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PROPOSED DESIGN BASIS, STANDARDS AND SPEIFICATIONS

1. General

Hill roads mostly have to negotiate through difficult topography, inhospitable terrain and extremes of climatic conditions. As such, design of hill roads to predetermined standards, considering importance of safety and free flow of traffic, is necessary so that travel is safe and comfortable. Design standards have been laid down keeping above in view.

2. Basic Principles of Geometric Design

- Design criteria of hilly terrain should be applied for those roads located mostly in hilly terrain, where stretches of plain/rolling terrain are short and isolated.
- Application of a uniform design standard for the entire length of the project road is desirable for safety and smooth flow of traffic. The use of optimum design standards will reduce the possibility of early obsolence of facilities likely to be brought about by inadequacy of original standards.
- The design standards also recommend absolute minimum values. However, these minimum values should be adopted, only where major site constraints do not make it feasible to adopt ruling design standards, wherever specified, from techno-economic considerations and efforts should be made to adopt ruling values than the minimum values, as far as possible. Where even the minimum design standards can not be adopted for inescapable reasons arising out of serious site constraints, proper informatory / cautionary signs should be put up sufficiently before the specific road stretches to inform the road users of the reduction in design speed and existence of very sharp curves and steep grades.
- The standards have been classified separately for mountainous and steep terrain like lower values of design speed, radii, curve etc. The stretches should be classified as mountainous or steep depending on predominant terrain in stretch and accordingly standards adopted for that stretch.
- Safety should be built in into design elements.

3. Design Standards for Horizontal and Vertical Alignments

3.1 Width of Road land, Roadway, Carriageway & Shoulders

Desirable width (metre) of road land (ROW) for 2 lane NH standard of hill roads should be as per the following Table No. 1 (IRC 52-2001).

Table No. - 1

Sl. No.	Road Classification	Open areas		Built-up areas	
		Normal	Exceptional	Normal	Exceptional
1.	National Highways – 2 Lane	24	18	20	18

Efforts will be made to ensure that the minimum ROW is achieved by Land Acquisition, wherever feasible. Width of carriageway, shoulder and roadway for 2-lane NH Standard of hill roads will be as per the following Table No 2 (IRC:52-2001)

Table No. 2 - Widths of Carriageway, Shoulder and Roadway (m)

Road Classification	Carriageway (m)	Paved Shoulder (m)	Hillside Drain (m)	Parapet on Valley side including Soft Shoulder	Roadway (m)
2-lane N.H. Standard	7.00	2x1.50	0.45	0.45+1.10 = 1.55	12.00

- In hard rock stretches or unstable locations, where excessive hill cutting may lead to slope failure, width of roadway may be reduced by 0.8 m on two lane road. Where such stretches are provided continuously for a long distance, suitable passing places should be provided (Clause 7.2 of I.R.C.:52-2001). But there is no such case.
- On horizontal curves, roadway width shall be increased to provide for extra widening at curves, as per Table – 10 of I.R.C.: 52-2001.
- The clear roadway width on culverts & causeways (measured from inside to inside of parapet walls or kerbs) should be as per Table.2 indicated above.
- For 2 lane bridges, the clear width between kerbs shall be 7.5 m.

3.2 Design Speed

Table -3 Design Speeds (Km/h)

Road Classification	Mountainous Terrain		Steep Terrain	
	Ruling	Min.	Ruling	Min.
National Highways – 2- Lane	50	40	40	30

Normally, 'ruling design speed' should be the guiding criteria for correlating the various geometric standards. Minimum design speed may, however, be adopted in sections where site conditions and very high costs do not permit adoption of ruling design speed.

3.3 Sight Distance

Visibility is an important requirement for safety on hill roads. For this, it is necessary that sight distance of sufficient length is available to permit drivers enough time and distances to control their vehicles to avoid accident. The following two types of sight distance have been considered in the design of the hill roads along the project corridor:

Stopping sight distance, which is the clear distance ahead needed by a driver to bring his vehicle to a stop before meeting a stationery object in his path.

Intermediate sight distance is defined as twice the stopping sight distance.

Table – 4

Design values of stopping and intermediate sight distance for various speeds

Speed (Km/h)	Design Values (m)	
	Stopping sight distance	Intermediate sight distance
25	25	50
30	30	60
35	40	80
40	45	90
50	60	120

Table – 5 – Criteria for measuring sight distance

Sl. No.	Sight Distance	Driver's eye height	Height of Object
1	Safe stopping sight distance	1.20 m	0.15 m
2	Intermediate sight distance	1.20 m	1.20 m

On hill roads, stopping sight distance is absolute minimum from safety angle and must be ensured, regardless of other considerations.

3.4 Camber/Crossfall on Straight Sections

A uni-directional camber/Crossfall towards hillside may be given with regard to factors such as the direction superelevation at the flanking horizontal curve, drainage and problem of erosion of downhill face, for which the following values are adopted:

For Bituminous surfacing – 2.0 to 2.5% (1 in 50 to 1 in 40)

Crossfall for earthen shoulder should be at least 0.5 percent more than the pavement camber subject to a minimum of 3%. On superelevated sections, the shoulders should normally have the same Crossfall as the pavement. This is generally applicable for hill roads, where straight reaches are very few and the road is mostly on curves.

3.5 Lateral Clearance

The minimum lateral clearance (i.e. the distance between the extreme edge of the carriageway and the face of the nearest structure/obstruction) should be equal to normal shoulder width.

3.6 Vertical Clearance

Minimum vertical clearance of 5.0 metres should be provided over the entire roadway at all overhanging cliffs and tunnel/semi tunnel sections, if any.

3.7 Horizontal Alignment

(i) The horizontal alignment should be fluent and blend well with surrounding topography and it should be coordinated carefully with the longitudinal profile. Necessary correction, if required in the existing alignment, is to be made.

(ii) Breaks in the horizontal alignment at the locations of the cross drainage structures and sharp curves at the end of long stretches of straight sections should be avoided.

(iii) Short curves give appearances of kinks, particularly for small deflection angles and should be avoided. The curves should be sufficiently long and have sufficient transition lengths of about 150 metres for a deflection angle of 5 degree and this should be increased by 30 metres for each degree decrease in the deflection angle.

(iv) Non standard curves are to be examined thoroughly and efforts would be made to improve the same to confirm to N. H. Standards, subject to availability of land and site conditions.

3.8 Superelevation

(i) Superelevation to be provided along the horizontal curves is calculated from the following formula.

$$e = \frac{V^2}{225\ R}$$

Where, e = Superelevation in metre per metre width of roadway.

V = Design speed of vehicle in Kilometer per hour

R = Radius of the curve in metre

(ii) Superelevation obtained from the above formula should be kept limited to the following values.

(a) Steep terrain-------------7% maximum

(b) Mountainous terrain----10% maximum
(Not bound by snow)

(c) Mountainous terrain-----7% maximum
(Snow bound)

Efforts will be made to provide 7% superelevation along the project corridor.

(iii) In case where the transition curve cannot be provided due to site constraints, two-third of the calculated superelevation may be attained on the straight length and the balance one-third on the circular curve length.

(iv) For proper drainage of the road, the superelevation should not be less than the camber appropriate to the type of wearing surface.

(v) Superelevation at culverts on curves:

The top surface of the wearing course on the slab culverts should have the same cross profile as the approaches. Superelevation may be given on the abutments keeping the deck slab, thickness uniform, as per design. The level of the top of the slab of the culverts should be same as the top level of the approaches.

(vi) Radii beyond which superelevation is not required are given in Table 6

Table – 6 – Radii beyond which Superelevation is not required

Design Speed (Km/h)	Radii (m) for camber of				
	4%	3%	2.5%	2%	1.7%
20	50	60	70	90	100
25	70	90	110	140	150
30	100	130	160	200	240
35	140	180	220	270	320
40	180	240	280	350	420
50	280	370	450	550	650

3.9 On a horizontal curve, the centrifugal force is balanced by the combined effects of superelevation and side friction. The basic equation for this condition is:

$$\frac{v^2}{g\,R} = e+f$$

$$\text{or, } R = \frac{V^2}{127\,(e+f)}$$

Where,

v = Vehicle speed in metre/second

V = Vehicle speed in Km/hr

g = Acceleration due to gravity in metre/second square

e = Superelevation ratio in metre per metre

f = Coefficient of side friction between vehicle tyre & pavement (taken as 0.15)

r = Radius in metre

Table – 7. Minimum Radii of Horizontal curves for the Project Road

Classification of road	Mountainous Terrain				Steep Terrain			
	Areas not affected by snow		Snow bound areas		Areas not affected by snow		Snow bound areas	
	Ruling Min (m)	Absolute Min (m)	Ruling Min (m)	Absolute Min (m)	Ruling Min (m)	Absolute Min (m)	Ruling Min (m)	Absolute Min (m)
National Highways	80	50	90	60	50	30	60	33

Minimum length of the transition curve should be determined from the following two considerations and the larger of the two values adopted for design:

$$Ls = \frac{0.0215\ V^3}{CR}$$

Where,

Ls = length of transition in metres

V = Speed in Km/h

R = radius of circular curve in metres

$C = \frac{80}{75+V}$ (Subject to maximum of 0.8 and minimum of 0.5)

$$Ls = \frac{1.0\ V^2}{R}$$

Having regard to the above considerations, the minimum transition lengths for different speeds and curve radii are given in Table – 8 below

Table – 8

Minimum Transition Length for Different Speeds and Curve Radii

Curve radius (m)	Design Speed (Km/h)				
	50	40	30	25	20
15				NA	30
20				35	20
25			NA	25	20
30			30	25	15
40		NA	25	20	15
50		40	20	15	15
55		40	20	15	15
70	NA	30	15	15	15
80	55	25	15	15	NR
90	45	25	15	15	
100	45	20	15	15	
125	35	15	15	NR	
150	30	15	15		
170	25	15	NR		
200	20	15			
300	15	NR			

Curve radius (m)	Design Speed (Km/h)				
400	15				
500	NR				

NA – Not applicable

NR – Transition not required

The extra width of carriageway to be provided at horizontal curves on two lane roads is given in Table – 9 below:

Table – 9 – Widening of Pavement at Curves

Radius of Curve (m)	Up to 20	21 to 40	41 to 60	61 to 100	101 to 300	Above 30
Extra width (m) Two - Lane	1.5	1.5	1.2	0.9	0.6	Nil

Extra width shall be provided by increasing the width of the carriageway at uniform rate along transition curves to provide full width on circular curves. Entire widening of the pavement shall preferably be done on the inner side of the curves.

3.10 Set – back distance at horizontal curves

Lack of visibility in the lateral direction may arise due to obstructions like walls, cut slopes, high crops etc. Set back distance from the center line of the carriageway, within which offending obstructions can be cleared to ensure the needed visibility, can be determined from the following equations. However, in certain cases, due to variations in alignment, cross-section and the type and location of obstructions, it may be necessary to resort to field measurements to fix the exact limits of lateral clearance.

The set - back distance is calculated from the following equation.

$M = R - (R-n) \cos\phi$

Where, $\phi = \frac{S}{2(R-n)}$ radians;

M = the minimum set-back distance to sight obstruction in metres (measured from the center line of the road);

R = radius of curve at centre line of the road in metres

N = distance between the centre line of the road and the centre line of the inside lane in metres; and

S = sight distance in metres

In the above equation, sight distance is measured along the middle or inner lane.

3.11 Vertical Alignment

The vertical alignment should be provided for a smooth longitudinal profile consistent with category of road and the terrain. Grade changes should not be too frequent as to cause kinks and visual discontinuities in the profile.

Grades should be carefully selected keeping in view the design speed, terrain conditions and the nature of traffic expected on the road. It is difficult and costly to flatten the gradients later.

Broken – back grade lines i.e. two vertical curves in the same direction separated by a short tangent, should be avoided due to poor appearance and preferably replaced by a single curve.

Decks of small cross-drainage structures (i.e. culverts and minor bridges) should follow the same profile as the flanking road section, with no break in the grade line.

The vertical profile should be co-ordinated suitably with the horizontal alignment.

3.12 Gradients

Recommended gradients for the different terrain conditions except for hair-pin bends are given in Table 10 below:

Table 10 – Recommended Gradients for Different Terrain Conditions.

Classification of Gradient	Mountainous terrain and steep terrain having elevation more than 3000 m above the mean sea level	Steep terrain up to 3000 m Height above the mean sea level
(a) Ruling gradient	5% (1 in 20)	6% (1 in 16.7)
(b) Limiting gradient	6% (1 in 16.7)	7% (1 in 14.3)
(c) Exceptional gradient	7% (1 in 14.3)	8% (1 in 12.5)

Gradients up to the 'ruling gradient' will be used in design.

The 'limiting gradients' may be used, where the topography of the terrain in certain stretches and the site constraints do not make the adoption of ruling gradient techno-economically suitable.

3.13 Grade Compensation at Curves

The grade compensation at curves is calculated by the following formula:

$$\text{Grade Compensation (\%)} = \frac{30+R}{R}$$

Subject to maximum of 75 / R where, R is the radius of curve in metres

3.14 Vertical Curve

Vertical curves should be provided at all grade changes excepting those indicated in table 11 below:

Table –11 Minimum length of vertical curves

Design Speed (Km/h)	Maximum Grade change (percent) not requiring a vertical curve	Minimum length of vertical curve (m)
Up to 35	1.5	15
40	1.2	20
50	1.0	30

3.15 Hair Pin Bend

Hairpin bend, where unavoidable, may be provided as a circular curve with transition curve at both ends.

The following criteria should be adopted for design purpose:

a Minimum design speed - 20 Km/h

b. Minimum roadway width at apex for National Highway - 11.5 m for double lane

c. Minimum radius for the inner curve - 14.0 m

d. Minimum length of transition curve - 15.0 m

e. Gradient

Maximum - 1 in 40 (2.5%)

Minimum - 1 in 200 (0.5%)

f. Maximum Superelevation - 1 in 14.30 (7%)

4.4 Pavement Design

4.4.1 General

The project envisages widening and strengthening of the existing single / intermediate lane carriageway to two lane.

Pavement related activities will include:

- o Construction of bituminous overlays for strengthening of the existing pavement
- o Reconstruction of the badly damaged / failed pavement section, if any
- o New Pavement for 2 lane road, if needed
- o Widening the existing intermediate lane road to two lane with soft shoulders with same design of pavement as for the new pavement

4.4.2 Design of Overlay

The design will be based on the analysis of Benkelman Beam Deflection (BBD) test data, as described in IRC: 81-1997 and MoRT&H guidelines issued from time to time. The design process will typically involve the following steps:

- ❑ Evaluation of Homogenous Sections

  Based on the pavement condition survey, the project road will be divided into homogenous sections of equal performance, for which BBD tests will be conducted. The minimum length of such sections will be 1 Km, except in the case of localized failure or other situations requiring closer examination. A sufficient number of points will be selected for conducting the BBD tests on the project road so that these tests represent accurate pavement performance for the road sections. Points will be decided following IRC: 81-1997 and clause 4.11.2 (4) of TOR Appendix 3.1.

- ❑ Characteristic Deflection

  The BBD test data for each homogeneous section of equal performance after correction for temperature and seasonal variation will be analysed to determine the characteristic

- ❑ Design Life, Performance and Analysis Periods

  The design life, in accordance with the Terms of Reference, will be at least 20 years for flexible pavement and 30 years for rigid pavement. Two options of design, as indicated below, are proposed to be considered:

  Full design Life

	Flexible Pavement	Rigid Pavement
Performance Period	20 years	30 years
Analysis Period	15 years	30 years

Design for stage construction for flexible pavement

Design period initially will be for 15 years followed by strengthening in the form of providing a second overlay designed for the period of next 10 years.

Performance period: 15 years

Analysis period : 15 years

Choice of the final option will be based on the results of economic analysis, site conditions and other relevant factors.

- Design Traffic

  Based on the result of traffic projections and axle load survey, design traffic in terms of equivalent million standard axles (msa) will be computed for the performance and analysis periods of the various design options.

4.4.3 Methods of Pavement Evaluation

The methods of pavement evaluation comprise:

- Visual rating
- Evaluation of pavement surface condition
- Structural evaluation

(a) Visual Rating

The most common form of pavement evaluation is measuring the pavement distress through visual inspection. Visual rating is a simple method of inspecting the pavement surface for detecting and assessing the amount and severity of various types of distresses. Usually, manifestation of distresses occur in the form of:

- Rutting
- Corrugation
- Ravelling
- Cracking
- Patching
- Edge Breaking
- Pot Holes

Pavement condition survey for the project road has been done and data collected in the survey format given in the Preliminary Report.

Ruts affect the performance of a vehicle and increase the possibility of hydroplaning on wet pavements. Rut depth is defined as the depth of the depression in the wheel path. This depth is reported as the distance from a reference point on the pavement structure in the wheel path. The rut depth is measured using a 3 m straight edge. It is measure of permanent deformation of the pavement.

(b) Evaluation of Pavement Surface Condition

The second component of pavement evaluation consists of measuring pavement roughness. Roughness is an indication of the surface irregularities, which influence the riding quality. There are many reasons of measuring roughness. The most important is that the roughness is a good indication of how well the road is serving the users. The vehicle operating cost is also greatly affected by roughness. Hence, the roughness plays an important role in pavement management decisions.

Pavement roughness has been measured using Towed Fifth Wheel Bump Integrator. Appendix 3.2

(c) Structural Evaluation of Pavement

The design of a rehabilitation treatment requires as assessment of the strength of the pavement structure and its load supporting ability. The performance of a flexible pavement is closely related to the elastic deflection under loads or its rebound deflection. Measurement of transient deflection of pavement under design wheel loads serves as an index of the strength of the pavement to carry traffic loads under the prevailing conditions. Of the various equipments used for the purpose, Benkelman Beam is the most commonly used one.

The structural evaluation of the existing pavement has been made using the Benkelman Beam Deflection Technique in accordance with IRC: 81-1997.

4.4.4 Design of New Pavement

Design of new pavement will be done for both flexible pavement and rigid pavement to enable pavement option study.

(a) Design of Flexible Pavement

Guidelines in IRC:37-2012 and the latest MoRT&H instructions/circulars will be used for the design of flexible pavement. The design process will include:

- Homogeneous Sections

  The homogeneous sections for new construction for the portion of widening of the existing intermediate lane carriageway to 2-Lane will be based on the type of soil in embankment, traffic and strength of borrow area soil.

- Subgrade CBR

  Based on the results of tests from borrow area soils, the CBR value of subgrade soil to be used for the design of pavement will be selected for each of the above homogeneous sections and bypass alignments. In stretches where reconstruction is warranted, the soil in the sub-grade will be tested to ascertain CBR value, which will be adopted for the design of pavement. CBR has been adopted to be 7% in instant case.

- Design Life

  In accordance with the Terms of Reference, the design life of the flexible pavement will be 15 years. Two options of design are proposed:

  (i) Full design period 15 years
  Performance period 15 years
  Analysis period 15 years

(ii) Design for stage construction

Design initially for a period of 10 years and at the end of this period, provide an overlay designed for the next 5 years.

Performance period 10 years
Analysis period 15 years

- Design Traffic

  Based on the projections of future traffic on the project road and the bypasses, and also the results of axle load survey, design traffic in terms of equivalent million standard axles (msa) will be computed for the performance and analysis periods of the various design options.

- Thickness of Pavement Layers

  Using appropriate values for design traffic (msa) and subgrade CBR, the thickness of component layers of the pavement will be calculated for various homogeneous sections of the project road, the stretches of the existing road for reconstruction and the bypasses.

  Layer thickness will be determined in accordance with IRC:37-2012

  The design of flexible pavements will also be checked by a second method based on other widely used international practice, i.e. AASHTO Design method

4.5 Bridges and Cross Drainage Structures

4.5.1 Widening of an existing bridge is generally feasible in case of slab bridges with adequate substructure and foundation. In case of bridges with other structural forms, normally, the suitable option is reconstruction.

Upgrading to N.H. Standard will necessitate strengthening of the existing bridges. Assessment of the remaining strength of the existing bridges from analytical approach and field tests and formulation of strengthening scheme and the cost involved in implementation is often found economically unacceptable leaving reconstruction as the only suitable option.

Reconstruction of a bridge on a hill road has several constraints/problems viz.

i) Maintenance of traffic during construction is difficult. Lack of adequate space at the site makes re planning of construction activities a difficult task.

ii) As the existing bridge generally stands in the optimal location, siting of the new bridge at a different location has adverse effect on road geometry. If the new bridge is placed on the hillside, a kink in road alignment may result. On the other hand, if it is placed on the valley side, the length of bridge and the depth of foundation may considerably increase with consequent increase in the cost, besides difficulty in construction.

iii) In case reconstruction is proposed at the existing site, the existing bridge is to be dismantled and a suitable diversion road with a diversion bridge (usually Bailey Bridge) have to be constructed, which is a difficult proposition for a hill road.

4.5.2 Design Standards for New 2-lane Bridges

(a) Geometric Design

(i) The location of the proposed bridge will normally be by the side of the existing bridge and follow the road alignment unless:

- The site is considered to be landslide-prone
- The area is found to be unstable and declared as a "sinking zone"
- Site constraints warrant alternative road alignment for the additional.

(ii) The overall width (out to out of railing kerbs) of the deck slab will be kept equal to the top width of the approach road.

(iii) The span arrangement and span lengths provided will be such that piers/abutments are in line with those of the existing bridges/culverts and ensure smooth flow of water. The new spans are either equal to or multiple of the spans of old structure.

(iv) The distance between the existing and the proposed bridge will be governed by the requirements of the specific type of foundation adopted and its construction methodology.

(v) The linear water way provided will be guided by the waterway provided in the existing bridge and will be checked from the considerations of design discharge, effective and adequate drainage.

(b) Loading Standard

(i) The proposed new structures will be designed for 2 lanes of IRC class A/ Single lane of 70R whichever produces the worst effect.

(ii) Footpath where provided will be designed for alive load of 5KN/m^2.

(iii) Environmental loadings such as earth pressure, water current, seismic forces and temperature effect will be taken as per IRC/BIS Codes. IS-1893 will be followed in evaluating dynamic increment of earth pressure.

(c) Guiding Standards for Structures

The design of proposed structures will be carried out in accordance with the provisions of the following IRC Codes/Guidelines.

(i) Layout and General Features of bridge:

- IRC: 52 – 2001 - Alignment Survey and Geometric Design of Hill Roads
- IRC: SP – 48 – 1998 - Hill Road Manual
- IRC: 5-1998 - Section I, General Features of Design

(ii) Loads and Stresses:

- IRC: 6-2000 - Section II, Loads and Stresses

(iii) Superstructure – Material & Design:

- IRC: 18-2000 - Design Criteria for Prestressed Concrete Road Bridges
- IRC: 21-2000 - Section III, Cement Concrete (Plain & Reinforced)
- IRC: 22-1986 - Section VI, Composite Construction
- IRC: 40-2002 - Section IV, Brick, Stone & Block Masonry

(iv) Bearings:

- IRC: 83-1999 - Section IX. (Part I), Metallic Bearings
- IRC: 83-1987 - Section IX, (Part II), Elastomeric Bearings

- IRC: 83-2002 - Section IX, (Part III), POT Bearings

(v) Substructure and Foundation:

- IRC: 45-1972 - Recommendations for estimating the Resistance of soil Below Maximum Scour level in the Design of Well Foundations of Bridges
- IRC: 78-2000 - Section VII, Foundations and Structure

(vi) Falsework and Formwork:

- IRC: 87-1984 - Guidelines for the Design & Erection of False work for Road Bridges
- IRC: SP-33-1989 - Guidelines on Supplemental Measures for Design, Detailing and Durability of Important Bridge Structures

(vii) Protective works:

- IRC: 89-1997 - Guidelines for design and construction of river training and control works for road bridges (1st Revision)

Where IRC Codes are silent relevant BIS Codes will be followed. And where even BIS codes are silent. International codes/MOST, MORT&H guidelines will be adopted.

(d) Seismic Design

The project road falls in Seismic Zone V as per the classification specified in IRC: 6-2000

All bridges will be designed for Seismic forces as per clause 222.1 of the said code and the relevant amendments thereof.

(e) Soil Parameters

The Soil Parameters used in the preliminary design of foundations for Bridges will be taken from the report of soil investigation and information obtained from the local authorities / existing bridge design data.

The following soil parameters will be used for material for back fill behind abutment of bridges and culverts and the abutment structure will be designed accordingly.

ϕ = 30°

δ = 20°

γd = 18 KN/m^3

γsub = 8 KN/m^3

A 600 mm thick granular material filter behind abutment and adequate weep holes in abutment walls will be provided for proper drainage.

(f) Hydraulic Design

Where the new bridge is proposed adjacent to the existing bridge, the hydraulic design parameters of the existing bridge will be adopted for the new bridge also. The relevant hydraulic data for fixing linear waterway of bridges will be taken from the river hydraulic survey done by ACPL and hydraulic data obtained

(g) Foundations:

The types of foundations for the new bridges proposed to be located by the side of the existing bridges will be generally similar to those of the existing bridges. In other cases, the type of foundation will be guided by the report / recommendation of subsoil exploration.

Normally for the major bridges, concrete well foundations will be provided. For minor bridges, shallow open foundation / R. C. C. Raft will be provided keeping in view the SBC of the founding strata. The depth of foundation would be generally kept equal to that of the existing structures.

(h) Substructure:

RCC wall type or column piers and wall type / spill through abutments will be provided based on the design requirements, site conditions / constraints. The design will be carried out in accordance with IRC:78. The shape, size and alignment of the new substructures will be matching with those of the existing structures and aesthetic and hydraulic considerations.

(i) Superstructure:

The type of Superstructure will, in general, be same for the existing and new bridges. MORT&H Standard Drawings of RCC Beam and slab and

PSC girder super-structure will be adopted, wherever applicable. RCC slab will form the deck for all new culverts, Multi-box structure will be adopted for the minor bridges and culverts, if found appropriate. Steel-concrete composite superstructure will be preferred, as these require less construction materials and less construction time.

(j) Railings:

Reinforced concrete railings in M-30 grade concrete following MORTH Standard Drawings will be provided.

(k) Crash Barrier:

Properly designed RCC Crash barrier in M 40 grade concrete of shape & size, as recommended in IRC: 5 Code will be provided on all bridge decks. In hilly terrain W-type Steel crash barrier may also be erected for convenience.

(l) Expansion Joints:

Filter type expansion joints shall be provided for small span bridges with max. 20 mm movement of deck span and strip seal joints for movements upto about 80 mm, as per MORTH Specifications.

(m) Wearing Course:

40 mm thick asphaltic concrete in 2 layers of 20 mm each over 15 mm thick mastic asphalt layer will be adopted.

(n) Approach Slab:

R. C. C. approach slabs, 3.50 m long and 300 mm thick in M-30 concrete will be used at either end of the new bridges and culverts

(o) Drainage Spouts:

100 mm ϕ drainage spouts will be used for deck drainage

(p) Reinforcement and Prestressing Cables:

High yield strength TMT deformed bars conforming to IS-1786 will be used as reinforcement in all R. C. works. 12 T 13 Prestressing strands conforming to IS-6006 will be used in PSC works.

(q) Protection Works:

Protection works for the major bridges will be provided matching with the protection works used in the existing bridges. IRC-89-1997 will be followed in detailing the protection works.

(i) Return/Wing walls of appropriate length will be provided in bridges and culverts, where necessary, to stop the spilling of earth into the waterway.

(ii) Flooring will be provided if required, over the base raft of culverts to guard against damage of the base raft.

(iii) Peripherial cut-off- walls around the base raft of culverts and flexible boulder apron on both upstream and downstream sides will be provided to reduce chances of undermining of the bridge foundations.

(iv) Adequate measures, will be taken to protect the structures from impact of falling masses dislodged from hill slope.

(v) Properly designed breast walls would be provided on the hill side of the existing road at various locations for stability of the hill slope.

4.6 Design of Structures for Protective Works

4.6.1 Introduction

A journey through a hill road is charming. But this journey might turn nightmarish during rainy season if caught between two landslides or sinking or sliding zones.

Traffic flow in hill roads is frequently disrupted during the months of May to September due to-

(i) failure of hill side slope resulting in hazardous land slides,

(ii) failure of valley side slope with sudden subsidence / collapse of part / portion of the road,

(iii) sinking or sliding of a portion of road down the slope causing large cleavages along / across the layout, and

(iv) Formation of causeways draining huge quantity of rain water from the uphill side to the valley over the road pavement.

These disruptions not only causes severe inconvenience, but also results in a huge economic loss warranting adequate & appropriate protective works.

The primary objective of planning and designing of protective works is to eliminate the chances of occurrence of these disruptions where possible or to minimize the frequency and duration of this occurrences where elimination appears impracticable.

4.6.2 Causes of instability of road on hill slope

The instability of a hill road is rooted in the instability of the hill slope. The primary causes of these instabilities are:

(i) presence of weak, loose fragmented materials embedded in erodable matrix,

(ii) inadequate drainage,

(iii) toe erosion of valley side slope by river,

(iv) presence of loose, uncompacted soil mass deposited on road alignment due to landslides,

(v) progressive slipping of the soil mass along the inclined soil-rock interface, and

(vi) erosion of the valley side slope at the outfall of the culverts.

4.6.3 Preventive and protective measures

(i) Drainage

Adequate drains in the form of catch water drains, collecting flow from hill side to bring it to side drain leading to cross drains and further discharge into natural drainage channels through valley side drain / chutes, if erosion is likely on valley side, are essential for stability of road. Elaborate proposals for adequate effective drainage have been prepared and presented separately.

(ii) Use of geo-nets

Geo-net covers followed by vegetation growth have been used to protect hillside slope.

(iii) Spurs

There is no such case.

(iv) Energy Dissipaters

Steps and blocks have been proposed at the outfall of culverts on steep slope to dissipate energy and avoid sudden jump of the flow to reduce erosion at the outfall.

4.6.4 Slope protection Structures

Retaining walls & breast walls have been used extensively to contain & protect slopes – both in case of cutting in the hillside or filling on the valley side.

(i) Retaining Walls

Retaining walls have generally been proposed to be constructed of dry stone masonry with strengthening bands of R. R. Masonry in cement mortar.

In general, retaining walls upto 4 m height have been proposed to be constructed in R. R. Masonry, walls from 4m to 8m in RR dry masonry with 1:6 cement masonry bands or with a course of cement concrete 1:4:8 throughout the section both in lengthwise and breadthwise directions of the retaining wall to break the joints and cover up short comings in the execution of dry retaining walls.

(ii) Breast Walls

Breast walls i.e. masonry or R.C.C. structures supporting the uphill slopes have been provided in various stretches to guard against failure of slopes by slumping, sliding or toe failures. Such walls perform the following functions:

(a) They keep the road edge defined and protect the drain to some extent.

(b) The hill slope to the extent of Breast Wall height will remain protected from slips. Any side above this height will flow over the top of the wall.

(c) It would not allow continuity of the flowing mass of soil and would thus facilitate the clearance of slides.

(d) Assistance in drainage from hill slope though weep holes in breast wall on to the side drain in front of the wall.

(iii) Reinforced Earth Walls

These will be provided when the alignment goes to the valley side in an overhanging manner.

4.6.5 Principles of design

4.6.5.1 Retaining Walls

The retaining walls proposed are of gravity type. The design procedure of gravity-type of walls consists of stability checks against failure due to –

(i) Overturning

(ii) Sliding

(iii) Excessive base pressure at toe

(iv) Tension in masonry

Under the actions and effects of the following:

(i) Vertical gravity load

(ii) Earth pressure

(iii) Seismic effects on Sl (i) & Sl (ii) and

(iv) Vehicular surcharge on valley side walls

4.6.5.2 Practical Proportions

For average dry conditions, the approximate dimensions of various components of th wall are related to height H by the rule of thumb as follows:

(i)	Width of base	:	0.40H + 0.30 m
(ii)	Width of foundation	:	0.50H + 0.30 m

(iii) Top thickness of the wall is generally kept as : 0.60 m

(iv) Minimum depth of foundation : 0.10H + 0.30 m

(v) Back is generally vertical and front bater : 1 in 4

4.6.5.3 The design process

(i) Gravity load and load effect

These are evaluated on the basis of the preliminary dimensions obtained from the above relations.

(ii) Earth Pressure

The magnitude of earth pressure varies widely depending on the deformation at the soil wall boundary / movement of the wall. The walls have been designed for active earth pressure where the extent of soil mass behind the wall is adequate for the development Rankine / Coulomb Wedge. The force due to earth pressure on wall has been calculated by the expression.

F = $0.50\gamma H^2 K_A$

Where, γ is the unit weight of soil,

H is the height of earth retained

& K_A is the active earth pressure coefficient given by Rankine / Coulomb

Where a thin layer of soil mass is sandwiched between the wall and the underlain inclined rock surface, the pressure has been determined from the exponential expression developed for silos.

The dynamic earth pressure for seismic condition has been evaluated following the Mononobe – Okabe approach using simplified expressions developed by Whitman as follows:

F dynamic = $0.50\gamma H^2 (1-\alpha v)$. K_A dynamic

and K_A dynamic = $K_A + 0.75\ \alpha h$

where αv = vertical seismic acceleration coefficient

αh = horizontal seismic acceleration coefficient

KA dynamic = dynamic earth pressure coefficient

and F dynamic = force due to earth pressure under seismic condition.

(iii) Effect of Superimposed Load

A surcharge equivalent to 1.2 m height of earthfill has been considered in the design. The earth pressures and it's effect are calculated using the above development.

(iv) Stability Checks

There have been performed and dimensions of the wall modified till the specified factor of safety against the different mode of failures have been achieved keeping in view that sliding failure, being progressive and ductile, is preferred.

4.6.5.4 Breast Walls

The design of breast wall has been guided by the following consideration:

i) Of necessary the height of these walls has been kept low, i.e. 1.50 m to 3.0 m since they occupy lot of usable space in the cross section and generally the height has been kept as 1.50 m.

ii) Front batter has usually been kept 1:3 against 1:4 – 1:6 for retaining walls.

4.7 Slope Stability, Drainage Measures & Treatment of Sinking Zones

4.7.1 Landslide is a major hazard on hill roads. Study of stability of natural/man made slopes and control of landslides thus forms an integral part of hill road design and construction. An analysis of the causative factors will be undertaken and corrective stability measures, as outlined in Chapter 11 of IRC:SP:48-1998 will be recommended. Removal of loose materials and/or overhanging mass, flattening/shaping up of slopes, provision of catch/trap water drains etc. will be generally proposed for minor slopes. For major slides, provision of benching of slopes, transverse and longitudinal drains in addition to removal of loose overhanging mass on the hill slopes will be generally proposed. Detailed design of drainage in the major slide prone areas has been done in DPR stage.

4.7.2 Topography of hill generates numerous watercourses. Water flowing from the hill – both surface and subsurface need to be diverted through a network of drains to check adverse effects of water on the slope stability and road structure. Horizontal and vertical catch water drains will be provided on the hill slope and connected to the road side drains/natural water course through chutes for stability of the road as per guidelines laid down in Chapter 8 of IRC:SP:48-1998.

4.7.3 It is anticipated that the initial sloughing and/or slide might have occurred on a relatively harder rock Slope. The backfill material placed during repair might have remained intact during dry season. However, during rainy season due to seepage water, weak planes reappear and materials slide off at Places along the slope causing heavy damages. To prevent or minimize this continuous process of damage and repair, properly designed concrete retaining walls founded on rock and/or supported by short piles/caissons socketed into rock along the slope will be proposed. This will help to retain the backfill materials placed in the sinking area, thus minimizing the chances of further sinking of the pavement. Also Rock Anchor may be used for specific locations depending on the recommendation of Geologist.

DESIGN OF FLEXIBLE PAVEMENT

1.0 Introduction

The existing single/two lane carriageway will be widened to two lanes. There will be eccentric widening mostly and concentric widening in stretches with reference to the existing carriageway to accommodate the two lanes with paved shoulder suitably within the right of way (ROW). Pavement design will, therefore, comprise: -

New construction: Widening configuration – eccentric widening: 1/2 lane carriageway with each lane of 3.5m width, paved shoulder 1.5m width at 2.5% slope & unpaved shoulder 2.0m width at 3.5% slope.

1.1 Design of flexible pavement.

1.1.1 In consonance with design standards adopted, the flexible pavement has been designed for 15 years service life. This agrees with Manual of specification and standards for four laning and two laning. Also IRC 37 of 2012 indicates such design for 15 years.

1.1.2 CBR of Subgrade

The borrow area soil, as revealed from laboratory tests, is mostly of CL or ML-CL classification and SM or SM-SC classification in the end stretch having MDD of 18 to 18.3 / cum at OMC 10.62% - 13.48% and 4 days soaked CBR of 7.6% to 8.8%. Improvement of borrow soil to attain a minimum CBR of 5% will be attained.

1.1.3 Design Traffic

As recommended by Traffic Analyst the design VDF is 1.50. Traffic Analysis has resorted to the rigorous analysis of regression etc. on the growth rates derived by the elasticity method and the various growth rates are produced in the following table for Traffic Information. The probable cumulative million standard axles have been calculated from the probable date of completion of the project road and opening to traffic in the year 2017 to 15 years design period. ESA computations have been done on the basis of different growth rates. The design of pavement has been done considering the highest volume of Bus, 2 Axle Truck & MAV among the count stations appropriate to CSA of 20.00 msa and further strengthening is proposed to be carried out to extend the life at the appropriate time based on deflection measurements as per IRC:81-1997.

1.1.4 Homogeneous section

The design CBR value being more or less same throughout, the entire length of the project road has been designed for the highest of the traffic obtained in the count stations as detailed earlier for the package.

1.1.5 Design thickness of flexible pavement layers in new construction.

By IRC : 37-2012

From the pavement thickness design chart of IRC-37 of 2012 and cumulative standard axles of 20.00 msa, the pavement thickness is found to be 690 mm for design life of 15 years. Plate 3 of page 26 of IRC:37-2012 has been considered.

Pavement design as per IRC:37-2012 is based on mechanistic pavement design principle which has evolved from theoretical, laboratory and pavement performance studies on Indian pavement materials and pavements constructed in India. In IRC:37-2012, for analysis, DBM layer with 60/70 bitumen and an annual average pavement temperature (AAPT) of 35°C have been used. The vertical strain between the dual wheels and the horizontal tensile strain at the bottom of the DBM layer below one of the wheels are assumed to be the design criteria for fatigue and rutting failure of the pavement. Apart from the axle load, the design thickness depends on tyre pressure and the wheel configuration. The standards taken for single wheel load, tyre pressure and wheel configuration are at variance with different codes of practices. IRC:37-2012 adopts 20.5 KN as single wheel load, 310 mm as centre to centre distance between dual wheels and 560 Kpa as tyre pressure whereas shell Pavement Design Manual, London adopts these parameters as 20.0 KN, 315 mm & 600 Kpa and Austroads adopts these parameters as 20.5 KN, 330mm & 550-700 Kpa respectively, as basis of mechanistic pavement design approach.

The bituminous pavement design charts in India are calibrated as per constant AAPT of 35°C throughout the design period. However, pavement design, which takes into account temperatures prevalent in various seasons as well as various regions, would definitely give more reliable results compared to the pavement design that assumes single value of AAPT throughout the whole design period.

1.1.6 Design of Flexible Overlay

Overlay corresponding to 20.00 msa will have the following pavement composition:

40mm BC + 100mm DBM + 75mm BM + 250mm WMM over a layer of 300mm GSB for drainage.

æ Pavement Composition for New Paved Shoulder of Carriageway:

It is proposed that the pavement composition for new paved shoulder shall comprise, as follows:

GSB	:	300 mm
WMM Base Course	:	250 mm
BM	:	75 mm
DBM	:	100 mm
BC	:	40 mm
		690 mm

1.2 Flexible pavements for Service Roads / Merge Lanes

There is no such case.

Paved Shoulders:

Flexible pavement of main carriageway will be repeated in paved shoulders on both sides carriageway.

15 years Axle Load = 20.00 msa

Adopted Cumulative Equivalent Single Axle repetition = 20.00 msa

Referring to Fig-4 & Plate –3, IRC:37-2012 corresponding to 4-day soaked CBR of 5% the recommended pavement layers are –

GSB	-	300 mm
WMM	-	250 mm
DBM	-	100 mm
BC	-	40 mm
		690 mm

Environmental Impacts

Soil Survey consisting of Test Pits and G.T.I Bore holes, carried out at requisite intervals, shows that soil conditions do not vary substantially along the project length. Thus, one pavement cross-section design will serve for the entire project length. The project area experiences high rainfall and the roadbed soil is predominant in clay which is susceptible to swelling. The design considerations will therefore, include the aspect of constructing an efficient drainage system capable of removing excessive moisture in earliest time. As such, drainage layer has been provided upto the slope face of road embankment.