राष्ट्रीय राजमार्ग एवं अवसंरचना विकास निगम लिमिटेड

NATIONAL HIGHWAYS & INFRASTRUCTURE DEVELOPMENT CORPORATION LTD.

FINAL DETAILED PROJECT REPORT
SUDHMAHADEV - DRANGA TUNNEL

CONSULTANCY SERVICES FOR PREPERATION OF DETAILED PROJECT REPORT AND PROVIDING PRE-CONSTRUCTION ACTIVITIES IN RESPECT OF THE FOLLOWING STRETCH ON NH-244 (OLD NH-1B) IN THE STATE OF JAMMU AND KASHMIR.

(1) SUDHMAHADEV- DRANGA TUNNEL OF APPROX. LENGTH 4.5 KM AND ITS APPROACH ROAD ON CHENANI - SUDHMAHADEV-GOHA ROAD PORTION.

(2) VAILOO TUNNEL OF APPROX. LENGTH 10.0 KM UNDER SINTHAN PASS AND ITS APPROACH ROAD ON GOHA-KHELLANI- KHANABAL ROAD PORTION.

(3) ROAD PORTION FROM 82.675 TO 82.925 AT KM 83 ON BATOTE-KISHTWAR ROAD SECTION OF NH-244.

(4) EXTENDED ROAD SECTION FROM GOHA TO KHELLANI OF 30 KM LENGTH

PACKAGE-1 – KM 0+000 TO KM 6+405
PACKAGE-2 – KM 6+405 TO KM 12+850
VOLUME - II - DESIGN BASIS REPORT (STRUCTURES)

FEBRUARY 2020

IN ASSOCIATION WITH

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1. INTRODUCTION

1.1 Project Background

The Ministry of Road Transport and Highways (MORT&H) is poised to develop all remote and strategically important roads in hilly terrains to perennial routes. In continuation to these developments National Highways and Infrastructure Development Corporation Limited (NHIDCL) has been appointed by MORT&H, to implement these projects.

NHIDCL has been assigned the work of Consultancy Services for Preparation of Detailed Project Report and providing Pre-Construction activities for the construction of a Road Tunnel and its approaches enabling all weather connectivity along the stretches on NH-244 in the State of Jammu and Kashmir. NHIDCL has entrusted TPF Getinsa Eurostudios SL in association with Rodic Consultants Private Limited, to carry out **Consultancy Services for Preparation of Detailed Project Report and providing Pre-Construction activities to Sudhmahadev – Dranga Tunnel and its approach roads on Chenani – Sudhmahadev – Goha road portion of NH-244 (old NH-1B**) in the State of Jammu and Kashmir.

The Index Map showing the stretches of National Highways, described above as a part of project road, is presented in **Fig. 1** (enclosed).

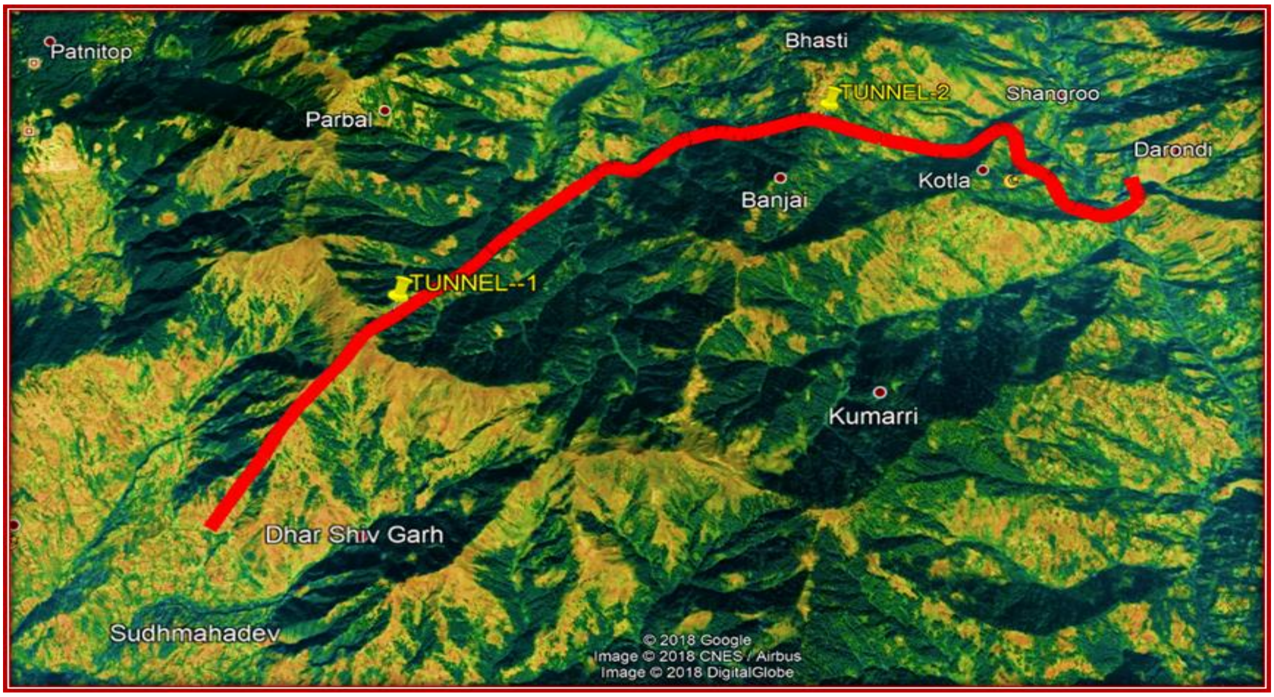


Figure 1: Index Map

1.2 Applicable design codes and documents

The design basis given in these documents follows the requirement based on the Indian codes/standards/specifications or as per applicable manual. In addition, the design basis basically follows the Limit State Design (LSD).

The design basis follows the requirement as set forth in the following design documents and will form the basis for design. Additional standards and specifications required for the design will be given in the relevant sections of these criteria.

1. IRC:112-2019, Standard Specifications and Code of Practices for Concrete Road Bridge
2. IRC:6-2017, Standard Specifications and Code of Practices of Road Bridges, Section-II, Loads and Stresses include amendment
3. IRC:78-2014, Standard Specifications and Code of Practices of Road Bridges, Section-VII, Foundation & Substructures
4. IRC:83-2014(Part-IV), Standard Specifications and Code of Practices of Road Bridges, Section-IX- SPHERICAL AND CYLINDRICAL BEARINGS.
5. IRC:5-2015, Standard Specification and Code of Practice of Road Bridges, Section-I, General Design Features
6. IRC: SP:65-2005, Guidelines for Design and Construction of Segmental Bridges
7. IRC: SP:66-2005, Guidelines for Design of Continuous Bridge
8. IRC: SP:67-2005, Guidelines for use of External and Unbonded Prestressing Tendons in Bridge
9. IRC: SP:69-2011, Guidelines and Specifications for Expansion Joints
10. IRC: SP:114-2018- Guidelines for Seismic Design of Road Bridges
11. IS:14268-1995, Code of practice for Uncoated Stress Relieved Low Relaxation Seven-ply Strand for prestressed concrete-specification
12. IS:1786-2002, Code of practice for High Strength Deformed Steel bars and wires for concrete reinforcement.
13. IS:6403-1981, Code of practice for determination of bearing capacity of shallow

foundations.

14. IS:2911 Part-1(Concrete piles) Sec-2(Bored cast In-situ piles) Code of practice for design and construction of pile foundation
15. IS:8009(Part 1 & 2), Code of practice for calculation of settlements of foundations.
16. IS:816-1969(R1998) Code of practice for use of metal arc welding for general construction in mild steel.
17. IS:2062-2011 hot rolled medium and high tensile structural steel — specification
18. IS:4000-1992(R2003) High strength bolts in steel structures – code of practice.
19. IS:3757-1985(R2003) Specification for high strength structural bolts
20. IS:2629-1985(R2016) Recommended practice for hot-dip galvanizing of iron and steel
21. Joseph E Bowles, "Foundation Analysis and Design".
22. However, in specific case, Equivalent International codes / Equivalent standard documents shall be referred.

MoRTH Specifications

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. DESIGN REQUIREMENTS

2.1 Design Life

The design service life of the bridge shall be 100 years in accordance with Clause 5.8.1 of IRC: 112-2019. The design service life is the period for which the structures are to be used for their intended purpose with anticipated maintenance, but without loss of reliability or structural, operational and aesthetic integrity.

The full-service life is required for the main structural components such as foundations, abutments, piers, bridge girders, pylons, stay cables etc.

2.2 Width of Carriageway

The minimum features in the cross section of the Project shall be as shown in Table 1.

Table 1: Width of carriageway

Bridge Section / Viaducts on Main Alignment		
Cross Sectional Elements:	Elevated Carriageway	1x7.50 = 7.50 m
Main Carriageway	Inspection/Maintenance Path/Footpath	2x1.50=3.00 m
	Median	0.00 m
	Crash Barrier	2x0.50 m = 1.00
	Railing	2 x 0.50 m = 1.00 m
	Sub Total	12.50 m

Bridge Section / Viaducts Near Tunnel		
Cross Sectional Elements:	Elevated Carriageway (Including Kerb Shyness)	1x9.00 = 9.00 m
	Crash Barrier	2x0.50 m = 1.00
	Sub Total	10.00 m

2.3 Design Speed

The design speed of this Project as per Table 2 of IRC:73-2015 shall be as under:

Table 2: Design Speed

Design Speed	Main alignment	100 km/h

2.4 Utility Services of Structures

The following structures shall be designed to carry utility services specified under Table 3.

Table 3: Utility Services

Bridge	Utility service to be carried	Remarks
2-Lane Bridge	Electric cable, OFC Cable and water supply pipeline	Bridge shall be of two lane

3. DESIGN LOAD

3.1 Dead Load(G)

- **Self - Weight**

The characteristic self-weight of structural or non-structural permanent loads on the bridge can be determined based on the specific weights of the materials and of the dimensions of the structures.

The following unit weights of materials are used in accordance with Clause 203 of IRC: 6-2017:

Reinforced concrete	2.5 t/m3
Unreinforced concrete	2.5 t/m3
Pre-stressed concrete	2.5 t/m3
Asphalt concrete	2.2 t/m3
Soil	2.0 t/m3
Steel	7.85t/m3

- **Superimposed Dead Load**

The specific weight for road surfacing on a concrete deck is based on a surfacing with a thickness of 65mm. The following specific weights mentioned below shall be used:

Road surfacing - concrete deck 0.065 x 22 = 2.00 KN/m^2 (Approx.)

The following self-weights of safety barriers on structures mentioned below shall be used:

1	Railing	5 x 2 = 10.00 kN/m
2	Crash barrier	10 x 2 = 20.00 kN/m
3	**Total**	**= 30.00 kN/m**

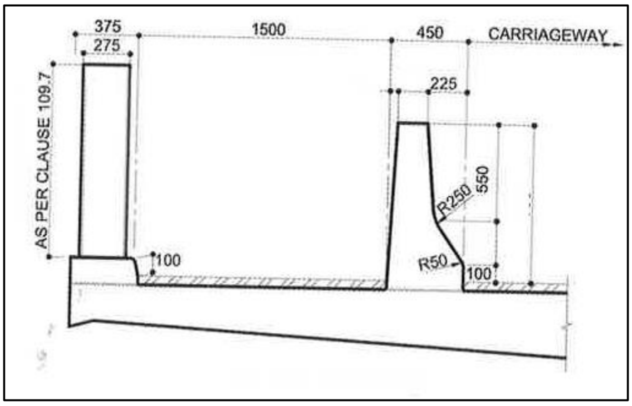


Figure 2: Details of concrete crash barrier and railing

3.2 Pre-stressing force

Pre-stressing force shall be classified as a permanent action caused by controlled forces and/or controlled deformations imposed on a structure.

3.3 Creep and Shrinkage

Creep and shrinkage effects shall be considered in accordance with IRC:112-2019, and it shall be considered as permanent load. The average relative humidity ratio should be taken as 80%.

Creep and shrinkage factors are calculated for individual structural elements with account taken of the member thickness, the age of the concrete when loaded and the nature and timing of the applied loading.

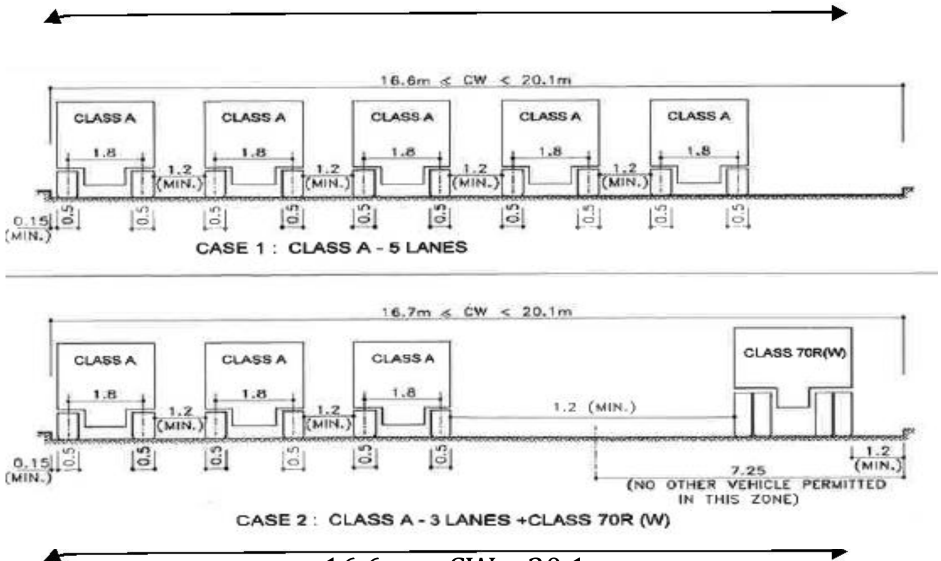
3.4 Live Load(Q)

- **Vehicle Load**

The carriageway live load combination shall be considered in accordance with Clause 204.3 of IRC: 6-2017 as shown in the table below. Since the bridge has 3 lanes in with carriageway width of 11.0m, the carriageway live load combination (3) is to adopt.

Table 4: Live load combination

SI. No.	Carriageway Width (CW)	No. of Lanes for Design Purposes	Load Combination
1)	Less than 5.3	1	One lane of Class A considered to occupy 2.3m. The remaining width of carriageway shall be loaded with 500kg/m2
2)	5.3m and above but less than 9.6m	2	One lane of Class 70R OR two lanes for Class A
3)	9.6m and above but less than 13.1	3	One lane of Class 70R for every two lanes with one lanes of Class A on the remaining lane OR 3 lanes of Class A
4)	13.1m and above but less than 16.6m	4	One lane of Class 70R for every two lanes with one lane of Class A for the remaining lanes, if any, OR one lane of Class A for each lane.
5)	16.6m and above but less than 20.1	5	
6)	20.1m and above but less than 23.6	6	
		16.6 m < CW < 20.1 m	



16.6 m < CW < 20.1 m

Figure 3: Live load combination

The design live load shall consist of two standard wheeled vehicles; Class 70R vehicle (Wheeled) and Class A Train of vehicles.

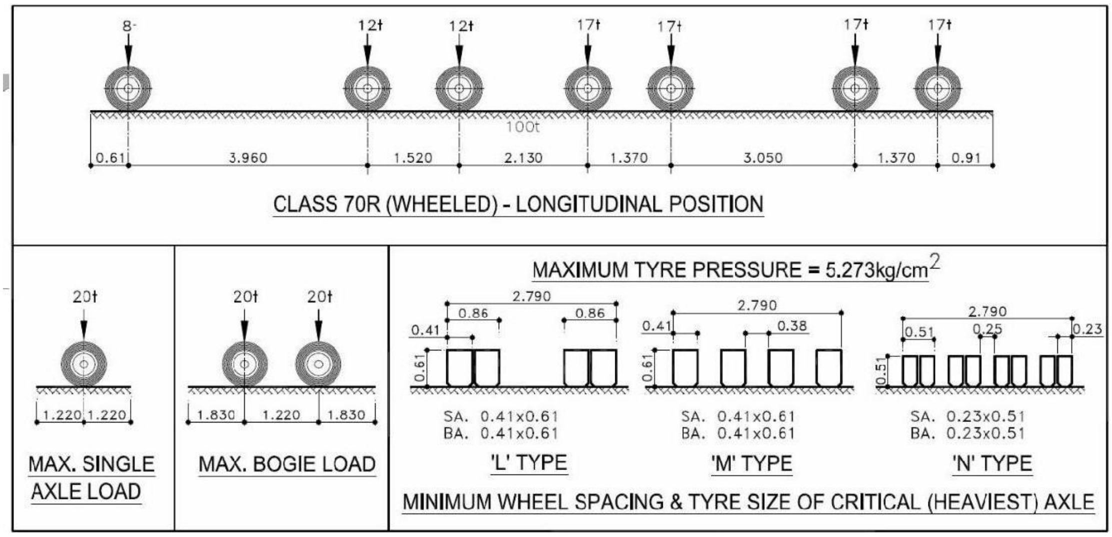


Figure 4: Class 70R vehicle (wheeled)

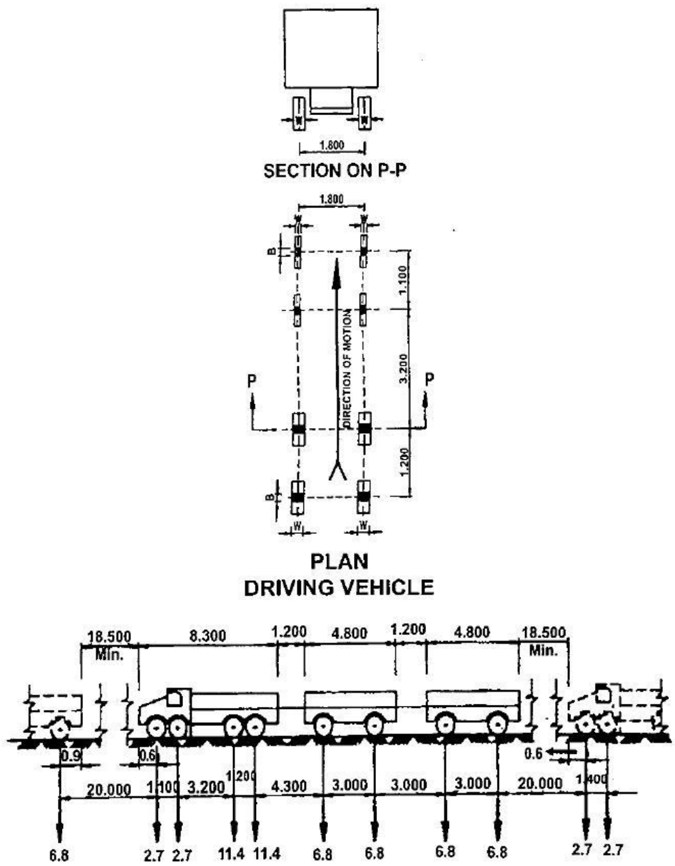


Figure 5: Class A Train of vehicle

The ground contact area of the wheels of Class A shall be as under;

Table 5: Ground contact area of the wheels of Class A

Axle load (tonne)	Ground contact area	
	B (mm)	W (mm)
11.4	250	500
6.5	200	380
2.7	150	200

The minimum clearance, f between outer edge of the wheel and the roadway face of the kerb and the minimum clearance, g, between the outer edges of passing or crossing vehicles on multi-lane bridges shall be as given below:

Table 6: Minimum Clearance

Clear carriageway width	g	f
5.3m(*) to 6.1m(**)	Varying between 0.4m to 1.2m	150 mm for all carriageway width
Above 6.1 m	1.2m	

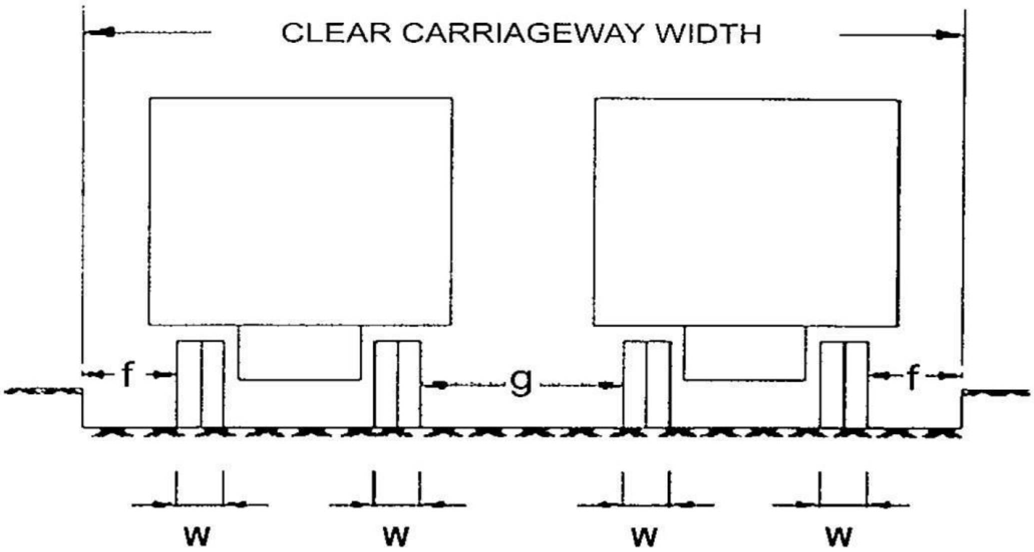


Figure 6: Clear carriageway width

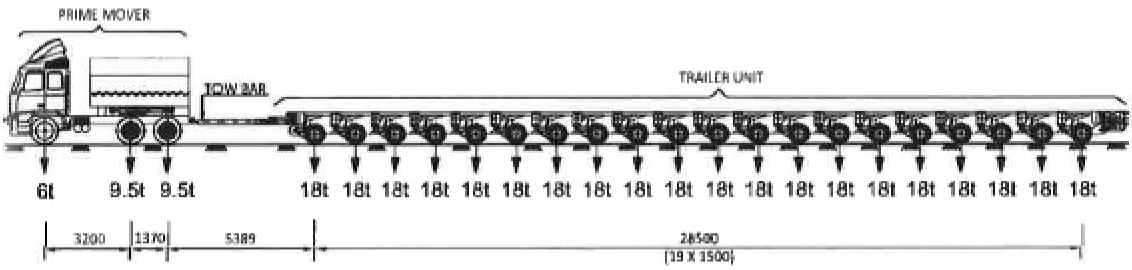


Figure 7: Typical Axle Arrangement of Special Vehicle

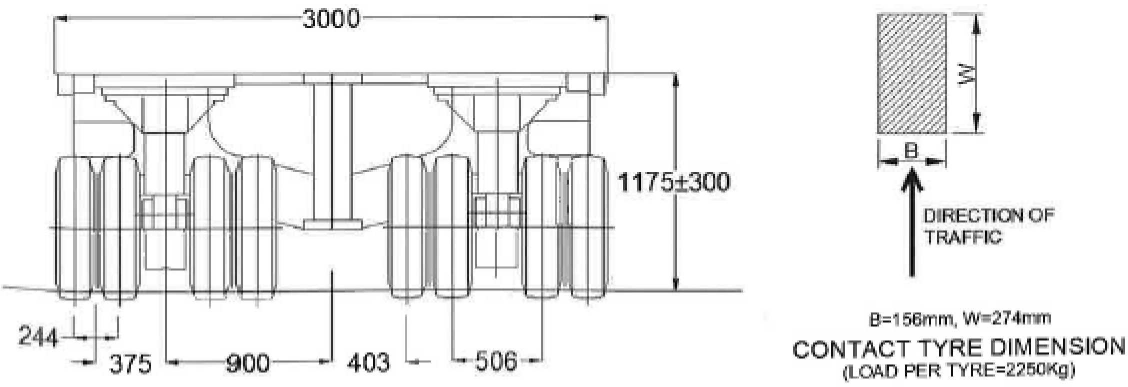


Figure 7A: Transverse Wheel Spacing of Special Vehicle

- **Congestion factor (Fcf)**

Congestion factor will not be taken into consideration as the location is not close to areas such as ports, heavy industries and mines and any other areas where frequent congestion of heavy vehicles may occur.

- **Footway Load**

For all parts of bridge floors accessible only to pedestrians and animals and for all footways the loading shall be 400 kg/m2 as per Clause 206.1 of IRC: 6-2017.

For the design of foot over bridges the loading shall be taken as 500 kg/m2 as per Clause 206.1 of IRC: 6-2017.

For effective spans of over 7.5 m but not exceeding 30 m, the intensity of load shall be determined according to the following equation as per clause 206.3 (b) of IRC:6-2017.:

$$P = P' - \left(\frac{40L - 300}{9}\right)$$

For effective spans of over 30 m, the intensity of load shall be determined according to the following equation as per clause 206.3 of IRC:6-2017:

$$P = \left(P' - 260 + \frac{4800}{L}\right)\left(\frac{16.5 - W}{15}\right)$$

Where,

P1 = 400 kg/m2 or 500 kg/m2 as per Clause 206.1 of IRC: 6-2017

P = the live load in kg/m2

L = the effective span of the main girder, truss or arch in m, and

W = width of the footway in

- **Impact factor (Qim)**

Impact factor shall be considered in accordance with Clause 208 of IRC: 6-2017 and Fig. 3.7 as shown in figure below.

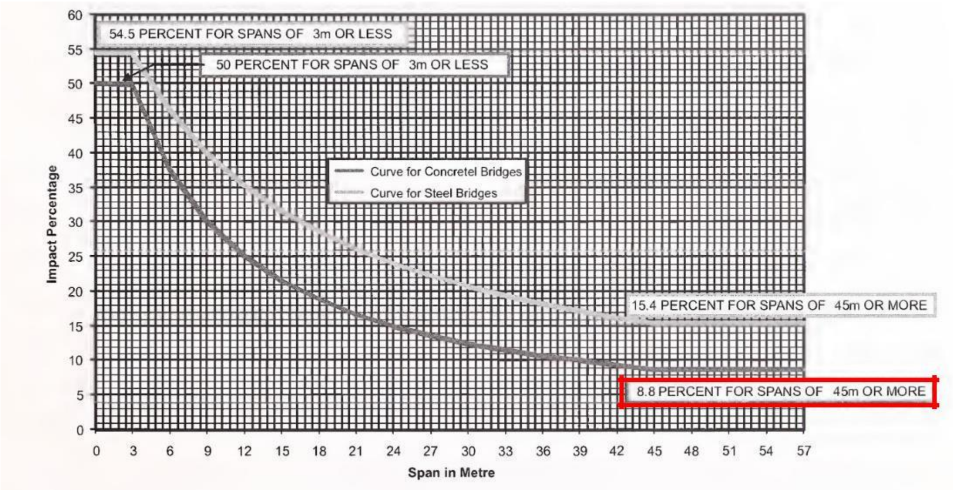


Figure 7: Impact percentage for highway bridges

Impact factors shall not be added to the walkway loading as per Clauses 208.4 of IRC: 6-2017.

- **Reduction in the longitudinal effect**

Reduction in longitudinal effect on bridge having more than two traffic lanes shall be in accordance with Clause 205 of IRC: 6-2017.

Table 7: Reduction in longitudinal effect

Number of lanes	Reduction in longitudinal effect
For two lanes	No reduction
For three lanes	10% reduction
For four lanes	20% reduction
For five or more lanes	20% reduction

- **Braking force (Fb)**

The braking effect on a simply supported span or a continuous unit of spans or on any other type of bridge unit shall be assumed to have the following value as per clause 211.2 of IRC:6-2017.

In the case of a single lane or a two-lane bridge: twenty percent of the first train load plus ten percent of the load of the succeeding trains or part thereof, the train loads in one lane only being considered for this sub-clause. Where the entire first train is not on the full span, the braking force shall be taken as equal to twenty percent of the loads on the span or continuous unit of spans.

In the case of bridges having more than two-lanes: as in (i) above for the first two lanes plus five per cent of the loads on the lanes more than two.

Note: The loads in this Clause shall not be increased on account of impact.

The force due to braking effect shall be assumed to act along a line parallel to the roadway and 1.2 m above it. While transferring the force to the bearings, the change in the vertical reaction at the bearings should be considered.

The distribution of longitudinal horizontal forces among bridge supports is affected by the horizontal deformation of bridges, flexing of the supports and rotation of the foundations.

- **Fatigue load**

Fatigue load is specified on new Clause 204.6 of amendment to IRC:6-2017. The truck defined in the figure below shall be used for the fatigue life assessment of concrete bridge. 50% of the impact factors mentioned in Clause 208 of IRC:6-2017 shall be applied to this fatigue load.

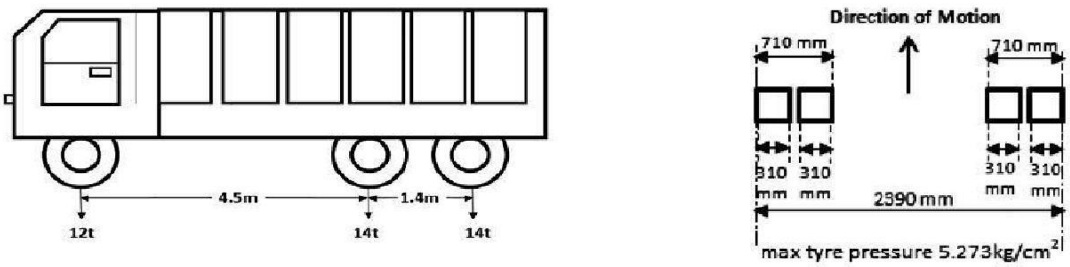


Figure 8: (a) Fatigue Truck (b) Transverse wheel Spacing and Tyre Arrangement

The single passage of the fatigue load along the longitudinal direction of the bridge shall be used. The minimum clearance between outer edge of the wheel of the fatigue vehicle and roadway face of the kerb shall be 150mm. The fatigue check shall be carried out under frequent combination of Serviceability Limit State (SLS), with load factors for fatigue load, taken as equal to 1.0. For design for fatigue limit state, reference shall be made to IRC:112 for Concrete Bridge.

3.5 Wind Load(W)

- **Design wind force on superstructure**

Wind loads shall be taken in accordance with Clause 209 of IRC: 6-2017. The wind speed at the location of bridge shall be based on basic wind speed map as per figure 10 of IRC: 6-2017.

The basic wind speed for the project area is 39 m/s, return period of 100 years. The hourly mean wind speed and wind pressure shall be obtained by multiplying the corresponding wind speed value by the ratio of basic wind speed at the location of bridge to the value corresponding to table 12 of IRC: 6-2017 which is shown hourly mean wind speed and wind pressure for a basic wind speed of 36m/s.

Table 8: Hourly mean wind speed and wind pressure

H (m)	Bridge Situated in			
	Plain Terrain		Terrain with Obstructions	
	V_z (m/s)	P_z (N/m^2)	V_z (m/s)	P_z (N/m^2)
Up to 10 m	27.80	463.70	17.80	190.50
15	29.20	512.50	19.60	230.50
20	30.30	550.60	21.00	265.30
30	31.40	590.20	22.80	312.20
50	33.10	659.20	24.90	373.40
60	33.60	676.30	25.60	392.90
70	34.00	693.60	26.20	412.80
80	34.40	711.20	26.90	433.30
90	34.90	729.00	27.50	454.20
100	35.30	747.00	28.20	475.60

Design wind force on the deck of main bridge shall be as per Clause 209.3 of IRC 6-2014.The transverse wind force F_T can be taken as acting at the centroids of the appropriate area and it can be estimated from:

$$F_T = P_z \times A_1 \times G \times C_D$$

Where,

P_Z: Hourly mean wind pressure in N/m2 A1: Solid area in m2

G: Gust factor (to be decided after wind tunnel test)

C_D: Drag coefficient depending on the geometrical shape of bridge deck (1.3 if b/d (slab width to depth ratio) =32.4/4=8.1≥6)

Longitudinal force on the deck of main bridge FL should be taken as 25% of the transverse wind load as per Clause 290.3.4 of IRC 6-2017.

An upward or downward vertical wind load FV acting at the centroid appropriate areas, for the deck of main bridge can be derived from:

$$FV = P_z \times A_3 \times G \times C_L$$

Where,

P_Z: hourly mean wind pressure in N/m2 at height H A_3: area in plan in m2

C_L: Lift coefficient which shall be taken as 0.75 for normal type of box girders as per Clause 209.3.5

Gust factor (G=2.0 for highway bridges up to a span of 150m)

- **Design wind force on the substructure**

Wind Load on the substructure shall be accounted in accordance with Clause 209.4 of IRC: 6-2017.

3.6 Centrifugal forces (Fcf)

Where a road bridge is situated on a curve, all portions of the structure affected by the centrifugal action of moving vehicles are to be proportioned to carry safely the stress induced by this action in addition to all other stress to which they may be subjected. The centrifugal force shall be determined from the following equation:

$$C = WV^2/127\ R$$

where,

C = Centrifugal force acting normally to the traffic (1) at the point of action of the wheel loads or (2) uniformly distributed over every meter length on which a uniformly distributed load acts, in tonnes.

W = Live load (1) in case of wheel loads, each wheel load being considered as acting over the ground contact length specified in Clause 204 of IRC: 6-2017, in tonnes, and (2) in case of a uniformly distributed live load, in tonnes per linear meter.

V = the design speed of the vehicles using the bridge in km per hour, and

R = the radius of curvature in meters.

The centrifugal force shall be considered to act at a height of 1.2 m above the level of the carriageway. No increase for impact effect shall be made on the stress due to centrifugal action. The overturning effect of the centrifugal force on the structure as a whole shall also be duly considered.

3.7 Construction loads

The construction loads associated with the erection method of the superstructure shall be taken into account. However, each individual case shall be investigated in complete detail. In the detailed design stage, the structures are to be checked for actual construction loads at each construction stage and the actual loads indicated on the relevant drawings.

3.8 Water Currents Load (Fwc)

On pier parallel to the direction of the water current, the intensity of pressure shall be calculated from the following equation as per Clause 210.1 of IRC: 6-2017:

$$P = 52KV^2$$

Where,

P = intensity of pressure due to water current, in kg/m^2

V = the velocity of the current at the point where the pressure intensity is being calculated,

K = a constant having the following values for different shapes of piers (=0.66 for semi-circular ends)

3.9 Temperature (Fte)

The bridge temperature shall be considered in accordance with Clause 215.2 of IRC:6-2017.

- **Uniform Temperature**

Maximum and minimum air shade temperatures shall be obtained from Figs. 15 and 16 of IRC 6-2017. Maximum and minimum air shade temperatures in vicinity of Srinagar are approximately 45.0°C and - 05°C respectively. Therefore, the mean of maximum and minimum air shade temperature is equal to 20 °C.

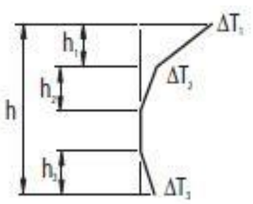
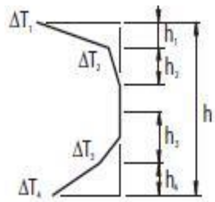
As the bridge location has a difference between maximum and minimum shade temperature greater than 20 °C; the bridge temperature to be assumed when the structure is effectively restrained as per the table shown in Clause 215.2 of IRC-6, is equal to mean of maximum and minimum air shade temperature ± 10° whichever is critical, which corresponds in this case to 30°C and 10°C.

Uniform temperature variation is considered as a long-term loading. The elastic modulus for uniform temperature effects will be taken as 0.5 times the instantaneous elastic modulus according to Clause 6.4.2.5 of IRC: 112-2011.

- **Temperature Difference**

Effect of temperature difference within the superstructure shall be assumed as shown in the Table 9

Table 9: Design temperature differences for concrete box girder (ref. to Fig 17a of IRC-6-2017)

Positive Temperature Differences				Reverse Temperature Differences				
	h1 = 0.3h but ≤0.15m h2 = 0.3h but ≥0.10m but ≤0.25m h3 = 0.3h ≤ 0.15m				h1 = h4 = 0.2h ≤ 0.25m h2 =h3= 0.25h ≤ 0.25m			
Surfacing thickness	1	2	3	Surfacing thickness	1	2	3	
50mm	17.8	4.0	2.1	50mm	-10.6	-0.7	-0.8	-6.6

3.10 Buoyancy (Gb)

For piers and foundation under the influence the water flow, the effects of buoyancy as specified in Clause 213 of IRC: 6-2017 shall be considered.

3.11 Earth Pressure (Fep)

The effect of earth pressure shall be calculated in accordance with Coulomb's theory for earth retaining structures. Soil properties for earth pressure load shall be per the recommendations of geotechnical engineer. The center of pressure exerted by the backfill, when considered dry, is located at an elevation of 0.42 of the height of the wall above the base and 0.33 of height of wall when considered wet as per Clause 214.1 of IRC: 6-2017.

4. ACCIDENTAL LOADS

4.1 Seismic Force (Feq)

Seismic design loads shall be obtained in accordance with Clause 219 of IRC: 6-2017. The seismic acceleration can be calculated by the following equation.

$$(Z/2) \times (I) \times (S_a/g)$$

Where,

Z = Zone factor (=0.24 according to table 16 of IRC: 6-2017)

I = Importance Factor (=1.2 according to table 19 of IRC: 6-2017)

Sa/g = Average response acceleration coefficient for 5 percent damping of load resisting elements depending upon the fundamental period of vibration T

Design response spectrum for seismic analysis is derived by the figure 20 of IRC 6-2017.

Considering the foundation support layer after scour, the values for hard soil condition (Type I) are used for the response acceleration factor. And, 5 percent damping is applied for preparing the response spectrum.

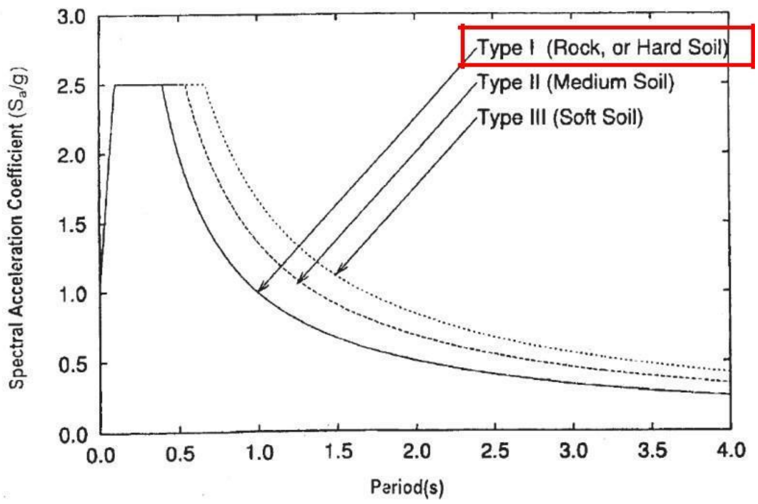


Figure 9: Response spectra

The derivation of the above is based on the following mathematical expression. For hard soil sites, type I soil with N>30

$$\frac{S_a}{g} = \begin{cases} 1 + 15\,T, & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.40 \\ 1.00/T & 0.40 \le T \le 4.00 \end{cases}$$

Ductile detailing is mandatory for piers of bridges located in seismic zones V. The forces on various members obtained from the elastic analysis of bridge structure are to be divided by Response Reduction Factor for the design of pier and bearing. For design of foundation, the seismic loads should be taken as 1.35 times the forces transmitted to it by concrete substructure as per Clause 219.8 of IRC:6-2017, so as to provide sufficient margin to cover the possible higher forces transmitted by substructure arising out of its over strength.

4.2 Response Reduction Factors

Response reduction factors as per Table 20 of IRC 6:2017 shall be as follows;

Table 10: Response Reduction Factors

Bridge Component		'R' With Ductile Detailing	'R' without Ductile Detailing (for Bridges in zone II only)
a) Superstructure of integral / Semi integral bridge /Framed bridges		2.0	1.0
b) Other types of Superstructure, including precast segmental construction		1.0	1.0
Substructure			
(i) Masonry/PCC Piers, Abutments		1.0	1.0
(ii) RCC wall piers and abutments transverse direction (where plastic hinge can not develop)		1.0	1.0
(iii) RCC wall piers and abutments in longitudinal direction (where hinges can develop)		3.0	2.5
(iv) RCC Single Column		3.0	2.5
(v) RCC/PSC Frames	a) Column	4.0	3.0
	b) RCC beam	3.0	2.0
	b) PSC beam	1.0	1.0
(vi) Steel Framed Construction		3.0	2.5
(vii) Steel Cantilever Pier		1.5	1.0
Bearings and Connections (see note v also)		1.0	1.0
Stoppers (Reaction Blocks) Those restraining dislodgement or drifting away of bridge elements. (See Note (vi) also)		1.0	1.0

5. LOAD COMBINATIONS

5.1 Limit States

Load combinations to design bridge elements under various limit state are specified well in IRC: 6-2017. Therefore, this Project give priory to apply IRC:6-2017.

For the design of Bridges Limit State Design (LSD) has been adopted and appropriate load combinations are selected according to the IRC:6-2017. With the identified loading effects, two limit state conditions shall be verified with the partial factor method. A limit state is defined as a state where the bridge structure satisfies given requirements. The limit states applied to the design are:

The Ultimate Limit State (ULS)

The Serviceability Limit State (SLS)

The SLS corresponds to the boundary between acceptable and unacceptable states during normal operation of the bridge. The ULS corresponds to states prior to structural collapse of the entire or parts of the bridge structure.

5.2 The Ultimate Limit State (ULS)

Loads are required to be combined to check the equilibrium and the structural strength under Ultimate Limit State (ULS). The equilibrium of the structure shall be checked against overturning, sliding and uplift. It shall be ensured that the disturbing loads (overturning, sliding and uplifting) shall always be less than the stabilizing or restoring actions. The structural strength under ultimate limit state shall be estimated in order to avoid internal failure or excessive deformation. The equilibrium and the structural strength shall be checked under basic, accidental and seismic combinations of loads.

- **Load Combination of Flood and Seismic Loads**

Different scour condition shall be considered subject to short term or long-term effect. Non-scour shall be considered when bridge elements are checked under the short-term effect, construction stage and bridge completion. Meanwhile scour condition shall be under the long-term effect as service stage.

In seismic combinations, especially, maximum depth of scour shall be reduced subject to flood or low water level as below.

The maximum depth of scour (2.0x dsm) below the Highest Flood Level (HFL) for the design of piers having individual foundations without any floor protection may be considered in accordance with Clause 703.3.1.1 of IRC:78-2014 as follows.

- Flood without seismic combinations: maximum depth of scour is considered (for piers: 2.0 x dsm)
- Flood with seismic combinations: 0.9 times of maximum depth of scour (for piers: 2.0 x dsm x 0.9)
- Low water level with seismic combinations: 0.8 times of maximum depth of scour (for piers: 2.0 x dsm x 0.8)

➢ **Equilibrium Combinations**

The following combinations are specified in amendment to IRC:6-2017

Table 11: Equilibrium Combinations

Loads / Case	Basic Combination			Accidental Combination	Seismic Combination
	(1)	(2)	(3)	(4)	(5)
Permanent Loads:					
Dead Load	1.0/0.9	1.0/0.9	1.1/0.9	1.0/1.0	1.1/0.9
Surfacing	1.35/1.0	1.35/1.0	1.35/1.0	1.0/1.0	1.35/1.0
Prestress	1.0/1.0	1.0/1.0	1.0/1.0	1.0/1.0	1.0/1.0
Variable Loads:					
Live Load	1.5/0.0	1.15/0.0	1.15/0.0	0.75/0.0	0.2/0.0
(Special Vehicle)	(1.0/0.0)	(-)	(-)	(-)	(-)
Temperature Load	0.9/0.0	1.5/0.0	0.9/0.0	0.5/0.0	0.5/0.0
Wind Load	0.9/0.0	0.9/0.0	1.5/0.0	-	-
Accidental Load	-	-	-	1.0/0.0	-
Seismic Load	-	-	-	-	1.5/0.0
Construction Dead Load	1.1/0.9	1.1/0.9	1.1/0.9	-	-
Construction Wind Load	1.2/0.0	1.2/0.0	1.5/0.0	-	-
Hydraulic Load	1.0/1.0	1.0/1.0	1.0/1.0	1.0/0.0	1.0/0.0

* If the special vehicle is combined, no other vehicle, wind, seismic, braking force and dynamic impact on the live load need to be considered.

** In case of seismic combination, two cases of flood and low water level are considered.

*** Wind load and temperature load need not be taken simultaneously as per the 'Amendment to IRC:6-2017'

- **Structural Strength Combinations**

The following combinations are specified in amendment to IRC:6-2017.

Table 12: Structural strength combinations

Loads / Case	Basic Combination		Accidental Combination	Seismic Combination
	(1)	(2)	(3)	(4)
Permanent Loads:				
Dead Load	1.35/1.0	1.35/1.0	1.0	1.35/1.0
Surfacing	1.75/1.0	1.75/1.0	1.0	1.75/1.0
Prestress	1.0	1.0	1.0	1.0
Variable Loads:				
Live Load	1.5	1.15	0.75	0.2
(Special Vehicle)	(1.0)	(-)	(-)	(-)
Wind Load	0.9	1.5	-	-
Accidental Load	-	-	1.0	-
Seismic Load during service	-	-		1.5
Seismic Load during construction				0.75
Hydraulic Load	1.0	1.0	1.0	1.0

* If the special vehicle is combined, no other vehicle, wind, seismic, braking force and dynamic impact on the live load need to be considered.

** In case of seismic combination, two cases of flood and low water level are considered.

5.3 The Service Limit State (SLS)

Loads are required to be combined to satisfy the serviceability requirements. The serviceability limit state check shall be carried out in order to have control on stress, deflection, vibration, crack width, settlement and to estimate shrinkage and creep effects. It shall be ensured that the design value obtained by using the appropriate combination shall be less than the limiting value of serviceability criterion as per the relevant code. The rare combination of loads shall be used for checking the stress limit. The frequent combination of loads shall be used for checking the deflection, vibration and crack width. The quasi-permanent combination of loads shall be used for checking the settlement, shrinkage creep effects and the permanent stress in concrete.

The following combinations are specified in amendment to IRC:6-2017

Table 13: Service limit state combinations

Loads / Case	Rare Combination			Frequent Combination			Quasi-Permanent Combination
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Permanent Loads:							
Dead Load	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Surfacing	1.2/1	1.2/1	1.2/1	1.2/1	1.2/1	1.2/1	1.0
Prestress	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Settlement Effects	1.0/0	1.0/0	1.0/0	1.0/0	1.0/0	1.0/0	1.0/0
Variable Loads:							
Live Load	1.0	0.75	0.75	0.75	0.2	0.2	-
(Special Vehicle)	(1.0)	(0.75)	(-)	(-)	(-)	(-)	(-)
Temperature Load	0.6	1.0	0.6	0.5	0.6	0.5	0.5
Wind Load	0.6	0.6	1.0	0.5	0.5	0.6	-
Hydraulic Load	1.0	1.0	1.0	1.0	1.0	1.0	-

* If the special vehicle is combined, no other vehicle, wind, seismic, braking force and dynamic impact on the live load need to be considered.

** Wind load and temperature load need not be taken simultaneously as per the 'Amendment to IRC:6-2017'

5.4 The Combination for Design of Foundation

For checking the base pressure under foundation and to estimate the structural strength which includes the geotechnical loads, the partial factor for loads shown in below shall be used.

Table 14: Foundation combinations

Loads / Case	**Combination -1**		**Combination -2**		**Seismic Combination**		**Accidental Combination**	
	-1	**-2**	**-3**	**-4**	**-5**	**-6**	**-7**	**-8**
Permanent Loads:								
Dead Load	1.35	1.35	1	1	1.35		1	1
Surfacing	1.75	1.75	1	1	1.75		1	1
Prestress	1	1	1	1	1		1	1
Settlement Effects	1.0/0	1.0/0	1.0/0	1.0/0	1.0/0		1.0/0	1.0/0
Variable Loads:								
Live Load	1.5	1.15	1.3	1	0.75/0	0.2	0.75/0	0.2
(Special Vehicle)	-1	(-)	-1	(-)	(-)	(-)	(-)	(-)
Temperature Load	0.9	0.9	0.8	0.8	0.5	0.5	0.5	0.5
Wind Load	0.9	1.5	0.8	1.3	-	-	-	-
Accidental Load	-	-	-	-	-	-	1	1
Seismic Load	-	-	-	-	1.5	1.5	-	-
Construction Dead Load	1.35	1.35	1	1	1	1	1	1
Hydraulic Load	1.0/0	1.0/0	1.0/0	1.0/0	1.0/0	1.0/0	1.0/0	1.0/0

* If the special vehicle is combined, no other vehicle, wind, seismic, braking force and dynamic impact on the live load need to be considered.

** In case of seismic combination, two cases of flood and low water level are considered.

*** Wind load and temperature load need not be taken simultaneously as per the ‘Amendment to IRC:6-2017.

6. MATERIALS

6.1 Concrete Grade

The minimum Grade of concrete in various elements shall be as under for moderate conditions of exposure as per IRC 112-2011:

Major Bridge

All RCC M 35

PSC I Beam Girder M 45

PSC Box Girder M 50

All PCC M 25

Reinforcement Steel

- High yield strength deformed bar shall be of grade Fe-415/Fe-500/Fe-500D
- Mild steel bar shall be of grade Fe-240

Structural Steel

Grade Designation	Quality	Ladle Analysis, Percent, *Max*					Carbon Equivalent (CE), *Max*	Mode of Deoxidation
		C	Mn	S	P	Si		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
E 350	A BR B0	0.20	1.55	0.045	0.045	0.45	0.47	Semi-killed/killed
	C	0.20	1.55	0.040	0.040	0.45	0.45	Killed

6.2 Seismic Zone

The project road is in a seismic zone IV. It is proposed to design the bridges for seismic forces as mentioned in modified clause 222 of IRC: 6-2017.

6.3 Pre-stressing System

a. System (Post tensioning) : 12T13/19T13 multiple strand system of "Freyssinet" or "ISMALCCL" or equivalent

b. Cables (Post tensioning) : 12T13/19T13 with strands of 12.7mm nominal dia.

c. High Tensile Steel

(for both post/pre- tensioning)

Strands : Nominal 12.7 mm dia 7 ply low relaxation Strands conforming to class 2 of IS:14268-95

d. Area : 98.7 sq.mm per strand (nominal cross section area)

e. Ultimate load : 183.71 KN per strand

f. Modulus of Elasticity : 1.95×10^5 Mpa

g. Sheathing (Post tensioning) : 75 mm OD/90mm OD Bright metal corrugated flexible sheathing for 12T13/19K13 cables respectively.

h. Friction Coefficient (Post tensioning) 0.17/radian

i. Wobble Coefficient (Post tensioning) 0.0020/m

j. Anchorage Slip (Post tensioning) 6mm average

k. Loss of force due to relaxation : 2.5% at 0.7 UTS after 1000 hrs. The final relaxation values for design shall be 3.0 times the value as per cl 11.4 of IRC: 18-2000

6.4 Bearings

Spherical bearings shall be designed as per IRC: 83 (& IV) and shall conform to Cl.2004 of MORT&H Specifications for Road & Bridges Works (5th Revision). RCC solid slab superstructures of culverts and minor bridges shall directly rest on pier/abutment caps with a tar paper in bearing.

Spherical bearings shall be proposed for long span simply supported superstructures and continuous superstructures. The loads and forces on the bearings shall be calculated to enable the manufacturer to design these bearings and these shall be designed as per IRC:83 (Part IV) 2014.

6.5 Expansion Joints

The following types of Expansion Joints shall be adopted:

Single Strip seal expansion joints shall be proposed for superstructures having movements up to 70mm.

The strip seal joints shall conform to Cl. 2606 of MORTH's Specification for Road and ~Bridges works (5th Revision).

Modular expansion joints shall be prepared for superstructures having movement more than 80mm. The modular strip seal joint shall conform to Cl. 2607 of MORTH's Specification for Road and Bridges works (5th Revision).

Concrete Clear Covers:

For all reinforcement	- As per IRC: 112 and 78 For other covers and inter
duct spacing	- As per IRC: 112

7. DURABILITY AND SERVICEABILITY

7.1 Durability

➢ **Exposure Condition**

As per the table 14.1 of IRC: 112-2011, service environment is considered to be moderate for this project.

➢ **Minimum Concrete Cover**

Cover to the reinforcement shall be the minimum clear distance measured from the surface of the concrete to the closest reinforcing bars. Minimum concrete cover is decided based on durability provisions as per Clause 14.3.2 of IRC 112-2011.

The clear concrete cover to reinforcement shall not be less than the following

Table 15: Concrete cover

S. No.	Location	Cover (mm)
1	Cast-in-situ Concrete exposed to weather	50
2	Concrete of all substructure elements in contact with earth	75
3	Concrete of all substructure elements exposed to weather	50
4	Superstructure cast-in-place concrete exposed to weather	50
5	Concrete of well foundation in contact with earth	75
6	Precast superstructure elements • Outside faces • Inside faces	 50 40
7	Post-Tensioned tendons	75

Note

- Where bundled or paired bars are used then the equivalent diameter shall be considered in determining cover requirements.

7.2 Crack width

Crack width check shall be carried out as per Clause 12.3.4. Crack width shall not exceed the admissible value for moderate exposure condition defined in Table 12.1 of IRC 112-2011 for the load combinations as given below.

Under Quasi permanent load combination for RCC = 0.3 mm.

Under Frequent load combination for PSC members with Bonded tendons = 0.2 mm.

All transverse spanning elements of the superstructure shall be considered as reinforced concrete with regards to the application of crack control requirements.

Further minimum reinforcement for reinforced concrete members for crack control shall be provided as per Clause 12.3.3. In pre-stressed members if the concrete is in compression under rare combination, then only minimum reinforcement for early thermal and shrinkage cracking shall be provided as per Clause 16.5.4 of IRC: 112-2011.

8. FOUNDATION DESIGN

8.1 Design Discharge of Foundation

To provide for and adequate margin of safety, the scour for foundation shall be designed for a larger discharge over the design discharge determined as per IRC:5 as given below:

Catchment area in km2	Increase over design Discharge in percent
0 - 3000	30
3000 - 10000	30 - 20
10000 - 40000	20 - 10
Above - 40000	10

NOTES:

i) For intermediate values of catchment area, linear interpolation may be adopted.

ii) The minimum vertical clearance above the HFL already determined as per IRC:5 need not be increased due to larger discharge calculated above.

8.2 Mean Depth of Scour

The mean scour depth below Highest Flood Level (HFL) for natural channels flowing over scourable bed can be calculated theoretically from the following equation:

$$dsm = 1.34 \times (D_b^2/K_{sf})^{1/3}$$

Where,

Db = The design discharge for foundation per meter width of effective waterway.

Ksf = Silt factor for a representative sample of bed material obtained up to the level of anticipated deepest scour.

"Ksf" is given by the expression $1.76\sqrt{dm}$, dm being the weighted mean diameter in millimeter.

The value of Ksf for various grades of sandy bed are given below for ready reference and adoption:

Type of bed material	**dm**	**sf**
Coarse silt	0.04	0.35
Silt/fine sand	0.081 to 0.158	0.5 to 0.7

Medium sand	0.223 to 0.505	0.85 to 1.25
Coarse sand	0.725	1.5
Fine bajri and sand	0.988	1.75
Heavy sand	1.29 to 2.00	2.0 to 2.42

8.3 Maximum Depth of Scour for Design of Foundation

The maximum depth of scour below the Highest Flood Level (HFL) for the design of piers and abutments having individual foundations without any floor protection may be considered as follows.

- **Flood without seismic combination**

i) For piers - 2.0 dsm

ii) For abutments - a) 1 .27 dsm with approach retained or lowest bed level whichever is deeper.

b) 2.00 d with scour all around.

- **Flood with seismic combination**

For considering load combination of flood and seismic loads (together with other appropriate combinations given elsewhere) the maximum depth of scour given in Clause 703.3.1 .1 may be reduced by multiplying factor of 0.9.

For low water level (without flood conditions) combined with seismic combination maximum level of scour below high flood level can be assumed as 0.8 times scour.

8.4 DEPTH OF FOUNDATION

- **General**

The foundation shall be designed to withstand the worst combination of loads and forces evaluated in accordance with the provisions of Clause 706. The foundations shall be taken to such depth that they are safe against scour or protected from it. Apart from this, the depth should also be sufficient from consideration of bearing capacity, settlement, liquefaction potential, stability and suitability of strata at the founding level and sufficient depth below It. In case of bridges where the mean scour depth 'dsm' is calculated with the depth of foundation shall not be less than those of existing structures in the vicinity.