Part-I

OUTLINE DESIGN CRITERIA - RAILWAY GEOMETRY, BRIDGES AND VIADUCTS

CONTRACT NO: NGNDD01

INDEX

OUTLINE DESIGN CRITERIA

RAILWAY GEOMETRY, BRIDGES AND VIADUCTS

Section D1 - GENERAL, CODES AND STANDARDS

D1.1 Purpose and Scope

D1.1.1 The Outline Design Specifications hereto provide minimum standards that are to govern the Design of the Permanent Works.

D1.1.2 The Outline Design Specifications shall be read in conjunction with the Outline Construction Specifications where ever appropriate.

D1.1.3 The design and construction of the Permanent Works shall comply with codes of practice and standards current at the time of submission of Tender Documents. Regulations made and requirements issued by the Government of India and by relevant utility authorities shall be followed and specified.

D1.1.4 Alternative or additional codes, standards and specifications proposed by the DDC shall be internationally recognised codes and shall be equivalent to or better than, Indian Standards issued by the Bureau of Indian Standards or any other Indian professional body or organisation, subject to being, in the opinion of the Engineer, suitable for incorporation or reference into the Specifications.

D1.2 Codes and Standards

Design and loading requirements for the structures shall be not less than the following Indian Standards and Codes of Practice, together with all applicable amendments.

Where other standards and codes of practice are referred to in the text of other Appendices then the designer is expected to apply those Standards and Codes of Practice unless the designer can show that an economic case exists for use of an Indian Standard. However preferences of codes will be as follows :–

(1) IRS - Where any structures supporting railway tracks.

(2) IRC

(3) IS

(4) BS

(5) AASTO

Indian Railway Standards (IRS)

IRS - Bridge Rules for loading (Ministry of Railways)

IRS - Code of practice for steel bridges.

IRS- Code of practice for plain, reinforced and pre-stressed concrete for general Bridge construction. Second Revision – 1997.

IRS- Code of practice for the design of substructures and foundation of bridges

.

Indian Roads Congress Standards (IRC)

IRC 5:	1985	Standard Specifications and Code of Practice for Road Bridges, Section I - General Features of Design
IRC 6:	2000	Standard Specifications and Code of Practice for Road Bridges, Section II – Loads and Stresses
IRC 10:	1961	Recommended Practice for Borrowpits for Road Embankments Constructed by Manual Operation
IRC 11:	1962	Recommended practice for the design of layout of cycle tracks
IRC 18:	1985	Design Criteria for Prestressed Concrete Road Bridges (Post-Tensioned Concrete)
IRC 19:	1977	Standard Specifications and code of Practice for Water Bound Macadam
IRC 21:	1987	Standard Specifications and Code of Practice for Road Bridges Section III–Cement Concrete (Plain and Reinforced)
IRC 22:	1986	Standard Specifications and Code of Practice for Road Bridges, Section VI – Composite Construction
IRC 24:	1967	Standard Specifications and Code of practice for Road Bridges, Section V – Steel Road Bridges
IRC 36:	1970	Recommended Practice for the Construction of Earth Embankments for Road Works
IRC 37:	1984	Guidelines for the Design of Flexible Pavement
IRC 45:	1972	Recommendations for Estimating the Resistance of Soil below the maximum Scour Level in the Design of Well Foundations of Bridges
IRC 48:	1972	Tentative Specifications for Bituminous Surface Dressing Using Pre-coated Aggregates
IRC 75:	1979	Guidelines for the Design of High Embankments
IRC 78:	2000	Standard Specifications and Code of Practice for Road Bridges, Section VII (Parts 1 and 2), Foundations and Substructure
IRC 83:	1987	Standard Specifications and code of practice for Road Bridges, Section IX - Bearings Part I & II: Bearings (Metallic and Elastomeric)
IRC 87:	1984	Guidelines for the Design and Erection of False Work for Road Bridges

IRC 89:	1997	Guidelines for Design and Construction of River Training and Control Works for Road Bridges
IRC: SP 11	1988	Handbook of Quality Control for Construction of Roads and Runaways

D1.5 IS: Codes

National Building Code

SP 7:	1983	Bureau of Indian Standards**.**
IS 73:	1992	Paving Bitumen
IS 150:	1950	Ready mixed paint brushing, finishing stoving for enamel colour as required
IS 205:	1992	Non-ferrous metal Butt Hinges
IS 206:	1992	Tee and strap hinges
IS 207:	1964	Gate and shutter hooks and eyes
IS 208:	1987	Door handles
IS 210:	1993	Grey iron castings
IS 215:	1995	Road tar
IS 217:	1988	Cutback Bitumen
IS 269:	1989	33 grade Ordinary Portland Cement.
IS 278:	1978	Galvanised steel barbed wire for fencing
IS 280:	1978	Mild Steel wire for general engineering Purposes
IS 281:	1991	Mild Steel sliding door bolts for use with Padlocks
IS 362:	1991	Parliament hinges
IS 363:	1993	Hasps and staples
IS 383:	1970	Coarse and fine aggregates from natural Sources for concrete
IS 432:	1982	Mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement
	(Part 1)	Mild steel and medium tensile steel bars
	(Part 2)	Hard-drawn steel wire
IS 453:	1993	Double-acting spring hinges
IS 455:	1989	Portland slag cement
IS 456:	2000	Code of practice for plain and reinforced concrete
IS 457:	1957	Code of practice for general construction of plain and reinforced concrete for dams and other massive structures
IS 458:	1988	Precast concrete pipes (with and without reinforcement)

IS 459:	1992	Corrugated and semi-corrugated asbestos cement sheets
IS 460:	1985	Test sieves
IS 516:	1959	Method of test for strength of concrete
IS 650:	1991	Standard sand for testing cement
IS 733:	1983	Wrought aluminium and aluminium alloy bars, rods and sections for general engineering purposes
IS 737	1986	Wrought aluminium and aluminium alloy sheet and strip for general engineering purposes
IS 771	1979	Glazed fire-clay sanitary appliances
	(Part 1)	General requirements
	(Part 2)	Specific requirements of Kitchen and laboratory sinks
	(Part 3/Sec. 1)	Specific requirements of Urinals - Slab Urinals
	(Part 3/Sec. 2)	Specific requirements of Urinals - Stall Urinals
IS 774:	1984	Flushing cistern for water closets and urinals
IS 775:	1970	Cast iron brackets and supports for wash basins and sinks
IS 777:	1988	Glazed earthenware wall tiles
IS 778:	1984	Copper Alloy gate, globe and check valves for water works purposes
IS 779:	1994	Water meters
IS 780:	1984	Sluice valves for water works purposes (50 to 300 mm size)
IS 781:	1984	Cast copper alloy screw down bib taps and stop valves for water services
IS 783:	1985	Code of practice for laying of concrete pipes
IS 800:	1984	Code of practice for general construction in steel
IS 814:	1991	Covered electrodes for manual metal arc welding of carbon and carbon manganese steel
IS 875:	1987	Code of practice for design loads (other than earthquake) for buildings and structures
IS 883:	1994	Code of practice for design of structural timber in building
IS 909:	1992	Under-ground fire hydrant, sluice valve type
IS 1003:		Timber panelled and glazed shutters

(Part 1)	1991	Door shutters
(Part 2)	1994	Window and ventilator shutters
IS 1030:	1989	Carbon steel castings for general engineering purposes
IS 1038:	1983	Steel doors, windows and ventilators
IS 1077:	1992	Common burnt, clay building bricks
IS 1080:	1986	Design and construction of shallow foundation in soil(other than raft ring and shell)
IS 1161:	1979	Steel tubes for structural purposes
IS 1195:	1978	Bitumen mastic for flooring
IS 1230:	1979	Cast iron rainwater pipes and fittings
IS 1237:	1980	Cement concrete flooring tiles
IS 1239:	1990	Mild steel tubes, tubular and other wrought steel fittings
	(Part 1)	Mild steel tubes
	(Part 2)	Mild steel tubular and other wrought steel pipe fittings
IS 1322:	1993	Bitumen felts for water proofing and damp-proofing
IS 1341:	1992	Steel butt hinges
IS 1343:	1980	Code of practice for Pre-stressed Concrete
IS 1346:	1991	Code of practice Waterproofing of roofs with bitumen felts
IS 1458:	1965	Railway bronze ingots and casting
IS 1489:	1991	Portland Pozzolana Cement.
IS 1536:	1989	Centrifugally cast (spun) iron pressure pipes for water, gas and sewage
IS 1537:	1976	Vertically cast iron pressure pipes for water, gas and sewage
IS 1538:	1993	Cast iron fittings for pressure pipes for water, gas and sewage
IS 1566:	1982	Hard-drawn steel wire fabric for concrete reinforcement
IS 1592:	1989	Asbestos cement pressure pipes
IS 1703:	1989	Copper alloy float values (horizontal plunger type) for water supply fittings
IS 1726:	1991	Cast iron manhole covers and frames
IS 1729:	1979	Sand cast iron spigot and socket soil waste and

		ventilating pipes, fitting and accessories
IS 1732:	1989	Dimensions for round and square steel bars for structural and general engineering purposes
IS 1785:	1983	Plain hard-drawn steel wire for prestressed concrete
	(Part 1)	Cold-drawn stress – relieved wire
	(Part 2)	As drawn wire
IS 1786:	1985	High strength deformed steel bars and wires for concrete reinforcement.
IS 1791:	1985	Batch type concrete mixers
IS 1795:	1982	Specifications for pillar taps for water supply purposes
IS 1834:	1984	Hot applied sealing compound for joint in concrete
IS 1838:	1983	Pre-formed fillers for expansion joint in concrete pavements and structures (non extruding and resilient type)
	(Part 1)	Bitumen impregnated fibre
IS 1888:	1982	Method of load tests on soils
IS 1892:	1979	Code of practice for sub surface investigations for foundations
IS 1893:Part-I	2001	Criteria for earthquake resistant design of structures
IS 1904	1986	Design and construction of foundations in soils General Requirements
IS1905:	1987	Code of practice for Structural use of unreinforced Masonry
IS 1948:	1961	Aluminium doors, windows and ventilators
IS 1949:	1961	Aluminium windows for industrial buildings
IS 1977:	1976	Low Tensile Structural steel
IS 2004:	1991	Carbon steel forgings for general engineering purposes
IS 2062:	1992	Steel for general structural purposes
IS 2074:	1992	Ready mixed paint, air-drying, red oxide-zinc chrome, priming
IS 2090:	1983	High tensile steel bars used in prestressed concrete
IS 2114:	1984	Code of practice for laying in-situ terrazzo floor finish
IS 2116:	1980	Sand for masonry mortars

IS 2119:	1980	Code of practice for construction of brick-cum-concrete composite
IS 2202:	1991	Wooden flush door shutters
IS 2326:	1987	Automatic flushing cisterns for urinals
IS 2386:	1963	Methods of test for aggregates for concrete
	(Part 1)	Particle size and shape
	(Part 2)	Estimation of deleterious materials and organic impurities
	(Part 3)	Specific gravity, density, voids, absorption and bulking
	(Part 4)	Mechanical properties
	(Part 5)	Soundness
	(Part 6)	Measuring mortar making properties of fine aggregates
	(Part 7)	Alkali – aggregate reactivity
	(Part 8)	Petrographic examination
IS 2430:	1969	Methods of sampling of aggregate for concrete
IS 2548:	1996	Plastic seats and covers for water closets
IS 2556 -	1994/95	Vitreous sanitary appliances
	(Part 1)	General requirements
	(Part 2)	Wash-down water closets
	(Part 3)	Squatting pans
	(Part 4)	Wash-basins
	(Part 5)	Laboratory sinks
	(Part 6)	Urinals and Partition plates
	(Part 7)	Accessories for sanitary appliances
	(Part 8)	Pedestal close coupled wash-down and symphonic water closets
	(Part 9)	Pedestal type bidets
	(Part 14)	Integrated squatting pans
	(Part 15)	Universal water closets
IS 2681:	1993	Non-ferrous metal sliding door bolts (aldrops) for use with padlocks
IS 2690:	1993	Burnt - clay for flat terracing Tiles
IS 2692:	1989	Ferrules for water services
IS 2720		Methods of Tests for Soils

IS 2751:	1979	Recommended practice for welding of mild steel plain and deformed bars used for reinforced construction
IS 2906:	1984	Specification for sluice valves for water works purposes (350 to1200 mm size)
IS 2911:	1979	Code of practice for design and construction of pile foundations
	(Part 1)	Concrete piles
	Section 1	Driven cast –in-situ concrete piles
	Section 2	Bored cast-in-situ concrete piles
	Section 3	Driven precast concrete piles
	Section 4	Bored precast concrete piles
	(Part 3)	Under-reamed piles
	(Part 4)	Load test on piles
IS 2950:	1981	Code of practice for design and construction of raft foundations
IS 3370:	1965	Code of practice for concrete structures for the storage of liquids
IS 3564:	1995	Hydraulically regulated door closers
IS 3812:	1981	Flyash for use as pozzolanans and admixture
IS 3847:	1992	Mortice night latches
IS 3955:	1967	Code of practice for design and construction of well foundations
IS 3989:	1984	Centrifugally cast (spun) iron spigot and socket soil, waste and ventilating pipes, fittings and accessories
IS 4082:	1996	Recommendations on stacking and storage of construction materials and components at site
IS 4138:	1977	Safety code for working in compressed air
IS 4326:	1993	Earthquake resistant design and construction of buildings – code of practice
IS 4656:	1968	Form vibrators for concrete
IS 4736:	1986	Hot-dip zinc coatings on mild steel tubes
IS 4826:	1979	Hot-dipped galvanised coatings on round steel wires
IS 4925:	1968	Concrete batching and mixing plant
IS 4926:	1976	Ready mixed concrete
IS 4968:	1976	Method for sub surface sounding for soils

IS 5525:	1969	Recommendations for detailing of reinforcement in reinforced concrete works
IS 5529:	1985	Code of practice for in-situ permeability tests
IS 5640:	1970	Method of test for determining aggregate impact value of soft coarse aggregate
IS 5816:	1970	Method of test for splitting tensile strength of concrete cylinders
IS 5889:	1994	Vibratory plate compactor
IS 5892:	1970	Concrete transit mixers and agitators
IS 6003:	1983	Specification for indented wire for prestressed concrete
IS 6006:	1983	Specification for uncoated stress relieved strands for prestressed concrete
IS 6051:	1970	Code for designation of aluminium and its alloys
IS 6248:	1979	Specification for metal rolling shutters and rolling grills
IS 6403:	1981	Code of practice for determination of bearing capacity of shallow foundations
IS 6603:	1972	Stainless steel bars and flats
IS 6760:	1972	Slotted countersunk head wood screws
IS 6911:	1992	Stainless steel plate, sheet and strip
IS 7181:	1986	Horizontally cast iron double flanged pipes for water, gas and sewage
IS 7196:	1974	Hold fast
IS 7205:	1974	Safety code for erection of structural steel work
IS 7231:	1984	Specifications for plastic flushing cisterns for water closets and urinals
IS 7273:	1974	Method of testing fusion-welded joints in aluminium and aluminium alloys
IS 7293:	1974	Safety code for working with construction machinery
IS 7320:	1974	Concrete slump test apparatus
IS 7534:	1985	Sliding locking bolts for use with padlocks
IS 7861:	1975	Code of practice for extreme weather concreting
	(Part 1)	For Hot Weather concreting
	(Part 2)	For Cold Weather concreting
IS 7969:	1975	Safety code for handling and storage of building materials

IS 8009	1976	Calculation of settlement of foundations
IS 8041:	1990	Rapid – hardening Portland cement
IS 8112:	1989	43 grade ordinary Portland cement
IS 8142:	1994	Method of test for determining setting time of concrete by penetration resistance
IS 8500:	1991	Structural steel-micro alloyed (medium and high strength qualities)
IS 9013:	1978	Method of making, curing and determining compressive strength of accelerated cured concrete test specimens
IS 9103:	1979	Admixtures for concrete
IS 9284:	1979	Method of test for abrasion resistance of concrete
IS 9417:	1989	Recommendations for welding cold worked bars for reinforced concrete construction
IS 9595:	1996	Recommendations for metal arc welding of carbon and carbon manganese steels
IS 9762:	1994	Polyethylene floats (spherical) for float valves
IS 10262:	1982	Recommended guidelines for concrete mix design
IS 10379:	1982	Code of practice for field control of moisture and compaction of soils for embankment and subgrade
IS 12269	1987	53 grade ordinary Portland cement
IS 12894:	1990	Fly ash lime bricks
IS 13630:	1994	Ceramic tiles – methods of tests
IS 13920	1993	Ductile detailing of Reinforced Concrete Structures subjected to Seismic Forces

Foreign Standards

ASTM D-297	Methods for Rubber Products - Chemical Analysis
ASTM D-395	Compression set of vulcanised rubber
ASTM D-412	Tension testing of vulcanised rubber
ASTM D-429	Adhesion of vulcanised rubber to metal
ASTM D-573	Accelerated ageing of vulcanised rubber by the oven method
ASTM D-624	Tear resistance of vulcanised rubber
ASTM D-797	Young's Modulus in flexure of elastomer at normal and subnormal temperature
ASTM D-1149	Accelerated Ozone cracking of vulcanised rubber
ASTM D-1559	Test for resistance to plastic flow of bituminous

		mixtures using Marshall apparatus
ASTM D-2166		Test methods for Unconfined Compressive strength of Cohesive Soils
ASTM D-2172		Extraction, quantitative, of bitumen from bituminous paving mixtures
ASTM D-2434		Test methods for permeability of Granular Soils
ASTM D-2240		Indentation hardness of rubber and plastic by means of a Durometer
ASTM D-3080		Method for Direct Shear Test of Soils under Consolidated Drained Condition
ASTM E-11		Specification for wire cloth sieve for testing purposes
AASHTO DM 57-80		Materials for embankments and subgrade
AASHTO DM 147-67		Materials for aggregate and soil (1980) base and surface courses
AASHTO DM 282-80		Joints sealments, not poured, elastomeric type, (ASTM : D 3406) for Portland cement cure rate pavements
BS 410:	1986	Specification for test sieves
BS 812:		Testing aggregates
BS 1154:	1992	Specification for natural rubber compounds
BS 1377:	1990	Methods of test for soils for Civil Engineering purposes
BS 5400:Part 4.	1990	Code of Practice for Design of Concrete Bridges.
BS 5930	1981	Code of Practice for Site Investigations
BS 5950		Structural use of Steelwork in Buildings
BS 6177	1982	Guide to selection and Use of Elastomeric Bearings for Vibration Isolation in Buildings
BS 8007	1987	Code of Practice for Design of Concrete Structures for Retaining Aqueous Liquids
BS 8110 Parts I and II		Structural use of Concrete
Part 9. Section 9.1		Code of Practice for Design of Bridge Bearings

Other Publications

Indian Standard Hand Book on Steel sections Part I

Indian Railways Manual on Design and Construction of well and pile foundations.

UIC/772 – R The International Union of Railways Publication.

IEC International Electromechanical Commission

Section D2 - GEOMETRIC DESIGN CRITERIA FOR RAILWAY ALIGNMENT

D2.1 Criteria

D2.1.1 The horizontal and vertical alignments of the railway are given in the Drawings provided by the Employer.

D2.1.2 The DDC shall design the civil engineering works to these alignments. However, subject to the provisions of the Contract, minor changes to the given alignments may be made, where clear benefits can be demonstrated, and in order to suit the specific characteristics of his design.

D2.1.3 The railway alignment design shall comply with the requirements of the following Clauses D2.2 to D2.8.

D2.2 Horizontal Alignment

D2.2.1 The limits for radii for horizontal circular curves shall be as follows :

Minimum radius: (as per the alignment)

- running track : 120metres
- within depots : 120metres

D2.2.2 Whenever possible the track shall be straight throughout the length of the stations. The presence of external restrains may necessitate limited encroachment of transition curves at station ends but this shall be avoided whenever possible. Where encroachment is unavoidable this shall be limited such that the vehicle throw does not affect the platform nosing clearance.

D2.2.3 Circular curve radii shall be selected to be the maximum practicable. The radius selected for any particular curve shall not be so large as to unnecessarily impose more severe curvature of the track at either end of that curve.

D2.2.4 The combination of circular curves and their related transition curves shall be chosen such that the length of pure circular arc between transitions is not less than the following :

- Desirable minimum 50 metres
- Absolute minimum 25 metres

D2.2.5 For any consecutive circular curves with opposite direction of curvature the length of straight track between the ends of the curves or of the transitions where these are required shall be not less than:

- Desirable minimum 25 metres
- Absolute minimum 15 metres

When it is not possible to provide a straight portion of 15m, no straight portion shall be provided and the transitions extended accordingly. The rate of change of cant and versine over both transitions shall be kept the same in such cases.

D2.3 Cant and Speed

D2.3.1 The curve speed cant relationship shall be based on the following equations:

Equilibrium cant E $= \frac{11.82 \times Ve^2}{R}$ (Standard Gauge)

E $= \frac{13.78 \times Ve^2}{R}$ (Broad gauge)

Maximum permissible speed Vm = $0.29\ [R\ (E_a+D)]^{0.5}$ (Standard Gauge)

Vm = $0.27\ [R\ (E_a+D)]^{0.5}$ (Broad gauge)

where R = horizontal curve radius in metres.

Vm = maximum permissible speed in kilometres per hour.

V_e = equilibrium speed in kilometres per hour.

E = equilibrium cant in millimetres.

E_a = actual applied cant in millimetres.

D = maximum allowable deficiency of cant in millimetres.

D2.3.2 The maximum allowable applied cant for ballasted and ballastless track shall be :

	Absolute Maximum	Desirable Maximum
Standard gauge	125mm	110 mm
Broad gauge	150 mm	125 mm

D2.3.3 The deficiency of cant shall be limited to:

(i)	Maximum allowable deficiency of cant on plain line for CWR and jointed track	100 mm
(ii)	Maximum allowable deficiency of cant on turnouts and crossings of CWR and jointed track	75 mm
(iii)	Limit of negative cant on switches and crossings for CWR and jointed track	75 mm

D2.3.4 The track shall be designed on the basis of maximum line speeds. These will be:

Curve Radius (m)	Max. Speed (km/hr) Broad Gauge	Max. Speed (kmph) Standard Gauge
200	60	60
250	65	65
300	75	75
350	80	80
400	80	80
>450	80	80

The table is based on cant up to 150mm and cant deficiency of up to 100mm where required. However, subject to the provisions of the contract, speed restrictions may be introduced where this is dictated by external constraints and operational requirements.

D2.3.5 Applied cant shall be specified to the nearest millimetre for concrete track and to the nearest 5 mm for ballasted track.

D2.3.6 Track at terminus stations shall continue past the end of the platforms by 25 metres where stabling or refuge tracks are not required.

D2.4 Transition Curves

D2.4.1 In general for all running and depot lines transition curves shall be provided wherever possible between a circular curve and adjoining straight, between the different radii of a compound curve and at the adjoining ends of circular curves forming reverse curves. Transition curves are not required in sidings.

D2.4.2 Transition curves shall be in the form of cubic parabolas or clothoid spirals for which the equations are :

a. cubic Parabolas

(i) $y = \frac{d^3}{6RL}$

(ii) $A = \frac{d^2}{2RL}$

(iii) $S(\text{Approximate}) = \frac{L^2}{24R}$

. clothoid spiral

$$S = \frac{L^2}{24R} - \frac{L^4}{2688R^3}$$

where L = length of transition

R = radius of circular curve

S = shift

y = offset from tangent

d = distance along transition

A = deviation angle of transition

D2.4.3 The cant gradient or cant deficiency gradient shall be subject to the following limits:

(i) Absolute maximum = 1 : 500

(ii) Preferred = 1 : 750

D2.4.4 The rate of change of cant or cant deficiency shall be limited to:

(i) Absolute maximum = 55 mm/sec.) for plain

(ii) Desirable maximum = 35 mm/sec) track

D2.4.5 Transition curves will not normally be required between different radii of a compound curve where the change of radius of curvature does not exceed 15% of the smaller radius and provided that the cant deficiency and/or cant excess criteria are not exceeded for either curve.

Where a compound curve is employed with a change of radius greater than 15% of the smaller radius, or where the cant deficiency or cant excess criteria necessitates a change in cant between the circular curves, a suitable transition curve shall be interposed between the two parts of the curve. The length of such a transition shall be equal to the difference between the required transition lengths at each end of the curve.

When the actual shift of any calculated transition curve would be less than 10mm the actual transition curve may be omitted. In this case, the required change of cant shall take place over the calculated length of the transition, or 15 m which ever is the greater, and in the same location as if the transition had been provided.

D2.5 Vertical Alignment

D2.5.1 Vertical curves shall wherever possible be positioned such that coincidence with horizontal transitions is avoided. Where such coincidence is unavoidable the largest practicable vertical curve radius shall be employed.

D2.5.2 Vertical curves shall, for each location, be selected on the basis of the largest practicable vertical curve radius subject to the following limit :

Minimum desirable radius 2500 m

D2.5.3 The length of constant grade between consecutive vertical curves shall be as follows:

(i) Desirable minimum 50 m

(ii) Absolute minimum 25 m

D2.5.4 At point and crossing work vertical curves shall not coincide with any part of the overall length of switches or of cast crossings. At other point and crossing work vertical curves shall be avoided whenever possible. Where they cannot be avoided the vertical curve radius shall be 3000 m or more

D2.5.5 At station ends the tangent point of the vertical curve shall be permitted to encroach within the length of the platform to a limited extent. This length of encroachment shall be such that the vertical offset of the curve from the station gradient at the platform end shall not exceed 15mm.

D2.6 Gradients

D2.6.1 The limits for gradients shall be as follows :

- For running lines the desirable maximum gradient shall be 3% and where unavoidable shall be 4%. Where gradients of 1% or less are used they may be unrestricted in length. Gradients above 3.0% shall be kept as short as possible.
- At stations the track shall be level or of constant gradient not steeper than 0.2% throughout the platform length except for the limited lengths of vertical curves as specified in Clause D2.5.5 above.
- A drainage gradient shall be provided for all viaducts, other than at stations, as follows :
- Desirable minimum 0.5%
- Absolute minimum 0.25%

- Sidings shall be level or shall fall away from the main line switch at a gradient not exceeding 0.25%. Train berths shall be level or shall fall towards the buffer stops at a gradient not exceeding 0.25%.

D2.7 **Levels**

D2.7.1 All levels shall be quoted in metres correct to three decimal places and shall be above mean sea level (MSL).

D2.7.2 Rail level on canted track will refer to the level of the running edge of the lower rail.

D2.8 Points and Crossing Work

D2.8.1 General

Whenever possible points and crossing work shall not coincide with vertically or horizontally curved track.

Where it is not possible to avoid coincidence with vertical curves the switches and stock rails shall not be laid on vertical curves.

Points and crossing work shall not coincide with horizontal transitions.

No part of the switches, switch operating gear or crossing nose shall be over a structural movement joint.

D2.8.2 Scissors Crossovers

Scissors crossovers shall be based on a transitioned crossover with vertical rails.

The switch points and turnout radius shall be standard UIC or approved equivalent, designed to accommodate a minimum operational speed of 40 km/hr.

D2.8.3 Turnouts

Turnouts shall be based on a transitioned turnout with vertical rails.

The speed through the turnout shall be 50 km/hr.

Operational speed in the Depot shall be 20 km/hr.

D2.8.4 Trackwork Requirement :

The Contractor shall design the viaduct structures in accordance with trackwork requirements. All the structural elements of the viaducts including the locations of expansion joints shall be designed so that they will not interfere with the operation of the trackwork requirement and turnouts and crossovers.

Section D3 - RAILWAY DESIGN REQUIREMENTS

D3.1 General

D3.1.1 The Railway Envelope is defined as the extent of works to be constructed to allow installation and operation of the railway equipment.

D3.1.2 The DDC shall be responsible for the design, of a first stage primary concrete. Others will undertake the design of the secondary concrete, trackslabs and trackwork under contracts with the NMRC. A fundamental obligation of the DDC is to co-ordinate and co-operate with the Trackwork DDC and Contractor so that the design of all components of the railway are compatible.

D3.1.3 The design of all railway operating equipment, including signals and signalling cables, the traction power electrification equipment, electrical cables, electrical and mechanical equipment, telecommunication links, etc. that are required for the railway will be undertaken by others under contracts with the Employer. Similar co-ordination and co-operation obligations as expressed in Clause D3.1.2 above apply.

D3.1.4 The DDC shall include in the civil works blind holes, plinths, trenches etc. as required by the Systemwide Contractors. The Systemwide Contractors will supply and fit brackets, nuts and bolts and other fixings for the support of its equipment. The extent and detail of such provisions are to be determined by the DDC making due enquiries, through design co-ordination, from Contractors engaged to provide railway-operating equipment and from the Trackwork DDC. Some details of the likely fixing to be provided are given below but it is stressed that this information may not be complete or comprehensive for the DDC.

D3.1.5 The DDC shall be responsible for co-ordinating his design with other DDCs and with the Employer's Representative and for ensuring that the design incorporates such fixings as are required in order to avoid any necessity for contractors to drill, weld, burn or cut any part of a structure.

D3.1.6 Telecommunication

DDC shall allow for mounting plates or other agreed fixings for the lineside telephones and associated cables at spacings to be determined by the Systemwide Contractors.

D3.1.7 Setting out

The DDC shall provide permanent survey monuments and shall provide full details of co-ordinates and levels to the Trackwork DDC.

D3.1.8 Second pour concrete

The Trackwork Contractor will carry out the second pour concrete for the trackwork. In this regard, the DDC shall include design of starter bars in the primary concrete pour to facilitate anchorage of the second pour concrete if so required. The DDC shall co-ordinate with the Trackwork DDC as to the size and location of the starter bars. The DDC shall design drainage pipes, channels and catch basins to be in the first pour concrete.

D3.2 Stray Current Corrosion Control

D3.2.1 The DDC shall incorporate into his design precautions to minimise stray current corrosion caused by DC traction power returns through the rails. These requirements do not apply to traction power at 25 kV 50 Hz..

D3.2.2 The Trackwork DDC will design electrical insulation of the Trackwork.

D3.2.3 The DDC's design shall include throughout in situ concrete structures in the vicinity of return rails a longitudinal, continuous, low resistance, electrical path. The DDC shall allow for sufficient longitudinal reinforcement to be electrically bonded, to form an effective stray current interception and collection path.

D3.2.4 The continuous electrical path shall be provided by ensuring full and reliable electrical connection throughout the structure.

D3.2.5 The electrically continuous path shall be provided through the steel reinforcement either by continuous welding of structural reinforcement or by the provision of additional welded mesh reinforcement. Where welded structural reinforcement is used to form a grid, welded cross-connections shall be at a minimum spacing of :

(a) for longitudinal bars, 600 mm measured in the transverse direction;

(b) for transverse bars, 6 m measured in the longitudinal direction.

D3.2.6 The DDC shall make provision for the monitoring of this continuous electrical path during construction and the DDC will be required to demonstrate to the Engineer during construction that the required electrical resistance has been achieved.

D3.2.7 The continuous electrical path will be made approximately in 100 metre sections. At these sections the DDC shall include in the design, terminals as required from the continuous electrical path through the structures to external connections. The terminals shall be suitable for the connection of 70 mm^2 copper cable. At each connection, four such terminals shall be provided, two of which shall be kept as spares and suitably protected. Similar terminals, spare terminals and connections shall be provided over any joint of the structure.

D3.2.8 General requirements for earthing and bonding the structures are to be determined in liaison with the Systemwide Contractor.

D3.2.9 Cross bonding of the running rails, stray current return cabling etc. will be carried out by the Systemwide Contractor.

D3.2.10 The DDC shall take account in his design of the fact that the Contract will be integrated with others in the Project in respect of the control of stray currents, and may therefore carry stray currents arising from any foreseeable operating condition of the Project.

D3.3 Railway Cross Sections and Structure Gauges

D3.3.1 The Kinematic Envelope for the rolling stock of the railway and Structure Gauges for straight and curved track will be provided after finalisation of contract.

D3.3.2 The DDC shall ensure that the proposed size of structure is adequate to contain the equipment, required under Clause D3.1 above, outside the Structure Gauge.

D3.4 Clearances

Structures shall not infringe the clearances specified. See also Clause D3.3.2 above.

Section D4 - DESIGN LIFE AND SERVICEABILITY

D4.1 General

Clauses D4.2 to D4.6 below define the design life and serviceability requirements for the various elements of the structures.

The design life of a structure is that period for which it is designed to fulfil its intended function when inspected and maintained in accordance with agreed procedures. The assumption of a design life for a structure or component does not necessarily mean that the structure will no longer be fit for its purpose at the end of that period. Neither will it necessarily continue to be serviceable for that length of time without adequate and regular inspection and routine maintenance.

All Design Life criteria shall be confirmed.

D4.2. Civil Engineering Structures

The design life of all civil engineering structures shall be a minimum of 120 years unless otherwise specified or agreed.

D4.3. Building Structures

The design shall be a minimum of 50 years unless otherwise specified or agreed.

D4.4 Bridge Bearings and Movement Joints

Bridge bearings and movement joints shall have a minimum design life of 50 years apart from minor components that can be replaced without complete removal and without interruption to traffic. Such components shall have a service life of 20 years.

D4.5. Serviceability of Civil Engineering and Building Works

D4.5.1 The design shall include the effects of surface water conditions with the following return periods :

(a) 10 years, with a factor of safety of 1.4;

(b) worst predicted, with a factor of safety of 1.1.

D4.5.2 Paint systems for steelwork shall ensure a minimum life of 15 years for primer coat and 5 years for top coat before maintenance painting is required.

D4.5.3 The corrosion protection of non-structural steel items shall be appropriate to the accessibility of the item for inspection and maintenance.

D4.6. Serviceability of Mechanical and Electrical Equipment

Serviceability of electrical and mechanical equipment to be designed under this Contract shall be provided to the Employer’s Representative.

Section D5 - LOADS AND REQUIREMENTS

RAILWAY LIVE LOADS

D5.1 General

The railway loading applied to structures on the Project shall be in accordance with attached axle configuration of modern rolling stock except as detailed below. Dead loads shall be used that are in accordance with IRS Bridge Rules and IS 456 (for buildings) and IS 1911 for unit weights of materials.

D5.2 Nominal Loads

For the purpose of computing stresses and deformations, the following loads and consequential effects shall be taken into account as applicable.

- Dead loads DL
- Super Imposed Dead loads SIDL
- Live loads LL
- Dynamic effects DI
- Forces due to curvature or eccentricity of track CF
- Temperature effects T
- Frictional resistance of expansion bearings
- Longitudinal forces LF
- Long welded rail forces LR
- Racking forces RF
- Forces on parapets
- Wind pressure effect WL
- Forces and effect due to earthquake EQ
- Erection forces and effects DEL
- Buoyancy B
- Differential settlement DS

D5.3 Loading Combinations

The various combinations of loads and forces to which components of the structures can be subjected are given in the Table 12 of IRS CBC. Each component of the structure shall be designed/checked for all applicable combinations of these loads and forces. They shall resist the effect of the worst combination. The allowable unit stress in a member subjected to a particular combination loading shall not exceed the percentage indicated below against the respective combination.

The loading combinations indicated are not exhaustive. DDC shall analyse the effects of any other combination as deemed appropriate.

D5.4 Design Loads

Design shall include the effects of:

Static Loading: These shall consist of loads due to:

- Track: Load due to 60 Kg (UIC) rails and guard rail and fittings
- Track bed: RCC blocks or concrete pour or precast slabs in RCC with inserts and fittings in case of ballastless track (minimum 197 mm thick) or PSC sleepers over 250/300 mm of ballast for ballasted track.
- Other loads: As per Indian Railway Standards (IRS) and Bureau of Indian Standards (BIS)

Fatigue Loading:

The nominal loading for the design of members in accordance with BS 5400: Part 10 shall comprise trains with eight individual cars each having four axles, the axle loads and vehicle lengths will be provided by the Rolling Stock Consultant. The fatigue loading shall be applied in accordance with the requirements of BS 5400: Part 10 Clause 9.3.3 in conjunction with the following projected annual tonnage's of rail traffic per track. Clause 9.3.4 of BS 5400: Part 10 shall not be applied.

Dynamic Loading:

The static and fatigue loading given in above shall be multiplied by an appropriate dynamic factor as per IRS Bridge Rules.

Dynamic loading shall not be applied to piles, pile caps, centrifugal loads or braking/traction loads.

Longitudinal Loads:

Longitudinal forces of 20% axle load for tractive and 18% for the axle load for braking for the modern rolling stock

When a structure carries two tracks, both tracks shall be considered to be occupied simultaneously. Traction forces shall act on one track and braking forces acting on the other, with both acting in the same direction to produce the worst loading condition.

Longitudinal forces acting on the track shall be considered to be dispersed through the track before being transmitted to the substructure. This shall be calculated based on IRS Bridge Rules, IS Codes and relevant BS Codes.

Provision shall be made for effect of horizontal and longitudinal forces in the rail, especially in the girders with ballastless deck.

Additional permissible stresses while considering this contingency will be proposed by the DDC for review by the Employer’s Representative. Forces shall be calculated for continuous welded rail with a concrete structure interaction resulting from temperature differential of rail and concrete.

Longitudinal forces shall consider the effects on stability and safety arising from a broken rail in ballastless track.

Centrifugal load:

Train Derailment Load: Check for derailment loads shall be made as per IRS Bridge Rules.

Overhead Line Equipment (OLE) Loadings:

Viaducts and bridges under the tracks will be designed for OLE loading on both tracks, with OLE masts located on sides on footpaths.

D5.5 Wind Loading

The viaduct structure shall be designed for wind loading as per IS 875.

However, a bridge shall not be considered to be carrying any live load when the wind pressure at deck level exceeds 150 kg/m2. Wind load shall be taken as 400-kg/metre length of train in transverse direction and 90-kg/metre length in longitudinal direction. These are computed for length of train as seen in elevation normal to longitudinal axis. The transverse load will be applied to train as concentrated at axle locations at a height of 3.2 m or at C.G. of projected area of the vehicle as accepted by the Employer's Representative above top of lowest rail and normal to track. The horizontal force component transmitted to rails and superstructure by an axle will be treated as a concentrated load at rail having direct wheel flange to railhead contact.

D5.6 Temperature Loading

D5.6.1 Overall temperature and differential temperature effects shall be determined as per provisions of IRS or IRC Codes.

D5.7. Seismic Loading

Seismic effects shall be considered on all structures, as per provision of IRS or IRC, except culverts consistent with a horizontal acceleration of 0.07g and will be considered to act in any horizontal direction and 0.0375g in vertical direction. It is also required to check the structures for seismic forces as per IS:1893:2001.

D5.8 Erection Forces and Effects

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 taken into account. Allowance shall be made in the design for stresses caused in any member during erection. For extra allowance in permissible stresses when erection forces are also considered, Clause 1.3 may be seen.

D5.9. Shrinkage and Creep

Provision shall be made for the effects of shrinkage and creep of the concrete in the structure as per relevant codes.

D5.10 Differential Settlement

Consideration of the forces resulting from differential settlement shall be made where the nature of the chosen foundation system and the ground conditions indicate that such a condition may arise but not more than:

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

D5.11 Noise Abatement

Allowable Range of Noise Levels:

Generally, the allowable range of noise levels for different land uses are:

- Residential 50 – 70 dba
- Business & Commercial 75 dba
- Hospitals 60 dba

- Rural 45 - 50 dba

Provision of Noise Barriers:

Structures shall be designed to reduce noise to locally acceptable levels by provision of low vibration track forms, resilient base plates and also design of parapet walls and treatment of their track side surfaces. They can be supplemented by providing sound elimination material on sides of the viaduct superstructures. But in many locations, existing noise level itself may be much higher at 1.0 to 1.2 metres above walkway level. Noise barriers may be required in some lengths of viaducts and bridges passing through sensitive residential or hospital zones. The choice of type and their disposition along the parapet/railing is also closely related to aesthetics of the structure.

Section D6 - LIVE LOADS IN STATIONS

D6.1 Live Loads:

Live loads shall generally follow the requirements of IS 875, except where the loadings given below are more severe.

Platforms and Ticket Hall	5.0kN/m^2, or a concentrated load of 15kN on a square area of 300mm side, whichever is more onerous.
Staff Rooms, Toilets, Offices	3.0kN/m^2
Store Rooms	5.0kN/m^2
Plant Room	According to self-weight of machines

Circulation space within:-

(i) Control rooms 3.0kN/m^2

(ii) Plant rooms 5.0kN/m^2

D6.2 Loads due to Equipment

Self weight of various equipment listed below shall be considered

	Equipment
1.	24 kV Switch board (1 No./substation)
2.	380 V Switch board (No. according to design)
3.	AC Switch board (1 No.)
4.	Aux. Services Transformers (Accord. Employer’s Requirements)
5.	Inverter (1 No. if installed) and Batteries

Note : 1. The design of the station structure shall take into account the dimensions and weights of the actual equipment to be used.

2. In the design of the station structure due account shall be taken of all loadings resulting from the method and route to be taken for the installation and subsequent removal and replacement of the various items of plant and equipment.

Section D7 - ELEVATED STRUCTURES

STRUCTURAL SYSTEM AND ARTICULATION

D7.1 General

Viaducts and bridges form the predominant components of the NMRC'S on the Rail Corridor. The form, dimensions and design requires special consideration to resolve structural suitability, economy and aesthetics concerns. Viaducts for the corridor shall be generally twin C girder system, having all the required support system for cabling, OHE and the railway tracks, is the economical solution under normal circumstances.

Consideration shall be given to include in the design the following requirements:

- Long welded rails with track centres at 4.60m and suitable for kinematic profile of Standard Gauge schedule of dimensions of NMRC.
- The track shall be ballastless construction on the elevated segments

D7.2 Railway Requirements

D7.2.1 Provision for emergency evacuation shall be provided along the railway for the full length of the structure. Routes assigned for emergency evacuation shall be designed for footway loading in accordance with the requirements stated herein.

D7.2.2 The DDC shall note that there is a requirement to provide touch potential protection to passengers on the platforms. The design shall therefore include for a width of 2.5 metres from the platform edge to be insulated from ground earth by insertion of PVC and/or other insulating compounds. Metalwork railings etc. shall be kept a minimum of 2.5 metres from the platform edge unless similarly insulated.

D7.2.3 Parapets

Parapets shall be provided on both sides of all viaducts for the full length of the structure. They shall be designed to act as the support structure to the railway cabling as appropriate. Parapets shall be designed to resist a horizontal and a vertical force each of 150kg/m applied simultaneously to the top of railing or parapet

Parapets shall be provided for all transition structures to protect the guideway from intrusion by trespassers, vandals and road vehicles.

Parapets shall be designed to function as Noise Containment Barriers.

Parapets shall be designed to cater the forces of OHE (if any).

D7.3 Vertical Alignment

D7.3.1 Profile grade:

The superstructure shall be so designed that, when subject to dead load only, the rail level would be above the theoretical vertical profile of the system by an amount equal to permissible LL deflection for the structure.

Provision for super-elevation shall be made preferably as part of the track structure over the deck. The dead load is to be considered at such locations.

D7.3.2 Camber

The superstructure deck, including the soffit of any overhead structure above the deck, shall be cambered so as to compensate for the combined effect of:

- vertical curvature, if any;
- dead load deflection; and
- permissible live load plus-impact deflection as accepted by the Employer's Representative.

D7.3.3 Span/Depth ratios

Length-to-depth ratio should as far as possible be restricted to:

- Reinforced concrete member- 10
- Pre-stressed concrete member:
- Composite members - 16- Desirable 12

In Box girders these ratios shall be further subject to stipulations made with regard to internal dimensions required for inspection and future pre-stressing.

Desirable Minimum thickness of any RC member

- Deck - 200 mm
- Web of T-beam - 250 mm
- Web of prestressed girders - 150 + d
- If there are 2 cables at any level - 150+3d

(where d is the diameter of the cable duct.)

Box Girders: minimum member thickness:

- Deck slab - 200 mm
- Bottom flange - 300 mm
- Web - 250 mm
- or as required by IRS Concrete Bridge Code whichever is the greater thickness

In an aggressive environment, an additional thickness of 10 to 20 mm shall be used.

D7.3.4 Typical pier locations are shown on the drawings. Where topographical or service utility restraints dictate use of longer/continuous spans, pier locations may be adjusted to suit the proposed span lengths.

D7.3.4.1 The Consultant shall provide, by suitable choice of span lengths, a sufficiently stiff deck and supporting sub-structure to resist loading as defined in Clauses D5.1 to D5.8 above. Static and dynamic rail live load responses, at essential movement joint locations, shall be in compliance with the Employer's Requirements.

D7.3.4.2 Halving joints shall not be used unless absolutely essential.

D7.3.4.3 The design of the Permanent Works shall comply with the railway noise requirements detailed in Clause D5.11.

D7.3.4.4 Rail/Structural interaction analysis due to continuous welded rail with direct fixation or structure shall be performed in accordance with proven international practice.

D7.3.4.5 Approach slabs of sufficient sizes shall be provided between abutments and at-grade sections.

An approach slab shall be provided in rear of all abutment of elevated structures and bridges. This should not be less than 6 m in length nor be less than the length computed from the formula:

$L = 1.5\ h \tan(45^o – Ø/2)$

Where h = Depth from bottom of slab to bottom of abutment (top of footing)

Ø = Angle of internal friction of backfill soil in degrees

Slab shall be designed assuming that it does not receive any support from the backfill for a distance of not less than 4.0 m nor less than $h \tan(45^o - Ø/2)$ from back of abutment.

D7.4 Design Considerations

D7.4.1 Vibration and Deflection Limitations

The amplitude and frequency of vibrations of the viaduct and station structure shall be limited to international standards.

The overall deflection as specified elsewhere in the contract for elevated structure will be limited taking into consideration the effect of vibration in addition to other considerations.

Suitable provisions shall be provided at the ends of beams and jacking pads on pier caps shall be provided to allow for replacement of bearings and for any repairs during service.

Provision should be made for adequate fixtures of the superstructure to the substructure, if any loading or loading combination increased by 100% of live load plus impact is likely to cause uplift of any support.

D7.4.2 Design Procedures

Reinforced and Pre-stressed concrete members of elevated structures shall be designed in conformity with the provisions of IRS and IRC Codes.

D7.4.3 Method of Construction

Stresses in partially completed structures shall be analysed for appropriate critical conditions at various stages of the construction.

Any restriction on the construction operations resulting from the design assumptions shall be clearly specified on the contract drawings and specifications. Conversely, advantage may be taken by the designer of specified construction procedures or sequences to effect a more favourable distribution of loads or stresses.

D7.4.4 Movement/Expansion Joints

Movement/expansion joints and other necessary measures to control shrinkage and thermal effects shall be incorporated in the structural design so that the performance of architectural finishes or of any services are not adversely affected during normal working conditions.

Movement/expansion joints shall be designed to be easily maintained and replaceable.

D7.4.5 Design Surface Crack Width

For the serviceability limit state of cracking:

- Design surface crack width of reinforced concrete viaduct structures shall not exceed the values given in Table 10 of CBC-1997 (Correction slip No.1 dated 26.04.2000).
- Pre-stressed concrete viaduct structures shall be designed as per provisions of IRS and IRC Codes.
- Design surface crack width of reinforced concrete station structures exposed to weather shall not exceed the values given in Table 10 of CBC-1997 (Correction slip No.1 dated 26.04.2000).
- Pre-stressed concrete station structures that are exposed to the weather shall be designed as per IRS/IRC or other relevant codes. Structural elements that are fully protected from the weather may be designed as class 2.
- All aqueous liquid retaining structures and basements shall be designed to the requirements of BS 8007 unless otherwise varied by this specification.

D7.4.6 Temperature Effects

Temperature effects shall be taken into account in accordance with the requirements of IRS or BIS, where applicable.

The difference between maximum and minimum effective temperature shall be taken as 35°C.

D7.4.7 Not Used.

D7.4.8 Structural Members with Bearings

Consideration shall be given for the easy maintenance and replacement of viaduct and station bearings.

The minimum clearance between structural members separated by bearings shall be as follows:

- Precast Viaduct Beam/Cross Head : 150 mm
- In-Situ Viaduct Beam/Column : 250 mm
- Precast station Beam/Corbel : 175 mm

These are absolute minimum values and the requirement for easy maintenance and replacement of bearings shall prevail.

D7.4.9 Thermal Rail Forces

Provision shall be made for horizontal transverse and longitudinal forces due to temperature variation in rail. The forces shall be applied in a horizontal plane at the top of low rail as follows:

(1) Transverse Force. The transverse force (T) per linear metre of structure per rail shall be determined by the following formula:

$$T = \frac{650}{R} \text{ kN}$$

Where; R = radius of rail curvature in metres.

(2) Longitudinal Force. A longitudinal force shall be applied in accordance with Indian Standards.

D7.4.10 Access To Voids

Continuous access between the deck voids shall be provided wherever possible. An easily removable, watertight manhole access to deck voids shall be provided in every span.

D7.4.11 Pre-stressed Concrete

Non-shrink grout shall be used for grouting of post-tensioned tendon ducts.

Pre-stressing anchorages shall be detailed such that they are easily accessible for inspection and maintenance. The detailing shall also prevent the accumulation of water and dirt around the anchorage.

All assumptions made in the determination of the design pre-stress loads, e.g. curvature, friction, cross section and mechanical properties of strand and concrete shall be clearly stated on the drawings.

D7.4.12 Bearings

D7.4.12.1 In the selection of the bearing layout in viaducts and elevated stations, consideration shall be given to their performance in relation to the supporting structures, economy as well as maintenance and replacement of the bearings.

D74.12.2 Due care must be taken to ensure that no pair of bearings act against one another in service conditions to the detriment of the structure and to the bearings themselves.

A suitable bearing layout for the viaduct could be the 3-bearing system.

D7.4.12.3 Design Life

Bearings and their installations shall be designed to be compatible with the design life of the viaduct and the elevated stations.

Whenever the expected design life of the bearings is significantly less than that of the structure, provision shall be made for the removal and replacement of the whole or parts of the bearings.

D74.12.4 Type of Bearings

Bearings for the viaducts would preferably be Elastomeric Bearings, but types used by NMRC under similar applications will be acceptable.

For the elevated stations, elastomeric bearings or POT/PTFE would be acceptable. Where necessary and with the Engineer’s prior acceptance, vibration-reducing bearings shall be specified for the elevated stations.

The type of bearings and their installations to be adopted shall be such that they satisfy the requirements for their design life as stipulated in IRC-83 or UIC-772R.

D7.4.12.5 Bearing Design

Unless otherwise specified, bearings shall be designed in accordance with the requirements of IRC Codes or UIC.772R.

Bearings for viaducts and elevated stations shall be designed to allow for the following movements:

- Thermal expansion and contraction: An ambient range varying between 2°C to 47 °C should be considered for Noida-Greater Noida
- Shrinkage of concrete
- Creep in concrete
- Elastic shortening under prestress
- Displacements of structure under load:
  - Differential settlement between viaduct piers shall be considered.
  - Rotation and sway of columns and crossheads under the worst load combination including the effects of temporary loads during construction shall be considered.

Schedule listing the performance requirements for each type of bearings for viaduct and elevated stations shall be incorporated in the drawings. The schedule shall indicate the following:

- Dead load to be supported (SLS and ULS)
- Maximum and minimum vertical live load to be supported (SLS and ULS)
- Horizontal forces to be resisted (SLS and ULS)
- Rotation capacity required
- Translation capacity required (both reversible and irreversible). In the case of in-situ viaducts, the amount of pre-setting required for the bearings should be clearly indicated.

Calculations for movements of bearings shall take into account the variability of materials and conditions that the structure is expected to encounter during its design life.

In the above ULS and SLS mean Ultimate Limit State and Serviceability Limit State respectively as defined by IRS Concrete Bridge Code-1997.

Design of the bearings, derailment loads requirements specified in IRS Bridge Rules shall be taken into consideration. The corresponding viaduct rotation under derailment loads shall be controlled to minimise damage to the viaduct elements.

In the design of the bearings to resist lateral loads, friction between the bearing and mortar shall be ignored.

Mortar bedding composing of sand and either cement, polyester resin or epoxy resin shall have a crushing strength of at least twice the average contact stress. In the choice of bedding due consideration shall be given to the future removal and replacement of the bearing without damage to bedding or to the structural elements bonded to it.

Shear studs or bolts shall be provided to secure the bearing top and bottom plates to the structure. The shear studs or bolts shall be designed in accordance with international practice.

The fixing method to be adopted shall be such that it is convenient and possible to replace the bearings at some future date.

The designer shall ensure that the bearings can be produced to satisfy the design requirements; and that the space allowed for in the overall design is sufficient to accommodate the bearings and enable them to be inspected, maintained and replaced when required.

D7.5 Highway Clearances

The vertical and horizontal highway clearances required to structures shall generally be in accordance with the requirements described below.

D7.5.1 Vertical Clearances

The minimum clearance between the elevated structures and highways, railways, utility lines and other structures and property should be greater by a minimum of 250 mm on those prescribed by the agencies involved. The minimum vertical clearance below the bottom of the structure for any highway/road passing below will be 5.5 metres as prevailing presently. In case of minor roads/streets a lower clearance may be adopted with specific approval of the agency owning and/or maintaining the road/street.

D7.5.2 Horizontal Clearances

The clear span over the roads passing below the viaduct/bridge shall be determined after evaluation of present and future needs.

Protection shall be necessary for piers against accidental impact from road vehicles on a case by case basis. IRC-6-2000 shall be applied.

For supports located in the median or adjoining major roads where heavy goods vehicles pass at high speed and where adequate clearances are not available, the foundations and piers shall be designed for an impact force of 100t at a height of 1.2 m above road level in the direction of traffic. Higher permissible stresses shall be considered. The approach to the pier shall also be protected by non-mountable kerb and sand filling.

Where clearances are available and a suitably designed safety barrier can be provided, the pier shall not be checked for 100t impact force. The protection afforded should be such that when a car of 1.5t weight strikes the barrier at 110 kph and at an angle of 20^{o}, the wheels of the car will only just reach the pier. The clearance between the pier and safety barrier shall be 0.6 m or more, and the safety barrier shall be a guardrail or crash barrier, mounted on posts to form a free standing rail barrier.

D7.6 Viaduct Deck Furniture, Drainage and Waterproofing

Viaduct deck furniture, drainage and waterproofing system shall be designed for all effects and requirements of the railway as per IRS/IRC Codes.

Cast-in drains shall be used, provided with rodding eyes at every bend. Runoff on viaduct structures and bridges shall be collected through surface drains that shall lead to down drains at the support columns. The down drains shall be connected to a drainage system which shall consist of collection header pipe and manholes which shall discharge to the nearest suitable drainage system. Silt removal shall be provided where necessary.

D7.7 System wide Requirements

D7.7.1 Systemwide requirements must be considered in the development of the structural design. Such consideration shall include:

- The incorporation of a stray current corrosion control system
- The incorporation of an adequate water drainage system
- The necessary design of reinforcement in plinth and deck so as to avoid interference with and attenuation of the signalling circuits
- Special care taken with the location of gullies in points and crossing areas.
- Provision for future pre-stressing of cable/strands as per IRS code shall be made for all pre-stressed concrete members (External pre-stressing) as indicated in the conceptual drawings.

D7.7.2 Systemwide details are liable to changes as the requirements of various contracts become known and their designs are developed. The DDC shall be responsible for incorporating all Systemwide requirements as they become available.

D7.7.3 All details provided to meet Systemwide requirements shall be subject to the acceptance by the Employer's Representative.