2 DESIGN APPROACH AND STANDARDS

2.1 General Concept

The proposed alignment of expressway passes through mainly plain terrain. Considering the physical condition and cost effectiveness, the proposals are conceived and developed within the purview of the guidelines given below.

i) The desirable standards are preferably adopted.

ii) The minimum standards, are adopted for difficult sections where application of the desirable standards, would lead to exorbitant costs and resources.

Accordingly, design standards for geometric elements have been proposed under "desirable" and "minimum" categories. These proposed standards are consistent with and falls within the parameters recommended in the related standards of the Indian Roads congress and Ministry.

The key document for planning and design is IRC SP:99 "Manual for Specifications and Standards for Expressways " published by Ministry of Road Transport and Highways. Priority of Standards is as follows:

- Manual for Specifications and Standards for Expressways IRC:SP:99-2013
- Guidelines for Expressways Part – I and Part – II of MoRTH published by IRC in April 2010
- Relevant IRC codes / standards / manuals.
- Circulars of MoRTH
- Relevant IS Codes
- Others

Wherever there was interface with existing roads/ highways; surveys and investigations were conducted accordingly.

UPEIDA has also provided guidelines to be adopted on this project. These have been specifically followed during design development stage wherein Changes, if any, have been discussed and incorporated in consultation with UPEIDA.

2.2 Terrain Classification

The following terrain classification is recommended by IRC:

Terrain	Cross Slope (%)
Plain	<10
Rolling	10 - 25
Mountainous	25 -60
Steep	> 60

Based on study, the terrain in the project corridor is mostly plain with general cross slope of the country remaining less than 10%. Small length of project expressway can be classified as rolling terrain, however the design standard for plain terrain are adopted for entire project length.

2.3 Design Speed

The design speed of 120 Kmph for Expressway is adopted corresponding to the plain terrain.

2.4 Lane Requirement

Consultant's appraisal has shown that provision of 4-lane road configuration suffice to cater the projected traffic volume. The provisions of IRC:SP:99-2013 are followed. Same number of lanes are proposed in TOR.

2.5 Right of Way (ROW)

IRC:SP-99 suggests 90-120 m ROW for plain/rolling terrain in normal situations as indicated in the **Table 2.1**.

Table 2.1: Right of Way (ROW) in Plain/Rolling Terrain

S. No.	Section	ROW (m)
1	Rural Section	90-120
2	Rural sections passing through semi urban areas	120 (may be reduced in case of elevated expressway in viaduct is proposed)

It has been proposed to acquire 110 m land for the ROW, in consultation with UPEIDA. Additional land is required at the location of interchanges, toll plazas, project facilities etc as per design and same is proposed for acquisition.

The Consultant has furnished land acquisition details as per revenue records/maps for further processing.

2.6 Lane Width of Carriageway

The standard lane width for project Expressway is kept 3.75m. Expressway shall have a minimum of two lanes for each direction of travel and the same is adopted.

2.7 Median

The width of median is the distance between inside edges of carriageways. The width of median as per codal requirement is given in **Table 2.2**.

Table 2.2: Median Type and Width

S. No.	Type of median	Recommended median width (m)	
		Minimum	Desirable
1	Depressed	12.0	15.0
2	Flush	4.5	4.5
3	Flush (to accommodate structure/ pier on median)	8.0	8.0

Depressed median of 15.0m width was earlier recommended in consultation with UPEIDA. However, considering cost benefits and current practice on ongoing/ completed expressways in India, raised median of 5.5m (with kerb shyness) is being considered. MBCB (crash barriers) will be provided at both edges of median to avoid risk of cross-overs accidents. .

2.8 Cross Sectional Elements

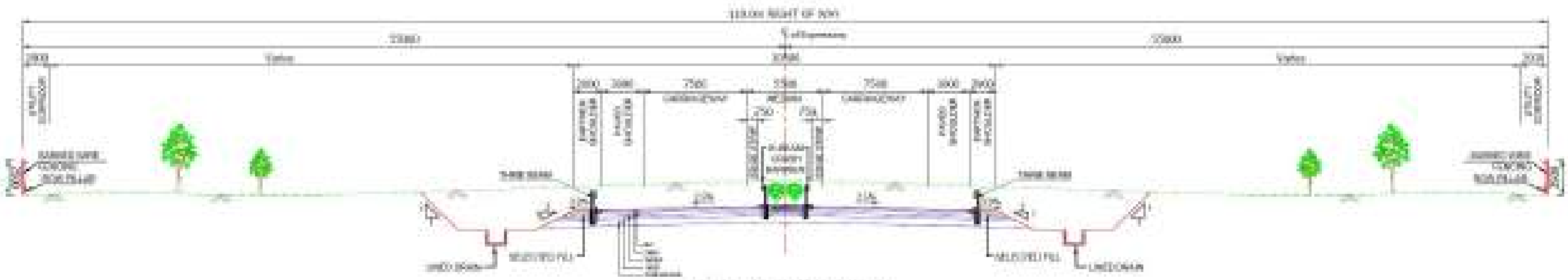
Cross sections types will depend on design, they all are with raised median. In straight reaches, a camber of 2.5% uniformly from centre to the each edge of the pavement surface (including paved shoulder) and 3.0% in the earthen shoulder is provided. The earthen shoulders would have 200mm granular cover as per codal requirement.

Typical cross-sections for the expressway in greenfield are presented in **Figure 2.1**.

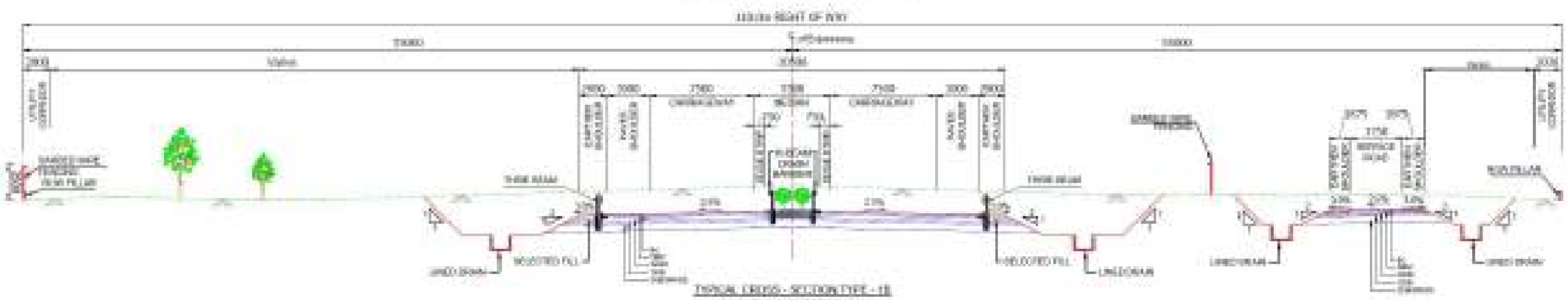
As per IRC, embankment slope can be recoverable or traversable with range varying from 1:3 to 1:6. As per discussions with UPEIDA, embankment slope of 2:1 is adopted. Since crash barriers are considered throughout the length of expressway, flatter slopes are not necessary.

Service road will generally be provided on one side. Width of service road will be kept as 3.75m all along the expressway except ROBs and MJBs locations. However, depending on the cross-roads connectivity and spacing of grade-separated structures, this may be widened to intermediate/ 2-lane in short sections. Service road shall also be of 2-lanes in 5 km length at start and end of project. The details of service roads are given in Chapter 4 of this report.

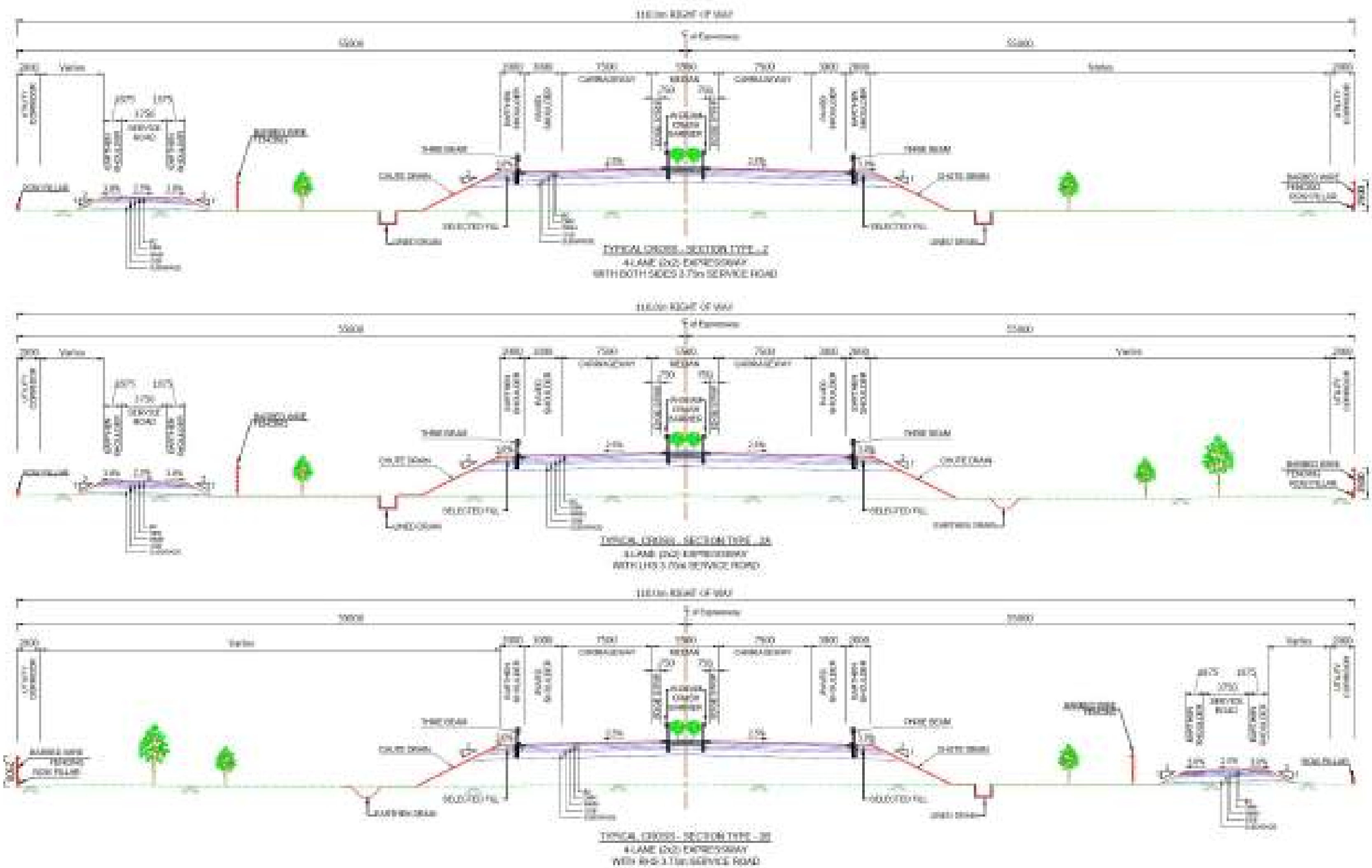
TYPICAL CROSS - SECTION TYPE - 1
4-LANE (2x2) EXPRESSWAY
WITHOUT SERVICE ROAD



TYPICAL CROSS - SECTION TYPE - 1A
4-LANE (2x2) EXPRESSWAY
WITHOUT SERVICE ROAD (FOR CUT SECTION)

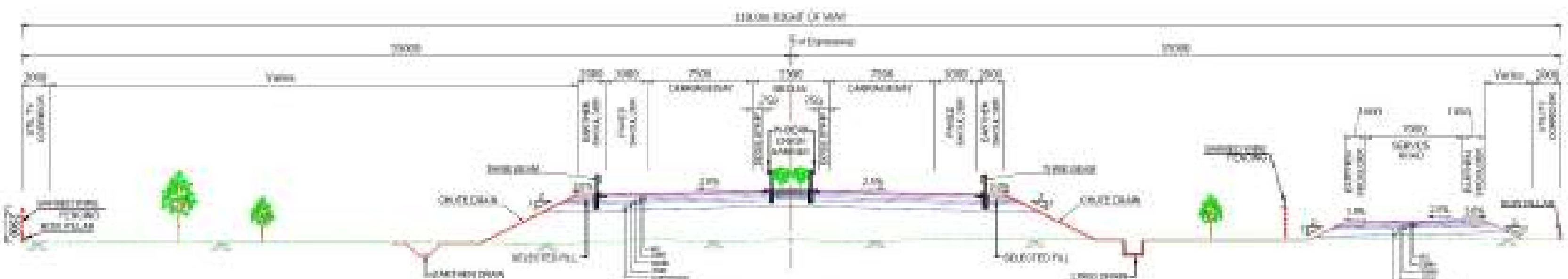


TYPICAL CROSS - SECTION TYPE - 1B
4-LANE (2x2) EXPRESSWAY
ONE SIDE SERVICE ROAD (FOR CUT SECTION)

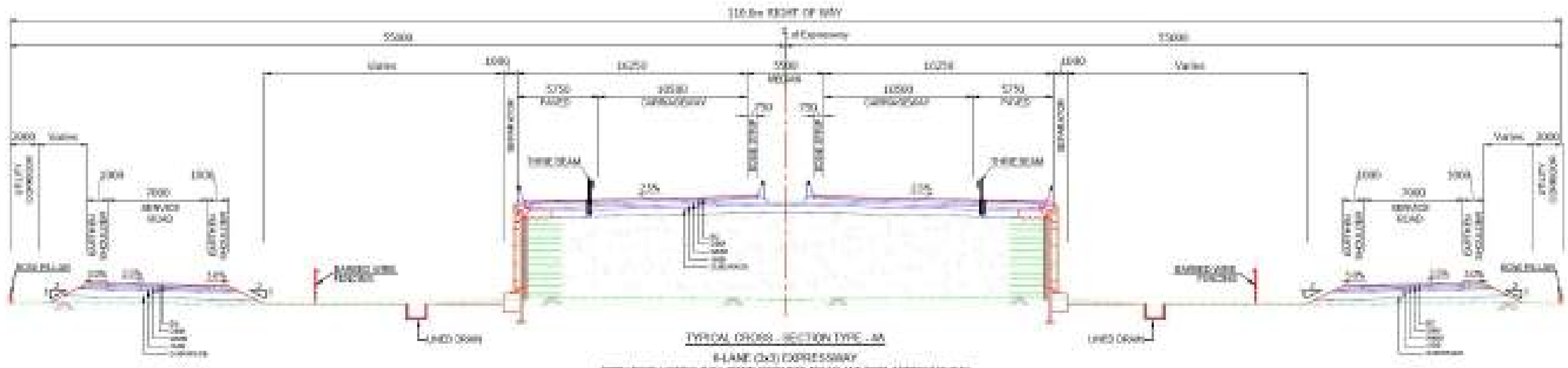

TYPICAL CROSS - SECTION TYPE - 2
4-LANE (2x2) EXPRESSWAY
WITH BOTH SIDES 3.75m SERVICE ROAD
TYPICAL CROSS - SECTION TYPE - 2A
4-LANE (2x2) EXPRESSWAY
WITH LHS 3.75m SERVICE ROAD
TYPICAL CROSS - SECTION TYPE - 2B
4-LANE (2x2) EXPRESSWAY
WITH RHS 3.75m SERVICE ROAD

TYPICAL CROSS - SECTION TYPE - 3
4-LANE (2x2) EXPRESSWAY
WITH BOTH SIDES 7.0m SERVICE ROAD

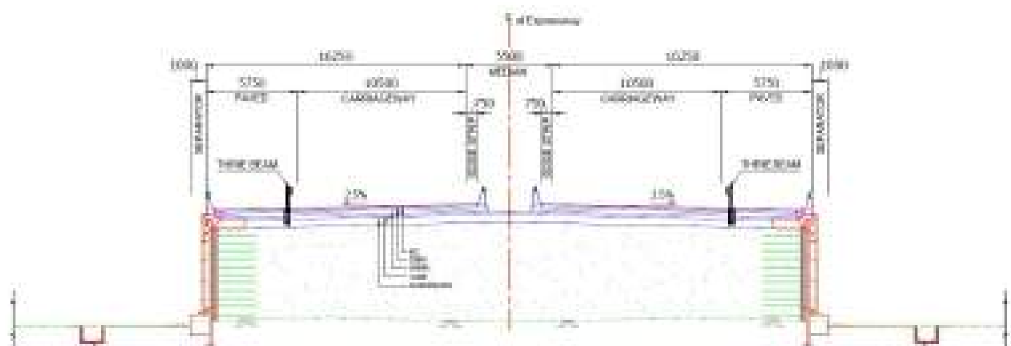
TYPICAL CROSS - SECTION TYPE - 3A
4-LANE (2x2) EXPRESSWAY
WITH LHS 7.0m SERVICE ROAD



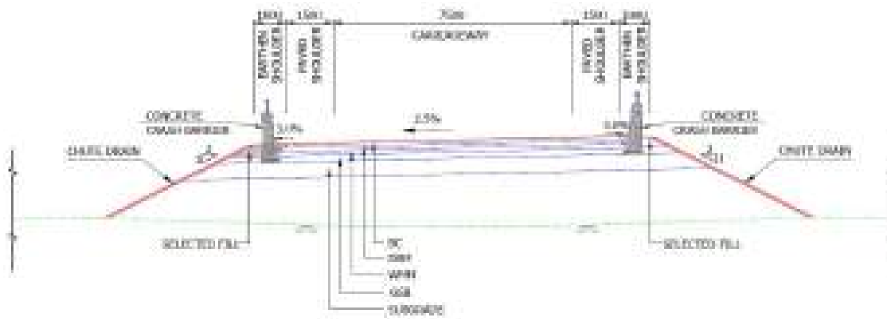
TYPICAL CROSS - SECTION TYPE - 3B
4-LANE (2x2) EXPRESSWAY
WITH RHS 7.0m SERVICE ROAD



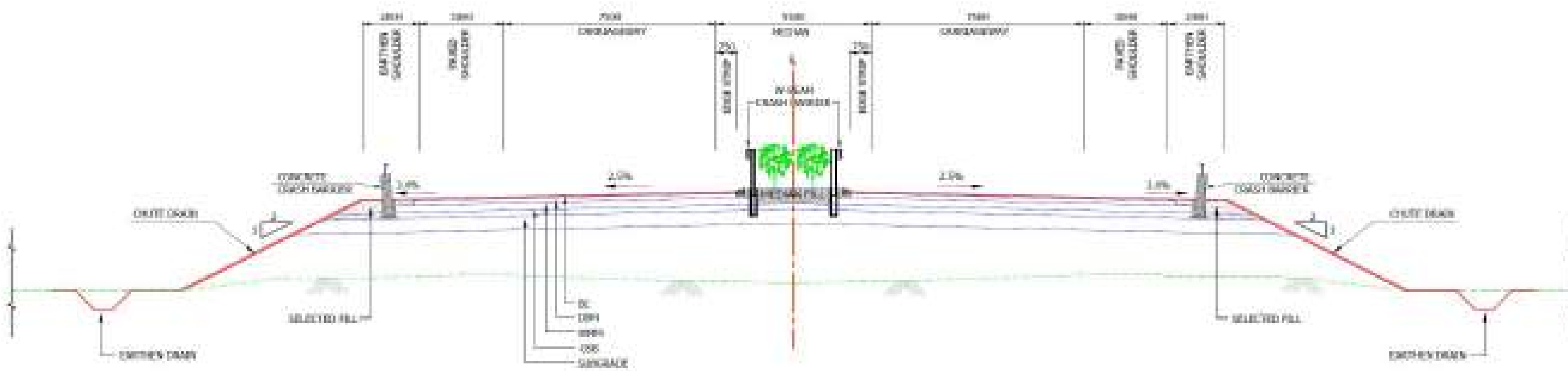
TYPICAL CROSS - SECTION TYPE - 4A
8-LANE (3x3) EXPRESSWAY
WITH BOTH SIDES 7.0m WIDE SERVICE ROAD (AT ROB APPROACHES)



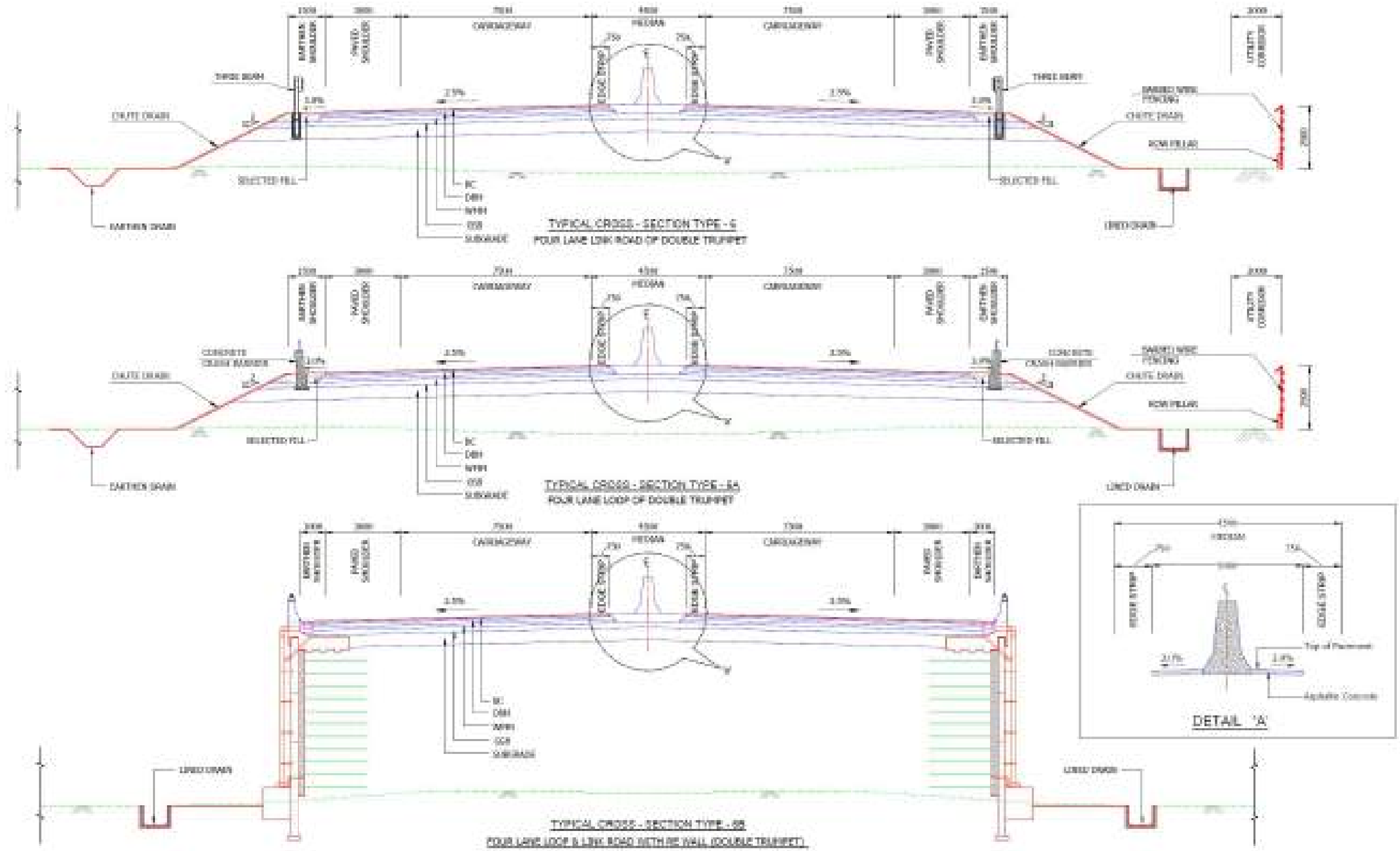
TYPICAL CROSS - SECTION TYPE - 4B
8-LANE (3x3) EXPRESSWAY
(AT FLYOVER APPROACHES)



TYPICAL CROSS - SECTION TYPE - 5
2-LANE DIRECTIONAL/SEMI DIRECTIONAL/LOOP RAMP AND SLIP ROAD OF INTERCHANGE



TYPICAL CROSS - SECTION TYPE - 5A
4-LANE LOOP OF TRUMPET INTERCHANGE


TYPICAL CROSS - SECTION TYPE - 6
FOUR LANE LINK ROAD OF DOUBLE TRUMPET
TYPICAL CROSS - SECTION TYPE - 6A
FOUR LANE LOOP OF DOUBLE TRUMPET
TYPICAL CROSS - SECTION TYPE - 6B
FOUR LANE LOOP & LINK ROAD WITH RE WALL (DOUBLE TRUMPET)
CARRIAGEWAY
MEDIAN
EDGE STRIP
PAVED SHOULDER
EARTHEN SHOULDER
UTILITY CORRIDOR
CHUTE DRAIN
EARTHEN DRAIN
SELECTED FILL
LINED DRAIN
ROW PILLAR
BARBED WIRE FENCING
THRIE BEAM
CONCRETE CRASH BARRIER
BC
DBM
WMM
GSB
SUBGRADE
DETAIL 'A'
Top of Pavement
Asphalt Concrete

2.9 Super Elevation

Super elevation has been provided for all the horizontal curves with radius upto 4000m in order to counteract the effect of centrifugal force. The Super-elevation will be attained gradually over the full length of the transition curve so that design super elevation is available at the starting point of the circular portion. In case where transition curve cannot be provided for some reason, two-third super elevation may be attained on the straight section before start of the circular curve and the balance one-third on the curve, however there are no such limitations on this study.

Super elevation has been limited to 5% for curves with radii 1000m or more. For curves with radii less than 1000m it has been limited to 7%.

2.10 Sight Distance

As per IRC recommendations, provision of desirable minimum sight distance (intermediate sight distance) shall be adopted normally. **Table 2.3** illustrates the sight distances specified in the manual (IRC:SP:99-2013).

Table 2.3: Sigh Distances for Plain Terrain

Speed (km/hr)	Safe Stopping Sight Distance (m)	Intermediate Sight Distance (m)
120	250	500

The minimum sight distance adopted is intermediate sight distance. These are available in entire length of expressway.

2.11 Horizontal Curves

The radius of horizontal curve shall not be less than the desirable minimum radius except at locations with sight constraints, where the radius shall not be less than absolute minimum. Wherever possible, higher radii shall be adopted. The horizontal curves with radius of curvature < 4000 m, transition curves are provided on both ends of circular curve. Minimum length of transition curve shall be 100m. There is no curvature less than desirable minimum radius on the project.

Table 2.4 illustrates minimum radius of horizontal curve specified by the manual (IRC:SP:99-2013).

Table 2.4: Radius of Horizontal Curve

Speed (km/hr)	Desirable Minimum Radius (m)	Absolute Minimum Radius (m)
120	1000	670

2.12 Vertical Gradient

The ruling and limiting maximum longitudinal gradients for plain terrain is recommended as 2.5% and 3.3% respectively. On pavement, minimum longitudinal gradient of 0.3% shall be provided for drainage. The criteria are met on the project expressway.

A minimum longitudinal gradient of 0.5%, if side drains are lined and 1.0% in case of unlined drain shall be adopted in cut- sections.

Both summit curves and valley curves will be introduced as per IRC guidelines. The length of summit curve and valley curves (L) is guided by S, the sight distance and the deviation angle (N).

(a) For Summit Curves (only to be designed for Intermediate Sight Distance):

When the length of the curve is greater than the sight distance
$L = NS^2 / 9.6$, where S = Intermediate sight distance

When the length of the curve is less than the sight distance
$L = 2S - 9.6 / N$, where S = Intermediate sight distance

(b) For Valley Curves:

When the length of curve is greater than the stopping sight distance

$$L = NS^2 / (1.5 + 0.035 S)$$

When the length of curve is less than the stopping sight distance

$$L = 2S - (1.5 + 0.035 S) / N$$

2.13 NH, SH, MDR, ODR and Village Road Crossings.

Interchanges / flyovers are provided at the locations of crossings of the National Highways and State Highways with the expressway for providing uninterrupted traffic circulation. Such interchanges on NH & SH will be provided with an integrated toll collection arrangement, the expressway being fully access control. Vertical clearance is 6.5 m at crossing with all National Highway and State Highway. VUP have been provided at locations of MDR /ODR, LVU are proposed on BT/WMM/Brick soling/Kachcha village road and PUP/CUP are proposed on earthen road. Nearby crossings in a particular stretch are bunched together and connected via service road. Guidelines provided by UPEIDA are adhered.

The median width is compatible with the median width of the adjacent pavement section. High containment crash barriers shall be provided on all the four sides of the median opening at structure.

2.14 Design Parameters

A summary of the design parameters adopted for general application in the design of the project road/ expressway is given in the **Table 2.5**.

Table 2.5: Design Parameters for Expressway Main Carriageway

S. No.	Design Element	Unit	Design Standards
1	Design Speed	km/h	120
2	Number of Traffic Lanes	No.	2 x 2 Lane/2 x 3 Lane at structure
3	Lane width	m	3.75
4	Edge Strip Median Side(Kerb Shyness) wherever applicable	m	0.75
5	Shoulder width • Paved • Surfaced/Earthen	 m m	 3.0 2.0

S. No.	Design Element	Unit	Design Standards
6	Median Width Raised	 m	 5.5m including shyness
7	Cross fall • Edge strip & Carriageway • Paved /Surfaced Shoulder • Earthen Shoulder (any change to be discussed with UPEIDA)	 % % %	 2.5 2.5 3.0
8	Embankment Slope (H:V).		2:1
9	Sight Distance (Intermediate)	m	500
10	Horizontal Curves • Desirable Min. Radius • Absolute Min. Radius • Max. Super elevation • Radius beyond which super elevation is not required	 m m % m	 1000 670 7 %, if radius of curve is less than the desirable minimum radius and 5%, if radius of curve is more than the desirable minimum radius. 4000
11	Transition Curve Length	m	L= 0.0215 V^3 / CR Where C=0.5 V = Design Speed R = Curve Radius
12	Vertical Alignment • Ruling Gradient • Limiting Gradient • Min. Length of Vertical Curve	 % % m	 2.5 3.0 100
13	Vertical Clearance and Size * • Flyover • Vehicular Underpass • Light Vehicular Underpass • Road over Rail • Under Power Lines	 m m m m m	 6.5 1x12.0 x 5.5 or 2x12.0x5.5 10.5 x 4.5 6.525 (to be modified as per guidelines of railway) 6.0 (Upto 650V) 6.5 (> 650V)

* *UPEIDA has shared broad guidelines to be adopted on Bundelkhand Expressway. The same are adhered.*

The Geometric Design Standards for Interchange Elements are given in the **Table 2.6.**

Table 2.6: Design Parameters for Interchanges

S. No.	Design Element	Unit	Design Standards	
			System interchange	Service Interchange
1	**Design Speed** • Loop • Semi Direct • Direct	 Km/h Km/h Km/h	 70 80 90	 60 70 70
2	**Stopping Sight Distance** • Loop • Semi Direct • Direct	 m m m	 120 140 170	 95 120 120

S. No.	Design Element	Unit	Design Standards	
			System interchange	Service Interchange
3	Radius of Curvature • Loop • Semi Direct • Direct	 m m m	 195 265 375	 140 195 195
4	Maximum Super elevation	%	5.0	
5	Longitudinal Gradient (Max) • Desirable • Absolute	 % %	 4.0 6.0	
6	Length of Vertical Curves	m	min = 0.6V	
7	Minimum Acceleration Length at entry	m	410, 325 & 245 for design seed of entry curves 60 km/h, 70 km/h & >=80 km/h respectively.	
8	Minimum Deceleration Length at exit	m	155, 140 & 120 for design seed of entry curves 60 km/h, 70 km/h & >=80 km/h respectively.	
10	Carriageway Width	m	7.5 (One way)	
11	Shoulder • Paved • Earthen	 m m	 1.5 (On both side) 1.0 (On both side)	

2.15 Design Standards for Bridges/Structures

The cross drainage structures are classified as culverts, minor bridges and major bridges depending up on the length of structure as per IRC standards. Structures up to 6m length fall into the category of culverts, more than 6m and up to 60m in length as minor bridges and beyond 60m as major bridges. All new structures are proposed for 6 lanes as per Manual of Specifications & Standards for Expressways IRC: SP: 99-2013.

The design standards and loading to be considered for culverts, bridges, underpasses, flyovers and ROB's are those laid down in the latest IRC codes and/or IS codes. Where the said codes are found wanting or are silent, other codes at National or International level are followed in consultation with the client. IRC SP:99 "Manual for Specifications and Standards for Expressways" will be referred for developing design and options.

(i) The Indian Road Congress (IRC) codes are the basis of bridge designs, underpasses and flyover/ROB's. For items not covered by later, provisions of Special Publications and Specification for Roads and Bridges published by IRC are followed.

(ii) Grades of concrete in case of newly proposed structures are as per MOST Specifications and IRC Standards. The minimum grade is M40 for PSC and M30 for RCC respectively. For PCC the minimum grade of M15 is adopted.

(iii) All the new structures are designed with Limit State method with latest revision of applicable codes.

(iv) Locations of new minor bridges are generally guided by the alignment of the highway. But, for major bridges, the bridge location and its alignment may override the highway requirement in that portion.

The deck will have camber/cross fall as per highway plan & profile drawing. The thickness of wearing coat has been provided as per latest MORT&H specifications.

(v) Open/ Pile/Well foundations will be adopted, depending on the sub soil strata based on Geotechnical investigation reports & type of structure.

2.15.1 Width of Structures

The road cross section will be carried over minor bridges/culverts. Deck width of all new structure for 6 lanes is as per IRC: SP: 99-2013 New Culverts:

Overall width of all new culverts shall be equal to roadway width of the approaches. The outer most face of crash barrier shall be in line with the outer most edge of the shoulder.

a) New Bridges:

The overall width of the bridges is kept same as required for 6-lane bridges as per IRC SP 99:2013. The crash barrier are provided at both ends of deck. Typical cross section of the new bridge for 6 lanes is given below in **Figure 2.2.**

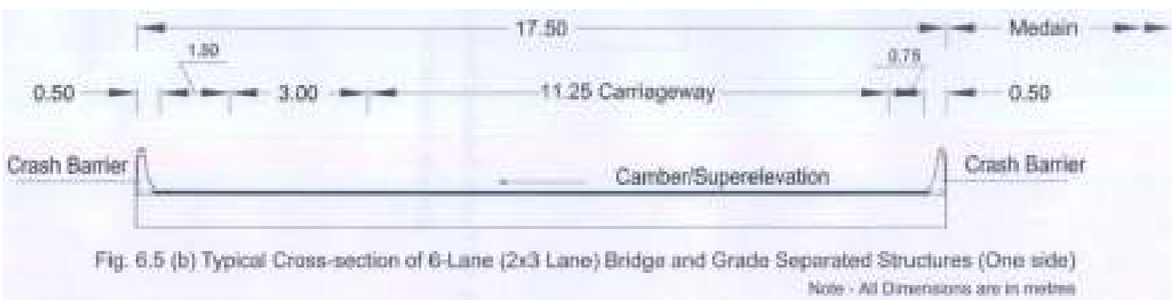


Fig. 6.5 (b) Typical Cross-section of 6-Lane (2x3 Lane) Bridge and Grade Separated Structures (One side)
Note - All Dimensions are in metres

Figure 2.2: Cross Section of New Bridge at Deck Level for 6 Lanes

b) Road over Rail (ROB):

The provision for bridges is also be applicable for ROB. The horizontal and vertical clearances are provided as per requirement of railway.

c) Grade Separated Structures:

The horizontal and vertical clearances are provided as per requirement. Typical cross section of the new grade separated structure is given below in **Figure 2.3.**

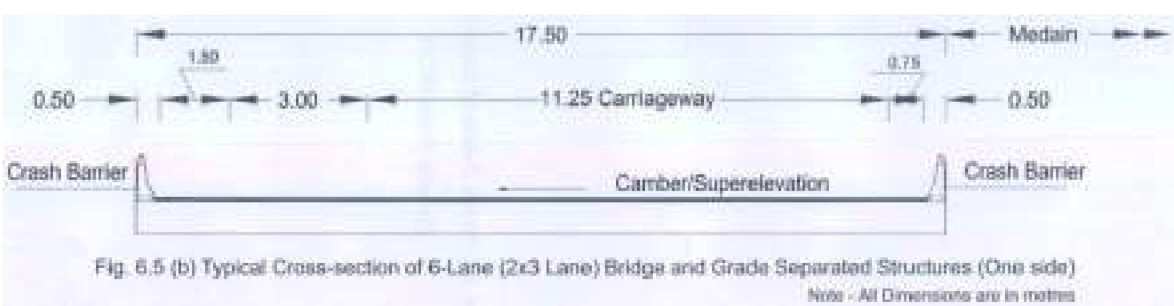


Fig. 6.5 (b) Typical Cross-section of 6-Lane (2x3 Lane) Bridge and Grade Separated Structures (One side)
Note - All Dimensions are in metres

Figure 2.3: Cross Section of Grade Separated Structure Vehicular/Pedestrian/Cattle Underpass for 6 Lanes

2.15.2 Proposal for Culverts

For culverts, following guidelines are followed:

i. For culverts minimum span and vent height is kept as per hydraulic and relevant codal requirements.

ii. In proposed alignment sufficient numbers of balancing box culverts are provided wherever alignment crosses through flat agricultural fields and lies in close vicinity to high embankments of railways and flood bunds.

iii. Culverts are designed for IRC Class-A/Class-70R Tracked/Class-70R Wheeled Loading as per relevant IRC provisions.

iv. Culverts are constructed for full formation width of the roadway.

2.15.3 Proposal for Bridges/Structures

In general, the following aspects are considered while planning for the new bridges and structures:

- Proper sitting of bridge and geometrics of approaches;
- Linear waterways and minimum vertical clearances;
- Satisfactory geotechnical conditions;
- Modular approach in design for both superstructure and substructures;
- Minimum number of the spans consistent with the road deck levels and minimum vertical clearance above design HFL

2.15.4 Design Loading

The bridges are designed to sustain safely the most critical combination of various loads, forces and stresses that can co-exist as per the provisions of IRC: 6-2017. The allowable stresses for various load combinations shall be adopted as per the relevant IRC codes.

a) Carriageway Live Load

The design load and stresses are as per IRC: 6-2017 including Special Vehicle(SV) Load, appropriate for the width of the carriageway shall be considered. All new structures shall also be designed when footpath is used as carriageway.

b) Tractive and Braking Force

The tractive and braking forces are considered as per the provisions of clause no. 211 of IRC: 6-2017.

c) Wind Forces

The effect of wind as per clause no. 209 of IRC: 6-2017 is considered for the design of the various components of the bridge.

d) Footpath Live Load

The footpath live load is considered as per the provisions of clause no. 206 of the IRC: 6-2017.

e) Seismic Forces

Project roads pass through seismic zone III. Seismic forces is calculated in accordance with clause number 219 of IRC: 6-2017.

f) Buoyancy Effects

The following buoyancy effects are proposed to be considered wherever applicable for the design of various components of the bridges:

For Foundations	100 %
For Substructure below water level	15 %

2.15.5 Durability & Maintenance considerations

In order to keep maintenance to a minimum during the operation and in order to facilitate the operations, the following is recommended:

- Utilize materials, which are resistant to aggressive conditions.
- Keep provision for replacement of bearings and expansion joint parts with reduced design life.
- Carriageways shall be provided with suitable cross camber along with suitably designed cross drainage arrangement for collection and disposal of rainwater to prevent any accumulation of water on the bridge during rain.

2.15.6 Safety Measures

- A suitably designed safety barrier are considered to hold the out-of-control vehicles on the carriageway from falling off.
- Approaches to the bridge, having height greater than 3m, are protected with suitable safety barriers
- All carriageways and footpath surfaces will have anti-skid characteristics to prevent skidding of vehicles.
- Safety barriers on both sides of raised median are considered to avoid cross over accidents.

2.15.7 Codes and Publications

The codes and publications (latest editions) used for the design of approach road and bridge components other than IRC SP:99 "Manual for Specifications and Standards for Expressways" published by Ministry of Road Transport and Highways and presented in **Table 2.7**. Some of them are listed below:

Table 2.7: Codes and Publications used for the Design

IRC: 5	Standard Specification and code of Practice for Road bridges, Section 1 – General Features of Design
IRC: 6	Standard specifications and code of practice for Road bridges (Section : II) Loads and Combinations (Seventh Revision)
IRC: 112	Code of practice for concrete road bridges
IRC : 22	Standard Specifications and Code of Practice for Road Bridges. Section VI - Composite Construction (Limit State Design)

IRC : 24	Standard Specifications and Code of Practice for Road Bridges. Section V - Steel Road Bridges (Limit State Design)
IRC: SP:13	Guidelines for the design of small bridges and culverts
IRC: 78	Standard Specification and code of Practice for Road bridges, Section VII – Foundation and Substructure.
IRC: 83 (Part I)	Standard Specification and code of Practice for Road bridges, Section IX – Bearing, Part I: Roller & Rocker Bearing
IRC: 83 (Part II)	Standard Specification and code of Practice for Road bridges, Section IX – Bearing, Part II: Elastomeric Bearings
IRC: 83 (Part III)	Standard Specification and code of Practice for Road bridges, Section IX – Bearings, Part III: POT, POT-CUM-PTFE, PIN and Metallic Guide Bearings
IRC: 83 (Part IV)	Standard Specification and code of Practice for Road bridges, Section IX – Bearing, Part IV: Spherical & Cylindrical Bearing
IRC : 89	Guide lines for design and construction of River Training and Control Works for Road Bridges
IRC: SP:35	Guidelines for inspection and Maintenance of Bridges
IRC: SP: 40	Guidelines on techniques for strengthening and Rehabilitation of Bridges.
IRC: SP: 87	Manual of specifications & standards for six laning of Highways through Public Private Partnership
IRC: SP: 99	Manual of specifications & standards for Expressways
MOST specifications	Specifications For Road and Bridge Works (5^{th} Revision, Reprint 2013)

Where the IRC Codes are silent, relevant Euro codes & AASHTO codes are followed. In case even the Euro & AASHTO codes are silent, sound engineering practice are adopted.

2.16 Drainage

Lined drain/ unlined drain will be proposed near embankment toes. A system of drain along the soft shoulder with chutes to dispose of water is used. Lined drains are generally considered between main carriageway and service road. Where there is no service road, unlined drains are considered.

For intra-pavement drainage, it is proposed to extend the Granular Sub Base (GSB) layer up to edge of embankment slopes.

Median drains and rain water harvesting system are also proposed.

2.17 Hydraulic and Hydrological Investigations and Methodology

The Project Expressway passes through areas of heavy intensity rainfall. Detail hydrological investigations are carried out to confirm the requirement of new structures on stream/ nala crossings and additional balancing culvert requirements.

A) Collection of Data and Design Assumptions

The hydraulic data of up-stream or down stream structures on the crossing streams along the project road/proposed alignment is assessed. These observations are supplemented with local inquiries at proposed bridge sites.

B) Return Period and Rainfall

As per IRC: 5 – 2015 (Standard Specifications and Code of Practice for Road Bridges, Section – 1, General Features of Design) the bridges are designed for a period of 100 years. A flood of this specified return period should pass easily through the structure, while an extraordinary and rare flood may pass without doing excessive damage to the structure or the road.

Topographical maps, obtained from Survey of India, on 1:50,000 and 1:2,50,000 scale, are utilized for the hydrological study of the corridor.

C) Cross-Sections and Longitudinal Section at Bridges

For the calculation of discharge of the stream by Area-Velocity method, topographical survey including levelling surveys are carried out across and along the watercourses to determine the cross-section and the longitudinal section of stream. A number of cross-sections are taken at regular intervals on both upstream and downstream side of the structure, including one at the proposed location of the structure in accordance with IRC specifications.

The following assumptions are made during peak discharge calculation:

For bridges where the cross section is not defined, the cross-sections is extended up to the HFL, in order to calculate the effective cross-section of flow.

The longitudinal section to determine the bed slope is taken at an approximate regular interval following the channel course extending on both the upstream and the downstream sides of the structure. Caution is exercised by following the curved flow line for longitudinal gradient, rather than a straight line.

Hydrology and Hydraulics of the Cross Drainage Structures

Assessment of Peak Discharge

The peak discharge and the HFL shall be calculated by following methods

- Empirical Method
- Area Velocity Method
- SUH Method
- Weir-Orifice Method

Empirical Method

Dickens Formula which is as under as per IRC SP-13.

$Q = C\ M^{3/4}$

Where

Q = Peak run-off (cumec)

M = Catchment area (sq km)

C = Coefficient of run-off, depends upon annual rainfall

The catchment area M is determined from toposheets, Coefficient of run-off C is determined from IRC SP-13 depending upon the intensity of rainfall. This formula gives a simplified approach and results are approximate. Comparison is made with alternative methods for important structures.

Ryve's formula which is as under as per IRC SP-13.

$Q = CM^{2/3}$

Where

Q = Peak run-off (cumec)

M = Catchment area (sq km)

C = Coefficient of run-off, depends upon annual rainfall

The catchment area M is determined from the toposheets, Coefficient of run-off C is determined from IRC SP-13 depending upon the intensity of rainfall. This formula gives a simplified approach and results are approximate. Comparison is made with alternative methods for important structures.

Area – Velocity Method (Manning's Formula)

In this method, discharge is calculated using the formula given below

Q = A x V

= A x [(1/n) x (R) 2/3 x (S)1/2]

Where,

Q	=	Discharge (cumecs)
A	=	Area of the cross section (sq. m.)
V	=	Velocity in (m/sec)
R	=	Hydraulic mean depth (m); R = A / P
P	=	Wetted perimeter of the stream (m)
S	=	Bed slope of the stream
n	=	Rugosity Co-efficient.

Synthetic Unit Hydrograph Method

This method is based on unit hydrograph principle, used when catchment area is greater than 10 sq miles. CWC has published Flood Estimation Reports for different zones for India. Comprehensive hydraulic analysis of various CD structures is carried out based on detailed topographical survey.

A detailed approach and equations of unit hydrograph has been given in the report "Estimation of Design Flood Peak", published by CWC and same is considered while designing.

Design discharge is taken as the maximum of the peak flood discharge by different methods provided it does not exceed the next highest discharge more than 50%. If it exceeds, it is restricted to that limit (As per Article 6.2.1 of IRC: SP: 13-2004).

Weir Orifice Method

This method is based on weir – orifice formulae for calculation of discharges. Either of the equation is used based on following criteria:

For,

h/ Dd > 0.25, weir formula is used for calculation of design discharge,

h/Dd < 0.25, orifice formula is used for calculation of design discharge.

Weir Formula:

$$Q = 1.706 \times C_w \times L \, [\, D_u + (u^2/2g)^{3/2} \,]$$

Orifice formula:

$$QF = C_o \times L \times D_d \times (2gh)^{0.5}$$

h = Du – Dd = Afflux generated

Du = Depth of water U/S

Dd = Depth of water D/S

Cw = coefficient to account for losses in friction and varies as follows:

(1) Narrow bridge opening with or without floors	0.94
(2) Wide bridge opening with floors	0.96
(3) Wide bridge opening with no bed floors	0.98

L = Clear Span (m)

u = U/S velocity

g = acceleration due to gravity

Co = Orifice formula coefficient. The values could be read from Fig. 15.3 of IRC-SP:13-2012.

Hydraulic Analysis for Design HFL

In hydraulic analysis, the Design HFL is calculated corresponding to the Design Discharge by Manning's Equation at the bridge site, as described above.

Afflux Calculation

When the waterway area of the opening of a bridge is less than the unobstructed natural waterway area of the stream, i.e. when bridge contracts the stream, afflux occurs. The afflux is calculated using Moles worth formula as given below:

$$h = \left(\frac{V2}{17.88} + 0.01524 \right) \left\{ (A/a)2 - 1 \right\}$$

Where,

h	=	afflux (meters)
V	=	average velocity of water in the river prior to construction (m/sec)
A	=	Unobstructed sectional area of the river at proposed site (sq.m)
a	=	Constricted area of the river at the bridge (sq.m)