GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS
(RAILWAY BOARD)

2015/Proj./Model DBR/2/2 New Delhi, dated 15.01.2018

To,

Chairman & Managing Directors,
(As per list attached)

Sub: Approval of Model Design Basis Report (DBR) for viaducts of Metro Systems.
Ref: (i) RDSO's letter No. UTHS/51 dated 18.12.2017
(ii)RDSO's letter No. CBS/Metro/Sub-Committee 08.01.2018

The revised Model Design Basis Report (September, 2017) for viaducts of Metro Systems has been examined in Board in consultation with RDSO and approval of Railway Board is hereby conveyed.

Accordingly, approved copy of DBR is enclosed for reference and necessary action.

Encl: As above

15.01.2018

(Ruth Changsan)
Director/MTP
Railway Board
☎ 011-23097061

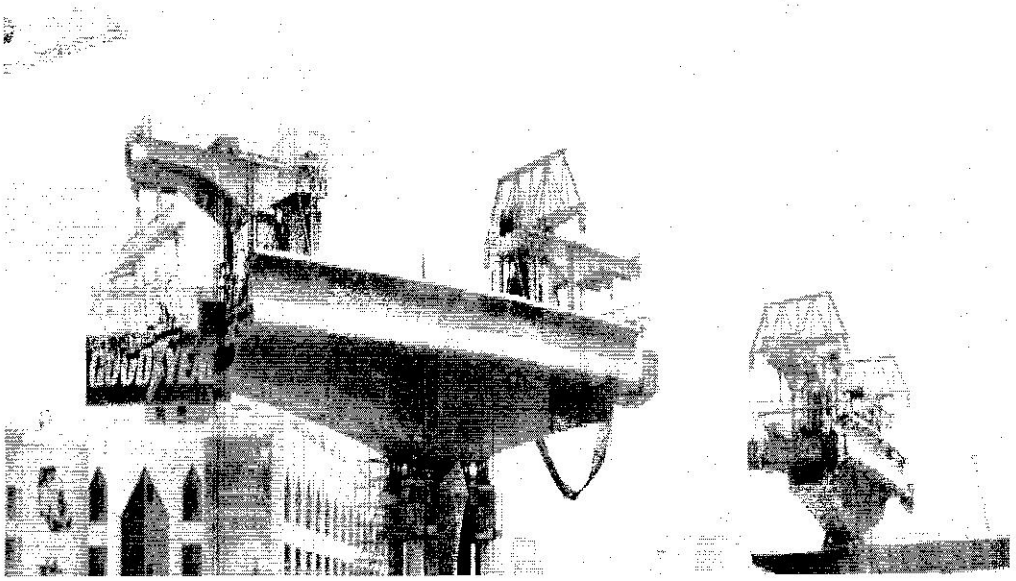
Copy to: (i) **Secretary**, Ministry of Housing & Urban Affairs (MoHUA), Nirman Bhavan, New Delhi-110001

(ii) **Executive Director/UTHS**, RDSO, Manak Nagar, Lucknow for information and uploading on RDSO's website please.

MODEL

DESIGN BASIS REPORT (DBR)

FOR VIADUCT OF METRO SYSTEM



Research Designs & Standards Organization,

Lucknow

September, 2017

Model Design Basis Report (DBR) for Viaduct of Metro System

1. INTRODUCTION

1.1 Brief description of project

1.2 Geometrical Design Feature: Gradient, Maximum Degree of Curve, Spacing of track

1.3 Scope of DBR

2. PROPOSED STRUCTURAL SYSTEM OF VIADUCT

2.1 Superstructure system: type, spans etc.

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

2.3 Bearing: bearing type;

2.4 Substructure system: type

2.5 Foundation system: type

2.6 Parapets: type

3. CLEARANCES FOR STRUCTURES

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

3.2 Clearance for Railway Traffic: Indian Railways Schedule of Dimensions (SOD) shall be applicable.

3.3 Clearances for Metro Traffic: As per approved SOD of specific Metro system.

4. STRUCTURAL MATERIALS AND PROPERTIES

4.1 Cement: Clause 4.1 of IRS CBC

4.2 Concrete

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

4.2.2 Young's Modulus : Clause 5.2.2.1 of IRS CBC

4.2.3 Modular ratio: Clause 5.2.6 of IRS CBC

4.2.4 Minimum grade of concrete for structural elements: Clause 5.4.4 of IRS CBC

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

4.2.6 Poisson's ratio: 0.15 for all concretes.

4.3 Reinforcing steel: As per Clause 4.5 & 7.1.5 of IRS CBC.

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

4.5.2 Prestress Losses: As per Clause 16.8.2 and 16.8.3 of IRS CBC.

4.5.3 Sheathing: As per Clause 7.2.6.4.2 of IRS CBC.

4.5.4 Anchorages: As per Clause 7.2.6.4.3 and Clause16.8.3.4 of IRS CBC

4.6 Structural steel for steel and composite bridges

4.6.1 Steel shall conform to IS: 2062.

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

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

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

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

4.7 Structural Steel for Miscellaneous Use:

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

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

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

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

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

5. LOADS

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

5.2 Super Imposed Dead Load (SIDL): Superimposed dead loads include all the weights of materials on the structure that are not structural elements but are permanent. It includes weight of track form plinth/ rails/ fasteners/ cables/ parapet/ hand-rail/OHE mast /cable trough/signaling equipment etc. and will be considered in the design as per the site conditions.

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

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

5.4 Live Load (LL): The simply supported structures shall be designed for one of the loading envelopes (Light, Medium or Heavy) tabulated in the Annexure I. The loading envelope chosen shall be as per the Rolling Stock planned to be used on the Metro system. Alternately, metro shall work out the EUDL chart for the actual train loads planned to be used and this EUDL chart shall be a part of the DBR.

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

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

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

5.6 Footpath Live Load: As per Clause 2.3.2 of IRS Bridge Rule.

5.7 Braking and Traction (BR/TR): The value of braking and traction forces will be taken as per rolling stock used, to be decided by Metro. For twin tracked decks carrying traffic in opposite directions, consideration should be given to braking forces from one train and traction forces from another, acting simultaneously which will be maximum longitudinal loading on a deck. For more than 2 tracks, Clause 2.8.4 of IRS Bridge Rules shall be considered.

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

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

5.8 Centrifugal Force (CF): On curved track, centrifugal forces shall be determined in accordance with Clause 2.5 of IRS Bridge Rules.

5.9 Gradient Effect: Shall be considered as per site condition.

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

5.11 Seismic Load (EQ): "Seismic Code for Earthquake Resistant Design of Railway Bridges" shall be followed. This code also covers load combination and ductile detailing aspects.

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5.12 Temperature effect: Clause 2.6 of IRS Bridge Rules.

5.12.1 Overall temperature (OT): As per Clause 215.2 of IRC:6.

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

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

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

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

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

(b) Rules specifying the loads for design of super-structure and sub-structure of bridges and for assessment of the strength of existing bridges should be done as per IRS: Bridge Rules.

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

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

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

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

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

5.19 Forces on parapets: As per Clause 2.10 of IRS Bridge Rules.

5.20 Derailment load:

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

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

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

6. LOAD COMBINATIONS:

6.1 Methodology: Provisions of Bridge Rule/IRS Concrete Bridge Code shall be followed for load combinations.

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

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

7. DESIGN PARAMETERS:

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

7.2 ULS check: As per IRS Concrete Bridge Code.

7.3 SLS Check: As per IRS Concrete Bridge Code.

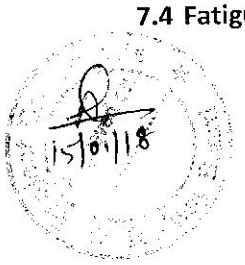
7.3.1 Crack Width:

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

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

7.3.2 Clause 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:



7.4.1 RCC and PSC structures

Clause 13.4 of IRS CBC shall govern.

7.4.2 Steel Structures

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

7.5 Durability:

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

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

7.6 Design life: As per Clause 15.1.3 and 16.1.3 of IRS CBC

7.7 Drainage:

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

8. DESIGN METHODOLGY

8.1 Bearing System

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

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

8.3.2 Soil structure analysis:

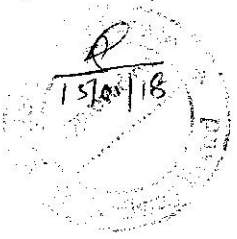
When designing elements forces or estimating displacements the soil stiffness shall be assessed based on the actual ground data.

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

(Any additional project specific information not covered above should be given)

10. DESIGN CODES AND STANDARDS

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



For Railway loading related issues:

i. UIC Codes

ii. Euro Codes

iii. Any other code which covers railway loading.

For other Design/ detailing related issues:

iv. IRC

v. IS

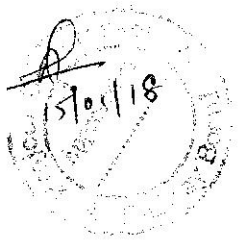
vi. Euro Code

vii. Other national codes.

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

11. DESIGN SOFTWARE:

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



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

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

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

   a= 2.54m, b=2.3m, c=10.3m, d=2.3m, e=2.5m, overall length of DMC/MC for combination-2 =19.98m (RMGL).

3. Standard Maximum Height of Centre of Gravity from Rail Level: 1830mm for 1676mm Gauge and 1700mm for 1435mm Gauge.

4 Maximum Axle Load 15.0t

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

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

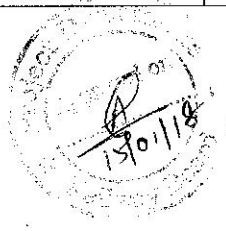
7. Loaded Length For Bending Moment, L is equal to the effective span in meters. For Shear, L is the loaded length in meters to give the maximum Shear in the Member under consideration.

8. EUDL (BM) The Equivalent Uniformly Distributed Load (EUDL) for Bending Moment (BM), for spans upto 10m, is that uniformly distributed load which produces the BM at the center of the span equal to the absolute maximum BM developed under the standard loads. For spans above 10m, the EUDL for BM, is that uniformly distributed load which produces the BM at one-sixth of the span equal to the BM developed at that section under the standard train loads considered.

9. EUDL (SF) EUDL for Shear Force (SF) is that uniformly distributed load which produces SF at the end of the span equal to the maximum SF developed under the standard train loads considered.

L (M)	EUDL(Tonne)		LF(Tonne)	
	SF	BM	TE	BF
0.5	30.00	30.000	3.00	2.70
1.0	30.00	30.000	3.00	2.70
1.5	30.00	30.000	3.00	2.70
2.0	30.00	30.000	3.00	2.70
2.5	32.40	30.000	6.00	5.40
3.0	37.00	30.000	6.00	5.40
3.5	40.29	30.000	6.00	5.40
4.0	42.75	30.459	6.00	5.40
4.5	44.67	33.252	6.00	5.40

L (M)	EUDL(Tonne)		LF(Tonne)	
	SF	BM	TE	BF
5.0	46.20	35.574	6.00	5.40
5.5	47.45	37.532	6.00	5.40
6.0	48.55	39.204	6.00	5.40
6.5	49.38	40.647	6.00	5.40
7.0	50.14	41.905	6.00	5.40
7.5	52.40	43.011	9.00	8.10
8.0	54.75	43.990	9.00	8.10
8.5	56.82	44.863	9.00	8.10
9.0	58.67	45.646	9.00	8.10
9.5	60.63	46.535	12.00	10.80
10.0	63.60	48.025	12.00	10.80
11.0	68.73	59.236	12.00	10.80
12.0	73.00	63.600	12.00	10.80
13.0	76.62	67.938	12.00	10.80
14.0	79.71	71.657	12.00	10.80
15.0	82.40	74.880	12.00	10.80
16.0	84.75	77.700	12.00	10.80
17.0	86.82	80.188	12.00	10.80
18.0	88.67	82.400	12.00	10.80
19.0	90.32	84.379	12.00	10.80
20.0	91.80	86.160	15.00	13.50
21.0	93.80	87.771	15.00	13.50
22.0	96.35	89.236	15.00	13.50
23.0	99.63	90.574	18.00	16.20
24.0	102.98	91.800	18.00	16.20
25.0	106.06	93.350	18.00	16.20
26.0	108.90	95.529	18.00	16.20
27.0	111.53	97.840	18.00	16.20
28.0	114.66	100.774	18.00	18.90
29.0	117.95	103.506	18.00	18.90
30.0	121.36	106.056	18.00	21.60
31.0	125.19	109.339	18.00	21.60
32.0	128.78	112.485	18.00	21.60
33.0	132.15	115.593	21.00	21.60
34.0	135.32	119.252	21.00	21.60
35.0	138.31	122.702	24.00	21.60
36.0	141.13	125.960	24.00	21.60
37.0	143.81	129.042	24.00	21.60
38.0	146.34	131.962	24.00	21.60
39.0	148.74	134.732	24.00	21.60
40.0	151.06	137.364	24.00	24.30
41.0	153.95	139.867	24.00	24.30



L (M)	EUDL(Tonne)		LF(Tonne)	
	SF	BM	TE	BF
42.0	156.71	142.251	24.00	24.30
43.0	159.87	144.525	24.00	27.00
44.0	163.05	146.695	24.00	27.00
45.0	166.09	148.768	24.00	27.00
46.0	169.00	151.278	24.00	27.00
47.0	171.79	153.804	24.00	27.00
48.0	174.88	156.255	24.00	29.70
49.0	178.04	159.189	24.00	29.70
50.0	181.30	162.005	24.00	32.40
51.0	174.12	164.711	24.00	32.40
52.0	188.17	167.312	24.00	32.40
53.0	191.41	169.816	24.00	32.40
54.0	194.53	172.227	24.00	32.40
55.0	197.54	175.069	24.00	32.40
56.0	200.44	177.836	24.00	32.40
57.0	203.24	180.606	24.00	32.40
58.0	205.94	183.699	24.00	32.40
59.0	208.56	186.687	24.00	32.40
60.0	211.11	189.576	27.00	35.10
61.0	214.04	192.370	27.00	35.10
62.0	216.88	195.074	27.00	35.10
63.0	219.99	197.691	30.00	37.80
64.0	223.12	200.663	30.00	37.80
65.0	226.14	203.575	30.00	37.80
66.0	229.08	206.476	30.00	37.80
67.0	231.93	209.663	30.00	37.80
68.0	235.00	212.756	33.00	40.50
69.0	238.11	215.760	33.00	40.50
70.0	241.30	218.678	36.00	43.20
71.0	244.66	221.513	36.00	43.20
72.0	247.93	224.300	36.00	43.20
73.0	251.10	227.392	36.00	43.20
74.0	254.21	230.400	36.00	43.20
75.0	257.22	233.453	36.00	43.20
76.0	260.15	236.697	36.00	43.20
77.0	263.00	239.857	36.00	43.20
78.0	265.78	242.935	36.00	43.20
79.0	268.50	245.936	36.00	43.20
80.0	271.17	248.862	39.00	45.90
81.0	274.12	251.716	39.00	45.90
82.0	277.00	254.500	39.00	45.90
83.0	280.08	257.216	42.00	48.60

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L (M)	EUDL(Tonne)		LF(Tonne)	
	SF	BM	TE	BF
84.0	283.18	259.869	42.00	48.60
85.0	286.20	262.458	42.00	48.60
86.0	289.15	264.988	42.00	48.60
87.0	292.03	267.459	42.00	48.60
88.0	295.09	270.199	42.00	51.30
89.0	298.18	272.893	42.00	51.30
90.0	301.33	275.593	42.00	54.00
91.0	304.52	278.498	42.00	54.00
92.0	307.83	281.340	42.00	54.00
93.0	310.97	284.121	45.00	54.00
94.0	314.04	287.117	45.00	54.00
95.0	317.05	290.094	48.00	54.00
96.0	320.00	293.040	48.00	54.00
97.0	322.89	296.205	48.00	54.00
98.0	325.70	299.304	48.00	54.00
99.0	328.48	302.342	48.00	54.00
100.0	331.23	305.518	48.00	56.70
101.0	334.19	308.236	48.00	56.70
102.0	337.09	311.096	48.00	56.70
103.0	340.17	313.901	48.00	59.40
104.0	343.24	316.652	48.00	59.40
105.0	346.26	319.351	48.00	59.40
106.0	349.22	321.998	48.00	59.40
107.0	352.12	324.597	48.00	59.40
108.0	355.17	327.147	48.00	62.10
109.0	358.24	329.852	48.00	62.10
110.0	361.37	332.581	48.00	64.80
111.0	364.61	335.261	48.00	64.80
112.0	367.78	338.154	48.00	64.80
113.0	370.90	340.002	48.00	64.80
114.0	373.96	343.800	48.00	64.80
115.0	376.97	346.550	48.00	64.80
116.0	379.92	349.252	48.00	64.80
117.0	382.83	351.908	48.00	64.80
118.0	385.69	354.742	48.00	64.80
119.0	388.50	357.560	48.00	64.80
120.0	391.29	360.390	51.00	67.50
121.0	394.25	363.610	51.00	67.50
122.0	397.17	366.777	51.00	67.50
123.0	400.24	369.980	54.00	70.20
124.0	403.30	373.287	54.00	70.20
125.0	406.32	376.541	54.00	70.20

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L (M)	EUDL(Tonne)		LF(Tonne)	
	SF	BM	TE	BF
26.0	409.28	379.743	54.00	70.20
127.0	412.20	382.898	54.00	70.20
128.0	415.25	385.997	57.00	72.90
129.0	418.31	389.113	57.00	72.90
130.0	421.42	392.350	60.00	75.60

Note: (1) For any other combination/vehicle to be permitted to run on the metro system, its EUDL for vertical load as well as longitudinal force(LF) shall be worked out and compared with design EUDL & LF given in table above.

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

(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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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 — 2DMC+1TC+2DMC+1TC+2DMC

2. Axle Distances: — a=1.92m,b= 2.5m, c=12.5m, d=2.5m, e= 1.92m, overall length of DMC/MC for combination-1 =21.34m (DMRC)

   a= 2.22m, b=2.45m, c=11.065m, d=2.45m, e=2.22m, overall length of DMC/MC for combination-2 =20.405m (Kolkata Metro)

   a= 2.45m, b=2.2m, c=12.5m, d=2.2m, e=2.4m, overall length of DMC/MC for combination-3 =21.75m (Kochi Metro)

3. Standard Maximum Height of Centre of Gravity from Rail Level: 1830mm for 1676mm Gauge and 1700mm for 1435mm Gauge.

4 Maximum Axle Load — 17.0t

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

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

7. Loaded Length — For Bending Moment, L is equal to the effective span in meters. For Shear, L is the loaded length in meters to give the maximum Shear in the Member under consideration.

8. EUDL (BM) — The Equivalent Uniformly Distributed Load (EUDL) for Bending Moment (BM), for spans upto 10m, is that uniformly distributed load which produces the BM at the center of the span equal to the absolute maximum BM developed under the standard loads. For spans above 10m, the EUDL for BM, is that uniformly distributed load which produces the BM at one-sixth of the span equal to the BM developed at that section under the standard train loads considered.

9. EUDL (SF) — EUDL for Shear Force (SF) is that uniformly distributed load which produces SF at the end of the span equal to the maximum SF developed under the standard train loads considered.

L (M)	EUDL(T)		LF(T)	
	SF	BM	TE	BF
0.5	34.00	34.000	3.40	3.10
1.0	34.00	34.000	3.40	3.10
1.5	34.00	34.000	3.40	3.10
2.0	34.00	34.000	3.40	3.10
2.5	35.84	34.000	6.80	6.10

L (M)	EUDL(T)		LF(T)	
	SF	BM	TE	BF
3.0	40.53	34.000	6.80	6.10
3.5	43.89	34.000	6.80	6.10
4.0	46.75	34.000	6.80	6.10
4.5	49.11	36.535	6.80	6.10
5.0	51.00	38.938	6.80	6.10
5.5	55.55	40.960	6.80	6.10
6.0	53.83	42.684	6.80	6.10
6.5	55.76	44.361	10.20	9.20
7.0	59.61	45.883	10.20	9.20
7.5	61.93	47.222	10.20	9.20
8.0	64.43	48.428	10.20	9.20
8.5	66.64	51.562	10.20	9.20
9.0	69.21	54.349	13.60	12.20
9.5	72.72	56.844	13.60	12.20
10.0	75.89	59.092	13.60	12.20
11.0	81.35	70.423	13.60	12.20
12.0	85.91	75.888	13.60	12.20
13.0	89.76	80.512	13.60	12.20
14.0	93.06	84.475	13.60	12.20
15.0	95.93	87.910	13.60	12.20
16.0	98.43	90.916	13.60	12.20
17.0	100.64	93.568	13.60	12.20
18.0	102.60	95.925	13.60	12.20
19.0	104.36	98.035	13.60	12.20
20.0	105.94	99.933	13.60	12.20
21.0	107.38	101.650	16.00	14.40
22.0	109.70	103.212	17.00	15.30
23.0	112.32	104.637	19.20	17.30
24.0	114.95	105.944	20.40	18.40
25.0	118.51	107.146	20.40	18.40
26.0	121.80	108.769	20.40	18.40
27.0	124.84	111.036	20.40	18.40
28.0	128.06	113.142	20.40	21.40
29.0	131.85	115.562	20.40	21.40
30.0	135.39	118.510	20.40	23.00
31.0	139.60	122.128	20.40	24.50
32.0	143.74	125.749	20.40	24.50
33.0	147.62	129.151	20.40	24.50
34.0	151.28	133.136	22.40	24.50
35.0	154.73	137.104	22.40	24.50
36.0	157.99	140.851	22.40	24.50
37.0	161.07	144.935	25.60	24.50

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L (M)	EUDL(T)		LF(T)	
	SF	BM	TE	BF
38.0	163.99	147.753	25.60	24.50
39.0	166.76	150.139	27.20	24.50
40.0	169.39	153.966	27.20	24.50
41.0	171.89	156.844	27.20	25.90
42.0	174.27	159.586	27.20	25.90
43.0	176.80	162.201	27.20	27.50
44.0	179.74	164.696	27.20	28.80
45.0	182.54	167.081	27.20	28.80
46.0	185.83	169.361	27.20	30.60
47.0	189.11	171.545	27.20	30.60
48.0	192.26	173.638	27.20	31.70
49.0	195.27	176.189	27.20	31.70
50.0	198.83	178.876	27.20	33.70
51.0	202.27	181.280	27.20	34.60
52.0	205.88	184.191	27.20	36.70
53.0	209.70	187.131	27.20	36.70
54.0	213.37	189.962	27.20	36.70
55.0	216.91	192.690	27.20	36.70
56.0	220.32	195.427	27.20	36.70
57.0	223.61	198.560	27.20	36.70
58.0	226.79	201.585	27.20	36.70
59.0	229.86	204.609	27.20	36.70
60.0	232.83	207.998	27.20	36.70
61.0	235.70	211.277	27.20	36.70
62.0	238.48	214.450	28.80	37.40
63.0	241.17	217.220	28.80	37.40
64.0	243.78	220.498	32.00	40.30
65.0	246.82	223.383	32.00	40.30
66.0	249.78	226.180	32.00	40.30
67.0	252.89	228.894	34.00	42.80
68.0	256.17	231.528	34.00	42.80
69.0	259.36	234.086	35.20	43.20
70.0	262.45	236.951	35.20	43.20
71.0	265.77	239.839	38.40	46.10
72.0	353.51	242.647	38.40	46.10
73.0	272.52	245.743	40.80	49.00
74.0	276.19	248.854	40.80	49.00
75.0	279.76	251.883	40.80	49.00
76.0	283.24	254.832	40.80	49.00
77.0	286.62	257.782	40.80	49.00
78.0	289.92	261.015	40.80	49.00
79.0	293.14	264.167	40.80	49.00

L (M)	EUDL(T)		LF(T)	
	SF	BM	TE	BF
80.0	296.28	267.315	40.80	49.00
81.0	299.33	270.731	40.80	49.00
82.0	302.32	274.063	41.60	49.00
83.0	305.23	277.315	41.60	49.00
84.0	308.07	280.490	41.60	49.00
85.0	310.85	283.590	44.80	51.80
86.0	313.81	286.618	44.80	52.00
87.0	316.85	289.570	44.80	52.00
88.0	319.87	292.468	47.60	55.10
89.0	323.15	295.294	47.60	55.10
90.0	326.36	298.058	47.60	55.10
91.0	329.50	300.760	47.60	57.60
92.0	332.68	303.404	47.60	58.10
93.0	336.05	305.991	47.60	58.10
94.0	339.35	308.523	47.60	58.10
95.0	342.86	311.065	47.60	61.20
96.0	346.38	313.845	48.00	61.20
97.0	349.81	316.569	48.00	61.20
98.0	353.18	319.297	51.20	61.20
99.0	356.48	322.254	51.20	61.20
100.0	359.72	325.345	51.20	61.20
101.0	362.89	328.519	51.20	61.20
102.0	366.00	331.632	51.20	61.20
103.0	369.05	334.872	54.40	61.20
104.0	372.04	338.190	54.40	61.20
105.0	374.97	341.445	54.40	63.40
106.0	377.85	344.639	54.40	63.40
107.0	380.77	347.774	54.40	64.30
108.0	383.85	350.850	54.40	64.30
109.0	386.88	353.870	54.40	66.20
110.0	390.10	356.834	54.40	67.30
111.0	393.33	359.746	54.40	67.30
112.0	396.49	362.605	54.40	69.10
113.0	399.61	365.415	54.40	69.10
114.0	402.95	368.173	54.40	70.40
115.0	406.24	370.885	54.40	70.40
116.0	409.62	373.550	54.40	73.40
117.0	413.09	376.169	54.40	73.40
118.0	416.51	378.908	54.40	73.40
119.0	419.86	381.723	54.40	73.40
120.0	423.16	384.492	54.40	73.40
121.0	426.41	387.375	54.40	73.40

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L (M)	EUDL(T)		LF(T)	
	SF	BM	TE	BF
122.0	429.60	390.331	54.40	73.40
123.0	432.75	393.239	54.40	73.40
124.0	435.84	396.100	54.40	73.40
125.0	438.88	398.915	57.60	74.90
126.0	441.87	401.945	57.60	74.90
127.0	444.82	404.937	57.60	74.90
128.0	447.72	407.883	57.60	74.90
129.0	450.82	411.289	57.80	76.50
130.0	453.89	414.664	60.80	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 worked out and compared with design EUDL & LF given in table above.

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

(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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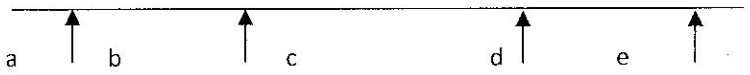
EQUIVALENT UNIFORMLY DISTRIBUTED LOAD & LONGITUDINAL FORCE CHART FOR HEAVY METRO LOADING

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

1. Train Formation — 2DMC+1TC+2DMC+1TC+2DMC.

2. Axle Distances: — a=2.4m, b= 2.2m, c=12.8m, d=2.2m, e= 2.4m, overall length of DMC/MC for combination-1 =22.0m (Mega Metro, Ahmadabad).



3. Standard Maximum Height of Centre of Gravity from Rail Level: 1830mm for 1676mm Gauge and 1700mm for 1435mm Gauge.

4. Maximum Axle Load — 18.0t

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

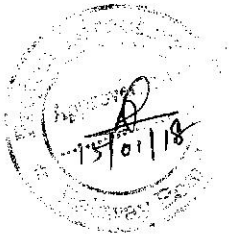
6. Braking Force (BF) — 18% of Vertical Axle Load for DMC/MC/TC.

7. Loaded Length — For Bending Moment, L is equal to the effective span in meters. For Shear, L is the loaded length in meters to give the maximum Shear in the Member under consideration.

8. EUDL (BM) — The Equivalent Uniformly Distributed Load (EUDL) for Bending Moment (BM), for spans upto 10m, is that uniformly distributed load which produces the BM at the center of the span equal to the absolute maximum BM developed under the standard loads. For spans above 10m, the EUDL for BM, is that uniformly distributed load which produces the BM at one-sixth of the span equal to the BM developed at that section under the standard train loads considered.

9. EUDL (SF) — EUDL for Shear Force (SF) is that uniformly distributed load which produces SF at the end of the span equal to the maximum SF developed under the standard train loads considered.

L (M)	EUDL(T)		LF(T)	
	SF	BM	TE	BF
0.5	36.00	36.000	3.6	3.2
1.0	36.00	36.000	3.6	3.2
1.5	36.00	36.000	3.6	3.2
2.0	36.00	36.000	3.6	3.2
2.5	40.32	36.000	7.2	6.5
3.0	45.60	36.000	7.2	6.5
3.5	49.37	36.000	7.2	6.5



L (M)	EUDL(T)		LF(T)	
	SF	BM	TE	BF
4.0	52.20	37.845	7.2	6.5
4.5	54.40	41.102	7.2	6.5
5.0	56.16	43.805	7.2	6.5
5.5	57.60	46.080	7.2	6.5
6.0	58.80	48.020	7.2	6.5
6.5	59.82	49.693	7.2	6.5
7.0	60.69	51.149	10.8	9.7
7.5	63.84	52.429	10.8	9.7
8.0	66.60	53.561	10.8	9.7
8.5	69.04	54.571	10.8	9.7
9.0	71.20	55.476	10.8	9.7
9.5	74.27	56.292	14.4	13.0
10.0	77.76	58.411	14.4	13.0
11.0	83.78	71.869	14.4	13.0
12.0	88.80	77.760	14.4	13.0
13.0	93.05	82.855	14.4	13.0
14.0	96.69	87.223	14.4	13.0
15.0	99.84	91.008	14.4	13.0
16.0	102.60	94.320	14.4	13.0
17.0	105.04	97.242	14.4	13.0
18.0	107.20	99.840	14.4	13.0
19.0	109.14	102.164	14.4	13.0
20.0	110.88	104.256	14.4	13.0
21.0	112.46	106.149	14.4	13.0
22.0	113.89	107.869	18.0	16.2
23.0	116.77	109.440	18.0	16.2
24.0	119.40	110.880	18.0	16.2
25.0	122.98	112.205	21.6	19.4
26.0	126.55	113.428	21.6	19.4
27.0	129.87	115.360	21.6	19.4
28.0	132.94	117.669	21.6	19.4
29.0	135.81	119.818	21.6	22.7
30.0	139.86	122.976	21.6	22.7
31.0	143.30	125.977	21.6	22.7
32.0	147.60	128.790	21.6	25.9
33.0	151.85	132.349	21.6	25.9
34.0	155.86	135.868	21.6	25.9
35.0	159.63	139.392	21.6	25.9
36.0	163.20	143.520	21.6	25.9
37.0	166.57	147.425	25.2	25.9
38.0	169.77	151.124	25.2	25.9
39.0	172.80	154.634	25.2	25.9

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L (M)	EUDL(T)		LF(T)	
	SF	BM	TE	BF
40.0	175.68	157.968	28.8	25.9
41.0	178.42	161.140	28.8	25.9
42.0	181.03	164.160	28.8	25.9
43.0	183.52	167.040	28.8	25.9
44.0	185.89	169.789	28.8	29.2
45.0	188.96	172.416	28.8	29.2
46.0	191.90	174.929	28.8	29.2
47.0	195.32	177.334	28.8	32.4
48.0	198.75	179.640	28.8	32.4
49.0	202.04	181.851	28.8	32.4
50.0	205.20	183.974	28.8	32.4
51.0	208.24	186.607	28.8	35.6
52.0	211.85	189.249	28.8	35.6
53.0	215.32	191.928	28.8	35.6
54.0	219.28	195.040	28.8	38.9
55.0	223.07	198.039	28.8	38.9
56.0	226.80	200.831	28.8	38.9
57.0	230.40	203.722	28.8	38.9
58.0	233.88	206.417	28.8	38.9
59.0	237.23	209.288	28.8	38.9
60.0	240.48	212.400	28.8	38.9
61.0	243.62	215.410	28.8	38.9
62.0	246.66	218.787	28.8	38.9
63.0	249.60	222.171	28.8	38.9
64.0	252.45	225.450	28.8	38.9
65.0	255.21	228.268	28.8	38.9
66.0	257.89	231.270	32.4	42.1
67.0	261.03	234.699	32.4	42.1
68.0	264.07	237.600	32.4	42.1
69.0	267.44	240.417	36.0	45.4
70.0	270.82	243.154	36.0	45.4
71.0	274.11	245.915	36.0	45.4
72.0	277.30	249.000	36.0	45.4
73.0	280.41	252.000	39.6	48.6
74.0	283.91	255.191	39.6	48.6
75.0	287.33	258.509	39.6	48.6
76.0	291.03	261.739	43.2	51.8
77.0	294.73	264.885	43.2	51.8
78.0	298.34	267.951	43.2	51.8
79.0	301.85	270.939	43.2	51.8
80.0	305.28	274.212	43.2	51.8
81.0	308.62	277.493	43.2	51.8

L (M)	EUDL(T)		LF(T)	
	SF	BM	TE	BF
82.0	311.88	280.765	43.2	51.8
83.0	315.07	284.322	43.2	51.8
84.0	318.17	287.794	43.2	51.8
85.0	321.20	291.185	43.2	51.8
86.0	324.17	294.497	43.2	51.8
87.0	327.06	297.732	43.2	51.8
88.0	329.89	300.895	46.8	55.1
89.0	333.06	303.986	46.8	55.1
90.0	336.16	307.008	46.8	55.1
91.0	339.51	309.964	50.4	58.3
92.0	342.86	312.856	50.4	58.3
93.0	346.14	315.685	50.4	58.3
94.0	349.35	318.454	50.4	58.3
95.0	352.50	321.165	50.4	61.6
96.0	355.95	323.820	50.4	61.6
97.0	359.33	326.420	50.4	61.6
98.0	362.94	329.360	50.4	64.8
99.0	366.55	332.116	50.4	64.8
100.0	370.08	334.973	50.4	64.8
101.0	373.54	338.072	50.4	64.8
102.0	376.94	341.111	50.4	64.8
103.0	380.27	344.104	54.0	64.8
104.0	383.54	347.372	54.0	64.8
105.0	386.74	350.578	54.0	64.8
106.0	389.89	353.860	57.6	64.8
107.0	392.97	357.281	57.6	64.8
108.0	396.00	360.640	57.6	64.8
109.0	398.97	363.973	57.6	64.8
110.0	401.89	367.154	57.6	68.0
111.0	405.08	370.352	57.6	68.0
112.0	408.21	373.474	57.6	68.0
113.0	411.55	376.541	57.6	71.3
114.0	414.88	379.554	57.6	71.3
115.0	418.16	382.514	57.6	71.3
116.0	421.39	385.423	57.6	71.3
117.0	424.55	388.283	57.6	74.5
118.0	447.97	391.094	57.6	74.5
119.0	431.33	393.858	57.6	74.5
120.0	434.88	396.576	57.6	77.8
121.0	438.43	399.261	57.6	77.8
122.0	441.91	402.185	57.6	77.8
123.0	445.35	405.061	57.6	77.8

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L (M)	EUDL(T)		LF(T)	
	SF	BM	TE	BF
124.0	448.72	408.008	57.6	77.8
125.0	452.04	411.080	57.6	77.8
126.0	455.31	414.103	57.6	77.8
127.0	458.53	417.078	57.6	77.8
128.0	461.70	420.008	57.6	77.8
129.0	464.82	422.891	57.6	77.8
130.0	467.89	425.908	57.6	77.8

Note: (1) For any other combination/vehicle to be permitted to run on the metro system, its EUDL for vertical load as well as longitudinal force(LF) shall be worked out and compared with design EUDL & LF given in table above.

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

(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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