Alignment of Hill Roads: chapter-5

1. Administrative, developmental and strategic needs would determine the obligatory points to be connected by a hill road. Control points would be governed by saddles, passes, river crossings, and other natural features such as unstable areas.

2. For arriving at a few possible alternative alignments, investigation should start only from the obligatory summit points and proceed downwards

3. The alignment finally selected by linking the obligatory and control points should satisfy the requirements of geometries vis-a-vis the needs of traffic, as also the terrain and climatic conditions. Optimum alignment will be the one which yields the least overall transportation cost —costs of construction and maintenance of the road as well as the recurring cost of vehicle operation, and at the same time have least adverse impact on the environment and ecological balance.

4. The route should avoid the introduction of hair-pin bends as far as possible. If considered unavoidable, their number should be absolute minimum. Further, the bends should be located on stable and flat slopes. Location of hair-pin bends in valleys should be avoided. Also, a series of hair-pin bends on the same face of the hill should be avoided.

Resisting Length:

The concept of resisting length may be utilised as one of the criteria in assessing the suitability of alternative alignments.

The resisting length of a road is its effective length taking into account the total work done against the resistances. If two points are to be connected by the shortest distance in a straight line, the gradient may be steeper than the ruling gradient; therefore, it becomes necessary to increase the length so as to have the desired ruling gradient. This is especially true in the case of hill roads in view of high differences in elevation in relation to the horizontal distance

In practice, it is not possible to follow a uniform gradient; this gives rise to the adoption of effective rises and falls. This ineffective rise and fall is obtained by subtracting the actual difference in elevation between two points from the sum of ineffective rise and fall. (This is, the sum of total rise and total fall in excess of the 'floating gradients' – the gradients at which no tractive effort is involved by the vehicle to maintain the design speed.) The resistances considered are the friction and the potential energy overcome from moving from a point of lower elevation to that of a higher one.

The resisting length is obtained by adding to the actual length of the route, the product of the ineffective rise and fall and the reciprocal of the coefficient of friction between the vehicle tyres and the pavement surface.

Since, in hill roads, ineffective rises and falls are unavoidable, the particular alignment for which the resisting length is the minimum is the most desirable one. This criterion has to be used along with other requirements.

Procedure of Fixing the Alignment:

The following are the steps in fixing the alignment and translating it on to the ground:

(a) Reconnaissance survey

(b) Preliminary survey

(c) Determination of final centre line

(d) Final location survey.

The broad principles applicable to hill road location are:

(i) The alignment should be as direct as possible between obligatory and control points to be linked in order to achieve the maximum possible economy.

(ii) It should steer clear of obstruction and utility services such as overhead transmission lines and water supply lines.

(iii) Crossing of railway lines, water courses and ridges should be avoided as far as possible.

(iv) Large-scale cutting and filling should be avoided as far as possible. Use of tunnels to avoid deep cuts should be considered where feasible and economical.

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(v) The route should enable ruling gradient to be attained for most of the length.

(vi) Unstable hill features, water-logged areas, and areas subject to seepage should be avoided as far as possible.

After reconnaissance survey, the line and grade of the selected alternative is pegged. (‘Line’ relates to horizontal alignment and ‘grade’ to vertical alignment)

Trace Cut:

A trace cut consists of 1 to 1.2 m wide track constructed along the selected alignment to facilitate access to the area for inspection and further surveys. In general, gradients along the trace cut should be easier by 10 to 20% than the standard limiting gradients.

In areas of hard rock where cutting is expensive, dry rubble walls or filling may be used to gain access. Even timber platforms or bamboos supported over framework supported on ledges may be provided.

Preliminary Survey:

A preliminary should cover a strip of 15 m on either side of the centre line on straight reaches, and 30 m on either side on curved reaches. Traverse survey should be run along the trace with a theodolite.

Final Centre Line:

Also known as paper location, this should be marked on the plan. Horizontal and vertical curves should be fully designed.

Final Location Survey:

The final centre line should be laid out on the ground in the field. This involves staking out the centre line using a theodolite and detailed levelling. The stakes should be at 20 m intervals. Bench-marks should be established at intervals of 250 m and at all drainage crossings.

Longitudinal sections and cross-sections shall be taken at all staked stations. Cross-sections should extend up to the right of way and levels should be taken at 2 to 5 m intervals.

In the last stage of alignment survey, hydrological and soil investigations for the route should be carried out; this helps in deciding on the drainage and protection works.

Geological Consideration in Alignment:

Natural slope stability should be preserved while constructing hill roads. In view of this, geological and hydrological conditions should be studied and taken into consideration.

Stability of a slope depends on the nature of the rock, inclination or dip of the strata, geological defects like folds and faults, and the ground

Geometric Design Aspects of Hill Roads:

Right of Way or Road Land Width:

Desirable values of width are given in Tables 9.1 and 9.2.

Table 9.1 Desirable land widths (m) (IRC: 52–1982)

S. No.	Road classification	Open area		Built-up area	
		Normal	Exceptional	Normal	Exceptional
1.	NH and SH	24	18	20	18
2.	MDR	18	15	15	12
3.	ODR	15	12	12	9
4.	VR	9	9	9	9

Width carriageway, shoulder and roadway are given below:

Table 9.2 Carriageway, shoulder and roadway widths (IRC: 52–1982)

S. No.	Road classification	Width (meters)		
		Carriageway	Shoulder	Roadway
1.	NH&SH: Single-lane	3.75	2 × 1.25	6.25
2.	NH&SH: Double-lane	7.00	2 × 0.90	8.80
3.	MDR and ODR	3.75	2 × 0.50	4.75
4.	VR	3.00	2 × 0.50	4.00

Camber or Cross Fall:

On straight sections, the recommended values are:

Earth roads	3 to 4 percent
Gravel or WBM roads	2.5 to 3 percent
Thin bituminous surfacing	2.0 to 2.5 percent
High type bituminous surfacing	1.7 to 2.0 percent

The camber for shoulder should be 0.5% more than the pavement value, subject to a minimum of 3 percent. On super-elevated sections, the cross-fall of shoulders should be the same as that for the pavement.

Design Speed:

The design speeds for various categories of hill roads are given in Table 9.3.

Table 9.3 Design speeds (km/h) (IRC: 52–1982)

S. No.	Road classification	Mountainous terrain		Steep terrain	
		Ruling	Minimum	Ruling	Minimum
1.	NH and SH	50	40	40	30
2.	MDR	40	30	30	20
3.	ODR	30	25	25	20
4.	VR	25	20	25	20

Normally 'ruling design speed' should be the criterion for correlating the

Sight Distance:

Three types of sight distance are relevant to the design of summit, where vertical curves or horizontal curves are concerned – Stopping sight distance, intermediate sight distance, and overtaking sight distance.

On hill roads, stopping sight distance is the absolute minimum from the point of view of safety; wherever possible, intermediate sight distance should be provided to provide reasonable overtaking opportunities. Provision of overtaking sight distance is not feasible on hill roads. Intermediate sight distance is twice the stopping sight distance. Design values of stopping sight distance for different design speeds are set forth in Table 9.4.

Table 9.4 Design values of stopping sight distance for hill roads (IRC: 52–1982)

Horizontal Alignment:

In general, circular curves with spiral transitions at both ends should be used. Minimum radius curves should be adopted only when absolutely necessary. Compound curves and reverse curves may be used if a simple circular curve is not feasible. At reverse curves, sufficient gap should be ensured to provide the requisite transition curves.

Superelevation:

This is calculated from the formula –

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

e being the rate of superelevation; V, the design speed in km/h and R, the radius of the curve in metres. But this should be limited to 10 percent normally, and 7 percent in snowbound areas.

Minimum Radii on Horizontal Curves:

These are calculated from

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

Where, f = coefficient of lateral friction, taken as 0.15. The values for various classes of hill roads are given in Table 9.5.

S. No.	Classification of road	Mountainous terrain		Steep terrain	
		Ruling Min. (m)	Absolute Min. (m)	Ruling Min. (m)	Absolute Min. (m)
1.	NH and SH	80	50	50	30
2.	MDR	50	30	30	14
3.	ODR	30	20	20	14
4.	VR	20	14	20	14

These values are for areas not affected by snow. For snow-bound areas, the value may be a little more than these.

Transition Curves:

Spiral curves should be used as transition curves. Minimum length of transition curves depends on the curve radii and the design speeds.

For a design speed of 50 km/h and for a curve radius of 80 m, the minimum length of transition recommended is 55 m.

For a design speed of 20 km/h and for a curve radius of 15 m, the minimum length of transition is 30 m. The details of the requirements of transition curves are available in IRC: 52-1982.

Widening of Pavement on Curves:

An extra width of 1.5 m for two-lane and 0.9 m for single lane is recommended for a curve radius up to 20m.

Set-Back Distance at Horizontal Curves:

Vertical Alignment:

General:

Smooth longitudinal profile should be provided consistent with the category of the road and the terrain. Grade changes should not be very frequent. Grades should be carefully selected, since it is difficult and costly to change them later.

The vertical profile should be compatible with the horizontal alignment and should be properly co-ordinated with it.

Gradients:

Recommended gradients for different terrain conditions expect at hair-pin bends are given below:

Table 9.6 Recommended gradients for hill roads (IRC: 52–1982)

S. No.	Classification of gradient	Mountainous terrain and steep terrain having elevation more than 3000 m above MSL	Steep terrain up to 3000 m elevation above MSL
1.	Ruling	5%	6%
2.	Limiting	6%	7%
3.	Exceptional	7%	8%

The rise in elevation should not be more than 100 m in mountainous terrain and 200 m in steep terrain in 2 km length.

Design speed (km/h)	Min. grade change (%) not requiring a vertical curve.	Minimum length of Vertical Curve (m)
Upto 35	1.5	15
40	1.2	20
50	1.0	20

Summit Curves:

The length of summit curves is governed by the choice of sight distance- stopping sight distance or intermediate sight distance.

Valley/Sag Curves:

The length should be such that, for night travel, the headlight beam distance is equal to the stopping sight distance.

Ready-made charts for the length of vertical curves—both summit and valley curves are given in IRC: 52-1982.

Alignment Compatibility:

As a general rule, changes in horizontal and vertical alignments should be phased to coincide with each other, i.e., the vertical curve should roughly extend from the commencement to the end of the corresponding horizontal curve. Preferably, the horizontal curve should be somewhat longer than the vertical curve.

Sharp horizontal curves should not be introduced at or near the top of summit vertical curves or the lowest point of valley curves.

Hair-Pin Bends:

A hair-pin bend may be designed as a circular curve with transition curves at each end. Alternatively, compound circular curves may be provided, this gains significant elevation.

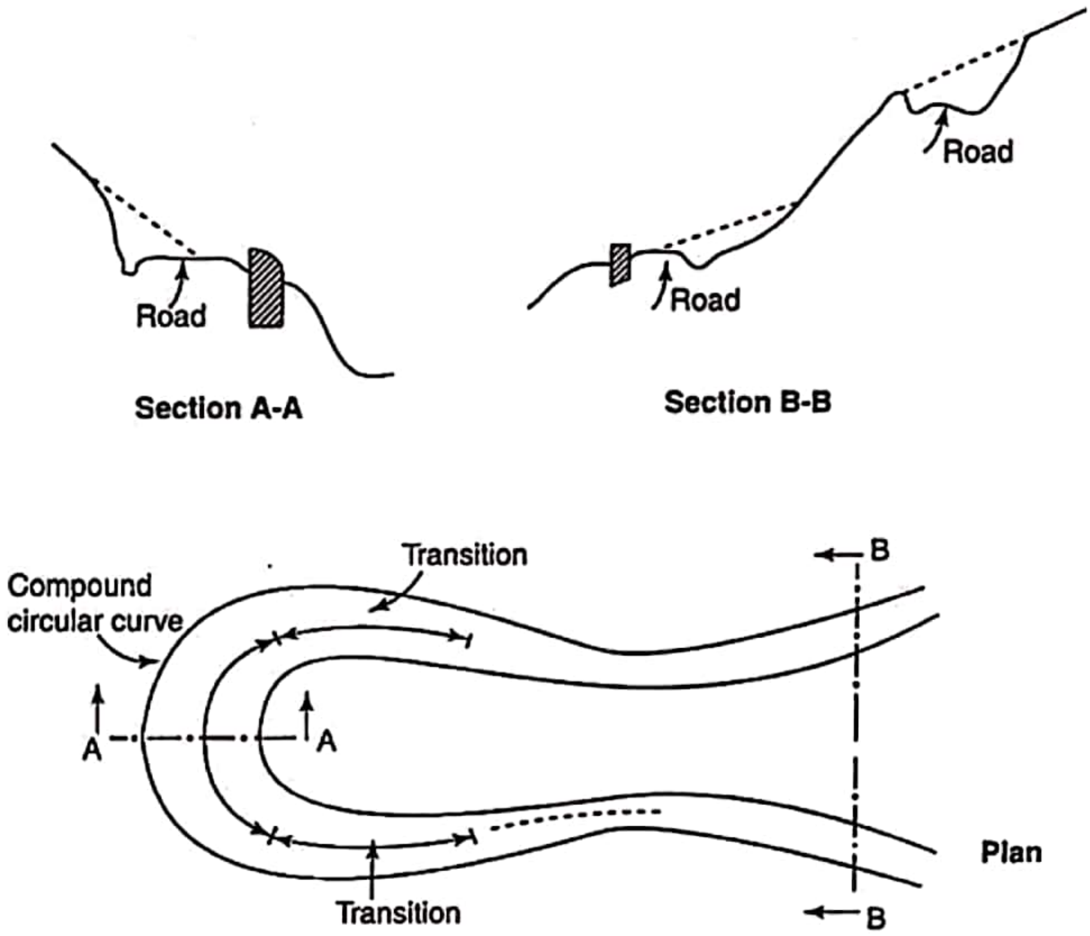
The following are the design criteria for hair-pin bends:

(i)	Minimum design speed	20 km/h
(ii)	Minimum roadway width at apex	
	NH and SH	11.5 m for double-lane 9.0 m for single-lane
	MDR and ODR	7.5 m
	VR	6.5 m
(iii)	Minimum radius for the inner curve	14 m
(iv)	Minimum length of transition	15 m
(v)	Gradient	
	Maximum	1 in 40 (2.5%)
	Minimum	1 in 200 (0.5%)

The main difference between a hair-pin bend and a sharp curve (in the horizontal plane) is that in the former, there is only a small horizontal distance separation, while in the latter, it could be significant, but without difference in level.

A minimum intervening length of 60 m should be provided between successive hair-pin bends. It is also preferable to have the width of the full roadway surfaced at hair pin bends.

A schematic of a hair-pin bend is shown in Fig. 9.1.



Pavement Surface for Hill Roads:

Since these are built in hilly regions where rainfall is generally heavy, a WBM surface is not considered suitable in view of its pervious nature, requiring frequent repairs. Cement concrete pavements are considered prohibitively costly and require more time for construction and provisions for joints and curing.

For these reasons, bituminous surfacing with a WBM base course is considered suitable for hill roads.

For cold regions, IRC recommends penetration (grouted) macadam with 175/225 penetration grade bitumen. Cut-backs may also be used with slight heating. A rapid curing cutback-RC-3- is considered to be suitable for use even in freezing temperatures.

In border areas, strategic hill roads are built with mastic asphalt surfacing in view of its capacity to carry heavy loads from even military tanks.

Periodic maintenance will help in keeping a hill road fit for continuous use.

Drainage Aspects of Hill Roads:

The drainage practices relevant to hill roads are given below:

(i) Camber:

This has already been covered under geometric design. This ranges from 2 percent (1 in 50) for high type bituminous surface to 2.5 to 3 percent (1 in 40 to 1 in 33) for WBM/gravel surface.

(ii) Side-Drains:

Side-drains are provided only on the hill side of the road. The size of the drain may be 0.60 m x 0.45 m of triangular shape and is unlined. Kerb and channel type of drain is recommended and is popularly used (Fig. 9.9).

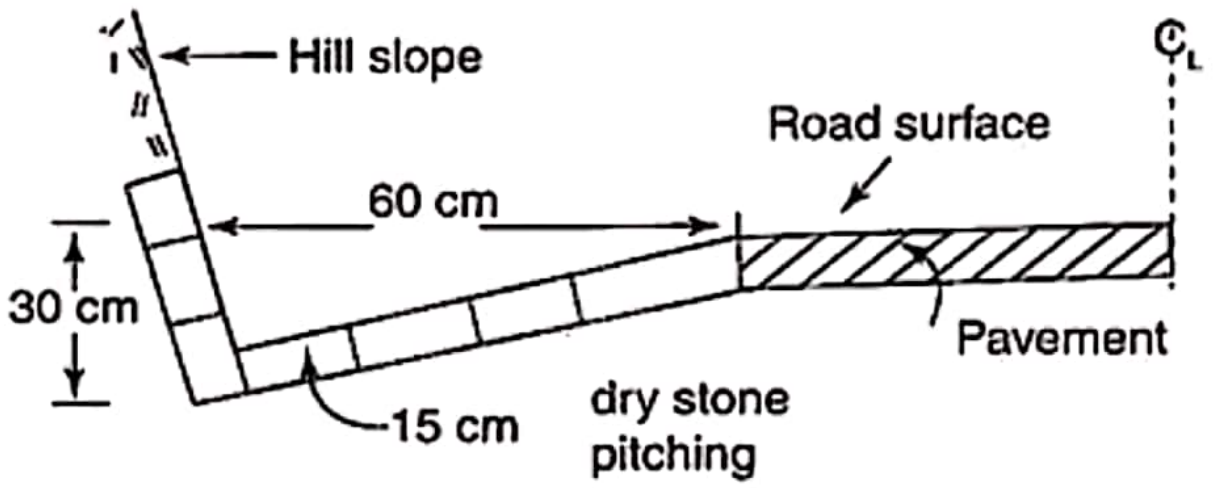


FIG. 9.9 *A typical kerb and channel drain*

(iii) Catch-Water Drains:

Catch-water drains are used to intercept the surface run-off from the hill slope, drain it parallel to the road and lead into a cross-drainage structure such as a culvert at a convenient location (Fig. 9.10).

It is necessary to design these for no overflow and for avoiding high velocity flow; it is therefore preferable to pave the bed and the sides.

(iv) Cross-Drainage and Protection Works:

Cross-drainage works such as culverts, causeways and scuppers have to be provided at reasonable intervals along the road to drain off the water from catch-water drains and side-drains to a safe location away from the road.

For important hill roads, culverts – pipe culverts, slab culverts and arch culverts – and minor bridges should be designed and constructed at appropriate intervals along the length of the road.

For minor or unimportant roads with low volume of traffic, causeways (or submersible bridges) and scuppers (or dry masonry coursed rubble culverts), which are less expensive may be provided.

(v) Sub-Surface Drainage:

The seepage flow and high ground water table may cause problems of stability underneath the roadway. Seepage flow may cause stability problems for the hill slope too.

Hence, a suitable sub-surface drainage system consisting of longitudinal and/or cross, drains, may be designed and constructed depending upon the depth to hard strata, amount and intensity of rainfall and other pertinent factors.

Maintenance Aspects of Hill Roads:

The following are the maintenance aspects of hill roads:

(a) Maintenance of drainage structures

(b) Clearance of snow in snow-bound areas

(c) Prevention and correction of land slides

(d) Control of avalanches.

(a) Maintenance of Drainage Structures:

The various component structures of the drainage system such as side-drains, catch-water drains, cross-drainage works such as scuppers, culverts and causeways, and sub-surface drains, if any, have to be cleaned periodically to remove the silt and other extraneous materials, so as to allow smooth flow of water.

As a precautionary measure, turfing and planting of trees on the hill slopes tend to reduce the velocity of the surface run-off and prevent the scouring action and erosion of unstable earth material.

(b) Clearance of Snow in Snow-Bound Areas:

In snow-bound areas such as the Himalayan region, the problem of snow-cover on the road is acute, especially during winter months. Compacted snow surfaces are dangerous and are traffic hazards; hence the need to remove snow and ice as fast as possible.

Snow markers or wooden poles with metre divisions marked on them are erected before the onset of winter. These will help locate the roadway and estimate the amount of snow clearance needed.

(c) Prevention and Correction of Landslides:

Landslides are a very common problem encountered in hill roads. These are common in geologically young hill ranges. During the construction of roads, a lot of cutting of the rock is involved, which disturbs the natural conditions and the balance of forces. Slips, subsidence (or significant settlements), and landslide will result.

Increase in shear stress and reduction in shear strength are primary reasons for the occurrence of landslides, from a geotechnical engineering point of view.

Possible causes for increase in shear stress are:

(i) Cuts and quarrying, removing part of lateral support.

(ii) External traffic loads, weights of structures, and water in reservoirs.

(iii) Increase in surcharge due to snow.

(iv) Increase in pore-water pressure.

(v) Earthquakes and blasting operations.

Reduction in shear strength may be caused by:

(i) Swelling and pore-water pressure increase.

(ii) Alternate swelling and shrinkage, leading to cracking and subsequent inundation.

(iii) Presence of faults, discontinuities, joints and cleavage planes.

(iv) Seepage pressures of percolating water.

(v) Tree roots and burrowing by animals.

Techniques of Prevention and Correction of Landslides:

(i) Effective drainage measures like catch-water drains

(ii) Afforestation

(iii) Provisions of French drains as part of sub-surface drainage.

(iv) Grouting and rock bolting.

(v) Provision of check-walls, breast walls and toe walls.

(vi) Turfing and growth of vegetation on slopes.

(vii) Chemical treatment.

References

1. Highway Engg" Khanna & Justo"
2. www.engineeringnotes.com/highway construction//hill-roads allignment-geometric-design-and-maintenance-of hill roads /48805

Assignment Question

Q1. What are the special points to be considered in the alignment of hill road ? Discuss

Q2. Explain why design, construction & maintenance of hill roads need special consideration.

Q3. Writing short notes on
(I) Resisting Length
(II) Prevention of land slide
(III) Hair pin bend

Q4 Discuss the maintenance problem in hill roads.

Q.5. Explain briefly various problems in hill road construction & how they are overcome.