Transportation Engineering I

Hill Roads

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Introduction

- A hill road may be defined as the one which passes through a terrain with a **cross slope of 25% or more.**

- The hilly regions generally have extremes of climatic conditions, difficult and hazardous terrains, topography and vast high altitude areas.
- Region is sparsely populated and basic infrastructural facilities available in plain terrain are absent.
- Hence, a strong stable and feasible road must be present in hilly areas for overall development of other sectors as well.

Type of Terrain	Cross Slope
Level	0-10%
Rolling	10-25%
Mountainous	25-60%
Steep	>60%

Table 6-1 Terrain Classification

S.No.	Terrain Type	Percent Cross Slope	Degree
1	Plain	0-10	$0^{\circ} - 5.7^{\circ}$
2	Rolling	> 10-25	$> 5.7^{\circ} - 14^{\circ}$
3	Mountainous	>25-60	$> 14^{\circ} - 31^{\circ}$
4	Steep	>60	$> 31^{\circ}$

Source: NRS 2070

Introduction

- **Design and Construction Problems**

- Characterized by highly broken relief (steep slopes, deep gorges) with vastly differing elevations.
- Geological condition varies from place to place.
- Hill slopes before construction may not be as stable due to increased human activities.
- Due to highly broken relief, construction of special structures should be done at different places. This increases the cost of construction.
- Variation in the climatic condition such as the change in temperature due to altitude difference, pressure variation, precipitation increases at greater height, etc.
- High-speed runoff occurs due to the presence of high cross slopes.
- Filling may overload the weak soil underneath which may trigger new slides.
- The need of design of hairpin bends to attain heights.

Special Consideration in Hill Road Design

- **Special Consideration in Hill Road Design**
  - **Alignment of Hill Roads**
    - Selecting an alignment in the hilly region is a complex task.
    - The designer should attempt to choose a short, easy, economical and safe comforting route.
  - **General Considerations**
    - When designing hill roads, the route is located along valleys, hill sides and if required over mountain passes.
    - Due to complex topography, the length of the route is automatically increased.
    - Due to harsh geological conditions, special structures also have to be provided.
    - In locating the alignment **special consideration** should be made in respect to the variations in:
      - Temperature
      - Rainfall
      - Atmospheric pressure and winds
      - Geological conditions

Special Consideration in Hill Road Design

- **Special Consideration in Hill Road Design**
  - **Temperature**
    - Air temperature is in the hills is lower than in the valley. The temperature drop being approximately 0.5° per 100 m of rising.
    - On slopes facing south and southwest snow disappears rapidly and rain water evaporates quickly while on slopes facing north and northeast rain water or snow may remain for the longer time.
    - Unequal warming of slopes, sharp temperature variations and erosion by water are the causes of slope failure facing south and southwest.

Special Consideration in Hill Road Design

- **Special Consideration in Hill Road Design**
  - **Rainfall**
    - Rainfall increases with increase in sea level.
    - The maximum rainfall is in the zone of intensive cloud formation at 1500-2500 m above sea level. Generally, the increase of rainfall for every 100 m of elevation averages 40 to 60 mm.
    - In summer very heavy storms may occur in the hills and about 15 to 25% of the annual may occur in a single rainfall. The effects of these types of rainfall are serious and should be considered well.

Special Consideration in Hill Road Design

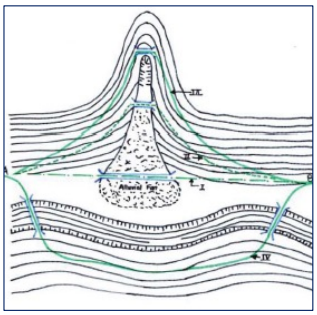
- **Special Consideration in Hill Road Design**
  - **Atmospheric pressure and winds**
    - It decreases with increase in elevation.
    - At high altitudes, the wind velocities may reach up to 25-30 m/s and depth of frost penetration is also 1.5 to 2m.
    - Intensive weathering of rocks because of sharp temperature variations which cause high winds.

Special Consideration in Hill Road Design

- **Special Consideration in Hill Road Design**
  - **Geological Conditions**
    - 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 water conditions.
    - The bedding planes in the case of sedimentary rocks should dip away from the cut slopes.
    - Cuts in granite, limestone and rubble are generally stable, while those in loam, clay, clay loam and shale are vulnerable.
    - Expertise of an engineering geologist and or a geotechnical engineer is valuable.

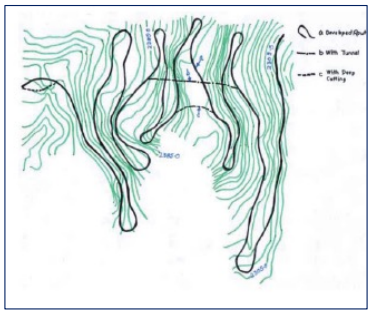
Special Consideration in Hill Road Design

- **Route Location in Hills**
  - **River route**
  - The location of a route along a river valley
  - Most common in hill road
    - Advantages
      - A gentle gradient
      - Low construction cost and operation cost
      - Availability of construction material
    - Disadvantages
      - Run through numerous horizontal curves
      - Requires the construction of large bridges
      - Necessary to construct special retaining structures and protection walls



Special Consideration in Hill Road Design

- **Route Location in Hills**
  - **Ridge route**
  - The road usually follows the top section of the hill system and crosses successively mountain pass.
    - Advantages
      - Least number of cross drainage structures
      - Road passes through relatively stable area
      - Less problem of avalanches
    - Disadvantages
      - Very steep gradient
      - A large number of sharp curves, i.e. hair pin bends
      - Extensive earthwork is required
      - Long length



Special Consideration in Hill Road Design

- **Geometric Design Aspects of Hill Roads**
  - Right of way, roadway, carriageway width
  - Design speed
  - Sight distance
  - Lateral and vertical clearance
  - Camber
  - Gradient

Special Consideration in Hill Road Design

- **Geometric Design Aspects of Hill Roads**
  - Right of way, roadway, carriageway width
    - Minimum width of 3.75m for single lane road (3.00 m for village roads)
    - Minimum shoulder width of 0.5m for rural roads and 1.25m for National road

	Total right of way (RoW) (m)	Setback distance from Road land boundary / (RoW) to Building line on either side (m)	Comment
District Road (Core Network)	20	6	10 m RoW on either side from road centre line
Village Road	15	3	7.5 m Row on either side from road centre line

Source: NRRS 2071

Special Consideration in Hill Road Design

- **Geometric Design Aspects of Hill Roads**
  - Design Speed
    - Based on the importance of the road and the type of terrain

Road Class	Plain	Rolling	Mountainous	Steep
I	120	100	80	60
II	100	80	60	40
III	80	60	40	30
IV	60	40	30	20

Table 7-1 Design Speeds, km/h

Road Class	Plain	Rolling	Mountainous	Steep
I	120	100	80	60
II	100	80	60	40
III	80	60	40	30
IV	60	40	30	20

Source: NRS 2070

Special Consideration in Hill Road Design

- **Geometric Design Aspects of Hill Roads**
  - Sight Distance
    - Adequate length should be available to permit drivers to control their vehicles
    - Stopping sight distance is the absolute minimum from the point of view of safety
    - Wherever possible, ISD is provided for reasonable overtaking opportunities

Speed, kmph	20	30	40	60	80	100	120
Stopping Distance, m	20	30	50	80	130	190	260

Table 8-1: Stopping distance

Speed, km/h	20	30	40	60	80	100	120
Stopping Distance,m	20	30	50	80	130	190	260

Source: NRS 2070

Special Consideration in Hill Road Design

- **Geometric Design Aspects of Hill Roads**
  - Sight Distance
    - Adequate length should be available to permit drivers to control their vehicles
    - Stopping sight distance is the absolute minimum from the point of view of safety
    - Wherever possible, ISD is provided for reasonable overtaking opportunities

Table 8.1-Safe Stopping Site Distance

Speed, km/hr	Perception and Brake Reaction Time, t (sec)	Coefficient of Longitudinal Friction	Safe Stopping Sight Distance, m
15	2.5	0.4	15
20	2.5	0.40	20
25	2.5	0.40	25
30	2.5	0.40	30
40	2.5	0.38	45
50	2.5	0.37	60

Source: NRRS 2071

Special Consideration in Hill Road Design

- **Geometric Design Aspects of Hill Roads**
  - Lateral and Vertical Clearance
    - To ensure visibility in the lateral direction
    - Minimum lateral clearance from the edge of the carriageway to nearest obstruction be equal to shoulder width
      - As per NRRS, normally 1m but may be reduced to minimum 0.5m in steep and difficult areas
      - Minimum set-back distance recommended is 3.2m
    - A vertical clearance of 5m measured from the crown of the road
      - In the case of overhead wires, poles, etc. at least 7m

9.1 Lateral clearance

Lateral clearance between roadside objects and the edge of the shoulder should normally be as given below

Hill road – normally 1.0 m but may be reduced to minimum 0.5 m in steep and difficult areas and where the cost of providing the full clearance is high.

Terai road – normally 1.5 m but may be reduced to a minimum of 1.0 m

9.2 Vertical Clearance

A vertical clearance of 5m should be ensured over the full width of roadway at all underpasses, and similarly at overhanging cliffs. The vertical clearance should be measured with reference to the highest point of the carriageway i.e the crown or super elevated edge of the carriageway. However, in the case of overhead wires, poles etc. clearance shall be at least 7.0 m above the road surface.

Source: NRRS 2071

Special Consideration in Hill Road Design

- **Geometric Design Aspects of Hill Roads**
  - Camber
    - On straight sections, the recommended values
    - Camber for shoulder should be 0.5% more than that a pavement and minimum 3%
    - At super elevated section, it should be same as in pavement.

Pavement type	Cement Concrete	Bituminous	Gravel	Earthen
Camber, %	1.5 to 2.0	2.5	4.0	5.0

Table 11-3 Camber, %

Pavement type	Cement Concrete	Bituminous	Gravel	Earthen
Camber, %	1.5 to 2.0	2.5	4.0	5.0

Source: NRS 2070

Special Consideration in Hill Road Design

- **Geometric Design Aspects of Hill Roads**
  - Camber
    - On straight sections, the recommended values
    - Camber for shoulder should be 0.5% more than that a pavement and minimum 3%
    - At super elevated section, it should be same as in pavement.

Table 13.1. Recommended camber cross slope

Camber		District Road (Core Network)		Village Road	
		Hill	Terai	Hill	Terai
Carriageway cross slope (%)	Earthen(existing)	5	5	5	5
	Gravel	4	4	4	4
	Bituminous Seal Coat	3	3	-	-

Source: NRRS 2071

Special Consideration in Hill Road Design

- **Geometric Design Aspects of Hill Roads**
  - Gradient
    - The gradients selected are close to maximum to reduce the earthwork and length of road and increased fuel consumption and reduction in operating speed
    - As per NRRS, ruling, limiting and exceptional gradients are 7, 10 and 12 respectively
    - The cumulative rise or fall in elevation should not exceed 100 m in mountainous terrain and 120 m in steep terrains.

Design Speed, kmph	20	30	40	60	80	100	120
Maximum Gradient, %	12	10	9	7	6	5	4

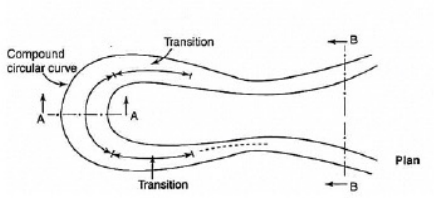
Table 10-1: Maximum gradients

Design Speed, km/h	20	30	40	60	80	100	120
Maximum Gradient,%	12	10	9	7	6	5	4

Source: NRS 2070

Special Consideration in Hill Road Design

- **Hair Pin Bend**
  - A reverse/compound curve formed by circumscribing the curve around the turning point.
  - Located on section having minimum cross-slope and maximum stability.
  - Minimum length of 60m between successive hair-pin bends.



Minimum Design Speed	20kmph
Minimum Radius of curvature	15m
Minimum length of transition curve	15m
Maximum longitudinal gradient	4%
Maximum superelevation	10%

Table 9-3 Hair Pin bends design parametres

Minimum design speed	20km/h
Minimum Radius of curvature	15m
Minimum length of transition curve	15m
Maximum longitudinal gradient	4%
Maximum superelevation	10%

Source: NRS 2070

Special Consideration in Hill Road Design

- **Hair Pin Bend**
  - A reverse/compound curve formed by circumscribing the curve around the turning point.
  - Located on section having minimum cross-slope and maximum stability.
  - Minimum length of 60m between successive hair-pin bends.

Asymmetrical

Table 11.1 Hairpin Bend Design Criteria

S.N.	Design standard	District Road (Core Network)	Village Road
		Hill	Hill
1	Minimum spacing between Hairpin Bends (m)	100 [1]	100[2]
2	Minimum radius of curve (m)	12.5	10
3	Minimum Roadway width at apex (m)	5.5 for a 4.5m roadway width 6.25 for a 5.25m roadway width	5 for a 4m roadway width
4	Maximum gradient (%)	4	4
5	Minimum gradient (%)	0.5 (max 1)[3]	0.5 (max 1)[4]
6	Maximum superelevation (%)	10	10
7	Minimum transition curve length (m)	15	15

Symmetrical

Source: NRRS 2071

Special Consideration in Hill Road Design

- **Hair Pin Bend – Length of Hairpin Bend**

Tangent length of reverse curve (T) is,

$$T = r\tan\frac{\beta}{2}$$

Where, r = radius of reverse curve,

β = Deflection angle

AE = BF = T + m

m = length of straight portion in between reverse & main curve

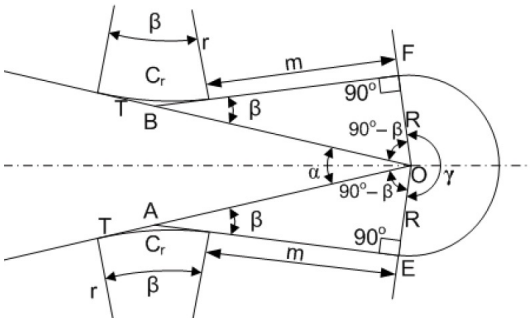
ΔAOE,

$$Tan\beta = \frac{OE}{AE} = \frac{R}{T+m} = \frac{R}{r\,tan\frac{\beta}{2}+m}$$

Where, R = Radius of main curve

From trigonometry, it is also be known that

$$Tan\beta = \frac{2\,tan\frac{\beta}{2}}{1-tan^2\frac{\beta}{2}}$$



Special Consideration in Hill Road Design

- **Hair Pin Bend – Length of Hairpin Bend**

Substituting this expression for tanβ becomes:

$$\frac{R}{r\tan\frac{\beta}{2}+m}=\frac{2\tan\frac{\beta}{2}}{1-\tan^2\frac{\beta}{2}}$$

$$R-R\tan^2\frac{\beta}{2}=2r\tan^2\frac{\beta}{2}+2m\tan\frac{\beta}{2}$$

$$(2r+R)\tan^2\frac{\beta}{2}+2m\tan\frac{\beta}{2}-R=0$$

$$Tan\frac{\beta}{2}=\frac{-2m\pm\sqrt{(2m)^2-4(2r+R)(-R)}}{2(2r+R)}$$

$$=\frac{-m\pm\sqrt{m^2+R(2r+R)}}{(2r+R)}$$

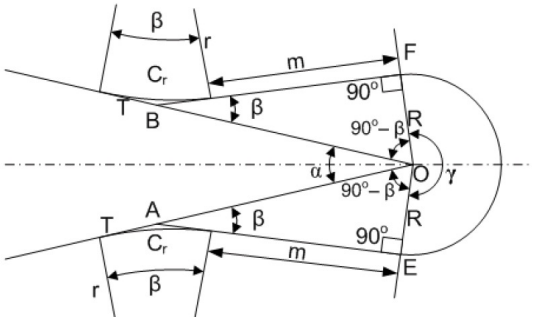
$$\therefore\ \gamma=360^\circ-2(90^\circ-\beta)-\alpha=180+2\beta-\alpha$$

The distance from the apex of the reverse curve to the centre of the main curve is :

$$AO=OB=\frac{T+m}{Cos\beta}=\frac{R}{Sin\beta}$$

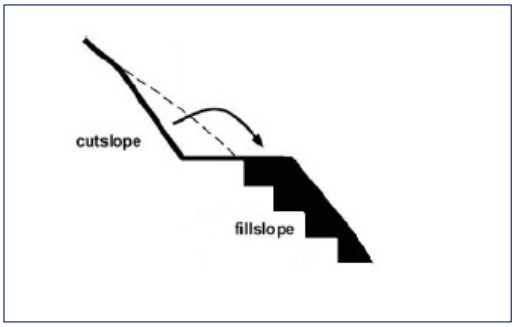
The length of main curve is $C=\frac{\pi Rr}{180}$

Total length of bend $S=2(C_r+m)+C$



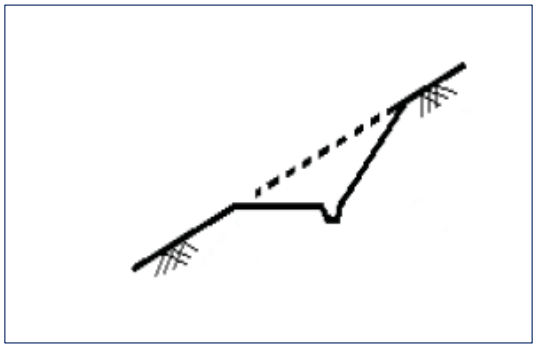
Special Consideration in Hill Road Design

- **Different types of hill road cross sections**
  - Cut and fill
    - Part of road section is filled with soil from cut part
    - For adequate stability, benches are made with height of 0.5m and length 1.5 to 3.0m



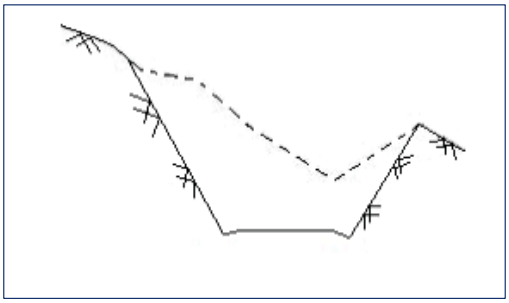
Special Consideration in Hill Road Design

- **Different types of hill road cross sections**
  - Bench cutting
    - Road section is formed by cutting only
    - Road bed is stable



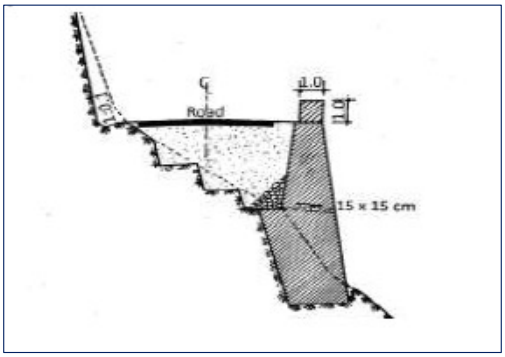
Special Consideration in Hill Road Design

- **Different types of hill road cross sections**
  - Box cutting
    - Trench type of cross section
    - Used when the location of road bed is unstable or unsuitable or formation level is to be lowered to meet geometric standard
    - Increase in earthwork



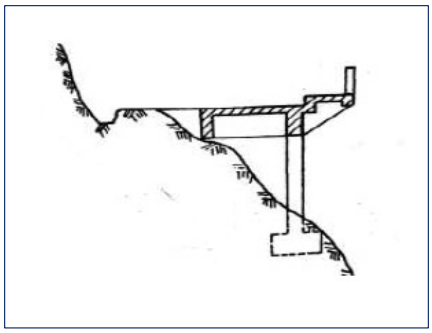
Special Consideration in Hill Road Design

- **Different types of hill road cross sections**
  - Embankment with retaining walls
    - Filling with the retaining wall reduces earthwork's cost, supports embankment soil and increases stability
    - Suitable when slope exceeds 30°



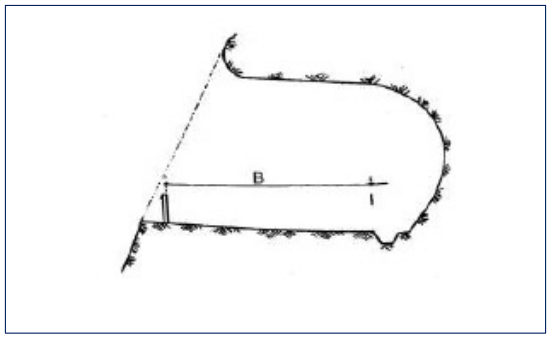
Special Consideration in Hill Road Design

- **Different types of hill road cross sections**
  - Semi bridge
    - If retaining wall needs to be at a substantial height, road bed with a semi-bridge type of structure may be constructed.



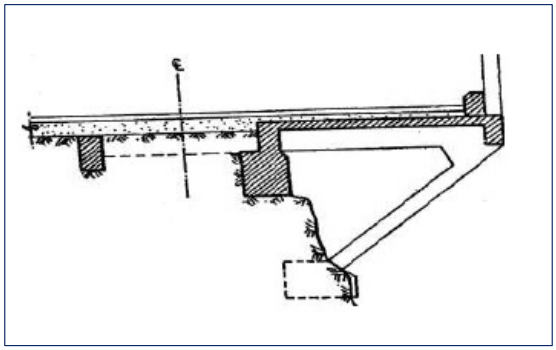
Special Consideration in Hill Road Design

- **Different types of hill road cross sections**
  - Semi tunnel
    - If rock is to be cut into steep hills, and rock is permitted to be overhang, semi-tunnel can be constructed to reduce rock works.



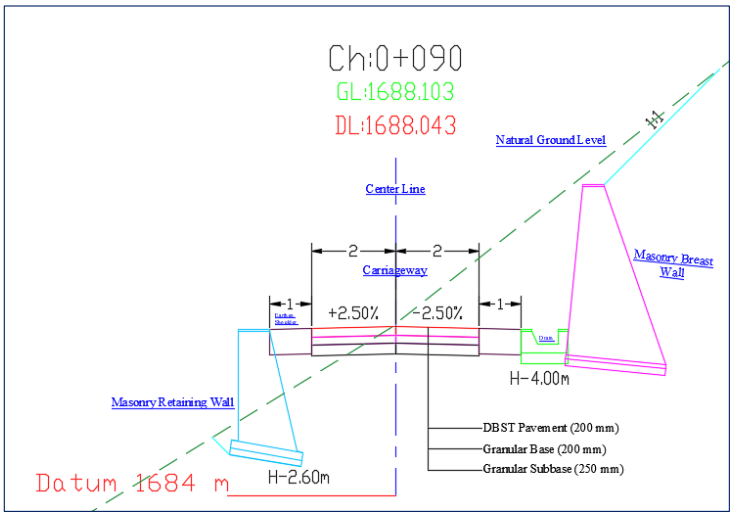
Special Consideration in Hill Road Design

- **Different types of hill road cross sections**
  - Platform
    - If the shifting of the route into the hillside lead to enormous rock, platforms are usually cantilevered out of the rock.



Special Consideration in Hill Road Design

- **Different types of hill road cross sections**



Special Structures in Hill Road

- **Special Structures in Hill Roads**
  - When constructing hill roads, a lot of special structures are required to counteract harsh geological and hydrological conditions as well as highly broken relief.
  - Following types of structures are mostly used in hill roads for strength, durability and stability.
    - Retaining Structures
    - Drainage Structures
    - Slope Protection Structures
    - Gully Control Structures
    - River Training Structures

Special Structures in Hill Road

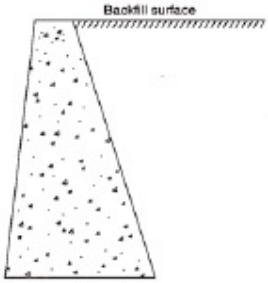
- **Special Structures in Hill Roads**
  - **Retaining Structures**
    - A wall constructed for supporting vertical or nearly vertical earth bank to resist earth pressure
    - Retaining walls are constructed on the cut hill side to prevent the slide towards the roadway
  - Situations where construction of retaining walls is required
    - Retain soil pressure
    - Places where the valley side surface gets saturated and likely to slip failure
    - Places where undercutting by a stream damage to the road
    - To achieve roadway width, where cutting into the hill is not economical or has to be restricted.

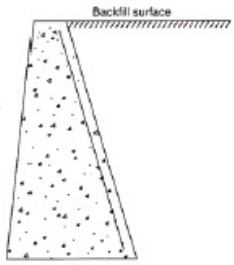
Special Structures in Hill Road

- **Special Structures in Hill Roads: Retaining Structures**
  - **Types of retaining walls**
    - According to materials used
      - Dry stone masonry
      - Dry stone with masonry band
      - Stone filled gabion wall
      - Stone masonry with cement sand mortar
      - Plain or reinforced concrete wall
      - Steel or timber
      - Reinforced earth

Special Structures in Hill Road

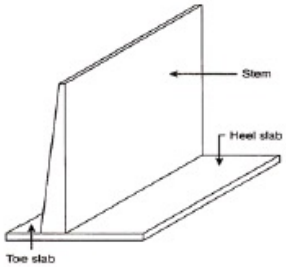
- **Special Structures in Hill Roads: Retaining Structures**
  - **Types of retaining walls**
  - According to structural function
    - Gravity wall – Resist earth pressure by means of their mass, constructed of the concrete, brick or stone masonry
    - Semi-gravity wall – Gravity wall provided with a small amount of reinforcement for reducing the mass of the concrete

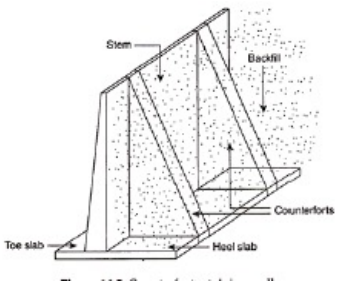




Special Structures in Hill Road

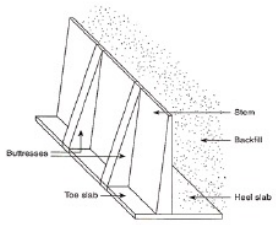
- **Special Structures in Hill Roads: Retaining Structures**
  - **Types of retaining walls**
  - According to structural function
    - Cantilever wall – Reinforced concrete walls in which lateral earth pressure is resisted by structural action of its members
    - Counterfort wall – Counter forts are provided on the backfill side above the heel slab

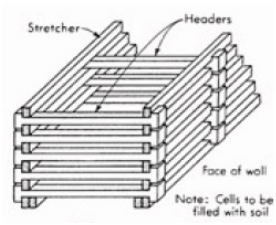




Special Structures in Hill Road

- **Special Structures in Hill Roads: Retaining Structures**
  - **Types of retaining walls**
  - According to structural function
    - Buttressed wall – The triangular beams are placed on the front side of the retaining wall
    - Crib wall – Composed of a series of stacked members creating hollow cells filled with soil or rock
    - Gabion wall – Steel wire cage filled with stone, constructed by stacking and tying wire cage filled rock on top of other. Usually battered towards slope.



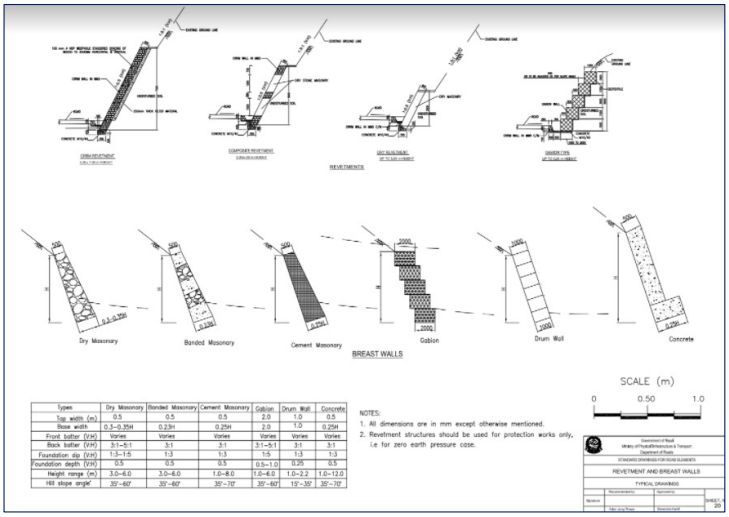


Special Structures in Hill Road

- **Special Structures in Hill Roads: Retaining Structures**
  - **Rule of Thumb Design**
    - Min. top width 0.45m to 0.6m
    - Front batter of 1 in 4 with rear side vertical
    - Base (0.4H + 0.3)
    - For height greater than 6m
      - Top width = 0.75m
      - Base (0.5H + 0.6)m

Special Structures in Hill Road

Special Structures in Hill Road



Source: Standard Drawings for Road Elements

Special Structures in Hill Road

- **Special Structures in Hill Roads**
  - **Drainage Structures**
    - The main problem that hill roads face are the harmful effect of water.
    - Water may come from different sources to the parts of the road. This water must be drained using any means necessary.
      - Drainage of water from hill slope – Catch water drain/Intercepting drain
      - Roadside Surface Drainage – Side drains
      - Cross Drainage Structures – Culverts/Causeways
      - Sub-surface Drainage System

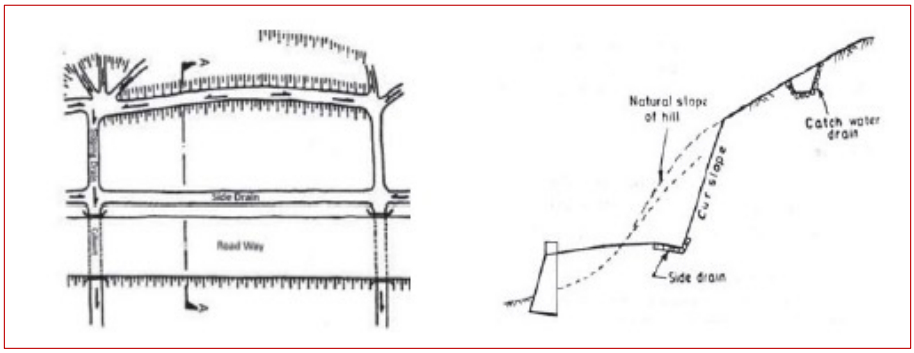
Refer Chapter 4 (Highway Drainage) for more

Special Structures in Hill Road

- **Special Structures in Hill Roads**
  - **Drainage Structures**
    - **Drainage in Hill Roads**
      - Surface drainage system
        - Camber
        - Side drains
        - Catch drains
        - Chute
        - Cross drainage structures
      - Sub-surface drainage system
        - Control of seepage flow
        - Reduction of water table
        - Prevention of capillary water and water vapour movement

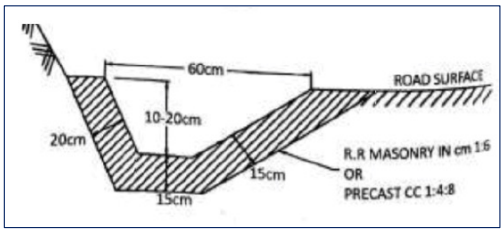
Special Structures in Hill Road

- **Special Structures in Hill Roads: Drainage Structures: Drainage in Hill Roads**
  - Catch drain
    - Ditches more or less parallel to the road
    - To catch and lead away the surface water coming from higher lying areas before it reaches the road
    - Trapezoidal cross-section



Special Structures in Hill Road

- **Special Structures in Hill Roads: Drainage Structures**
  - **Drainage in Hill Roads**
    - Side drain
    - Provided all along the hill side of the road
    - Usually constructed to such a shape that at emergency the vehicles could utilize this space for crossing
    - Shapes may be angular, saucer or kerb and channel drains



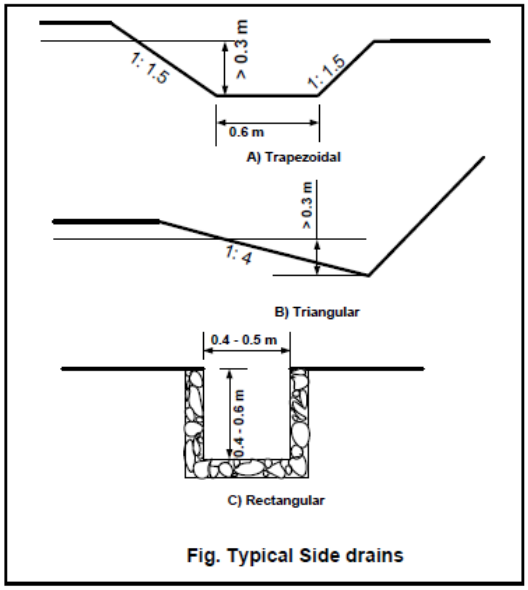
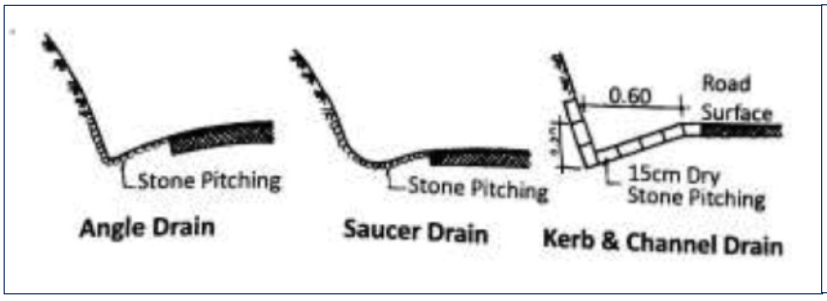
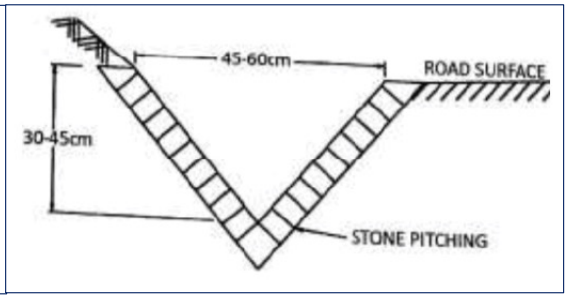


Fig. Typical Side drains

Special Structures in Hill Road

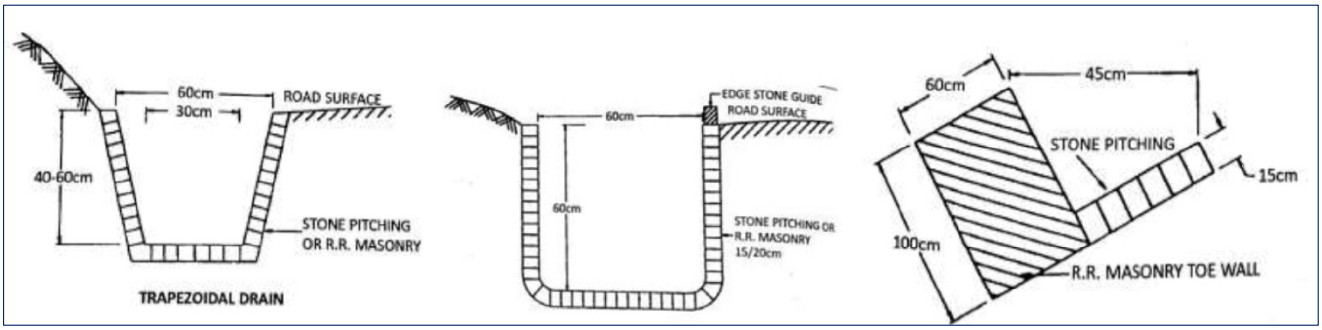
- **Special Structures in Hill Roads: Drainage Structures**
  - **Drainage in Hill Roads**
    - Side drain





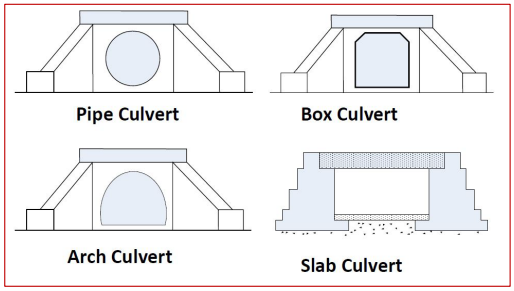
Special Structures in Hill Road

- **Special Structures in Hill Roads: Drainage Structures**
  - **Drainage in Hill Roads**
    - Side drain



Special Structures in Hill Road

- **Special Structures in Hill Roads: Drainage Structures: Drainage in Hill Roads**
  - Cross drainage structures
    - To drain off rain water collected in side drain and catch drain
    - Must be taken under the road
    - Provided with catch pits to collect debris and to prevent scouring
    - Culverts, causeways, etc.



Special Structures in Hill Road

- **Special Structures in Hill Roads: Drainage Structures: Drainage in Hill Roads**
  - Chutes
    - Use to bring down water from higher ground, usually collected in catch water drain
    - Lined or provided with energy dissipation to catch pit of culvert
    - Constructed with side walls that protect the channel banks against side splash erosion

Special Structures in Hill Road

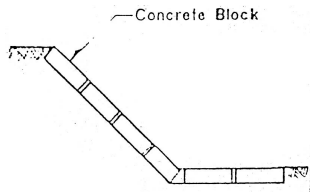
- **Special Structures in Hill Roads**
  - **Slope Protection Structures**
    - Landslides are very common due to steep slope.
    - Basic cause of landslide is the development of shear stresses more than the shear strength of the soil.
    - Fresh unturfed embankment and cut slopes are the least stable part of the road bed since the soil on the surface of the slopes is subjected to the direct action of sun, rain and wind.
    - **Causes of landslides**
      - Increase in moisture content of the soil in hill slopes which increases the pore water pressure.
      - Alternate swelling and contracting of the soil mass.
      - Seepage pressure of percolating groundwater.
      - Steeper slopes.
      - Human activities like blasting and using heavy vehicles at unstable zones.

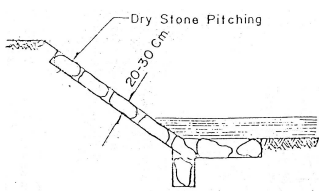
Special Structures in Hill Road

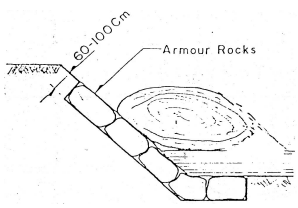
- **Special Structures in Hill Roads**
  - **Slope Protection Structures**
    - Vegetation Growth
      - Use of vegetation or it is part or vegetatative structure to prevent slope
      - Vegetataive turfing or grass is the most economical method

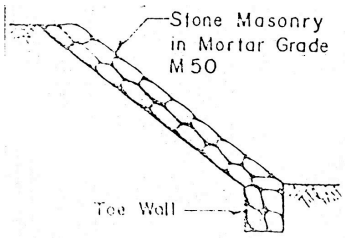
Special Structures in Hill Road

- **Special Structures in Hill Roads**
  - **Slope Protection Structures**
    - Stone pitching work
      - A slope is armored with stone pitching
      - Gives a strong covering
      - Freely drained and will withstand considerable water velocities
      - Dry stone, gabion, stone masonry, concrete block



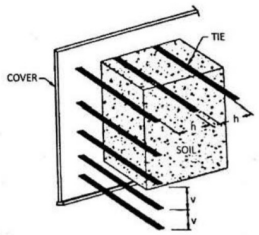






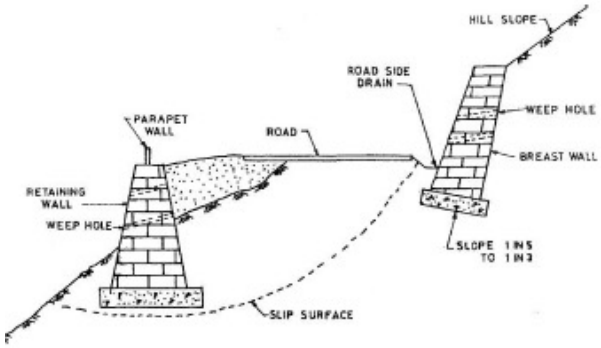
Special Structures in Hill Road

- **Special Structures in Hill Roads**
  - **Slope Protection Structures**
    - Reinforced Retaining wall
      - Retaining wall of composite construction material in which strength of fill is enhanced through the addition of inextensible tensile reinforcement in the form of strips, grids or geo-textiles.
      - Suitable for hill road because:
        - The fill material is readily available at cheaper cost.
        - Land required for embankment is less.
        - Cost effective, easy to construct and environment friendly.
        - Less alternation to natural slope.



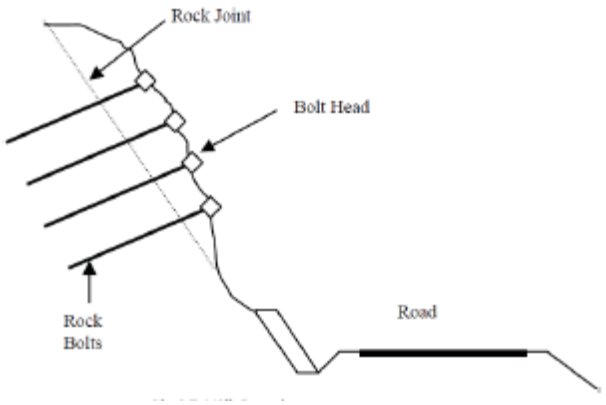
Special Structures in Hill Road

- **Special Structures in Hill Roads**
  - **Slope Protection Structures**
    - Revetment wall (Breast wall)
      - Provided on inner side of road and define road edge
      - Give protection to loose cut up hill slope, but does not resist lateral pressure
      - About 30cm thick
      - Gabion, dry stone, stone masonry, etc.



Special Structures in Hill Road

- **Special Structures in Hill Roads**
  - **Slope Protection Structures**
    - Rock bolting
      - Used for many years for the support of weak rocks
      - Consist of plain steel rods with a mechanical anchor at one end and a face plate and nut at the other
      - Space between the bolt and the rock can be filled with cement

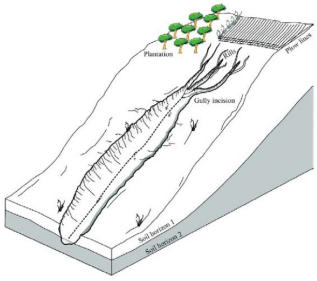


Special Structures in Hill Road

- **Special Structures in Hill Roads**
  - **Slope Protection Structures**
    - Shortcrete
      - Mixture of aggregate and Portland cement applied under pressure
      - Usually applied over a framework of reinforcing bars and steel mesh

Special Structures in Hill Road

- **Special Structures in Hill Roads**
  - **Gully Protection Structures**
    - Soil erosion/landside with steep sided drainage lines greater than 30 cm deep
    - Gullies are formed by an increase in surface run-off
      - Check dam or weir
      - Gully control dams
      - Chutes
      - Drop structure
      - Vegetative method
      - Stone pitching

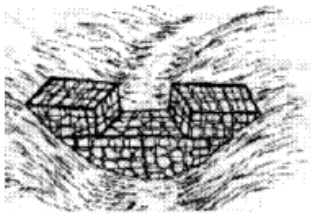


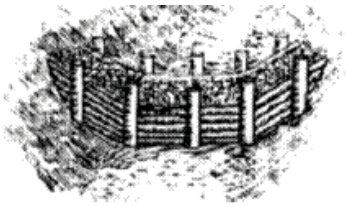
Special Structures in Hill Road

- **Special Structures in Hill Roads**
  - **Gully Protection Structures**
    - Check dam or weir
      - Constructed across gully bed to stop bed erosion
      - Diminish the velocity of water flow
      - Trap boulders and debris carried by water
      - Dry stone, gabions, masonry, concrete, etc. can be used

Special Structures in Hill Road

- **Special Structures in Hill Roads**
  - **Gully Protection Structures**
    - Gully control dams
      - One option for controlling an advancing gully is to 'drown' the gully head by building a dam just downstream.
      - The dam submerges the gully head and the subsequent reservoir of water removes the erosive force of water flowing over the head and prevents it from further erosion.



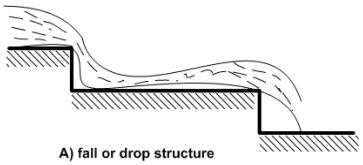


Special Structures in Hill Road

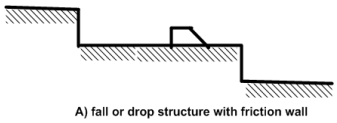
- **Special Structures in Hill Roads**
  - **Gully Protection Structures**
    - Chutes
      - Provided with energy dissipation at the outlet to help dissipate the energy gained when runoff flows down.

Special Structures in Hill Road

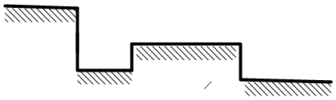
- **Special Structures in Hill Roads**
  - **Gully Protection Structures**
    - Drop Structure
      - Lowers the water level along its course, usually carrying water from catch drain to the side drain.



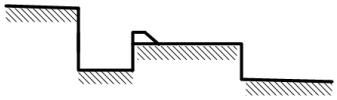
A) fall or drop structure



A) fall or drop structure with friction wall



A) fall or drop structure with stilling basin



A) fall or drop structure with stilling basin and friction wall

Special Structures in Hill Road

- **Special Structures in Hill Roads**
  - **River Training Structures**
    - **Problems created by river**
      - Frequent change in river course
      - Landslides in catchment
      - Change in bed slopes
      - Degradation of river bed downstream of a dam or barrage
      - Avulsion of one river into another

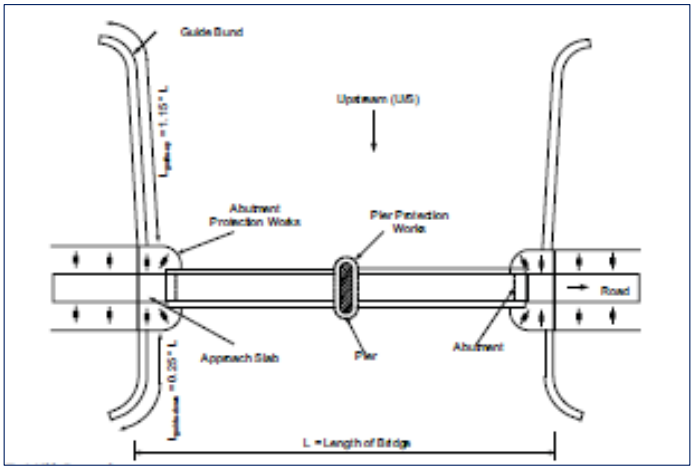
Special Structures in Hill Road

- **Special Structures in Hill Roads**
  - **River Training Structures**
    - Refers to structural measures which are taken to improve a river and its banks.
    - Important component in the prevention and mitigation of flash floods and general flood control.
      - Transverse Protection Structures – Check dams, spurs
      - Longitudinal Protection Structures – Levees or earth fill embankments, concrete embankments, revetments and rock riprap, sheet piles, etc.
      - Other Protection Structures – Sandbagging, channel lining, bamboo piles

Special Structures in Hill Road

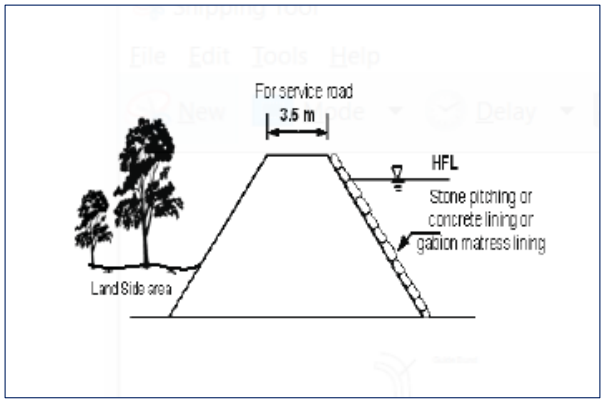
- **Special Structures in Hill Roads**
  - **River Training Structures**
    - Guide bund
      - Guides the river flow through opening structures.
      - Provided on either or both on the upstream and downstream of the structure.
      - Upstream length – 1L to 1.5L and downstream length is 0.25L to 0.4L.

        where, L is the length of the bridge



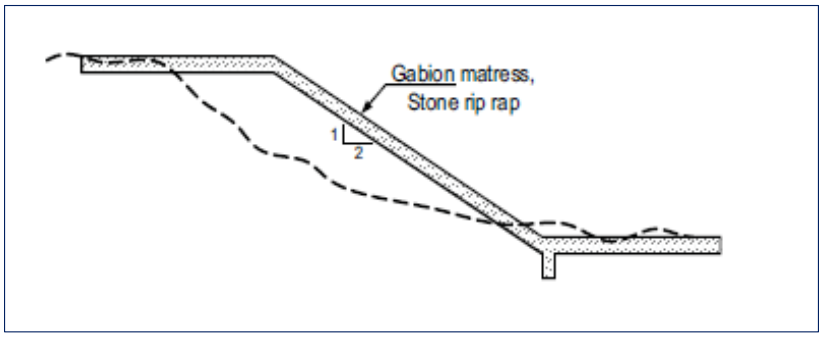
Special Structures in Hill Road

- **Special Structures in Hill Roads**
  - **River Training Structures**
    - Levees
      - Dam like earthen structure constructed along the river to protect surrounding area from flooding.



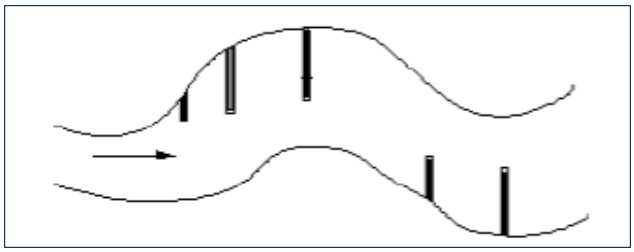
Special Structures in Hill Road

- **Special Structures in Hill Roads**
  - **River Training Structures**
    - Revetments (Ripraps)
      - Consists of a layered, various-sized rocks paced on a slopping bank.



Special Structures in Hill Road

- **Special Structures in Hill Roads**
  - **River Training Structures**
    - Spurs
      - Structure made to project flow from a bank into a stream or river deflecting the flow away from the side of river.
      - Help to train a river to flow along a desired course by preventing the erosion of the bank.
      - Gabions, bamboo, trunks and branches, masonry, concrete, etc.

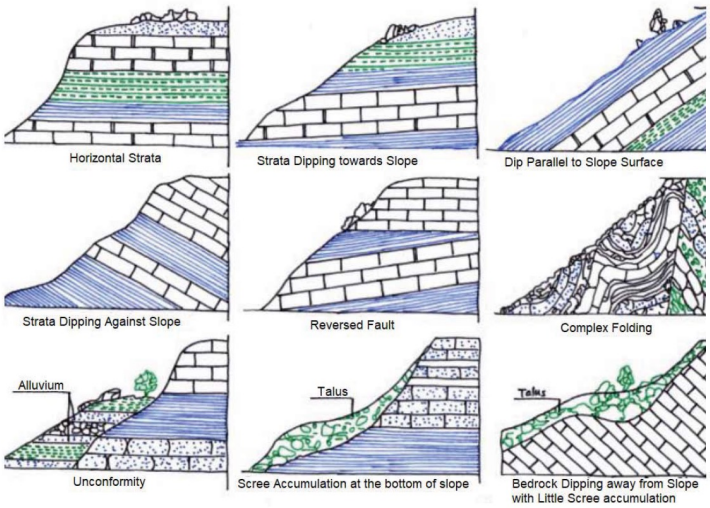


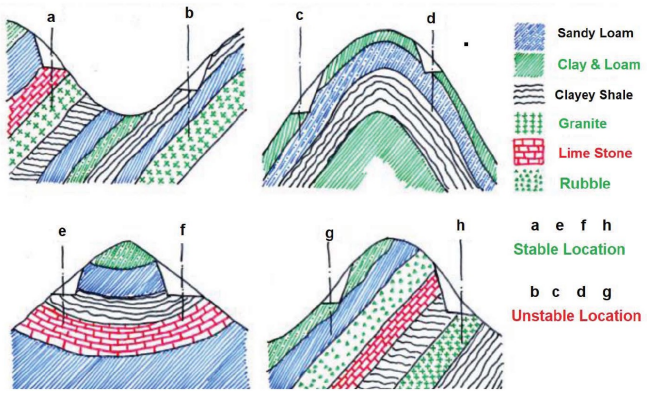
Special Structures in Hill Road

- **Special Structures in Hill Roads**
  - **River Training Structures**
    - Check dam
      - Refer previous slides/Chapter 4 (Highway Drainage)

Additional Materials [Special Considerations]

- **Special Considerations in Hill Road Design**





Hill Roads

Thank You!

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