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ABBRIVIATIONS

ADT	-	Average Daily Traffic
BBD	-	Benkelman Beam Deflection
BM	-	Bench Mark
BOQ	-	Bill of Quantities
CBR	-	California Bearing Ratio
DCP	-	Dynamic Cone Penetrometer
DPR	-	Detailed Project Report
EIA	-	Environmental Impact Assessment
EIRR	-	Economic Internal Rate of Return
GDP	-	Gross domestic product
GPS	-	Global Positioning system
GTS	-	Geodetic Triangulation Survey
HDM	-	Highway Design and Maintenance
HDMQ	-	Highway Design & Maintenance Model with Congestion Analysis Capabilities.
HFL	-	High Flood Level
ICB	-	International Competitive Bidding
IDA	-	International Development Agency
IRC	-	Indian Road Congress
LA	-	Land Acquisition
LIDAR	-	Light Detection and Ranging
LCB	-	Local Competitive Bidding
MOEF	-	Ministry of Environment and Forests
M/O RT & H	-	Ministry of Road Transport and Highways
MSA	-	Million Standard Axles
NHAI	-	National Highway Authority of India
NPT	-	Net Present Value
PCU	-	Passenger Car Unit
PESS	-	Preliminary Environmental Screening Study
PIU	-	Project Implementation Unit
PPR	-	Preliminary Project Report
PQ	-	Pre-Qualification
RAP	-	Resettlement Action Plan

RCC	-	Reinforced Cement Concrete
ROB	-	Road Over Bridge
RUB	-	Road under Bridge
SIA	-	Social Impact Assessment
TOR	-	Terms of Reference
VDF	-	Vehicle Damage Factor
WB	-	World Bank

1.0DESIGN STANDARDS

2.1 General

This chapter addresses important geometric design aspects: geometric design standards for the project corridor and detailing of highway design elements.

Geometric Design Standards: Geometric Standards form the basis of any design in a particular project. The formulation of these design standards is done with the objective to set standards/guidelines for designs, to avoid any inconsistency in design from one section to the other, and to provide a desired level of service and safety. The Terms of Reference for this project not only list a brief with regard to design requirement, but also specify the codes on the basis of which designs are to be carried out.

Design Standards given in relevant IRC codes, guidelines and special publications, and MORT&H circulars as applicable to the National Highways have been followed.

Highway Design Elements: With improvement proposals being finalized, and categorization of elements for design standards complete, the various highway design elements have been detailed.

2.2 Design Standards and Methodology

Codes and Guidelines

The Highway design using the Indian Road Congress “IRC:38-1988” Guidelines for the Design of radius of horizontal curve and “IRC:SP:23 & IRC:SP:73-2007” Guidelines for the Design of vertical curves have been followed.

The pavement has been designed using the Indian Road Congress “IRC:37-2012” Guidelines for the Design of Flexible Pavements. As this method has been developed in India to suit local conditions and the traffic composition, it is considered to be the most appropriate.

Geometric Design Standards

The summary of geometric design standards set for the project have been elaborated in the table below for quick reference (Table -2.1).

Table 2.1: Adopted Geometric Design Standards for the Project Corridor

S. No.	Description	unit	Proposed Standards
			Mountainous
1	**Design speed**		
	Ruling	km/hr	60
	Minimum	km/hr	40
2	**Right of Way (RoW)**	m	12 to 18

S. No.	Description	unit	Proposed Standards	
			Mountainous	
3	**Cross sectional elements**			
(a)	**Carriage way width**			
	Four lane	m	7+7	
(b)	**Shoulder width**	m	Hill Side	Valley Side
			1.9	1.9
(c)	Drain	m	0.6	-
(d)	Parapet	m	-	0.6
(e)	**Cross Slope**			
	Bituminous surface	%	2.5	
	Granular surface	%	3.5	
(f)	**Extra Widening of pavement at curves**		As per IRC: 38 -1988	
4	**Horizontal curve**			
(a)	Radius			
	Ruling Minimum	m	150	
	Absolute Minimum	m	75	
(b)	Superelevation (max)	%	7	
5	**Vertical curve**			
(a)	Length (min)			
	Ruling Minimum	m	30	
	Absolute Minimum	m	20	
6	**Maximum grade change not requiring vertical curve**	%	1.0% – 1.5%	
7	**Rate of change of superelevation**	m	1 in 60	
8	**Intersections**			
i)	*Minimum length of acceleration lane*	m	60m	
ii)	*Minimum length of deceleration lane*	m	60m	
iii)	*Minimum radius for left turn*	m	20m	
iv)	*Minimum radius for right turn*	m	14m	
v)	*Width of turning lane (inner radius of 30 m)*	m	3.5m	
vi)	*Rate of taper (min)*	m	1 in 15	
9	**Bus-shelters**			
i)	*Min. length of busbay*	m	15 m	
ii)	*Maximum length of pedestrian guard rail on either side of the*	m	22 x 2 m	

S. No.	Description	unit	Proposed Standards
			Mountainous
	busbay		
10	**Truck Laybye**		
i)	*Min length of laybye*	m	100m
ii)	*Min parking length for each vehicle*	m	15m
iii)	*Min parking width for each vehicle*	m	2.75m
iv)	*Min. width of raised separator between laybye and carriageway*	m	1m
v)	*Rate of taper (min)*	m	1 in 10
11	**Safety barriers**		
i)	*Bridge approaches and high embankments*	m	3m and above
12	**Clearance for Utility Lines**		
A)	Horizontal		As per IRC 32-1969
i)	*Street lighting poles*	m	1.5m min from edge of carriageway
ii)	*Overhead power and telecommunication lines*	m	10m min. from edge of roadway
B)	Vertical		As per IRC 32-1969
i)	*Ordinary wires/lines carrying voltage upto and including 110 volts and telecommunication lines*	m	5.5m minimum.
ii)	*Electric power lines carrying voltage upto and including 650 volts*	m	6.0m minimum.
iii)	*Electric power lines carrying voltage exceeding 650 volts*	m	6.5m minimum.

Terrain Classification

Terrain Classification: The design speed is the guiding criteria for correlating features such as sight distance, curvature and super elevation upon which the safe operation of the vehicle depends. The design speed recommended for different terrain classification system for the project highway is as follows:

Table 2.2 Terrain Classifications

S.No	Terrain Classification	Percentage cross slope of the country	Design Speed	
			Rulling	Minimum
1	Plain	0 – 10	100	80

S.No	Terrain Classification	Percentage cross slope of the country	Design Speed	
			Rulling	Minimum
2	Rolling	> 10 – 25	80	65
3	Mountainous	> 25 – 60	50	40
4	Steep	> 60	40	30

2.3 Design Standards: Bridges

General

A broad design philosophy is drawn up giving due considerations to the observations made on the existing structures with regards to their general performance, span arrangements, formation levels, visual observations of river bed material etc.

Subsequent articles deal with various considerations for design of bridges comprising materials, loads and load combinations, exposure condition, reference codes and standards, cover to reinforcement, design methodology, etc. This will be suitably revised/ improved upon wherever required depending upon the actual findings at the time of carrying out subsequent works.

Proposal of Structures

In hilly region it is preferable that number of foundations shall minimum. This will necessitate the construction of large span bridges at most of the locations in hilly areas. Aesthetics of bridges in hilly terrain plays a very important role and therefore all efforts shall be made to match the structure with the environment.

It is not always possible to keep the bridges on the straight alignment in hilly terrains. This will necessitate providing of bridges on horizontal and vertical curves. Horizontally curved bridges will be most suitable for sharp turns and will help in reduction of hill cutting for the approaches.

Following type of super-structures will be most suitable for large span bridges-

- Structural steel girders/trusses
- Large span arch bridges
- Reinforced concrete pre-cast bridges
- Pre-cast Post tensioned concrete bridges

It may be a better solution to provide structural steel girders/truss type super-structure over deep gorges. Launching of truss or cantilever truss may be a better solution. Moreover since the project road is in heavy seismic zone, therefore all efforts shall be made to reduce the overall weight of the super-structure. Structural steel will be an ideal solution to reduce the overall weight of the super-structure for large span bridges over deep gorges.

Long bridges with large span can be constructed as balanced cantilever using cast-in-situ pre-stressed box girders. Props are not required for the construction of such type of bridges.

Piers shall be avoided in the mid-stream where velocity of water is more than 5.0m/second. It is generally seen that it is very difficult to construct sub-structure in such locations and there are possibility of bridge being washed away. Thus all efforts shall be made to provide large spans for the mid-stream in order to avoid any pier.

Circular/cellular circular/wall type piers shall be used after considering the aesthetics and economy. Solid wall type abutments/counter fort type abutments based on the height shall be selected. Counter fort type abutments are generally provided if height of the abutments is more than 10.0 meters.

Formation Width of New Bridges and Culverts

The formation width of structure has been proposed as per MORT&H Circular No. RW/NH/33044/2/88-S&R(B) dated 21st October 2009. The width of bridge on Four lane National Highway without and with footpath are as under –

Description	Bridge without footpath (m)	Bridge with footpath (m)
Carriageway	11.5	8.5
Kerb Shyness	-	1.0 (2x0.5)
Footpath	-	1.5 (1x1.5)
Safety Kerbs	-	-
Crash Barrier	1.0 (2x0.5)	1.0 (2x0.0.5)
Railing	-	0.5 (1 x 0.50)
Overall Width	12.5	12.5

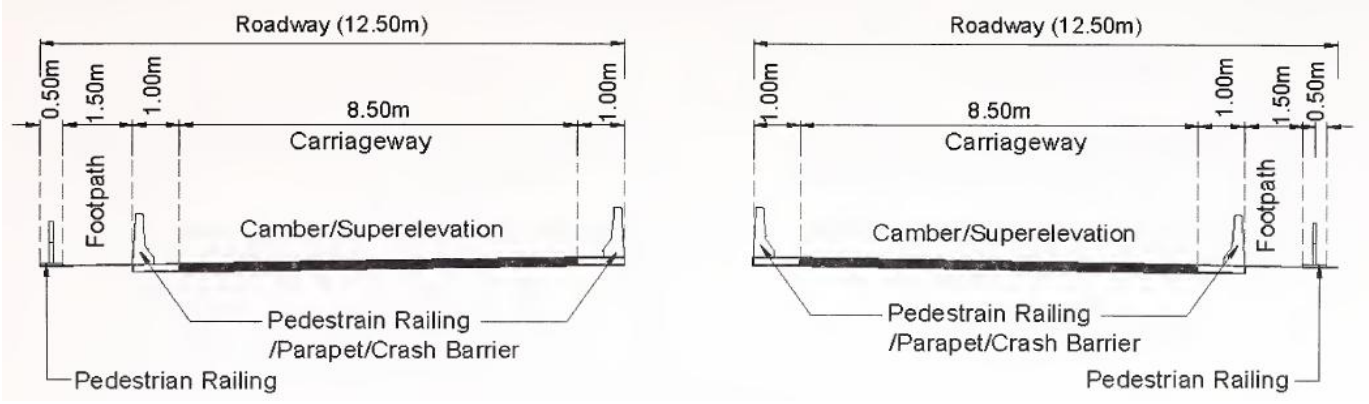

Fig. 7.3.3: Cross Section of Bridge at Deck Level – with Footpath 4-Lane Divided Highway

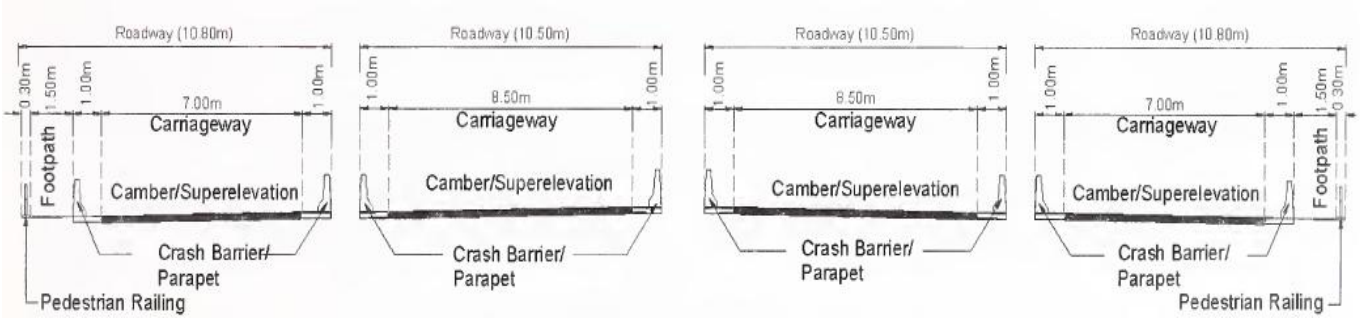

Fig. 7.3.4: Cross Section of Bridge at Deck Level – with Road Bridges and Footpath

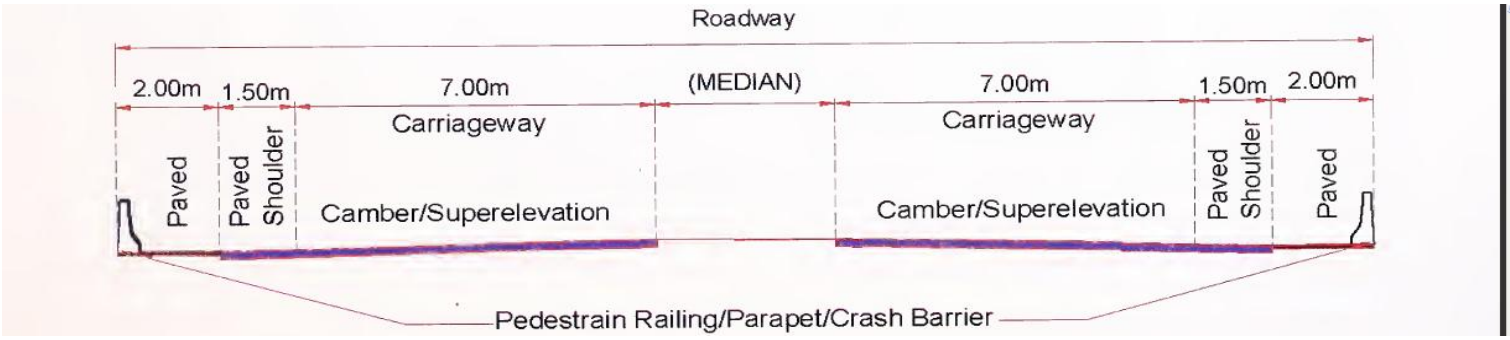

Fig. 7.3.2: Cross Section of Slab/Box Culvert at Road Level 4-Lane Divided Highway

Design Standard Consideration

A) Materials

Concrete Grade

Grade of concrete in various elements will be as under for moderate conditions of exposure:

- PSC Superstructure M-40
- RCC Superstructure M-35
- RCC Sub structure M-30/35
- RCC Solid slab M-30
- Composite Deck Slab M-35
- Bored Cast in Situ pile M-35
- Crash Barrier M-40
- RCC Retaining wall M-25
- PCC course M-15

Reinforcement Steel

High yield strength deformed bar shall be of grade Fe-500 conforming to IS: 1786

Structural Steel

High Strength Structural Steel shall be conforming to IS 2062 - 2011.

B) Pre-stressing System

a)	System	: 19T13 multipull strand system of "Freyssinet" or "ISMALCCL" or equivalent
b)	Cables	: 19T13 to 12T13 cables with strands of 12.7mm nominal dia.
c)	High Tensile Steel	:
	- Strand	: Nominal 12.7mm dia. 7 ply Uncoated Stress relieved low relaxation strands conforming to IS: 14268
	- Area	: 98.7 sq.mm per strand (nominal cross sectional area)
	- Ultimate load	: 183.71 KN per strand
	- Modulus of Elasticity	: 1.95x105MPa
d)	Sheathing Duct	: 100mm OD corrugated HDPE sheathing for 19T13 and 12T13 cables.
e)	Friction Coefficient (k)	: 0.17/radian, Table 5, IRC 18:2000
f)	Wobble Coefficient	: 0.002/m, Table5, IRC 18:2000
g)	Anchorage Slip	: 6mm average
h)	Loss of force due to relaxation after 1000 hr	: 3.8% at 0.765 UTS

C) Structural Steel

Composite construction consisting of structural steel girders with cast-in-situ deck slab may be proposed over deep valleys by keeping in view the seismic zone of the project roads. Superstructure weight shall be substantially reduced by using structural steel girders. Structural steel shall conform to IS: 2062-2011.

D) Bearings

Tar paper bearings will be proposed under simple supported RCC solid slab bridge. Reinforced elastomeric bearings will be proposed under RCC T-beam and slab type superstructure. The design of Elastomeric bearings will be as per the recommendation of IRC: 83 (Part II) and will conform to Cl. 2005 of MoRT&H Specifications for Road & Bridge Works (5th Revision).

POT-PTFE bearings (Fixed/ Guided/ Free) will be proposed under Steel Concrete Composite Superstructures. These bearings will be designed and tested as per IRC: 83 (Part III) and conforming to Cl. 2006 of MoRT&H Specifications for Road & Bridge Works (5th Revision).

E) Expansion Joints

The following types of expansion joints are proposed:

Filler type expansion joints are proposed for minor bridges with solid slab superstructures having span lengths not exceeding 10 meters. This type of joint will conform to Cl. 2605 of MOST's Specifications for Road & Bridge Works (5th Revision).

Single Strip seal expansion joints shall be proposed for superstructures having movements up 80mm. (± 40mm).The strip seal joints will conform to Cl. 2607 of MOST's Specification for Road and ~Bridges works (5th Revision).

Concrete Clear Covers:

For all reinforcement	-	As per Cl. 304.3 of IRC: 21-2000
For other covers and inter duct spacing	-	As per Cl 16 of IRC: 18-2000

F) Loads and Load Combinations

a. Dead Loads

Following unit weights will be assumed in the design as per IRC Codes.

- Pre-stressed Concrete - 2.5 t/cu.m
- Reinforced Concrete - 2.5 t/cu.m
- Plain Cement Concrete - 2.5 t/cu.m
- Structural steel - 7.85 t/cu.m
- Dry Density of Soil - 1.8 t/cu.m
- Saturated Density of Soil - 2.07 t/cu.m

b. Superimposed Dead Loads

- Wearing Coat : 40mm thick Bituminous concrete wearing course with 25mm thick mastic asphalt for major bridge,
  : 40mm thick bituminous concrete wearing course for minor bridge,
  : considering allowances for future overlay of 25mm for design purpose.
- Crash barriers : For design purpose 0.8t/m per side is considered.

c. Live Loads

- Three lane of IRC Class A.
- One lane of IRC Class 70R (wheeled/ tracked)
- One lane of 70R & one lane Class A
- Whichever produces worst effects?

For design of 2-lane Bridge the combination of above live load will be as per IRC: 6-2014.

Impact factor will be as IRC: 6-2014 for the relevant load combinations.

d. Longitudinal Forces

The following effects will be considered for calculating the longitudinal forces in the design- Braking forces as per the provision of IRC: 6:2014.

Frictional resistance offered to the movement of free bearings due to change of temperature.

Distribution of longitudinal forces due to horizontal deformation of bearings/frictional resistance shall be carried out as per IRC: 6:2014 by assuming stiff supports.

e. Centrifugal Forces

Bridges on a horizontal curve shall be designed for centrifugal forces based on the following equation-

C = W*V2/127R,

Where C = Centrifugal force acting normal to the traffic.

W = Carriageway Live Load

V = Design speed of the Vehicles using the bridge in km per hour.

R = Radius of curvature in metres.

The centrifugal force shall be considered as per IRC 6-2014.

f. Water Current Forces

The effect of water current forces shall be calculated in accordance with IRC: 6-2014 on sub structure and foundations. High flood level and Velocity shall be calculated based on the details received from relevant Government departments or Local inquiries.

g. Impact Forces

All the sub- structure and foundations in the river shall be designed for the impact due to striking of rolling boulders on the sub-structure in mountainous terrain. The magnitude of force shall be decided based on field studies and in consultation with client.

h. Earth Pressure Forces

Earth pressure forces will be calculated as per the provisions of IRC: 6-2014 assuming the following soil properties:

Type of soil assumed

For backfilling	:	As per Appendix 6 of IRC:78-2014 with dry density of 1.8 t/cu.m and saturated density of 2.07 t/cu.m

Angle of Internal Friction	:	$\phi = 30°$
Angle of Wall Friction	:	$\delta = 20°$
Coefficient of Friction `μ' at base	:	tan (2/3 ϕ), while ϕ is the Angle of internal friction of substrata Immediately under the foundations.

2 Live load surcharge will be considered as per the provisions of IRC:78-2014 i.e. equivalent of 1.2m height of fill.

i. Wind Effect

Structures will be designed for wind effects as stipulated as per IRC: 6-2014.

j. Seismic Effect

Suitable consideration should be made in detailed design as per provision of IRC: 6-2014.

The project road falls under seismic zone (). Horizontal seismic force shall be calculated using the following formula-

Feq = Ah X (Dead Load + Appropriate Live Load)

Where, Ah = Horizontal seismic co-efficient = (Z/2) X (Sa/g)/(R/I)

Z = Zone factor

I = Important factor and is taken as 1.5 for important Bridges.

R = Response reduction factor and is equal to 2.5

Sa/g = Average response acceleration coefficient depending upon fundamental period of vibration T

T = Fundamental period of Bridge in seconds in horizontal vibrations.

The vertical seismic coefficient shall be considered in the case of structures built in seismic zone (). The vertical seismic coefficient shall be considered as half of the horizontal seismic force. Both horizontal and vertical seismic forces shall be assumed to act simultaneously for the design of bridge components.

k. Temperature Range

The bridge structure/components i.e. bearings and expansion joints, will be designed for a temperature variation of considering extreme climate as per IRC 6-2014 .

The superstructures will also be designed for effects of distribution of temperature across the deck depth as applicable.

l. Differential Settlement Effects

Differential Settlement effects for continuous superstructure units will be appropriately assessed for each structure. However in any case of differential settlement shall be accounted for in the design as per IS 1904-1986.

m. Differential Shrinkage Effects

A minimum reinforcement of 0.2% of cross sectional area in the longitudinal direction of the cast-in-situ slab shall be provided to cater for differential shrinkage stresses in superstructures with in-situ slab over pre-cast girders as per IRC: 22-2008.

However, effects due to different shrinkage and/or different creep shall be duly accounted for in the design.

n. Buoyancy

100% buoyancy shall be considered while checking stability of foundations irrespective of their resting on soil/weathered rock/or hard rock. However, the maximum base pressures will also be checked under an additional condition with 50% buoyancy in cases where foundations are embedded into hard rock. Pore pressure uplift limited to 15% shall be considered while checking stresses of the substructure elements.

In the design of abutment, the effects of buoyancy shall be considered assuming the fill behind abutment has been removed by scour.

o. Load Combination

All members will be designed to sustain safely the MORTH critical combination of various loads and forces that can coexist. Various load combinations as relevant with increase in permissible stresses considered in the design shall be as per IRC: 6-2014 and IRC: 78-2014.

In addition, the stability of bridge supporting resting on neoprene/POT–PTFE bearings will be checked under one span dislodged condition. The load case will be checked with seismic/wind load combinations.

p. Exposure Condition

Moderate exposure conditions will be considered while designing various components of the bridge.

Design Criteria

The main design criteria will be to evolve design of a safe structure having good durability conforming to the various technical specifications and sound engineering practices.

The design of structural components will conform to the criteria laid down in the latest edition of the following codes of practice, standard specifications, guideline/circular of MoRT&H, IRC and BIS published up to the date of commencement of DPR contract.

Various codes of practices which shall be used for the design of culverts and bridges are mentioned below:

IRC STANDARDS

1) IRC:5-1998 : Standard Specifications and Code of Practice for Road Bridges, Section I- General Features of Design (Seventh Revision)
2) IRC:6-2014 : Standard Specifications and Code of Practice for Road Bridges, Section II- Loads and Stresses (Revised Edition)
3) IRC:7-1971 : Recommended Practice for Numbering Bridges and Culverts (First Revision)
4) IRC:18-2000: Design Criteria for Prestressed Concrete Road bridges (Post - Tensioned Concrete) (Third Revision)
5) IRC:21-2000: Standard Specifications and Code of Practice for Road Bridges Section III – Cement Concrete (Plain and Reinforced)(Third Revision)
6) IRC:22-2008: Standard Specifications and Code of Practice for Road Bridges Section VI – Composite Construction (Limit States Design)(Second Revision)
7) IRC:24-2010: Standard Specifications and Code of Practice for Road Bridges, Steel Road Bridges (Limit State Method) Third Revision
8) IRC:40-2002: Standard Specifications and Code of Practice for Road Bridges Section V – Steel Road Bridges (Second Revision)
9) IRC: 45-1972: Recommendations for Estimating the Resistance of Soil Below the maximum scour Level in the Design of Well Foundations of Bridges.
10) IRC:54-1974: Lateral and Vertical Clearances at Underpasses for Vehicular Traffic
11) IRC:78-2014 : Standard Specifications and Code of Practice for Road Bridges Section VII-Foundation and Substructure (Revised Edition)
12) IRC:83-1999 : Standard Specifications and Code of Practice for Road Bridges Section IX – Bearings, Part I: Metallic Bearings (First Revision)
13) IRC:83-1987 : Standard Specifications and Code of Practice for Road Bridges Section IX – Bearings, Part II: Elastomeric Bearings
14) IRC:83-2002 : Standard Specifications and Code of Practice for Road Bridges Section IX – Bearings, Part III: POT,POT-CUM-PTFE,PIN and Metallic Guide Bearings
15) IRC:89-1997: Guidelines for Design and Construction of River Training & Control Works for Road Bridges (First Revision)
16) IRC:112-2011: Code of Practice for Concrete Road Bridges

IRC-SP (SPECIAL PUBLICATION)

1) IRC:SP: 13-2004 : Guidelines for the Design of Small Bridges and Culverts (First Revision)
2) IRC: SP: 18-1978: Manual for Highway Bridge Maintenance Inspection.
3) IRC: SP: 33-1989: Guidelines on Supplemental Measures for Design, Detailing & Durability of Important Bridge Structures.
4) IRC: SP: 35-1990: Guidelines for Inspection and Maintenance of Bridges.
5) IRC:SP:48-1998 : Hill Road Manual
6) IRC:SP: 40-1993: Guidelines on Techniques for Strengthening and Rehabilitation of Bridges
7) IRC:SP: 47-1998 : Guidelines on Quality Systems for Road Bridges (Plain, Reinforced, Prestressed and Composite Concrete)
8) IRC: SP: 51-1999: -Guidelines for Load Testing of Bridges.
9) IRC: SP:73-2007 : Manual of Standards and Specifications for 2-lanning of State Highways on BOT Basis

British standards, in absence of Indian standards

1) BS 5400-PartIX (For design of POT/POT-PTFE Bearings)

MORT&H Specifications

1) The specifications for road and bridges works of Ministry of Road Transport & Highways (latest editions) published by Indian Road congress shall be used for materials to be used for construction of bridge.
2) MORT&H standards plans for single, double and triple cell box culverts with and without earth cushion.
3) Standard Drawings for Road Bridges RCC Solid Slab Superstructure (22.5 skew) for spans 4m to 10m

INDIAN STANDARDS

1) IS:456-2000: Plain and Reinforced Concrete (Fourth Revision)
2) IS:2502-1963: Code of practice for bending and fixing of bars for concrete reinforcement
3) IS: 2062-2011 : Hot Rolled Medium & High Tensile Structural Steel
4) 1904-1986: Code of Practice for Design and Construction of Foundation in Soil: General Requirement .

3.0 DETAILED DESIGN

Bridge Proposal

S.No.	Chainage (m)	Type	SPAN
1	4+020	Truss	1 x 80m
2	14+850	Truss	1 x 80m
3	23+620	Truss	1 x 80m
4	32+400	PSC	13x30m
5	35+600	RCC Girder	1 x 24m