NOIDA METRO RAIL CORPORATION LTD.						
Part Design & Construction of Elevated Viaduct and 10 nos. of Elevated Stations for Extension Projects of NMRC's Aqua Line from Botanical Garden to Noida Sec-142 (from Chainage (-) 383.959 to 12130.143) and from Depot Station to Boraki MMTH (Chainage 28678.253 to 31263.482).						
E-Tender no. - NMRC/Projects/NGNECC/2026/457						
ADDENDUM-1 SUMMARY SHEET						
Sr. No.	**Volume**	**Document Name**	**Clause No./Item No.**	**Page No.**	**Addendum/Corrigendum**	**Remarks**
1	Volume-1	NIT	1.1.2	2	Date of Pre-Bid Meeting, Last Date of Seeking Clarifications & Issue of Addendum is modified.	Replace NIT's Page 2 by 2R.
2	Volume-1	NIT	1.1.3.1 (i)	3	Typographical error in Clause 1.1.3.1 (i) is corrected.	Replace NIT's Page 3 by 3R.
3	Volume-1	NIT	1.1.3.2 A	10	Similar work definition is modified.	Replace NIT's Page 10 by 10R.
4	Volume-1	NIT	1.1.3.2 A	11	Clause for demonstration of similar work experience in case of JV/Consotrium is modified.	Replace NIT's Page 11 by 11R.
5	Volume-1	NIT	Note C of 1.1.3.2 A	12	Clause for submission of ongoing works is modified.	Replace NIT's Page 12 by 12R.
6	Volume-1	ITT	F5	48	Addition of clause for submission of Performance Bank Gaurantee	Replace ITT's Page 11 by 11R.
7	Volume-1	FOT	Appendix-1	70	Limit of AOA in PI Insurance is modified.	Replace FOT's Page 12 by 12R.
8	Volume-4	ODS	ODS	01 to 38	ODS is modified and replaced.	ODS is modified and page 1 to 38 are replaced by 1R to 38R.
9	Financial Package	BOQ	Financial Package		BOQ is modified and replaced.	BOQ is modified and replaced.

Tender documents on sale	From 13.05.2026 to 12.06.2026 (up to 15:00 hrs.) on e-tendering website http://etender.up.nic.in. Tender document can only be obtained online after registration of tenderer on the website http://etender.up.nic.in. For further information in this regard bidders are advised to contact on 0120-4344483/84
Cost of Tender documents	INR 23,600/- (inclusive of 18% GST) Non-Refundable (Payment of tender document cost/tender fee is to be made only by RTGS, NEFT & IMPS. No other mode of payment will be accepted. The details of bank account of NMRC are mentioned below. The bidders are required to upload scanned copies of transaction of payment of tender document cost/tender fee including e-receipt (clearly indicating UTR No. & tender reference i.e. NGNECC-01 must be entered in the remarks at the time of online transaction of payment, failing which payment may not be considered) at the time of online bid submission). (Copy of GST registration no. to be provided along with Tender document cost/tender fee).
Last date of Seeking Clarifications	**27.05.2026** ~~26.05.2026~~ upto 17:00 hrs. Queries/clarifications from bidders after due date and time shall not be acknowledged.
Pre-bid Meeting	**26.05.2026** ~~25.05.2026~~ at 11:00 hrs.
Last date of issuing addendum	**02.06.2026** ~~01.06.2026~~
Date & time of Submission of Tender online	Tender submission start date: 05.06.2026 (09:00 hrs). Tender submission end date: 12.06.2026 (15:00 hrs).
Date & time of opening of Tender online	12.06.2026 at 15.30 hrs.
• Authority for purchase of tender documents (in case of physical tenders), seeking clarifications and submission of completed tender documents • Place of pre-bid meeting	General Manager/Projects Noida Metro Rail Corporation, Block-III, 3rd Floor, Ganga Shopping Complex, Sector-29, Noida 201301 Email: nmrcprojects@gmail.com Website: www.nmrcnoida.com

To facilitate payment of Tender Fee and Tender Security through RTGS, NEFT & IMPS, the details of bank account of NMRC is mentioned below:

Name of Bank	Bank's Address	Account Name & No.	Account Type	IFSC code
State Bank of India	State Bank of India (04077) – Sector 18, Noida, Gautam Budh Nagar, Uttar Pradesh -201301	A/C No. 37707840592	Current	IFSC Code: SBIN0004077

1.1.3 QUALIFICATION CRITERIA:

1.1.3.1 Eligible Applicants:

i. The tenders for this contract will be considered only from those tenderers (proprietorship firms, partnerships firms, companies, corporations, LLP, consortia or joint ventures) who meet requisite eligibility criteria prescribed in the sub-clauses of Clause 1.1.3 of NIT. In the case of a JV or Consortium, all members of the Group shall be jointly and severally liable for the performance of whole contract.

Performance of each JV/Consortium partner shall also be judged on quarterly basis. In case, the performance of the partner(s) is not found satisfactory, actions as deemed appropriate by the Employer may be taken including termination of contract or termination of any of JV/Consortium member(s) from the contract i.e. Part Termination of the contract. In case of part termination of contract, the Performance Security(ies) submitted by the member(s) for their portion of work in contract as per their share in JV/Consortium shall be forfeited and the scope of the work/duties assigned to the defaulting JV/Consortium member(s). In such a case, remaining works pertaining to the scope of defaulting member of JV, may be completed by other member(s) of JV in the following manner:

a) At their own, if they have adequate technical competence to the satisfaction of Employer.

b) By subcontracting such scope of work of defaulting member(s) to technically competent Agency with the consent of Employer & without any financial implication to the Employer. In such cases, the limit of subcontracting the works up to 50% of total scope of work shall not apply.

c) By induction of new member having adequate technical competence and meeting the original tender eligibility conditions, acceptable to the Employer in JV/Consortium replacing the defaulting member(s) & without any financial implication to the Employer. The new member(s) shall be jointly & severally liable for the performance of the whole contract and also shall submit the Performance Security from their bank account for an amount equivalent to the amount of forfeited amount of Performance security of defaulting member.

In case of **(a)** ~~(i)~~ & **(b)** ~~(ii)~~ above, forfeited amount of Performance Security(ies) of the defaulting member(s) shall be submitted by other member(s) of the JV/Consortium.

Further, the performance of each of JV/Consortium member may also be specifically stated in the Work experience Certificate /

"Beneficial owner "will be as under:

i. In case of a company or Limited Liability Partnership, the beneficial owner is the natural person(s), who, whether acting alone or together, or through one or more juridical person(s), has a controlling ownership interest or who exercises control through other means. Explanation –

   a. "Controlling ownership interest "means ownership of, or entitlement to, more than twenty-five per cent of shares or capital or profits of the company.

   b. "Control "shall include the right to appoint the majority of the directors or to control the management or policy decisions, including by virtue of their shareholding or management rights or shareholders agreements or voting agreements;

ii. In case of a partnership firm, the beneficial owner is the natural person(s) who, whether acting alone or together, or through one or more juridical person, has ownership of entitlement to more than fifteen percent of capital or profits of the partnership;

iii. In case of an unincorporated association or body of individuals, the beneficial owner is the natural person(s), who, whether acting alone or together, or through one or more juridical person, has ownership of or entitlement to more than fifteen percent of the property or capital or profits of such association or body of individuals;

iv. Where no natural person is identified under (i) or (ii) or (iii) above, the beneficial owner is the relevant natural person who holds the position of senior managing official;

v. In case of a trust, the identification of beneficial owner(s) shall include identification of the author of the trust, the trustee, the beneficiaries with fifteen percent or more interest in the trust and any other natural person exercising ultimate effective control over the trust through a chain of control or ownership.

"Agent "is a person employed to do any act for another, or to represent another in dealings with third persons.

Certificate of Compliance:
An undertaking shall be taken from bidders as per Appendix-26 of FOT, certifying that the bidders fulfil all the requirements contained in the aforesaid clause.

1.1.3.2 Minimum Eligibility Criteria:

A. Work Experience: The tenderers will be qualified only if they have successfully completed work(s), completion date(s) of which falling during last seven (07) years ending last day of the month previous to the month of tender submission as given below

(i) At least One "similar works" *each of value of INR 1,013.66 crore or more.

OR

(ii) Two "similar works" *each of value of INR 633.54 crore or more.

OR

(iii) Three "similar works" *each of value of INR 506.83 crore or more.

- The "Similar works" for this contract shall be "~~Design and~~ Construction of Metro/RRTS/High Speed rail Viaduct having a pre-stressed concrete super-structure as well as construction of elevated metro stations,"

- If the tenderer is a JV/Consortium having foreign partner(s) and above work(s) have been executed by the foreign partner of JV and the work(s) were done in the country of the foreign partner, then in addition to this the foreign partner must have executed works (which need not be similar in nature) of total put together of value INR 506.83 crores or more outside the country of the foreign partner.

- Individual Bidder or any substantial member of JV/Consortium should fulfil following conditions -

    a. Bidder should have successfully completed minimum 6 km or more of Elevated Metro/RRTS/High Speed rail viaduct in a single awarded contract.

    b. Bidder should have successfully completed minimum 4 nos. of Elevated Stations or more in Elevated Metro/RRTS/High Speed Rail in a single awarded contract.

    c. Bidder should have successfully completed Architectural Finishing Work for minimum 04 nos. Elevated stations or more in Elevated Metro/RRTS/High speed Rail in a single awarded contract.

    d. Bidder should have successfully completed PEB structure work for minimum 04 nos. Elevated stations or more in Elevated Metro/RRTS/High speed Rail in a single awarded contract.

    e. Further, in case the bid is submitted by a Joint Venture (JV)/Consortium, **any** ~~each~~ member of the JV/Consortium shall ~~independently~~ meet and demonstrate the similar work experience as stipulated above; failing which, the bid shall be treated as non-responsive and shall be rejected.

Further, in case the bidder does not have required work experience for "Pre-Engineered Building (PEB) works & Architectural Finishing work" for 04 nos. of Elevated Stations or more in Elevated Metro/RRTS/High Speed rail in a single awarded contract and intends to engage a sub- contractor for this work, the sub-contractor must have executed work of "Pre-Engineered Building (PEB) works & Architectural Finishing work " for minimum 04 nos. of Elevated Stations in Elevated Metro/RRTS/High Speed rail in a single awarded contract.

Notes:

a) Work experience of only substantial partner (partner with share of 26% or more in the JV / Consortium) shall be considered for evaluating of JV/Consortium.

b) The tenderer shall submit details of works executed by them in the Performa of Appendix-17 & 17A of FOT for the works to be considered for qualification of work experience criteria. Documentary proof of completion certificates from client clearly indicating the nature/scope of work, actual completion cost and actual date of completion for such work should be submitted. The offers submitted without this documentary proof shall not be evaluated. In case the work is executed for private client, copy of work order, bill of quantities, bill wise details of payment received certified by C.A., T.D.S certificates for all payments received and copy of final/last bill paid by client shall also be submitted.

c) Value of successfully completed portion of any ongoing work up to last day of the month

previous to the month of tender submission will also be considered for qualification of work experience criteria. **Completion of on-going work more than or equal to 80% as per 'Scope of Work' and verified by certificate issued by employer shall only be considered as significantly completed work for evaluation.**

d) For completed works, value of work done shall be updated to last day of the month previous to the month of tender submission price level assuming 5% inflation for Indian Rupees every year and 2% for foreign currency portions per year. The exchange rate of foreign currency shall be applicable 28 days before the submission date of tender.

e) If the above work(s) (i.e. "~~Design and~~ Construction of Metro/RRTS/High Speed rail Viaduct as well as construction of elevated metro stations, having a pre-stressed concrete super-structure" comprise other works, then client's certificate clearly indicating the amount of work done in respect of the "similar work" shall be furnished by the tenderer in support of work experience along-with their tender submissions.

f) If the qualifying work(s) were done by a contractor in JV/consortium having different constituents (consists of other than Indian Contractor or consists of Indian Contractor with less than 26% share), then the value of work as per their percentage participation in such JV/Consortium shall be considered.

g) Only work experience certificate having stamp of Name and Designation of officer along with the Name of client shall be considered for evaluation. However, if any work experience certificate has been issued prior to 01.07.2019 and if it is not stamped, the same shall be subjected to verification.

h) After opening of financial bids, the work experience credentials (work experience certificate along with other documents if any) of L-1 bidder shall be sent for verification & certification to the concerned client(s). In case of any concealment or misrepresentation of facts, appropriate action(s) in accordance with Tender Conditions shall be taken.

B. Financial Standing: The tenderers will be qualified only if they have minimum financial capabilities as below:

(i) T1 –Liquidity: It is necessary that the firm can withstand cash flow that the contract will require until payments received from the Employer. Liquidity therefore becomes an important consideration.

This shall be seen from the balance sheets and/or from the banking reference. Net current assets (as per proforma given in Annexure-8 of ITT), should show that the applicant has access to or has available liquid assets to meet cash flow of INR 60.34 Crores for this contract, the aggregate of the Net Current Assets will be considered for working out the Liquidity.

In Case of JV/Consortium: Requirement of liquidity is to be distributed between members as per their percentage participation and every member should satisfy the minimum requirement.

Example: Let Member-1 has percentage participation = M and Member-2 has percentage participation = N.

If minimum liquidity required is 'W', then liquidity of member-1 ≥(W*M)/100

and liquidity of member-2 ≥(W*N)/100

In case of joint venture/consortium, the Performance Security is to be submitted in the name of the lead member.

The Performance Guarantee should be valid for a period of 06 (six) months beyond the Defect Liability Period.

F5.2 The Tenderer has to furnish other Guarantees, Undertakings, and Warranties, in accordance with the provisions of the General Conditions of Contract and Special Conditions of Contract.

The Performance Bank Guarantee as above shall be encashable in any branch of the Issuing Bank located in Delhi, Noida or Greater Noida region only.

F5.3 Failure of the successful Tenderer to comply with the requirements of paragraphs F4 and F5 shall constitute sufficient grounds for the annulment of the award and forfeiture of the Tender Security.

FORM OF TENDER – APPENDIX-1

REQUIREMENTS UNDER GENERAL CONDITIONS OF CONTRACT

S. No.	DESCRIPTION	REF. TO CLAUSE NO.	REQUIREMENT
i	Amount of Performance Security	Clause 4.2 of the GCC	10% of the Contract Price in types and proportions of currencies in which the contract price is payable. In the event of variations during the execution of the contract which result in payments to the Contractor over and above the contract price, the Performance Security shall be adjusted in accordance with clause 4.2 of GCC.
ii	Latest 'date for commencement' of the Works	Clause 8.1 of the GCC	Date given in LOA or Employer's Notice to Proceed
iii	'Time for completion' of the work from the date of commencement of the work	Clause 8.2 of the GCC	36 Months
iv	Liquidated Damages	Clause 8.5 of the GCC	(i) Liquidated damages shall be levied as given in Appendix 2B of Employer's Requirements for not achieving the respective key date. (ii) The maximum limit of Liquidated Damages shall be 10% of the total Contract Value. (iii) Total maximum limit of LD including sums payable by the employer to designated contractors is 15% as mentioned in GCC.
v	'Defects Liability Period' for the whole of the Works	Clause 10 of the GCC	52 weeks after the date of issue of Taking-Over Certificate for the Whole of the Works.
vi	Amount of advance payment	Clause 11.2 of the GCC	As per clause 11.2 of GCC
vii	Amount of Professional Indemnity Insurance (PII)	Clause 15.1 and 15.5 of the GCC	AOA (any one accident) limit equal to 6% of the **total** contract value ~~against Schedule 'A'~~ of BOQ in respect of 'design and construct' with AOY (any one year) limit of 2 incidents in a year. In the Professional Indemnity insurance Policy, the deductable amount shall not be more than 5% of AOA limit. PII Policy shall be obtained within four weeks from 'date of commencement' and shall be valid for five years after date of issue of 'Performance Certificate'. Wherever the contractor submits policy for shorter period / annual renewable policy, the same shall be renewed before its expiry date. In such situation, the performance guarantee shall

INTRODUCTION

This ODS pertains to Viaduct Portion of the Noida Metro Rail Corporation Extension.

1.1 SCOPE OF PROJECT

The Viaduct for Metro Project comprises of simply supported Precast Pre-tensioned twin U-girder (each U-girder supporting one track only)/Post tensioned Segmental Box Girder with RCC sub-structure and bored cast in situ pile /open foundation. The standard gauge of 1435 mm shall be followed. The Centre-to-Centre distance between two tracks shall be as per approved SOD of NMRC. However, PSC I-Girder / Balanced Cantilever / Steel Composite Girders have been proposed at sharp curves / special spans /crossover/ turnout / railway crossing / highway crossing.

1.1.1 Scope of Design Basis Report (DBR)

This ODS 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.

The ODS shall be read in conjunction with the Outline Construction Specifications where appropriate.

1.1.2 Site Particular

The project corridor is located in state of Uttar Pradesh.

- Maximum Temperature 47.8^{o}C (as per Annexure-F of IRC 6)
- Minimum Temperature -0.4^{o}C (as per Annexure-F of IRC 6)
- Rainfall season July-August
- Average Rainfall 800-1000mm
- Seismic Zone IV

1.1.3 Units

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

1.1.4 Codes

All relevant codes as listed in DBR shall be of latest revision including all amendments & corrections.

2 TRACK GEOMETRY, TRACK STRUCTURE AND ROLLING STOCK'

Track Geometry, Track Structure & Rolling Stock should be as per the approved SOD of NMRC. Summary of Important parameters are given below:

Gauge : Standard Gauge 1435 mm.
Track C/C distance: as per SoD
Rolling stock width: 2900mm.

Maximum Gradient: as per SoD

Track: Ballast less

3 ROADWAY AND RAILWAY CLEARANCES

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

3.1 CLEARANCES FOR ROAD TRAFFIC

Clearance for road traffic shall be as per clause 104.4.2 of IRC: 5 i.e. 5.50m at 0.250m (0.225m (width of the crash barrier) + 0.025m (clearance between crash barrier and pier shaft)) from pier shaft outer line i.e. at face of crash barrier. In all cases 5.5m clearance shall be kept from road level to soffit level of Metro structure.

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

3.2 CLEARANCES FOR ROLLING STOCK OF NMRC

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

4 DESIGN LIFE & SERVICEABILITY

The life of main structural systems should be 100 years (as per clause-15.1.3 & 16.1.3 of IRS-CBC & 3.6.5 of IRS steel Bridge code).

5 MATERIALS PARAMETERS

5.1 CONCRETE

I. Young's Modulus & Modular ratio

A. Young's Modulus

Clause-5.2.2.1 of IRS-CBC shall be followed.

Grade of Concrete (N/mm^2)	**Modulus of Elasticity (kN/mm^2)**
M10	18.0
M15	22.0
M20	25.0
M25	26.0
M30	28.0
M35	29.5
M40	31.0
M45	32.5
M50	34.0
M55	35.0
M60	36.0

B. Modular Ratio:

Modular Ratio including long term effects such as creep shall be taken as per clause 5.2.6 of IRS-CBC i.e. $m_1=280/f_{ck}$ for tensile reinforcement & $m_2=420/f_{ck}$ for compression reinforcement.

II. Grade of Concrete & Cover

Minimum grade of concrete should be as per clause-5.4.4 of IRS-CBC. For exposure conditions referred in Clause-5.4.1 of IRS-CBC. The cover should be as per clause 15.9.2 of IRS-CBC.

In case of foundation, cover shall be taken as 75mm for all conditions of exposure.

III. Cement

As per Clause 4.1 of IRS-CBC.

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

The maximum water-cement ratio shall be as per clause 5.4.3 & Table-4(a) of IRS-CBC. The total chloride content by weight of cement shall be as per Clause 5.4.6 of IRS-CBC.

IV. Density

Density of concrete shall be 25 kN/m^3 for PSC and RCC, 25 kN/m^3 for Plain cement concrete and 26 kN/ m^3 for Wet concrete.

V. Poisson's Ratio

Poisson's ratio for all grades of concrete shall be 0.15.

VI. Thermal Expansion Coefficient

Coefficient of thermal expansion (a) has been considered as 11.7 x10^{-6} ^oC in accordance with Clause-2.6.2 of IRS-Bridge Rules.

VII. Time-Dependent Characteristics of Materials

i) Long-term losses should be calculated in accordance with Clause-16.8.2 of IRS-CBC.

ii) The design shall be done according to construction sequence to be adopted in site.

5.2 PRESTRESSING STEEL FOR TENDONS

Prestressing steel shall be as per clause 4.6 of IRS-CBC. Characteristic strength of prestressing tendons shall be as per clause 16.2.4.3 of IRS-CBC.

i) **Prestressing Units** (as per Table-2, Class-II of IS 14268)

All Prestressing steel units shall be of 0.6" strands type (Nominal diameter =15.2mm, Area=140 mm^2).

ii) **Breaking Strength & Breaking Stress** (as per Table-1, Class-II of IS 14268)

Breaking strength of strand	= 260.7 kN
0.2% Proof Load	= 234.6 kN
0.1% proof Load (85% of UTS)	= 221.6 kN
Minimum breaking stress	= 1860 MPa

iii) Density: **=**78.5 kN/m^3

5.2.1 Young's Modulus

Young's modulus of Prestressing steel shall be taken as 195.0GPa as per § 4.6.2.1 of IRS -CBC for the Strands confirming to IS: 14268.

5.2.2 Prestressing

Jacking Force shall be as per Clause- 16.8.1 of IRS-CBC.

Other Parameters:

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

Diameter of Sheathing 107mm ID for 19K15 , 86mm ID for 12K15 and 69mm for 7K15 as per clause 6.2.1 of technical specifications. Wobble / Curvature shall be 0.0020 /m & 0.170 as per clause Table 26A of IRS-CBC.

Clear Cover shall be provided from outer diameter of duct. Minimum center to center spacing between ducts shall be taken w.r.t outer diameter of duct.

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

5.3 REINFORCEMENT STEEL (REBARS)

High strength deformed (HYSD) reinforcement bars of Fe-500D grade, conforming to IS 1786 and Clause 4.5 & 7.1.5 of IRS-CBC shall be used.

I. Young's Modulus: E= 200,000 Mpa

II. Yield Stress: f_y = 500 MPa.

III. Density: 78.5 kN/m^3

5.4 STRUCTURAL STEEL (FOR COMPOSITE BRIDGES & OTHER STRUCTURES IF ANY)

I. Introduction

Structural steel shall be used for special composite bridges and for miscellaneous use such as railing, supporting utilities, coverings etc.

II. Structural Steel for Miscellaneous Use

The design of miscellaneous structure shall be done as per IS: 800 and related provisions.

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

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

Steel for General Structural Purposes (Grade E250, E350 – B0) shall be as per IS: 2062.

III. Structural Steel for Composite Bridges

A. General

Structural steel conforming to IS: 2062 shall be adopted.

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

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

IRC Code: 22 shall be referred for steel-RCC composite construction.

Welding shall be done following IRS Steel Bridge Code, IRS welded Bridge code or 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

*t-thickness

B. Young's Modulus shall be taken as 21,100kg/mm^2 as per Clause-A-1.3 of IRS-Steel Bridge Code.

C. Density: 7850 kg/m^3 as per clause 505.2.2.1 of IRC: 24.

D. Poisson's Ratio: 0.30 as per clause 505.2.2.1 of IRC: 24.

E. Thermal Expansion Coefficient: 12x10^{-6} as per clause 505.2.2.1 of IRC: 24.

Note: In case design of any component/member is done using foreign code, material shall confirm to the specifications of the relevant foreign code.

5.5 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 (a) Central Ground water board (CGWB), (b) Ground water table reported in Geotechnical report provided by NMRC in tender documents, (c) Ground water table reported in Geotechnical report provided by Design & Build contractor.

The design Ground water table shall be taken as 4.0m higher than the Base value for evaluation of effects for design purposes.

5.6 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 is not liquefiable.

5.7 SOIL PARAMETERS

The borehole, which provide lesser vertical & Horizontal capacity of pile or lesser SBC in case of open/Well foundation, shall be referred in design among 1 & 2 as referred below. For Pile foundation, in case one bore hole provide lesser Horizontal capacity and other provide lesser vertical capacity then lesser values of horizontal & vertical capacity obtained from two boreholes shall be referred.

1) As per soil investigation report in the tender document.

2) As per soil investigation done by contractor.

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.

6 LOADS TO BE CONSIDERED FOR DESIGN

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

6.1 DEAD LOAD

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.

6.1.1 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 following assumptions.

S.No.	Element	Unfactored Load
1	Parapet/Railing	*
2	Plinth	3.40 t/m
3	Rail+Pads (All 4)	0.30 t/m
4	Cables	0.07 t/m
5	Cable trays#	0.01 t/m
6	Deck drainage concrete (Avg. thk. 62.5mm)	0.24 t/m
7	Miscll. (OHE Mast, Signaling , etc.)	0.40 t/m
8	Solar Panel (wherever applicable)	30kg/sqm
9	Noise Barrier (wherever applicable)	0.2 t/m
10	PTM Pipe Line	0.06t/m

*Parapet/Railing weight shall be calculated as per actual. The load due to parapet/railing shall be considered as fixed type and load factor applicable for dead load shall be consider for this component. All other SIDL shall be considered as variable.

 # in case cable through cell is used; its weight will be 0.74 t/m

In case of cross-over, actual track weight including plinths shall be considered for design.

6.2 SHRINKAGE & CREEP

Shrinkage and Creep effects will be calculated as per Clause 5.2.3 & 5.2.4 of IRS CBC.

6.3 PRE-STRESS FORCE (PR)

The pre-stressing force calculation will be as per Clause-16.8 of IRS-CBC. The loss of pre-stress due to friction will be calculated as per Clause-16.8.3 of IRS-CBC.

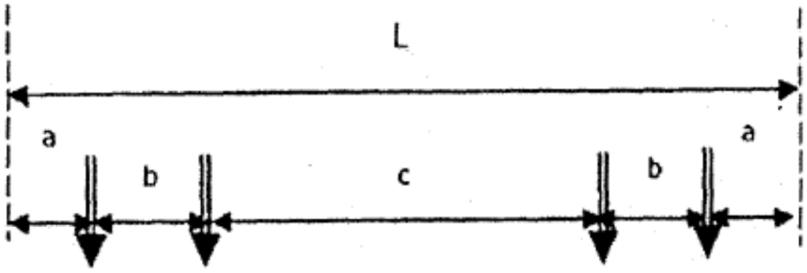
For calculation of long-term effects, the relative humidity to be considered as per Annexure A.7 of IRC 112 shall be (70(max) +47(min))/2 = 58.5%

Provision of emergency cables and future cables in prestressing shall be made as per clause 16.9.9 & 16.9.10 of IRS:CBC.

6.4 LIVE LOAD (LL)

6.4.1 Railway Vehicular Load

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



All axle loads = 16 tons

Maximum number of successive cars=6

Where,

Configuration 1 :

L = 22.100m (Length of a car)

a = 2.250m (overhang)

b = 2.500m (Wheel base in a bogie)

c = 12.600m (Distance between Axle-2 and Axle-3 in the car)

Configuration 2 :

L = 22.100m (Length of a car)

a = 2.605m (overhang)

b = 2.290m (Wheel base in a bogie)

c = 12.310m (Distance between Axle-2 and Axle-3 in the car)

Moving load analysis shall be carried out in order to estimate the maximum longitudinal force, max shear and max BM. The simply supported structures shall be designed for Medium Metro Loading Envelopes as tabulated in Annexure-I of Model DBR of RDSO.

In case of Twin U-Girder, each U-Girder will support only one track.

These superstructures and sub-structures will be checked for one track loaded condition as well as both tracks loaded condition (Single Span as well as Both Spans loaded condition).

However, for any other configuration (Axle load, and Axle spacing) of Modern Rolling stock including maintenance, machinery, crane etc., shall be within the loading envelope of present live load configuration.

6.4.2 Dynamic Augmentation

CDA will be considered as specified in clause 2.4.1.1 of IRS Bridge Rule. No reduction for double track loading will be considered.

6.4.3 Footpath Live Load

Footpath live load shall be taken as 490 kg/sqm. as per clause 2.3.2 of IRS Bridge Rules. As footpath live load is to be considered with carriageway live load without impact, this design will not be critical for any design except the parapet. The parapet will be designed for this loading.

6.4.4 Longitudinal Force

Braking load is taken as 18% of the unfactored Axle load.

Traction load is taken as 20% of the unfactored Axle load.

Since both the tracks are supported by a single girder, hence tractive force of one track and braking force of another track will be taken in the same direction to produce worst condition of loading.

As per Clause-2.8.5 of IRS-Bridge Rules, 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 except during checking of Rail stress.

6.4.5 Centrifugal Forces Due to Curvature of Superstructure

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

$$\mathbf{C} = \frac{W v^2}{127\,\mathrm{R}}$$

Where W is Live load reaction & C is Centrifugal force (unit of C & W shall be same), v is maximum design speed in km/h and *R* is radius of curvature in m. This force is assumed to act at a height of 1.830 m above rail top level on safer side.

Design Speed of Live load of 95 km/h will be considered for computation of centrifugal force for curvature up to 450m radius. For sharper curves, speed restrictions as per SOD shall be followed.

6.4.6 Racking Force

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

6.5 TEMPERATURE EFFECTS

6.5.1 A) Overall Temperature (OT)

The loads shall be considered as per Clause-2.6 of IRS-Bridge Rules and Clause-215 of IRC: 6. Temperature variation of $\pm$ 35°C will be considered details of which are given below

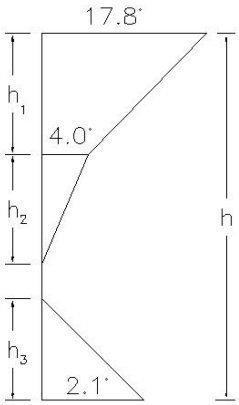
Maximum Temperature considered as per Annex. F of IRC 6: +47.8°C

Minimum Temperature considered as per Annex. F of IRC 6: -0.4°C

Temperature variation as per clause 215.2 of IRC 6 will be =(47.8-(-0.4)/2+10=±34.1°C **say 35^{O}C.**

B) Differential Temperature (DT)

The provision given in § 215.4 of IRC 6, shall be considered to compute effect of differential temperature gradient in absence of any provisions in IRS code. The differential gradient of temperature along depth of superstructure has been reproduced below for ready reference. Short term modulus of elasticity as per Table given under clause 5.1 of DBR shall be used to calculate the effects.



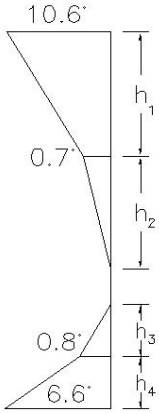
Positive Temperature Difference

$h_1 = 0.3h < 0.15m$

$h_2 = 0.3h > 0.1m$

$< 0.25m$

$h_3 = 0.3h < 0.15m$



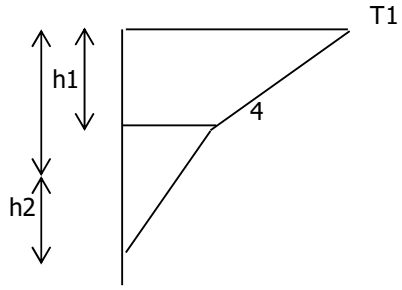
Negative Temperature Difference

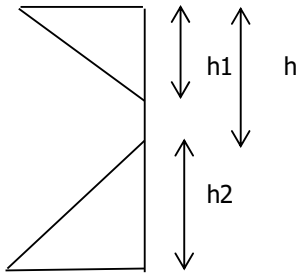
$h_1 = h_4 = 0.2h < 0.25m$

$h_2 = h_3 = 0.25h < 0.25m$

Note: *For purpose of these calculations no reduction shall be made for presence of track plinths.*

Temperature Difference for Concrete Bridge Decks





Positive Temperature Difference

h1 =0.6h

h2 =0.4m

H(m)	T1°c
0.2	18
0.3	20.5

Negative Temperature Difference

H(m)	T1°c
0.2	4.4

Temperature Difference across Steel and Composite Sections

Note: *For purpose of these calculations no reduction shall be made for presence of track plinths.*

6.5.2 Resistance to Movement of Elastomeric Bearings (BS)

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

The bearing resistance will produce lateral force on the substructure and foundation. The bearing resistance shall be calculated as (V_L $\square_L$ - V_R $\square_R$), where V_L and V_R are the shear rating of the left and right elastomeric bearings respectively and $\square_L$ and $\square_R$ are the deck movement at elastomeric bearing location. The above force will be zero when both side spans & supporting bearings are identical, in such case 10% of V_L $\square_L$ shall be considered for design of substructure and foundation.

6.5.3 Rail Structure Interaction (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.

A rail structure interaction [RSI] analysis is required because the continuously welded running rails are continuous· over the deck expansion joints. The interaction occurs because the rails are directly connected to the decks by fastening system.

1. Rail structure interaction studies shall be done as per provisions of "RDSO Guidelines for carrying out Rail-Structure Interaction studies on Metro System (version-2)". The following shall be adhered to:

a) Track resistance in loaded and unloaded conditions shall be obtained from cl. 3.2.6 Track Stiffness of "RDSO Guidelines for carrying out Rail-Structure Interaction studies on Metro System (version-2)". As per the clause, the

recommended values for track stiffness for ballasted tracks are 60kN/m and 20kN/m for loaded and unloaded track respectively and recommended values of track stiffness for ballast less tracks are 60kN/m and 40kN/m for loaded and unloaded tracks respectively. The elastic limit is 2 mm for ballasted tracks and 0.5 mm for ballast less tracks. No change in track stiffness is permitted on account of actual track behavior.

b) The temperature variations, to be used for analysis, shall be taken as per provisions of cl. 3.2.8 Temperature Variations of "RDSO Guidelines for carrying out Rail-Structure Interaction studies on Metro System (version-2)". The following shall be used for analysis:

-The temperature of the bridge does not deviate from the reference temperature by more than $\pm$ 35 ^{0}C

-The temperature of the rail does not deviate by more than $\pm$ 50^{0}C.

-The difference in temperature between deck and track does not exceed $\pm$ 20^{0}C.

-The reference temperature is the temperature of the deck and the rail when the rail is fixed.

c) Maximum additional stresses in rail in tension as well as compression on account of rail-structure interaction shall be within the permissible limits as prescribed in cl. 3.3.1 Additional Stresses in Rails of "RDSO Guidelines for carrying out Rail-Structure Interaction studies on Metro System (version-2)". The limit prescribed in the document shall be used as it is and no benefit on account of lesser axle load of actual rolling stock shall be permitted.

d) The provisions of cl. 3.3.2 Displacements of Bridge Elements of "RDSO Guidelines for carrying out Rail-Structure Interaction studies on Metro System (version-2)" shall be adhered to.

e) Checks must be performed for break in rail continuity due to unusual conditions such as fractures or for maintenance purposes. The provisions of cl. 4.8 "Rail Gap Analysis of RDSO Guidelines for carrying out Rail-Structure Interaction studies on Metro System (version-2)" shall be followed.

f) Minimum (unfactored) LWR force of 1.6t/m of span length shall be considered for design irrespective of number of tracks.

2. Software and general methodology to be used for carrying out Rail Structure interaction analysis must be validated before adopting the same. A well-established document such as UIC 774-3R may be used for validation.

3. Representative stretches must be chosen for carrying out Rail-Structure interaction which shall include special spans. The same shall be got approved from the engineer.

4. LWR forces shall be considered in appropriate load combinations as specified in cl. 7.0 Load Combinations (Ground IIIb) of the DBR.

6.6 WIND LOAD (WL)

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

As per § 5.3 of IS: 875 (Part 3)

Design Wind Speed, Vz **= $V_b.k_1.k_2.k_3.k_4$**

Where

V_b = Basic wind speed = 50 m/s for Noida Zone (as per National Building code).

K_1 = 1.08 for class IV type structure (§ table 1 of IS: 875 (Part 3)).
k_2 = 1.07 for category 2 (§ table 2 of IS: 875 (Part 3)) for 20m Height.
k_2 = 1.12 for category 2 (§ table 2 of IS: 875 (Part 3)) for 30m Height
k_3 = 1.0 (§ 6.3.3.1 of IS: 875 (Part 3)).
K_4=1.0 (for non-cyclonic zone as per clause 6.3.4)

However, a bridge shall not be considered to be carrying any live load when the wind pressure at deck level exceeds 150kg/m^2 as per clause 2.11.2 of IRS Bridge rule, however as it is a long viaduct therefore there is fair possibility that once wind pressure exceeds 150kg/m^2 train may be standing static over viaduct due to close of operation therefore in case of wind pressure above 150kg/m^2, train will be considered as static load i.e. no longitudinal loads or impact loads.

Wind load on train in transverse direction will be calculated based on exposed surface & intensity as per above given values & reference. These are computed for length of train as seen in elevation normal to longitudinal axis. The transverse load will be applied to train at center of projected area of the vehicle.

As per clause 209.3.4 of IRC: 6 the longitudinal wind load on Superstructure will be considered as 25% of Transverse load for Beam/Box/U/Plate girder bridges. In case of Truss Bridges longitudinal load on Superstructure will be considered as 50%.

As per clause 209.3.6 of IRC: 6 the longitudinal wind load on Live Load will be considered as 25% of Transverse Wind load considered on Live load.

In case of Pier & Pier cap full load will be considered.

The longitudinal load will be acted simultaneously with transverse load.

Effect of vertical wind load shall be considered in accordance with clause 209.3.5 of IRC: 6.

6.7 SEISMIC FORCE (EQ)

The purpose of this section is to summarize the methodology and the assumptions that shall be used for the seismic analysis.

6.7.1 Seismic Design

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Seismic design philosophy as stated in IRS Seismic Code has been considered. The peak ground acceleration denoted as zone factor is taken as 0.24 since Noida is situated in zone IV of seismic map of India.

6.7.2 Definition of Seismic Input

Spectral Acceleration (S_a/g vs T) as prescribed in IRS Seismic code, shall be used for seismic load computation.

6.7.3 Horizontal Seismic Coefficient

The horizontal seismic design coefficient shall be calculated as per following expression

$$\mathbf{A_h = (Z/2) * (I/R) * (S_a/g)}$$

Where,

Ah = 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 as per Table 3 of IRS Seismic Code
S_a/g = normalized pseudo spectral acceleration for corresponding to relevant damping of load resisting elements (pier/columns) depending upon the fundamental period of vibration T
Damping factor = 5% for reinforced concrete piers.

6.7.4 Response Reduction Factor

Response Reduction Factor "R" as per IRS Seismic code Table -3 shall be as given below

S.No.	Elements	Response Reduction Factor "R"
1	RCC Pier with ductile detailing	3.0
2	PSC Pier/Pier cap/Portal beam	2.0
3	Portal Pier with ductile detailing (Beam integral with pier)	3.0-In Longitudinal direction 4.0-In transverse direction
4	Bearing/Superstructure	2.0
5	Stopper	1.0
6	Foundations	2.0

1. Note: In addition to the response reduction factor given above, reinforcement detailing of Piers/Portal Piers shall conform to ductility/capacity design requirements

as per Annexure-B of IRS Seismic Code.

6.7.5 Vertical Seismic Coefficient

The seismic zone factor & time period (of Vertical motion) for calculating vertical seismic coefficient shall be considered as per clause 7.3.2 & 9.4.2 of IRS seismic code. The Zone factor for calculating the vertical seismic coefficient will be 2/3*Zone factor i.e. 2/3*0.24=0.16. For Pier & foundations, while calculating vertical seismic coefficient R=1 shall be considered.

6.7.6 Computation of Fundamental period of vibration

The fundamental time period shall be calculated by any rational method of analysis. Each pier is considered as a single degree of freedom oscillator with mass placed at the Centre of Gravity (COG) of the deck.

The time period can also be calculated based on expression given in Clause 8.1 of IRS Seismic Code, which is as follows:

$$T = 2\pi\sqrt{\frac{\delta}{g}}$$

Where δ = horizontal displacement at the top of pier due to horizontal force (= mg)
Where m = lumped mass at the top of pier.

a) Mass

- Permanent masses (Self Weights, SIDL) of:
  - (a) Full span longitudinally, which can be resisted by reaction blocks or POT/Spherical bearings during earthquake, at one side of the pier or half of spans on either side of pier in case seismic is resisted by bearings (For longitudinal seismic)
  - (b) Half of spans on either side of pier (For transverse seismic)
- Mass of the pier cap
- The earthquake acceleration will be considered on full mass and not buoyant mass.

It may be noted that while calculating lateral seismic forces, 50% live load is included in the seismic weight for transverse direction i.e. Minimum live load among 4 cases i.e. OSOT (one span one track), OSBT (One span both tracks), BSOT (Both span one track) & BSBT (Both span both tracks) will be considered, whereas no live load is included for seismic weight in longitudinal direction.

As per clause 2.8.5 of IRS: Bridge Rule, in transverse/ longitudinal seismic condition, only 50% of gross tractive effort / braking force/centrifugal force/racking force shall be considered.

b) Stiffness

- Stiffness shall be calculated with the concrete instantaneous modulus of elasticity, for all structural elements.

- Pier stiffness considering fixed base and free at deck location $K = 3EI_{eff}/L^3$
- $I_{eff}=0.75I_g$, as per clause 8.1 of IRS Seismic Code. In the calculation of fundamental time period, effective moment of inertia is considered.
- Flexibility of foundation soil system may be considered while calculating time period i.e. foundation and soil spring may be modelled while calculating time period.

  The static stiffness of soil spring shall be calculated as per Table-3 of Annexure-C of IS 2911 Part-1 (Section 2). While calculating the static soil stiffness, soil shall be considered as dry granular soil (for time period calculation) with uniform N values of 25 throughout the depth or actual soil stiffness for all cases, whichever is critical. In liquefaction zone no soil spring shall be considered.

  Only for calculating the time period, dynamic stiffness ($K_{dynamic}$) shall be used and it shall be taken as 3.5 times the static stiffness (K_{static}) i.e $K_{dynamic}= 3.5*K_{static.}$

  For calculating effect of seismic forces i.e. Axial load, BM, SF, Torsions etc. for design of members, the static value of soil springs as per clause 12.4.2 of the DBR shall be used.
- Time period of more than 4s shall not be allowed in any case; section needs to be resized when it exceeds 4s.

6.7.7 Direction Combinations

The seismic forces shall be assumed to come from any horizontal direction. For this purpose, two separate analyses shall be performed for design seismic forces acting along two orthogonal horizontal directions. The design seismic force resultant (that is axial force, bending moment, shear force and torsion) at any cross section of abridge component resulting from the analysis in the two orthogonal horizontal directions shall be combined according to the expressions given below.

a) $\pm EL_x \pm 0.3\ EL_y$
b) $\pm 0.3\ EL_x \pm EL_y$

Where
EL_X = Force resultant due to full seismic force along X direction, and
EL_Y = Force resultant due to full seismic force along Y direction

When vertical seismic forces are also considered, the design seismic force resultants at any cross-section of a bridge component shall be combined as below:

a) $\pm EL_x \pm 0.3\ EL_y \pm 0.3\ EL_z$
b) $\pm 0.3\ EL_x \pm EL_y \pm 0.3\ EL_z$
c) $\pm 0.3\ EL_x \pm 0.3\ EL_y \pm EL_z$

Where EL_X and EL_Y are as defined above and EL_Z is the force resultant due to full seismic force along vertical direction.

As an alternative to the procedure given above, the forces due to the combined effect of two or three components can be obtained on the basic square root of sum of square (SRSS)

$\sqrt{(EL_x^2 + EL_Y^2)}$ or $\sqrt{(EL_x^2 + EL_Y^2 + EL_Z^2)}$

6.8 ERECTION TEMPORARY LOADS (ETL)

Erection forces and effects shall be considered as per Clause-2.13 of IRS-Bridge Rules.

The weight of all permanent and temporary materials together with all other forces and effects which can operate on any part of structure during erection shall be considered in design. The loads arising from most onerous conditions of the construction methods adopted is awaited from the Contractor.

Special care shall be taken that no damage is caused by the construction contractor to the permanent structure. In case of any hole etc., drilled in permanent structural element, the same will be made good by using non-shrink, expansive, high strength grout and its strength shall be better than the structural element and will have to be demonstrated.

6.9 DERAILMENT LOADS (DR)

For vertical considerations, check shall be made in accordance with the IRS-Bridge Rules, Appendix-XXV with standard gauge in place of Broad gauge. For ULS and stability check, loading shall be proportional as per maximum axle load. This derailment load corresponds to an ULS load for SLS combinations (Group-V of IRS-CBC) a 1/1.75 coefficient will be applied to the derailment load. The Sacramento criteria need to be considered for U-Girder.

6.10 FORCES ON PARAPET

The parapets shall be designed to resist lateral horizontal force & a vertical force of 1.50 kN/m applied simultaneously at the top of the parapet as per Clause 2.10 of IRS Bridge Rules.

6.11 DIFFERENTIAL SETTLEMENT (DS)

Differential Settlement between two adjacent viaduct piers shall be as follows.

i) 12mm for Long Term settlement.

ii) 6 mm for Short Term settlement.

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

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

6.12 BUOYANCY LOADS

The design of the foundation shall be done considering design ground water table as referred in clause 5.5 of the DBR.

In case of river bridges, stability check and calculation of base pressure, full buoyancy shall be considered on submerged portion of substructure and foundation up to HFL or LWL as the case may be, irrespective of the type of soil on which the foundation will rest.

Hydro dynamic forces will be considered as per clause 6 of IRS Seismic code.

6.13 WATER CURRENT FORCES

Water current force in submerged portion of substructure and foundation shall be calculated as per Clause 5.9 of IRS Bridge Substructure & Foundation Code

6.14 VEHICLE COLLISION LOAD (VCL)

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

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

All structures near railway track shall be checked for accidental impact from derailed trains as per clause 2.16.4 of IRS Bridge Rules as per Addendum & Corrigendum Slip No. 50 dated 06.12.2022.

6.15 GRADIENT EFFECT

The bearing shall be sandwiched between two true horizontal surfaces. Steel Wedge shall be provided to cater longitudinal slope of superstructure.

6.16 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 declaration 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.

6.17 VIBRATION EFFECT

Effect of vibration due to movement of train on Viaduct structure will be taken into consideration. This will be checked in dynamic analysis.

7 LOAD COMBINATIONS

7.1 **Methodology:** Provisions of IRS-CBC shall be followed. The partial load factors and load combinations shall be as per Clause-11 and Table-12 of IRS-CBC as modified and shown below:

Load	**Abbreviations**
Dead load	DL
Super imposed dead load	SIDL
Prestressing	PS
Live Load	LL
Live load on footpath	LFP
Longitudinal force (Traction & Braking)	LF
Centrifugal force	CF
Over all temperature	OT
Differential Temperature	DT
Long welded rail force	LWR
Racking Forces	RF
Wind forces	WL
Earthquake	EQ
Differential settlement	DS
Derailment	DR
Erection load	ER

Limit state	**Loads**	**Symbol**	**G I**	**G II (EQ)**		**G II (WL)**		**G III (a)**	**G III (b)**	**G V**	**G VI**
				G IIa (EQ)	**G II b (EQ)**	**G IIa (WL)**	**G II b (WL)**	**Temperature**	**LWR**		
SLS Combinations	Dead Loads	DL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
	Prestressing	PS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
	Super Imposed Loads (fixed)	SIDL-1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
	Super Imposed	SIDL-2	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	

	Loads (variable)										
	Earthquake	EQ		1.00	1.00						
	Overall T	OT						1.00	1.00		
	LWR								1.00		
	Differential DT	DT						0.80	0.80		
	Differential settlement	DS	1.00								
	Live load	LL	1.10		0.50		1.00	1.00	0.50/ 1.00 (#)		
	Live load on footpath	LWP	1.00		0.50		1.00	1.00	0.50		
	Derailment Loads	DR								1.00(**)	
	Wind Load					1.00	1.00				
ULS Combinations	Dead Loads	DL	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.00
	Prestressing	PS	1.15/0.87 (*)	1.40	1.40	1.15 /0.87 (*)	1.15/ 0.87 (*)	1.15/ 0.87 (*)	1.15/ 0.87 (*)	1.15/ 0.87 (*)	1.15/ 0.87 (*)
	Super Imposed Loads (fixed)	SIDL-1	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.00
	Super Imposed Loads (variable)	SIDL-2	2.00	2.0	2.0	2.00	2.00	2.00	2.00	2.00	1.00
	Earthquake	EQ		1.60	1.25						
	Overall T	OT						1.50	1.50		
	LWR								1.50		
	Differential DT	DT						1.15	1.15		
	Differential settlement	DS									
	Live load	LL	1.75		0.50		1.40	1.40	0.70/ 1.4#		0.75
	Live load on footpath	LWP	1.50		0.50		1.25	1.25	0.61 25		0.75
	Derailment Loads	DR								1.00	
	Wind Load					1.60	1.25				
	Vehicle Collision										1.00

In each SLS and ULS cases, 6 basic load combination groups shall be considered, according to the IRS- CBC.

(*) 1.15/0.87: In accordance with IRS CBC article 11.3.3., when the Prestressing PR increases the section capacity vs. shear then PR is multiplied by 0.87. When the

Prestressing PR decreases the section capacity vs. shear then PR is multiplied by 1.15.

(**) Refer clause 6.9.

0.50 for two or more tracks and 1.0 for single track.

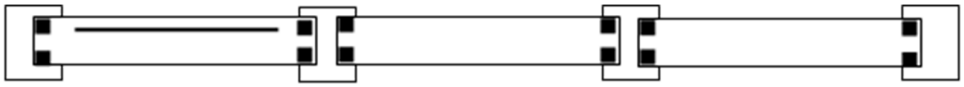
Notes:

1) ULS-Ultimate Limit state.
2) SLS-Serviceability Limit state
3) Wind load and earthquake loads shall not be assumed to be acting simultaneously.
4) Live load shall also include dynamic effect, force due to curvature exerted on tracks, longitudinal forces, braking forces and forces on parapet.
5) Crack width check shall be done in SLS case for combination G I only.
6) Load combination 1.0*DL + 1.0*SIDL + 1.5*EQ is to be followed in ULS case.
7) Load combination 1.5*DL + 1.5*SIDL + 1.5*EQ is to be followed in ULS case.

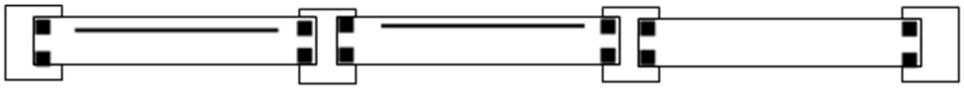
7.2 The Superstructure/bearing, sub-structure and foundation will be checked for one track loaded condition as well both track loaded condition, for single span and both spans loaded conditions, as the case may be.

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

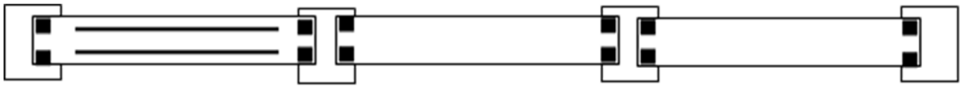
7.4 The analysis and design will be carried out for all possible cases of rolling train loads. All the supporting structures, such as superstructure, bearings, substructure and foundations shall be checked for the most onerous cases.



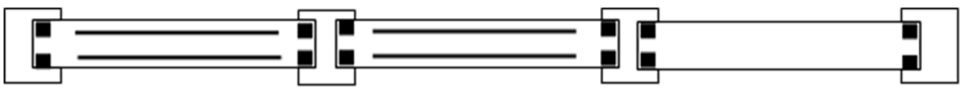
LL1: used for Deck Torsion, Bearing Compression, Uplift, Shaft check, Foundation check



LL2: LL2 used for Shaft check, Foundation check



LL3: used for Deck check, Bearing Compression check, Shaft check, Foundation check;



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

8 DESIGN CHECK FOR CONCRETE STRUCTURE

8.1 ALLOWABLE STRESSES FOR CONCRETE AT SERVICEABILITY LIMIT STATE (SLS)

The stresses at transfer and construction stage during service for prestressed cast in situ and segmental construction shall be as per Clause-16.4.2.2 (Concrete Compressive stress Limitations), Clause-16.4.2.3 (Steel stress Limitations), Clause-16.4.2.4 (Cracking), Clause-17.3.3 (Other types of Connections) and Clause-17.4 (Composite Concrete Constructions) of IRS-CBC.

Clause-10.2 (Serviceability Limit States) of IRS-CBC shall be used for RCC construction (Beams, Columns and Slabs).

Summary of Permissible Stresses

Precast or Cast-In-Situ Post-Tensioned Structures

No	Load Combination	Allowable compressive strength	Reference	Allowable tensile stress*	Reference
At transfer and/or construction stage					
1	DL +*DS + App.PR	0.5 fci but ≤0.4 fck	Cl 16.4.2.2(b) of IRS CBC	**1 MPa***	Cl 16.4.2.4(b) of IRS CBC
2	Group 1+50% EL	0.5 fci but ≤0.4 fck	(Cl 16.4.2.2(b) of IRS CBC	**1 MPa***	Cl 16.4.2.4(b) of IRS CBC
During Service					
3	SLS G I	0.4 fck	(Cl 16.4.2.2(a) of IRS CBC	No tension anywhere	cl 16.4.2.4(b) of IRS CBC
4	SLS G II	0.4 fck	(Cl 16.4.2.2(a) of IRS CBC	No tension anywhere	cl 16.4.2.4(b) of IRS CBC
5	SLS G III	0.4 fck	(Cl 16.4.2.2(a) of IRS CBC	No tension anywhere	

* In case of Segmental structures, no tension is permitted under any stage or any SLS Load combination as clause 17.3.3 of IRS-CBC.

** In case of Uniform compressive stress distribution in PSC structures, permissible stress shall not be more than $0.3f_{ck}$.

II RCC Structures

Permissible stress in Concrete (triangular compressive stress distribution) - $0.50f_{ck}$
Permissible stress in Concrete (Uniform compressive stress distribution) - $0.38f_{ck}$
Permissible stress in Steel - 0.75fy

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

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

8.3 ULS CHECK FOR RCC STRUCTURE

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.

9 DESIGN CHECK FOR STEEL/COMPOSITE STRUCTURE

The design of steel structure shall be done by IRS Steel Bridge Code/IRS-Welded Bridge. In case of steel structure, IRS-steel bridge code shall be followed and Load combination G1 shall be used. While designing for composite action IRC :22 shall be referred with load combinations as given in table under clause 7.1.

10 DURABILITY & CRACK WIDTH

10.1 DURABILITY

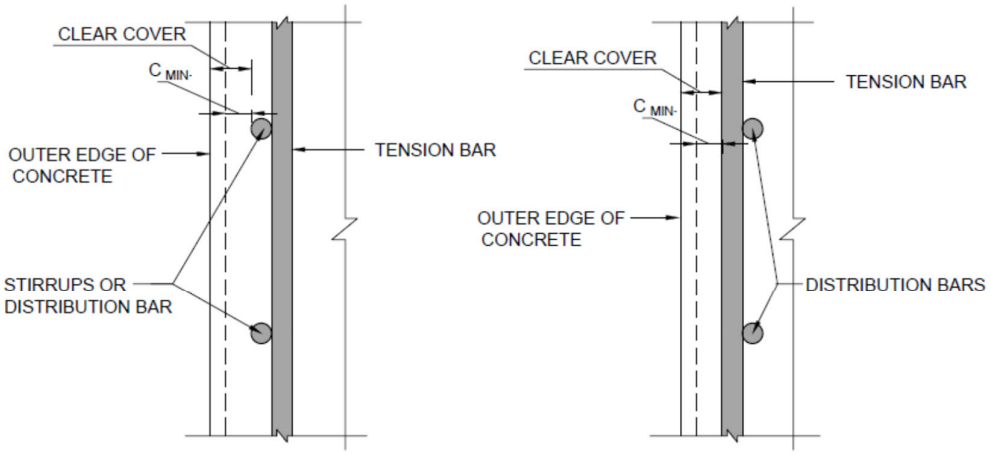
Provision of Clause-5.4 of IRS-CBC shall be followed. The exposure condition of present corridor is Moderate and in case of Nallah crossing the exposure condition may be treated as "Severe".

10.2 CRACK WIDTH CHECK

For SLS Combination, Group - I, crack width in reinforced concrete members shall be calculated as per Clause-15.9.8.2.1 of IRS-CBC.

The allowable crack width should be as per Clause 10.2.1 (a) (CS-1-12/2014) based on the exposure condition defined in Clause 5.4.1 of IRS-CBC and table-10 of IRS-CBC.

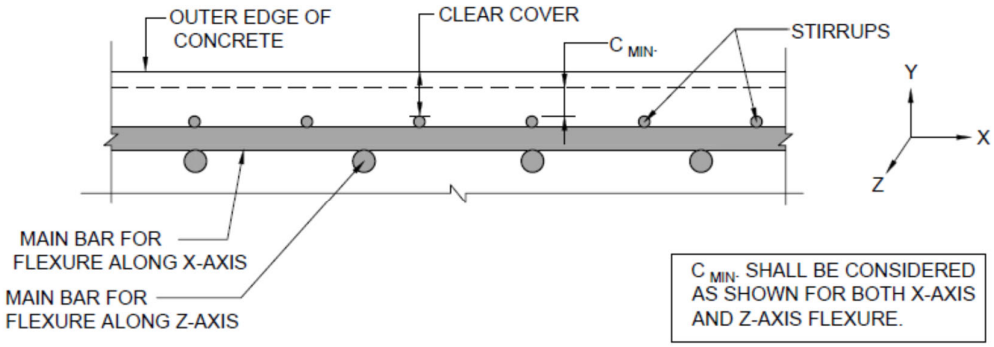
For crack control in columns, clause15.6.7 of IRS-CBC will be modified to the extent that actual axial load will be considered to act simultaneously.



CASE -1: OUTER LAYER OF BAR BEFORE TENSION BAR

CASE -2: TENSION BAR OUTER LAYER

MEMBERS SUBJECTED TO ONE WAY BENDING.



MEMBERS SUBJECTED TO TWO WAY BENDING.

CLEAR COVER AND C_{MIN} FOR CRACK WIDTH CALCULATION

10.3 DEFLECTION

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. Permissible values of deformation shall be in accordance with provision of UIC-776-3R.

11 FATIGUE

11.1 GENERAL

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

11.2 PRESTRESSED CONCRETE STRUCTURE

The fatigue shall be checked as per Clause-13.4 IRS-CBC. However, fatigue check for prestressed concrete structures does not need to be performed as long as the whole section (from top to bottom fiber) remains under compression under SLS load combination 1.

11.3 REINFORCED CONCRETE STRUCTURE

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

Fatigue check for reinforced concrete structures does not need to be performed unless it is a main structure member (i.e. the deck) supporting the traffic that consists of reinforced concrete. The permissible stress range in unwelded reinforcement as per clause 13.4.1 of IRS CBC shall be 155Mpa (under Live load) up to 16mm diameter & 120Mpa for bars exceeding 16mm diameter.

11.4 STEEL/STEEL COMPOSITE STRUCTURES

Clause-3.6 of IRS-Steel Bridge (up to latest correction slip) / Clause-13.2 of IRS-Welded Bridge code shall govern. If values are required to be used, the train closest to the actual train formation proposed to be run on the NMRC shall be used. Otherwise, detailed counting of cycles shall be done.

12 DESIGN METHODOLOGY

12.1 SUPERSTRUCTURE SYSTEM OF VIADUCT

The Superstructure of the viaduct comprises of simply supported Twin U-Girder.

However sharp curvature/ crossovers / turnouts/ railways crossings / highway crossings, PSC I -Girder/ Balanced Cantilever/Steel Composite girders/Steel Truss may be used. The minimum dimensions shall be considered as per Clause 16.9.6 of IRS-CBC.

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

Drainage

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

Solid Pier

The drainpipe of double wall HDPE corrugated pipes with water collection box at top, shall be located within or on outer face of solid pier.

Deck

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

12.2 BEARING SYSTEM AND ITS DESIGN METHODOLOGY

a) Bearing System

Considering the span configuration and safety aspects of the structural system (in normal and seismic condition), it is proposed to adopt elastomeric bearings placed underneath the Twin U-Girder for transfer of vertical forces and in-plane forces. The elastomeric bearings shall not be designed for seismic forces and seismic forces will be transferred to substructure via shear key/seismic restrainer. Elastomeric bearings/pads place vertically shall be used in between the Seismic stopper/seismic restrainer and the superstructure to mitigate the dynamic effects.

POT -PTFE bearing shall be designed as per IRC: 83 Part-III & Spherical bearing shall be designed as per IRC: 83 part-IV.

The elastomeric bearing shall be designed in accordance with EN 1337 part 1 and part 3 wherever required.

b) Replaceability of Bearings

While finalizing the proposed bearing system, it shall be kept in mind that accessibility and replacement of each part of bearing are of paramount importance as the design life of bearings is shorter than that of the structure. Keeping in view the above cited criteria, all the bearings and pier caps will be detailed for replacement of bearings in the future. The girders/end diaphragms shall be designed to facilitate the operations of jacks during maintenance as per clause 15.9.11.3 of IRS-CBC.

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

c) Uplift

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

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

12.3 SUBSTRUCTURE SYSTEM

a) Pier Cap

For designing the pier cap as corbel the provisions of Clause-17.2.3 of IRS-CBC should be followed. In case of shear span to effective depth ratio being more than 0.6, pier cap will be designed as flexural member.

Height of pedestal should be between 150mm and 500mm as per clause 710.10.2 of IRC: 78-Part 1.

The Pier cap shape shall be suitable at transition pier supporting different types of superstructures instead of providing raised/column pedestal over pier cap.

b) Piers

The effective length of a cantilever pier for the purpose of slenderness ratio calculation will be taken as per Table-18 of IRS-CBC. Ductile detailing is mandatory. In this project most of the columns are isolated columns with elastomeric bearing supporting the superstructure. In either direction the effective length will be taken as $2.3L_0$ (case 7). Here L_0 represent height of column from top of footing slab/Pile cap to top of pier cap. Effective length of portal column in longitudinal direction will be taken similar to singe column i.e. $2.3L_0$ and for transverse direction it should be taken as $1.5\ L_0$ (case 6).

The design of pier shall be done as per clause 15.6 of IRS CBC.

Prestressed Cantilever Pier

In case of vertically prestressed piers, minimum longitudinal reinforcement shall be provided as RCC column as per clause 15.9.4.1 of IRS CBC.

Shear reinforcement & ductile detailing shall be done as that of RCC column.

In all SLS combinations, column shall remain in compression.

Clause 16.6.1 of IRS CBC shall be applicable in case of prestressed piers/columns.

12.4 FOUNDATION SYSTEM

Foundation shall be designed as per IRS Bridge Substructure & Foundation Code, IRS Concrete Bridge Code, IRC-78: Part 1, Manual on the design and construction of well foundation; IS-2911 should be followed for design of foundations.

12.4.1 Pile Foundation

Foundation analysis and design will be based on IRS Code for Substructure & IRC-78. The forces applied by the pier are transferred to the bottom of the pile cap for this

purpose. Reactions in pile are calculated using Rivet theory. The various specific assumptions made for the pile and pile cap design are as follows:

a) Bored-cast-in-situ multiple pile groups will be adopted.

b) Minimum 1.0m diameter (unless specified otherwise in tender drawing) bored cast-in-situ vertical piles in soil/rock have been contemplated for the foundation of piers. Minimum number of pile in each pile cap shall not be less than 4.

c) Open foundation have been contemplated for the pier location with rocky strata at shallow depth.

d) For piles and pile caps, load combinations shall be considered as per IRS-CBC, Table-12. The various specific assumptions made for the pile and pile cap design including pile load testing shall be as per IS: 2911, IRC-78: Part 1 and IRS-Bridge Sub-structure and Foundation Code.

e) For pile carrying capacity, all SLS Load combinations as per IRS-CBC will be considered.

f) . Increase in vertical load capacity of pile shall be done as per Table-1 of IS 1893-Part-1.

g) The lateral load capacity of pile shall be evaluated either by using empirical formulae given in IS: 2911 (Part-1/ section-2) or by soil structure interaction analysis using Winkler's Spring model by limiting the lateral deflection as 1% of Pile diameter as per Cl. 709.3.5.2 of IRC: 78-Part 1.

h) Initial load tests (not on working pile) will be conducted as per IS: 2911 - Part IV. Initial test is proposed to be conducted for a load of 2.5 times as per the safe load based on static formula.

i) The working load on pile for vertical and horizontal loads shall be verified through routine load tests during construction.

j) In case of multiple pile system, spacing between the piles shall not be less than 3 times the diameter of pile in soil and 2.5 times the diameter when founded on rock.

k) In general, the top of pile cap shall be kept about min 500mm below the existing ground level and weight of the earth cover will be applied on top of pile cap when unfavorable. The earth cover on pile cap for any favorable effect (stability, soil horizontal capacity.) will be neglected.

l) The following limiting values shall not be exceeded for computation of safe load:

- Result of sub-structure investigation will be used for adopting the value of angle of internal friction "φ" and cohesion of soil "c" as per clause 5.7 of the DBR .
- Angle of wall friction δ shall be taken as equal to φ deg.
- Co-efficient of earth pressure "K" shall be taken as 1.0.
- Maximum overburden pressure at bottom of pile for calculation of shaft resistance and bearing resistance shall be limited to 15 times the diameter of the pile. The maximum depth shall be considered from existing ground level.

- For calculating the pile capacities, the design ground water table as per clause 5.5 of the DBR shall be considered.
- Bulk density corresponding to 100% saturation shall be calculated and used for working out submerged density of soil.
- In case of liquefiable strata, only submerged weight of soil shall be considered as overburden for vertical pile capacity calculation.

m) While finalizing length of pile, Clause 705.4.1 of IRC: 78-Part 1 shall also be followed.

n) Live load surcharge needs to be considered for pile group which is outside median and where live load is moving over pile cap. Normal Pile groups below median or where there is no live load over pile cap need not to be design for live load surcharge.

o) In case of foundations near railway crossing effect of railway live load surcharge shall be considered if applicable

Structural Design

a) Pile design shall be done according to § 15.6 of IRS CBC. However, for crack control in piles, § 15.6.7 of IRS CBC it will be clarified that actual axial load will be considered to act simultaneously.

b) Where there is a risk of liquefaction, the lateral soil resistance of the liquefied layer will be taken as zero.

c) Pile cap shall be designed based on § 15.8.3.1 of IRS –CBC 1997. No support from soil below pile cap shall be considered.

d) The thickness of the pile cap shall be kept at a minimum 1.5 times diameter of the piles for multiple-pile group as per IRC 78.

e) The structural design of the pile cap shall be carried out as per §10.2.2 & §15.4 and §15.8.3 of IRS CBC. Crack width shall be checked for load combination 1 as per §15.9.8.2 IRS CBC.

f) Minimum reinforcement in pile caps at top shall be at least 0.12% in each direction in case of compression and in case of tension, it shall not be less than 0.2%.

12.4.2 Soil Structure Analysis

When designing element forces or estimating displacements the soil stiffness and other parameters shall be assessed based on clause 5.7 of the DBR considering the design ground water table as per clause 5.5 of the DBR.

12.4.3 Well Foundation & Open foundation

Well Foundation & Open foundation shall be designed as per IRS Bridge Substructure & Foundation Code/ IRC: 78-Part 1.

13 CODAL PREFERENCE

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

For railway loading related issues:

i. UIC Codes
ii. Euro Codes
iii. Any other code, which covers railway loading.

For other Design/ detailing related issues:

i. IS
ii. IRC
iii. EURO
iv. AASHTO
v. Any international code with approval of NMRC.

OUTLINE DESIGN CRITERIA

FOR

GEOTECHNICAL WORKS

14 GENERAL, STANDARDS AND CODES

14.1 PURPOSE AND SCOPE

This section sets out the minimum requirements for geotechnical investigations, analysis, reporting, and design related to earthworks, foundations, substructures, slopes and associated works.
Geotechnical works include foundations, earthworks, deep excavations, slopes, embankments, and retaining structures.
The Contractor is responsible for determining the geology and geotechnical parameters of subsurface strata for design purposes. Any Geotechnical Investigation Report provided by the Employer is for information only, without warranty of accuracy or reliability, and must be supplemented by additional investigations or boreholes as required by the Contractor.

14.2 DESIGN CONSIDERATIONS

The Contractor shall design the structures and associated below-ground works to control and limit differential settlements of adjoining structures and road within permissible tolerances, ensuring serviceability and structural integrity.
All permanent cuttings and excavation slopes shall be designed to achieve long-term geotechnical stability with adequate factors of safety. Soil slopes shall be protected against erosion through hydroseeding or turfing, and where required based on slope gradient and soil type, shall be provided with engineered surface protection such as stone pitching or brick-on-edge lining.

15 SITE INVESTIGATIONS AND LABORATORY INVESTIGATIONS

15.1 GENERAL CONDITIONS

Subsurface Conditions
Regional engineering geological information along the rail alignment is generally available from publications of the Geological Survey of India. The Contractor shall independently verify subsurface conditions and assess their suitability for design and construction.
Seismic Conditions
Seismic loading and ground acceleration criteria are specified under the Structural provisions of these Design Criteria. Temporary works need not be designed for full design-level seismic forces, however, they shall be adequate to ensure public safety and prevent damage to adjacent structures or properties.
The design shall account for the effects of the design seismic event on slope stability and the potential for soil liquefaction, wherever applicable.

15.2 INVESTIGATION REQUIREMENTS

Existing information shall be supplemented with project-specific site investigations (SI). The intent and objectives of the SI shall be to collect all pertinent and reliable data and information

required to produce a safe and economic design and to meet tender and construction requirements.

For the purpose of these Criteria, the term SI shall be considered to include, but not be limited to, the following:

a) Compiling and reviewing pertinent existing geologic data.

b) Compiling and reviewing pertinent existing geotechnical data supplied and from adjacent projects.

c) Compiling and reviewing pertinent existing foundation, structure, substructure, and related data from adjacent projects.

d) Performing a detailed field reconnaissance.

e) Performing geophysical surveys.

f) Performing ground investigations that include, but are not limited to drilling, soil sampling, rock coring, groundwater sampling, in-situ field installations and testing, trial pits, geophysical surveys, slope protection strippings, and coreholes of retaining walls and other existing manmade structures.

g) Performing laboratory testing of soil, rock, and groundwater samples collected from the ground investigations (including chemical testing to identify potentially corrosive conditions).

h) As a minimum, the soils investigation programme shall consider the locations and lateral and vertical extent of:

i. Major structures (viaducts, bridge and crossing structures, portal structures, retaining structures, stations, commercial developments, ancillary structures, etc.).

ii. Earthworks (soil and rock excavations, embankment fills, land reclamations, areas requiring ground improvement, burrow pits and areas, disposal areas, etc.).

iii. Existing adjacent structures that may be influenced by proposed construction works (i.e., structures – adjacent to, above, or below excavations – that may be affected by construction works such as dewatering; structures deemed to have poor structural integrity; structures containing sensitive equipment or materials; structures with historic/cultural significance, etc.).

iv. Significant engineering geology features that may influence the proposed construction works (i.e., principal faults, shear zones, persistent jointing; mass wasting, landslips).

v. Ground investigation, as part of a comprehensive soils investigation programme, shall be conducted according to IS 1892, BS5930/BS1997-2 or AASHTO LRFD Bridge Design Specifications.

vi. Ground investigations, as part of a comprehensive soils investigation programme, shall be conducted according to IS 1892, BS 5930 / BS1997-2 or AASHTO LRFD Bridge Design Specifications.

The spacing and depths of investigation borings shall be consistent with the nature and extent of the proposed construction works and shall meet the more restrictive specifications stated in the standards cited above. Soil data shall be available at least up 6m below the founding level/Termination Level of foundation or as per above codes (whichever is more).

Due to the mixed lithological composition in project area the inter-perforation spacing in drilling explorations should not exceed 100 m. Depending upon the encountered strata, additional drilling preferably with minimum spacing of 20m as suggested in BS5930/ BS1997-2 shall be done in areas having varied lithology, weaker strata layers or areas having special structural importance.

Spacing:

− for high-rise and industrial structures, a grid pattern with points at 15 m to 40 m distance;

− for large-area structures, a grid pattern with points at not more than 60 m distance;

− for linear structures (roads, railways, channels, pipelines, dikes, tunnels, retaining walls), a spacing of 20 m to 100 m;

− for special structures (e.g. bridges, stacks, machinery foundations), two to six investigation points per foundation;

All aspects of the work shall be conducted under the direction of qualified geotechnical personnel. Detailed plans, technical specifications, and standard forms, outlining the proposed staffing and reporting formats, and indicating the types, locations, and proposed depths of investigations relative to the proposed construction works shall be prepared and submitted for review and acceptance prior to undertaking the work. Revisions to the SI programme, if required, shall be submitted for review and acceptance.
All Consultant-produced ground-investigation data shall be prepared up to internationally accepted standards using Association of Geotechnical and Geo-environmental Specialists (AGS) format or equivalent. All data shall be provided in both printed and electronic file formats.

15.3 INVESTIGATION METHODS GEOLOGIC STUDIES

Geologic studies shall include, but not be limited to, a review of pertinent and existing literature, aerial photographs, and remote-sensing data; a detailed field reconnaissance of the site; and preparation of project-specific maps and cross-sections.
Project-specific geologic maps shall be prepared at about 1:5000 scale, and geologic cross-sections shall be prepared at about 1:5000 scale, both horizontal and vertical. Suitable base maps for geologic maps shall be utilized.

15.4 GEOPHYSICAL SURVEYS

Geophysical surveys shall be accomplished where appropriate to provide site-specific information on depths and characteristics of overburden soils and bedrock.
Geophysical survey methods may be used to obtain subsurface information for planning other detailed SI studies, and for extending information between investigations.
For assessing the behavior of structure during earthquake, the contractor shall conduct cross hole seismic test/shear wave velocity test as per ASTM D4428/D4428M.

15.5 EXPLORATORY DRILL HOLES

Exploratory drilling in soil and rock, disturbed and undisturbed soil sampling, and rock coring shall be performed according to procedures outlined in IS 1892, BS 5930 BS1997-2 or AASHTO LRFD Bridge Design Specifications. Full-time monitoring by qualified geotechnical personnel is required not only to direct the drilling, sampling, and coring, but also to prepare field drill hole records.

15.6 OTHER GROUND-INVESTIGATION METHODS

Other ground-investigation methods commonly employed include, but are not limited to, the following:

a. Field testing: Standard Penetration, cone penetration, vane shear, pressure-meter permeability/water absorption, impression packer/discontinuity survey, acoustic borehole imaging, in-situ density, N-Schmidt hammer, plate load testing and pile load testing.

b. Field instrumentation: piezometers, inclinometers.

c. Trial pits with/without block sampling.

d. Inspection pits.

e. Geocore probes.

f. Hand auger borings.

g. Slope protection stripping.

h. Pumping tests.

i. Groundwater sampling.

15.7 GROUNDWATER

Stand pipe shall be installed during ground investigations *in all the boreholes* to measure current and seasonal fluctuations in groundwater levels *whether or not water is found during drilling.* The SI programme shall incorporate the details of a groundwater observation plan, including locations and details of stand pipe installations and frequency and duration of observations. It should also include chemical analysis of ground water. Full-scale groundwater pumping tests shall be conducted to develop design parameters for construction dewatering schemes, where required.

15.8 LABORATORY TESTING METHODS

15.8.1 General Methods

The laboratory testing programme shall be developed considering not only the particular site conditions and project requirements, but also the applicable design standards, codes, regulations. Prior to undertaking the work, detailed plans/proposals for the laboratory testing programme shall be prepared and submitted for acceptance along with technical specifications and standard forms, outlining the proposed staffing and reporting formats and the types and numbers of tests proposed.
Revisions to the laboratory testing programme, if required, shall be submitted for review and acceptance.
All Consultants-produced laboratory test data shall be prepared using internationally accepted standards e.g. AGS format, latest version. All data shall be provided in both printed and electronic file formats. All testing shall be conducted by laboratories holding current accreditation under International Standards Organisation/Bureau of Indian Standards.

15.8.2 Index/Classification Testing of Soil Samples

All index/classification test procedures for soils shall comply with the requirements of IS 2720/BS 1377. Tests shall include the determination of natural moisture content, specific gravity, particle size distribution (with and without hydrometer), Atterberg limits, in-situ bulk and dry density, and dry density and moisture content relationships.

15.8.3 Strength Testing of Soil Samples

Strength-test procedures for soils shall include single- and multi-stage, consolidated-drained and consolidated-undrained triaxial tests; unconsolidated undrained triaxial tests; laboratory vane shear tests; and pocket shear-meter tests, all according to IS 2720 (Part 11). Unconfined compressive strength testing for soils shall be according to IS 2720 (Part 10)/ASTM D2166, and consolidated drained direct shear testing shall be according to IS 2720 (Part 13)/ASTM D3080.

15.8.4 Consolidation Testing of Soil Samples

Consolidation test procedures for soils shall be based on one-dimensional, consolidation methods according to ARE 2720 (Part 14) or Clause 3 of BS 1377: Part 5, with some minor modifications as accepted.

15.8.5 Permeability Testing of Soil Samples

Laboratory test procedures of soil permeability shall include constant-head permeability methods for granular soils, generally according to IS 2720 (Part 17 or 36) or ASTM D2434, and variable-head permeability methods for cohesive soils, generally according to Soil Testing for Engineers by T. William Lambe. Permeability of in-situ materials shall be measured by constant-head or variable-head methods, using standpipe piezometers installed during the ground-investigation programme.

15.8.6 Chemical Testing of Soil and Groundwater Samples

Chemical test procedures for soils and groundwater shall include, as appropriate: determinations of resistivity, redox potential, pH, chloride ion content, sulphate ion content, total sulphate content, total sulphide content, organic content, and carbonate content, according to IS 2720 or BS 1377 or BS 812, or both, and identification of other potentially corrosive conditions.

15.9 GEOPHYSICAL INVESTIGATION

At several locations it would be difficult to carry boreholes along the alignment. Depending upon the site constraint and requirement, the contractor engaged must carry different methods of geophysical investigation to find the physical properties of strata underneath along the alignment. Any chances of encountering abrupt soil strata during construction stage must be avoided by carrying all the possible geophysical and geotechnical investigation.
Different type of geophysical methods for urban environment prior to construction:-

a) **Resistivity Imaging**

Specially indicated to find lateral lithological changes produced by faults or other geological structures. Electrical resistivity imaging survey determines sub-surface resistivity distribution by taking measurements on the ground. From these measurements, true resistivity of sub-surface can be estimated. The resistivity is related to various geological parameters like mineral and fluid content, porosity and degree of water saturation in rocks.

b) **Seismic Refraction**

Seismic refraction consists of recording the time taken for an artificially provoked surface vibration to propagate through the earth. *Some seismic refraction methods like MASW or MAM are very useful for getting the S-Wave velocity (shear wave velocity) of the foundation medium*. By processing the data recorded at various sensors, absolute velocities, velocity contrasts and depths of the underlying layers are determined. These results provide information about the characteristics of the overburden and the bedrock.

c) **Crosshole/Downhole/Uphole Surveys:**

Crosshole geophysical testing is generally conducted in the near surface (upper hundred meters) for site specific engineering applications. The primary purpose of obtaining crosshole data is to obtain the most detailed in-situ seismic wave velocity profile for site specific investigations and material characterization, Crosshole velocity data are valuable for assessing man-made materials, soil deposits or rock formations.

d) **Seismic Reflection Method:**

Deep seismic reflection surveying is the most advanced technique in geophysics with huge scale application for oil and gas exploration. Seismic energy is generated at the surface using either impulsive sources (dynamite) or continuous sources (vibroseis). The returned energy is recorded by a series of geophones installed along line at the surface. Reflection of the energy is caused by contrasts in acoustic impedance between the various strata. Data processing is a complex sequence of operations carried out usually on powerful computers using specialized software. The final product in a 2D or 3D dataset of seismic reflectors, which can then be correlated to specific geological interfaced through the use of borehole information. On a smaller scale, such as for civil engineering project site investigations, the methodology is identical, but the equipment and parameters are adjusted to provide a higher resolution at shallow depths.

e) **Ground Penetrating Radar (GPR) Method:**

Ground Penetrating radar, also known as GPR, Georadar, Subsurface Radar, Geoprobing Radar, is a totally non-destructive technique to produce a cross-section profile of subsurface without any drilling, trenching or ground disturbances. GPR profiles are used for evaluating the location and depth of buried objects and to investigate the presence and continuity of natural subsurface conditions and features.

The GPR operates by transmitting electromagnetic impulses into the ground through transmitter antenna. The transmitted energy is reflected from various buried objects or distinct contacts between different earth materials, across which there is a contrast in dielectric constant. The antenna then receives the reflected waves and displays them in real time on screen. Data is also saved in appropriate memory for later processing and interpretation.

GPR can detect objects of any material, metallic or non-metallic.

In addition to the soil investigation carried by geophysical and geotechnical methodology contractor needs to predict the geological condition ahead of cutter head by adopting below mentioned technique.