all addendums/notifications and correction slips only shall be used. **The codes referred are as per the year mentioned in table or latest, but not prior to that.**

10.1. IRS Codes

Sl	Code	Year	Description
1	IRS	2008	Bridge Rules
2	IRS	1997	Concrete bridge Code (Reprint 2014)
3	IRS	1991	Bridge substructures and foundation code.
4	IRS	1997	Steel bridge Code
5	IRS	1998	Indian Railway Bridge Manual
6	IRS	1985	Manual on the Design and Construction of Well and Pile Foundations
7	IRS	2017	Earthquake resistant design of Railway Bridges
8	IRS	2001	Welded Bridge Code

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9	IRS	2008	Fabrication Code (B1)

10.2. IRC Codes

SI	Code	Year	Description
1	IRC 5:	2015	Standard Specifications and Code of Practice for Road Bridges. Section I – General Features of Design
2	IRC 6:	2017	Standard Specifications and Code of Practice for Road Bridges, Section II – Loads and Stresses
3	IRC 11:	1962	Recommended Practice for the Design of Layout of Cycle Tracks
4	IRC 19:	1977	Standard Specifications and Code of Practice for Water Bound Macadam
5	IRC 22:	2008	Standard Specifications and Code of Practice for Road Bridges, Section VI – Composite Construction
6	IRC 24:	2010	Standard Specifications and Code of Practice for Road Bridges, Section V – Steel Road Bridges
7	IRC 37:	1984	Guidelines for the Design of Flexible Pavement
8	IRC 45:	1972	Recommendations for Estimating the Resistance of Soil below the maximum Scour Level in the Design of Well Foundations of Bridges
9	IRC 48:	1972	Tentative Specifications for Bituminous Surface Dressing Using Pre-Coated Aggregates
10	IRC 78:	2014	Standard Specifications and Code of Practice for Road Bridges, Section VII Parts 1 and 2, Foundations and Substructure
11	IRC 87:	1984	Guidelines for the Design and Erection of False Work for Road Bridges
12	IRC 89:	1997	Guidelines for Design and Construction of River Training and Control Works for Road Bridges
13	IRC:	SP 11	1988 Handbook of Quality Control for Construction of Roads and Runways
14	IRC:112	2011	Code of Practice for Concrete Road Bridges
15	IRC: SP:64-	2005	Guidelines for Design of Construction of Segmental Bridges
16	IRC: SP:67	-2005	Guidelines for Use of External and Unbonded Prestressing Tendons in Bridge Structures
17	IRC: SP:70	-2005	Guidelines for The Use of High-Performance Concrete in Bridges
18	IRC: SP:71	-2006	Guidelines for Design and Construction of Precast Pre-tensioned Girder for Bridges

10.3. IS Codes

SI	Code	Year	Description
1	SP 7:	2005	National Building Code
2	IS 73:	1992	Paving Bitumen
3	IS 150:	1950	Ready mixed paint brushing, finishing stoving for enamel colour as required
4	IS 205:	1992	Non-ferrous metal Butt Hinges
5	IS 206:	1992	Tee and strap hinge
6	IS 207:	1964	Gate and shutter hooks and eyes

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7	IS 208:	1987	Door handles
8	IS 210:	1993	Grey iron castings
9	IS 215:	1995	Road tar
10	IS 217:	1988	Cutback Bitumen
11	IS 269:	1989	33 grade Ordinary Portland Cement.
12	IS 278:	1978	Galvanised steel barbed wire for fencing
13	IS 280:	1978	Mild Steel wire for general engineering Purposes
14	IS 362:	1991	Parliament hinges
15	IS 363:	1993	Hasps and staples
16	IS 383:	1970	Coarse and fine aggregates from natural Sources for concrete
17	IS 432:	1982	Mild steel and medium tensile steel bars and hard- drawn steel wire for concrete Part 1 Mild steel and medium tensile steel bars Part 2 Hard-drawn steel wirereinforcement
18	IS 453:	1993	Double-acting spring hinges
19	IS 455:	1989	Portland slag cement
20	IS 456:	2000	Code of practice for plain and reinforced concrete
21	IS 457:	1957	Code of practice for general construction of plain and reinforced concrete for dams and other massive structures
22	IS 458:	1988	Precast concrete pipes (with and without reinforcement)
23	IS 459:	1992	Corrugated and semi-corrugated asbestos cement sheets
24	IS 460:	1985	Test sieves
25	IS 516:	1959	Method of test for strength of concrete
26	IS 650:	1991	Standard sand for testing cement
27	IS 733:	1983	Wrought aluminium and aluminium alloy bars, rods and sections for general engineering purposes
28	IS 737:	1986	wrought aluminium and aluminium alloy sheet and strip for general engineering purposes
29	IS 771:	1979	Glazed fire-clay sanitary appliancesPart 1 General requirementsPart 2 SpecificPart Part 3/Sec. 2 Specific requirements of Urinals - Stall Urinals3/Sec. 1 Specific requirements of Urinals - Slab Urinals requirements of Kitchen and laboratory sinks
30	IS 774:	1984	Flushing cistern for water closets and urinals
31	IS 775:	1970	Cast iron brackets and supports for wash basins and sinks
32	IS 777:	1988	Glazed earthenware wall tiles
33	IS 778:	1984	Copper Alloy gate, globe and check valves for water works Purposes
34	IS 779:	1994	Water meters
35	IS 780:	1984	Sluice valves for water works purposes (50 to 300 mm size)
36	IS 781:	1984	Cast copper alloy screw down bib taps and stop valves for water service
37	IS 783:	1985	Code of practice for laying of concrete pipes
38	IS 800:	2007	Code of practice for general construction in steel
39	IS 814:	1991	Covered electrodes for manual metal arc welding of carbon and carbon manganese steel
40	IS 875:	1987	Code of practice for design loads (other than earthquake) for buildings and structures

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41	IS 883:	1994	Code of practice for design of structural timber in building
42	IS 909:	1992	Under-ground fire hydrant, sluice valve type
43	IS 1003:		Timber panelled and glazed shutters Part 1 1991 Door shuttersPart 2 1994 Window and ventilator shutters
44	IS 1030:	1989	Carbon steel castings for general engineering purposes
45	IS 1038:	1983	Steel doors, windows and ventilators
46	IS 1077:	1992	Common burnt, clay building bricks
47	IS 1080:	1986	Design and construction of shallow foundation in soil (other than raft ring and shell)
48	IS 1161:	1979	Steel tubes for structural purposes
49	IS 1195:	1978	Bitumen mastic for flooring
50	IS 1200	Part 1	Methodology of measurement of Building and Civil Engineering Works.
51	IS 1230:	1979	Cast iron rainwater pipes and fittings
52	IS 1237:	1980	Cement concrete flooring tiles
53	IS 1239:	1990	Mild steel tubes, tubular and other wrought steel fittingsPart 1 Mild steel tube Part 2 Mild steel tubular and other wrought steel pipe fittings
54	IS 1322:	1993	Bitumen felts for water proofing and damp-proofing
55	IS 1341:	1992	Steel butt hinges
56	IS 1343:	1980	Code of practice for Pre-Stressed Concrete
57	IS 1346:	1991	Code of practice Waterproofing of roofs with bitumen felts
58	IS 1458:	1965	Railway bronze ingots and casting
59	IS 1489:	1991	Portland Pozzolana Cement
60 61	IS 1536:	1989	Centrifugally cast (spun) iron pressure pipes for water, gas and sewage
62	IS 1537:	1976	Vertically cast-iron pressure pipes for water, gas and sewage
63	IS 1538:	1993	Cast iron fittings for pressure pipes for water, gas and sewage
64	IS 1566:	1982	Hard-drawn steel wire fabric for concrete reinforcement IS
65	IS 1592:	1989	Asbestos cement pressure pipes
66	IS 1703:	1989	Copper alloy float values (horizontal plunger type) for water supply fittings
67	IS 1726:	1991	Cast iron manhole covers and frames
68	IS 1729:	1979	Sand cast iron spigot and socket soil waste and ventilating pipes, fitting and accessories
69	IS 1732:	1989	Dimensions for round and square steel bars for structural and general engineering purposes
70	IS 1785:	1983	Plain hard-drawn steel wire for prestressed concrete Part 1 Cold-drawn stress – relieved wire
71			Part 2 As drawn wireHigh strength deformed steel bars and wires for concrete reinforcement
72	IS 1786:	1985	
73	IS 1791:	1985	Batch type concrete mixers
74	IS 1795:	1982	Specifications for pillar taps for water supply purposes
75	IS 1834:	1984	Hot applied sealing compounds for joint in concrete
76	IS 1838:	1983	Pre-formed fillers for expansion joint in concrete pavements and structures (non extruding and resilient type) Part 1 Bitumen impregnated fibre

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77	IS 1888:	1982	Method of load tests on soils
78	IS 1892:	1979	Code of practice for sub surface investigations for foundations
79	IS 1893	2016	Criteria for earthquake resistant design of structures, Part 1 General Provisions and Buildings
80	IS 1904	1986	Design and construction of foundations in soils General Requirements
81	IS 1948:	1961	Aluminium doors, windows and ventilators
82	IS 1949:	1961	Aluminium windows for industrial buildings
83	IS 1977:	1976	Low Tensile Structural steel
84	IS 2004:	1991	Carbon steel forgings for general engineering purposes
85	IS 2062:	2006	Steel for general structural purposes
86	IS 2074:	1992	Ready mixed paint, air-drying, red oxide-zinc chrome, Priming
87	IS 2090:	1983	High tensile steel bars used in prestressed concrete
88	IS 2114:	1984	Code of practice for laying in-situ terrazzo floor finish
89	IS 2116:	1980	Sand for masonry mortars
90	IS 2119:	1980	Code of practice for construction of brick-cum-concrete composite
91	IS 2202:	1991	Wooden flush door shutters
92	IS 2326:	1987	Automatic flushing cisterns for urinals
93	IS 2386:	1963	Methods of test for aggregates 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 Petrographic examination
94	IS 2430:	1986	Methods of sampling of aggregate for concrete
95	IS 2548:	1996	Plastic seats and covers for water closets
96	IS 2681:	1993	Non-ferrous metal sliding door bolts (aldrops) for use with padlocks
97	IS 2690:	1993	Burnt - clay for flat terracing Tiles
98	IS 2692:	1989	Ferrules for water services
99	IS 2720	1972-2002	Methods of Tests for Soils (all Parts)
100	IS 2751:	1979	Recommended practice for welding of mild steel plain and deformed
101			bars used for reinforced construction
102 103	IS 2906:	1984	Specification for sluice valves for water works purposes (350 to1200 mm size)
104	IS 2911:	2010	Code of practice for design and construction of pile foundations Part 1 Concrete piles Section 1 Driven cast –in-situ concrete piles Section 2 Bored cast-in-situ concrete piles Section 3 Driven precast concrete piles Section 4 Bored precast concrete piles Part 3 Under-reamed piles Part 4 Load test on piles
105	IS 2950:	1981	Code of practice for design and construction of raft foundations.
106	IS 3067	1988	Code of Practice for General Design Details and Preparatory Work for Damp-Proofing and Water-Proofing of Buildings

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107	IS 3370:	2009	Code of practice for concrete structures for the storage of liquids
108	IS 3564:	1995	Hydraulically regulated door closers
109	IS 3812:	1981	Fly ash for use as pozzolan and admixture
110	IS 3847:	1992	Mortice night latches
111	IS 3955:	1967	Code of practice for design and construction of well foundations
112	IS 3989:	1984	Centrifugally cast (spun) iron spigot and socket soil, waste and ventilating pipes, fittings and accessories
113			
114			Recommendations on stacking and storage of construction materials and components at site
115	IS 4082:	1996	
116	IS 4138:	1977	Safety code for working in compressed air
117	IS 4326:	1993	Earthquake resistant design and construction of buildings – code of practice
118	IS 4656:	1968	Form vibrators for concrete
119	IS 4736:	1986	Hot-dip zinc coatings on mild steel tubes
120	IS 4826:	1979	Hot-dipped galvanised coatings on round steel wires
121	IS 4925:	1968	Concrete batching and mixing plant
122	IS 4926:	1976	Ready mixed concrete
123	IS 4968:	1976	Method for sub surface sounding for soils
124	IS 5525:	1969	Recommendations for detailing of reinforcement in reinforced concrete works
125	IS 5529:	1985	Code of practice for in-situ permeability tests
126	IS 5640:	1970	Method of test for determining aggregate impact value of soft coarse aggregate
127	IS 5816:	1970	Method of test for splitting tensile strength of concrete cylinders
128	IS 5889:	1994	Vibratory plate compactor
129	IS 5892:	1970	Concrete transit mixers and agitators
130	IS 6003:	1983	Specification for indented wire for prestressed concrete
131	IS 6006:	1983	Specification for uncoated stress relieved strands for prestressed concrete
132	IS 6051:	1970	Code for designation of aluminium and its alloys
133	IS 6248:	1979	Specification for metal rolling shutters and rolling grills
134	IS 6403:	1981	Code of practice for determination of bearing capacity of shallow foundations
135	IS 6603:	1972	Stainless steel bars and flats
136	IS 6760:	1972	Slotted countersunk head wood screws
137	IS 6911:	1992	Stainless steel plate, sheet and strip
138	IS 7181:	1986	Horizontally cast-iron double flanged pipes for water, gas and sewage
139	IS 7196:	1974	Hold fast
140	IS 7205:	1974	Safety code for erection of structural steel work
141	IS 7231:	1984	Specifications for plastic flushing cisterns for water closets and urinals
142	IS 7273:	1974	Method of testing fusion-welded joints in aluminum and aluminum alloys
143	IS 7293:	1974	Safety code for working with construction machinery

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144	IS 7320:	1974	Concrete slump test apparatus
145	IS 7534:	1985	Sliding locking bolts for use with padlocks
146	IS 7861:	1975	Code of practice for extreme weather concreting Part 1 For Hot Weather concreting Part 2 For Cold Weather concreting
147	IS 7969:	1975	Safety code for handling and storage of building Materials
148	IS 8009	1976	Calculation of settlement of foundations
149	IS 8041:	1990	Rapid – hardening Portland cement
150	IS 8112:	1989	43 grade ordinary Portland cement
151	IS 8142:	1994	Method of test for determining setting time of concrete by penetration resistance
152	IS 8500:	1991	Structural steel-micro alloyed (medium and high strength qualities)
153	IS 9013:	1978	Method of making, curing and determining compressive strength of
154	IS 9103:	1979	accelerated cured concrete test specimens Admixtures for concrete
155	IS 9284:	1979	Method of test for abrasion resistance of concrete
156	IS 9417:	1989	Recommendations for welding cold worked bars for reinforced concrete construction
157	IS 9595:	1996	Recommendations for metal arc welding of carbon and carbon manganese steels
158	IS 9762:	1994	Polyethylene floats (spherical) for float valves
159	IS 10262:	2009	Recommended guidelines for concrete mix design
160	IS 10379:	1982	Code of practice for field control of moisture and compaction of soils for embankment and subgrade
161	IS 10500:	1991	Drinking water specification
162	IS 12269:	1987	53 grade ordinary Portland cement
163	IS 12894:	1990	Fly ash lime bricks
164	IS 13630:	1994	Ceramic tiles – methods of tests
165	IS 13920:	2016	Ductile detailing of reinforced concrete structures subjected to seismic forces
166	IS 15388:	2003	Specifications for Silica Fume
167	SP 36	(Part 1):	Compendium of Indian Standards on Soil Engineering(Laboratory Testing)
168	SP 36	(Part 2):	Compendium of Indian Standards on Soil Engineering (Field Testing) Indian Standard Hand Book on Steel Sections Part-I CRRI and IOC, New Delhi Bituminous Road Construction Hand Book

10.4. International Codes

Sl	Code	Year	Description
1	BS 812		Testing Aggregates - Parts 117 to 119.
2	BS 1377		Methods of Test for Civil Engineering Purposes - Parts 1 thru 9.
3	BS 4395	Part 2	High strength friction grip bolts and associated nuts and washers for Structural Engineering Higher Grade
4	BS 4447		The performance of pre-stressing anchorages for post-tensioned construction

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5	BS 4449		Specification for Carbon Steel Bars for the Reinforcement of Concrete
6	BS 4486		Hot rolled and hot rolled & processed high tensile alloy steel bars for pre-tensioning of concrete
7	BS 4550		Methods of testing cement
8	BS 4592		Industrial Type Metal Flooring, walkways and stair treads
9	BS 4604	Part 2	The use of high strength friction grip bolts in structural steel work. Higher grade (parallel shank)
10	BS 4870		Approval testing of welding procedures
11	BS 4871		Approval testing of welders working to approved welding Procedures
12	BS 4872		Approval testing of welders when welding procedure approval is not required
13	BS 5075		Concrete admixtures
14	BS 5212		Methods for specifying concrete, including ready mixed Concrete
15	BS 5328		
16	BS 5400		Steel, concrete and composite bridges
17	BS 5400	Part 4	Code of practice for design of concrete bridges
18	BS 5400	Part 6	Specification for materials and workmanship, steel
19	BS 5606		Accuracy in building
20	BS 5896		High tensile steel wire and stand for the pre-stressing of concrete.
21	BS 5930:		Code of Practice for Site Investigations.
22	BS 5950	Part 2	Specification for materials, fabrication and erection: hot rolled sections
23	BS 6031		Code of Practice for Earthworks.
24	BS 6105		Corrosion-resistant stainless-steel fasteners
25	BS 6164		Safety in tunnelling in the construction industry.
26	BS 6349		Code of Practice for Dredging and Land Reclamation.
27	BS 6443		Penetrant flaw detection
28	BS 6681		Specification for malleable cast iron
29 30 31	BS 7079		Preparation of Steel substrates before application of paints and related products
32	BS 7385	Part 2	Evaluation and measurement for Vibrations in Buildings – E to Damage levels from Ground-Borne Vibrations
33	BS 7542		method of test for curing compound for concreter
34	BS 8000	Part 4	Code of Practice for Waterproofing
35	BS 8000	Part 5	Code of Practice for Below Ground Drainage
36	BS 8002		Code of Practice for Earth Retaining Structures
37	BS 8004		Code of Practice for Foundations

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38	BS 8007		Design of Concrete Structures for Retaining Aqueous Liquids
39	BS 8081		Code of Practice for Ground Anchorages
40	BS 8110		Structural use of concrete
41	BS 8301	Section 5	Code of practice for building drainage
42	BS 8550		Concrete – Specification of Materials
43	BS EN	1997	Eurocode 7: Geotechnical design
44	BS EN	1998	Eurocode 8: Design of structure for earthquake resistance
45	CIRIA	Report 44	Medical Code of Practice for working in compressed air
46	CIRIA	Report 80	A review of instruments for gas and dust monitoring Underground
47	CIRIA	Report 81	Tunnel water proofing
48	CIRIA	Report C515	Groundwater Control – Design and Practice
49	CIRIA	Report C580	Embedded Retaining Walls – Guidance for Economic Design
50	CIRIA	Report C660	Early Age Thermal Crack Control in Concrete
51	ASTM	C-1202	Test methods for Electrical indication of concrete's ability to resist
52			chloride ion penetration.
53	ASTM	C-1240	Micro Silica/Silica fume in concrete
54	ASTM	D-297	Methods for Rubber Products-Chemical Analysis
55	ASTM	D-395	Compression set of vulcanized rubber
56	ASTM	D-412	Tension testing of vulcanized rubber
57	ASTM	D-429	Adhesion of vulcanized rubber to metal
58	ASTM	D-573	Accelerated aging of vulcanized rubber by the oven method
59	ASTM	D-624	Tear resistance of vulcanized rubber
60	ASTM	D-797	Young's modulus in flexure of elastomer at normal and subnormal temperature
61	ASTM	D-1075	Effect of water on cohesion of compacted bituminous mixtures
62	ASTM	D-1143	Test method for piles under static axial comp. test
63	ASTM	D-1149	Accelerated ozone cracking of vulcanized rubber
64	ASTM	D-1556	In-situ density by sand replacement
65	ASTM	D-1559	Test for resistance to plastic flow of bituminous mixtures using Marshall apparatus
66	ASTM	D-2172	Extraction, quantitative, of bitumen from bituminous paving mixtures
67	ASTM	D-2240	Indentation hardness of rubber and plastic by means of a Durometer
68	ASTM	D-3689	Testing method of testing individual piles under static axial tensile load

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69	ASTM	D-4945	Test method for high strain dynamic testing of piles
70	ASTM	E-11	Specification for wire cloth sieve for testing purpose
71	ASTM:	Section 4:	Construction, Vol. 04.08: Soil and Rock I, and Volume 04.09: Soil and Rock II,
72	AASHTO	M6-81	Fine aggregate for Portland cement concrete
73	AASHTO	M31-82	Deformed and plain billet-steel bars for concrete reinforcement
74	AASHTO	M42-81	Rail-steel deformed and plain bars for concrete reinforcement
75	AASHTO	M54-81	Fabricated steel bar or rod mats for concrete reinforcement
76	AASHTO	M 81-75	Cut-back asphalt (rapid-curing type)
77	AASHTO	M 82-75	Cut-back asphalt (medium-curing type)
78	AASHTO	M85-80	Portland cement
79	AASHTO	M 140-80	Emulsified asphalt
80	AASHTO	M 147-67	Materials for aggregate and soil–aggregate sub-base, base and surface courses
81	AASHTO	M148-82	Liquid membrane-forming compounds for curing concrete
82	AASHTO	M154-79	Air-Entraining admixtures for concrete
83	AASHTO	M173-60	Concrete joint-sealer, hot-poured elastic type
84	AASHTO	M194-82	Chemical admixtures for concrete
85	AASHTO	M213-81	Preformed expansion joint fillers for concrete paving and structural construction
86	AASHTO	M 282-80	Joints sealants, hot poured, elastomeric-type, for port-land cement concrete pavements
87	AASHTO	M 294-70	Fine aggregate for bituminous paving mixtures
88	AASHTO	T22-82	Compressive strength of cylindrical concrete specimens
89	AASHTO	T23-80	Making and curing concrete compressive and flexural strength test specimens in the field
90	AASHTO	T26-79	Quality of water to be used in concrete
91	AASHTO	T96-77	Resistance to abrasion of small size coarse aggregate by use of the Los Angeles machine
92	AASHTO	T99-81	The moisture-density relations of soils using a 5.5-lb (2.5kg) rammer and a 12-in (305mm) Drop
93	ASHTO	104-77	Soundness of aggregate by use of sodium sulphate or magnesium sulphate
95	AASHTO	T176-73	Plastic fines in graded aggregates and soil by use of the sand equivalent test
96	AASHTO	T180-74	The moisture density relations of soils using a 10-lb (4.54kg) rammer and an 18-in (457mm) Drop
97	AASHTO	T182-82	Coating and stripping of bitumen-aggregate mixtures
98	AASHTO	T191-61	Density of soil In-place by the sand-cone method

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99	(API)		American Petroleum Industry (API) Standard 1104
100	UIC/772- R		The International Union of Railway Publication
101	UIC 772-R		Code for The Use Of Rubber Bearing For Rail Bridges
102	UIC 776-1R		Loads to Considered in Railway Bridge Design
103	UIC 776-3R		Deformation of Bridges
104	UIC 774-3R		Track/Bridge Interaction Recommendations for Calculations
105	Eurocode 0		Basis of Structural Design
106	Eurocode 1		Actions on Structures-Part2: Traffic Loads On bridges
107	Eurocode 2		Design of Concrete Structures-Part 1-1 General Rules and Rules for Buildings
108	Eurocode 2		Design of Concrete Structures-Part 2 Concrete Bridges-Design and Detailing Rules

10.5. Others

1. FIP Recommendations for the Acceptance of Post-Tensioning Systems
2. MOST Specifications for Road and Bridge Works
3. Miscellaneous: Any other codes & special publications as required and as mentioned in this report.

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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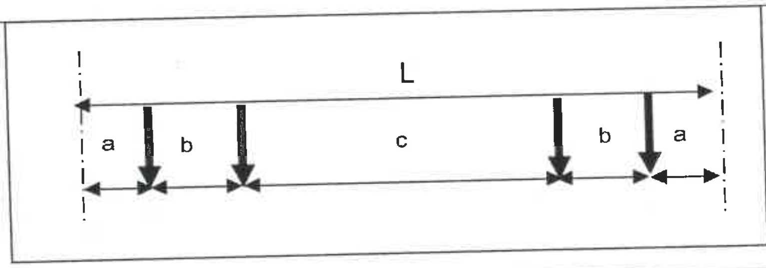
Annexure 1

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

Following Parameters have been taken for preparation of EUDL & LF Chart.		
1	Train Formation	MC+TC+MC+MC+TC+MC
2	Axle distances a=2.22 b= 2.4 c=12.5 L=21.74	
3	Standard Maximum Height of Centre of Gravity from Rail Level	1830mm for 1676mm Gauge
4	Maximum Axle Load	17
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, Lis equal to the effective span in meter s. For Shear, Lis 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 up to 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)	Force (SF) is that uniformly distributed load which produces SF at t h e end of t h e span equal to the maximum SF dev e loped under the standard train loads considered.

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L (MI	EUDL(T)		LF(T)	
	SF	BM	TE	BF
0.50	34.00	34.00	3.40	3.10
1.00	34.00	34.00	3.40	3.10
1.50	34.00	34.00	3.40	3.10
2.00	34.00	34.00	3.40	3.10
2.50	35.84	34.00	6.80	6.10
3.00	40.53	34.00	6.80	6.10
3.50	43.89	34.00	6.80	6.10
4.00	46.75	34.00	6.80	6.10
4.50	49.11	36.54	6.80	6.10
5.00	51.00	38.94	6.80	6.10
5.50	55.55	40.96	6.80	6.10
6.00	53.83	42.68	6.80	6.10
6.50	55.76	44.36	10.20	9.20
7.00	59.61	45.88	10.20	9.20
7.50	61.93	47.22	10.20	9.20
8.00	64.43	48.43	10.20	9.20
8.50	66.64	51.56	10.20	9.20
9.00	69.21	54.35	13.60	12.20
9.50	72.72	56.84	13.60	12.20
10.00	75.89	59.09	13.60	12.20
11.00	81.35	70.42	13.60	12.20
12.00	85.91	75.89	13.60	12.20
13.00	89.76	80.51	13.60	12.20
14.00	93.06	84.48	13.60	12.20
15.00	95.93	87.91	13.60	12.20
16.00	98.43	90.92	13.60	12.20
17.00	100.64	93.57	13.60	12.20
18.00	102.60	95.93	13.60	12.20
19.00	104.36	98.04	13.60	12.20
20.00	105.94	99.93	13.60	12.20
21.00	107.38	101.65	16.00	14.40
22.00	109.70	103.21	17.00	15.30
23.00	112.32	104.64	19.20	17.30
24.00	114.95	105.94	20.40	18.40
25.00	118.51	107.15	20.40	18.40
26.00	121.80	108.77	20.40	18.40
27.00	124.84	111.04	20.40	18.40
28.00	128.06	113.14	20.40	21.40
29.00	131.85	115.56	20.40	21.40
30.00	135.39	118.51	20.40	23.00
31.00	139.60	122.13	20.40	24.50
32.00	143.74	125.75	20.40	24.50
33.00	147.62	129.15	20.40	24.50
34.00	151.28	133.14	22.40	24.50
35.00	154.73	137.10	22.40	24.50
36.00	157.99	140.85	22.40	24.50
37.00	161.07	144.94	25.60	24.50
38.00	163.99	147.75	25.60	24.50
39.00	166.76	150.14	27.20	24.50
40.00	169.39	153.97	27.20	24.50
41.00	171.89	156.84	27.20	25.90
42.00	174.27	159.59	27.20	25.90
43.00	176.80	162.20	27.20	27.50
44.00	179.74	164.70	27.20	28.80
45.00	182.54	167.08	27.20	28.80
46.00	185.83	169.36	27.20	30.60

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47.00	189.11	171.55	27.20	30.60
48.00	192.26	173.64	27.20	31.70
49.00	195.27	176.19	27.20	31.70
50.00	198.83	178.88	27.20	33.70
51.00	202.27	181.28	27.20	34.60
52.00	205.88	184.19	27.20	36.70
53.00	209.70	187.13	27.20	36.70
54.00	213.37	189.96	27.20	36.70
55.00	216.91	192.69	27.20	36.70
56.00	220.32	195.43	27.20	36.70
57.00	223.61	198.56	27.20	36.70
58.00	226.79	201.59	27.20	36.70
59.00	229.86	204.61	27.20	36.70
60.00	232.83	208.00	27.20	36.70
61.00	235.70	211.28	27.20	36.70
62.00	238.48	214.45	28.80	37 40
63.00	241.17	217.22	28.80	37.40
64.00	243.78	220.50	32.00	40.30
65.00	246.82	223.38	32.00	40.30
66.00	249.78	226.18	32.00	40.30
67.00	252.89	228.89	34.00	42.80
68.00	256.17	231.28	34.00	42.80
69.00	259.36	234.09	35 20	43.20
70.00	262.45	236.95	35.20	43.20
71.00	265.77	239.84	38.40	46.10
72.00	353.51	242.65	38.40	46.10
73.00	272.52	245.74	40.80	49.00
74.00	276.19	248.84	40.80	49.00
75.00	279.76	251.88	40.80	49.00
76.00	283.24	254.83	40.80	49.00
77.00	286.62	257.78	40.80	49.00
78.00	289.92	261.02	40.80	49.00
79.00	293.14	264.17	40.80	49.00
80.00	296.28	267.32	40.80	49.00
81.00	299.33	270.73	40.80	49.00
82.00	302.32	274.06	41.60	49.00
83.00	305.23	277.32	41.60	49.00
84.00	308.07	280.49	41.60	49.00
85.00	310.85	283.59	44.80	51.80
86.00	313.81	286.62	44.80	52.00
87.00	316.85	289.57	44.80	52.00
88.00	319.87	292.47	47.60	55.10
89.00	323.15	295.29	47.60	55.10
90.00	326.36	298.06	47.60	55.10
91.00	329.50	300.76	47.60	57.60
92.00	332.68	303.40	47.60	58.10
93.00	336.05	305.99	47.60	58.10
94.00	339.35	308.52	47.60	58.10
95.00	342.86	311.07	47.60	61.20
96.00	346.38	313.85	48.00	61.20
97.00	349.81	316.57	48.00	61.20
98.00	353.18	319.30	51.20	61.20
99.00	356.48	322.25	51.20	61.20
100.00	359.72	325.35	51.20	61.20
101.00	362.89	328.52	51.20	61.20
102.00	366.00	331.63	51.20	61.20
103.00	369.05	334.87	54.40	61.20
104.00	372.04	338.19	54.40	61.20

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105.00	374.97	341.45	54.40	63.40
106.00	377.85	344.64	54.40	63.40
107.00	380.77	347.77	54.40	64.30
108.00	383.85	350.85	54.40	64.30
109.00	386.88	353.87	54.40	66.20
110.00	390.10	356.83	54.40	67.30
111.00	393.33	359.75	54.40	67.30
112.00	396.49	362.61	54.40	69.10
113.00	399.61	365.42	54.40	69.10
114.00	402.95	368.17	54.40	69.10
115.00	406.24	370.89	54.40	70.40
116.00	409.62	373.55	54.40	70.40
117.00	413.09	376.17	54.40	73.40
118.00	416.51	378.91	54.40	73.40
119.00	419.86	381.72	54.40	73.40
120.00	423.16	384.49	54.40	73.40
121.00	426.41	387.38	54.40	73.40
122.00	429.60	390.33	54.40	73.40
123.00	432.75	393.24	54.40	73.40
124.00	435.84	396.10	54.40	73.40
125.00	438.88	398.92	57.60	73.40
126.00	441.87	401.95	57.60	74.90
127.00	444.82	404.94	57.60	74.90
128.00	447.72	407.88	57.60	74.90
129.00	450.82	411.29	57.80	74.90
130.00	453.89	414.66	60.80	76.50
				77.80

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 work ed out and compared with design EUDL & LF given in table above.
2. When loaded length lies between the values give n in the t able above, the EUDL for Bending Moment and Shear can be interpolated.
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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