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The
Note's On
Hill Road

Hill roads

Introduction of Hill roads: (L)

The terrain having cross-slope of more than 25% comes under hilly terrain. The road laid in the area having cross-slope of 25% or more is called Hill road.

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Design and construction problem in hill roads: (L)

Design and construction of road in hill and mountains is more complex tasks than in plains. It is because the several factors associated with regions some of includes them:

(i) A hilly or mountainous area is characterized by a hilly broken relief with widely differencing elevations stepp slope. This may cause unnecessary increases in the length of the road.

(ii) The formation of rock differs in a wide range. The geological condition varied from spot to spot or place to place. This will make difficult to across the foundation and find suitable one for the road embankment and other structure

(iii) New earth fill for road embankment may overland the relatively weak under lying soil type on hell ~~speed~~ slope.

(iv) Due to presence of high cross-slope surface runoff reaches quickely to the road sides with high speed.

(v) Design of hair pin bends and to gain ~~Kighly~~. heights

(vi) Frequent blasting is required due to the presence of hard rocks

(vii) Cross-slope highly stable before construction may turn into more unstable after construction

(viii) Need of special road ~~struction~~ structure such as ~~culvts~~ culvert, aqueduct, retaining structure etc

Special consideration in geometric design of hill roads:
↳ Special consideration in geometric design of hill roads are:

(i) Route location and alignment survey:
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(a) River route:
↳ Location of route is along a river valley is called river route.

Advantages:
(i) Gentle gradient
(ii) Vehicle operation cost is low.
(iii) Ability of water and other constructive materials can used from river sides.

Disadvantages:
(i) It involves numbers of curves.
(ii) Construction of large numbers of bridges.
(iii) High earthwork
(iv) Necessary speed structure constructs.

(b) Ridge Route:
↳ Location of route along top of hill is called ridge routes.

Advantages:
(i) Less curves
(ii) More services to people of hilly sides.
(iii) Short length of road
(iv) Less retaining structure

Disadvantages:
(i) steep gradient
(ii) No service to people of other sides of river.
(iii) Less availability of construction materials.

Geometric design of hill roads.
(i) Gradients:
↳ The gradients for the given section of the road is normally selected maximum one in order to reduce the earthwork and route length But the method of establishing maximum gradient according to power output is not accurate, For high altitude hill roads.

↳ Effects of altitude on vehicles:

Altitude	1,0000	2,0000	3,0000	4,0000	5,0000
Engine power reduction	11.3%	21.5%	30.3%	39.2%	46.7%

(ii) Camber: The recommended values of camber for hill roads are given below:-

S.N	Types of surface	Camber (%)
1.	Subgrades, earthworks (earthroads & shoulders	3.0 to 4.0 : to(1/25)
2.	Gravel and WBM surface	2.5 to 3.0
3.	Bituminous surfacing	2.5 (1/40)
4.	High type bituminuous surface and cement concrete	2.0 (1/50)

It is provided for:
(i) To drain water(i.e rain) from the road surface as quickely as possible
(ii) To prevent percolation of rainwater from pavement's surface
(iii) To segregating of traffic stream (i.e, lane divide)
(iv) To provide aesthetic appearance

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(iv) **sight distance:** The stopping sight distance is calculated from the relation:

$$S.S.D = 0.278\,vt + \frac{v^2}{254f} \quad ----(i)$$

where,
V = design speed of vehicles kmph
t = reaction time (2.5sec)
f = coefficient of friction = 0.4 (taken)

For overtaking sight distance:

$$OSD = 0.556\,V_b + 0.278\,V_b T + 2S + 0.278\,VT \quad -- (ii)$$

where,
V = speed of overtaking vehicle, kmph
V_b = speed of overtaken vehicle = (V-16) kmph
S = Spacing of moving vehicle = $(0.2V_b+6)$ m
T = Overtaking time = $\sqrt{\frac{14.4S}{A}}$
A = acceleration in kmph/sec

(v) **Super elevation:** The super elevation to be provided at horizontal curves of hill roads is calculated from the relations:

$$e = \frac{v^2}{225R} \quad -- (iii)$$

where,
V = Designs speed
R = Radius of curve

(vi) **Radius of horizontal curves:** The radius of horizontal curves in hill roads (minimum) is calculated by the formula:

$$R_{min} = \frac{0.008v^2}{e+f} \quad ---(iv)$$

where,
R = Radius of curve (m)
e = super elevation, V = Design speed, kmph
f = coefficient of friction

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(vii) Widening of curves: Extra width of carriage way (We) at horizontal curves is calculated from the relation:

$$W_e = \frac{1^2 n}{R} + \frac{0.1V}{\sqrt{R}} \quad \text{--- (v)}$$

where,

n = number of lane

(viii) Set back distance: As it is not possible to provide visibility corresponding to overtaking sight distance all along the hill roads and the alignment is made so as to provide at least the safe stopping sight distance.

(ix) Transition curves: The length of transition curves is to be calculated from the formula;

$$L = \frac{0.0215V^2}{CR} \quad \text{— (vi)}$$

$$C = \frac{80}{V+57} \quad \text{--- (vii)}$$

where,

L = Length of transition (m)

R = Radius, (m)

V = design speed (kmph)

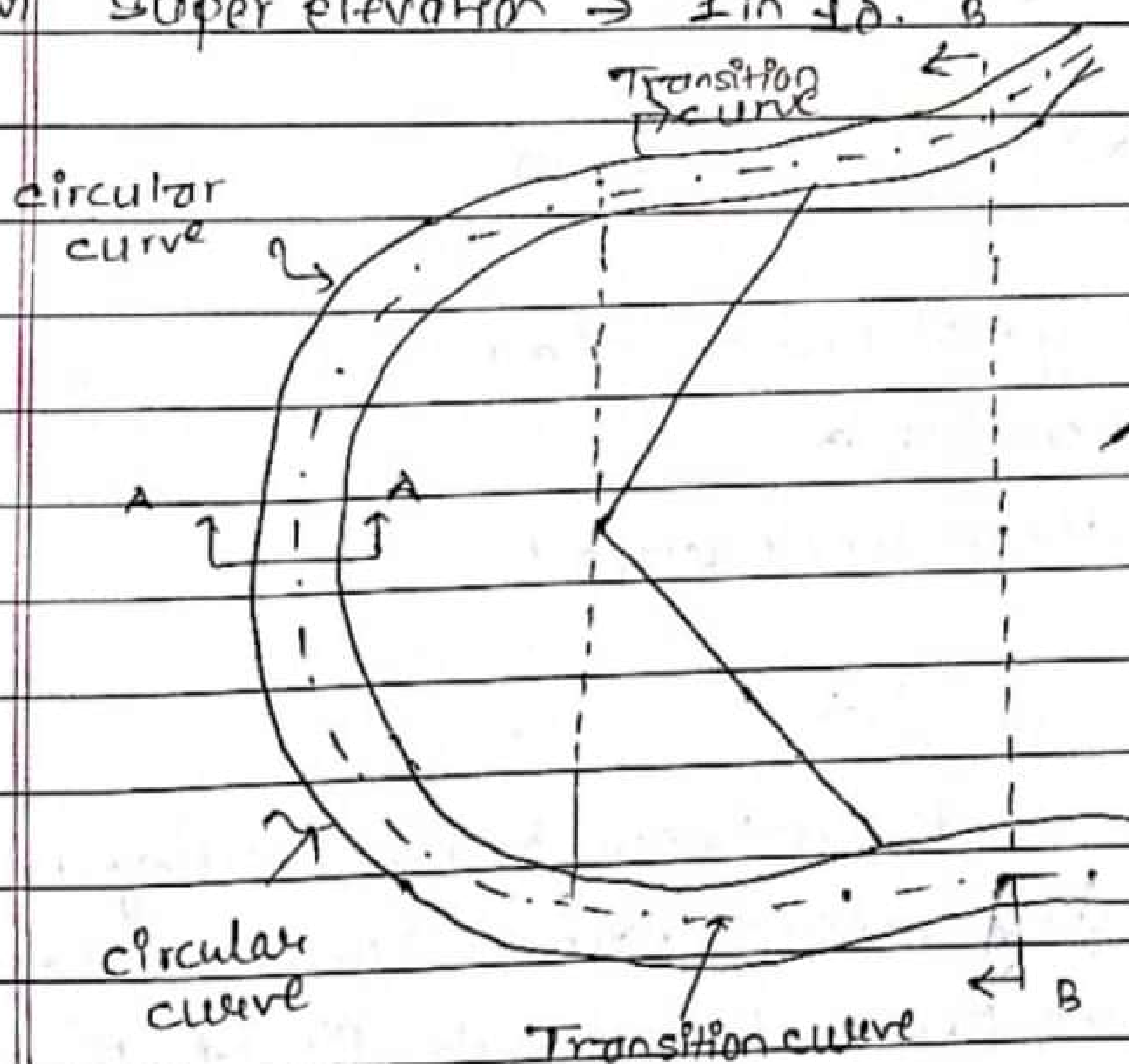
(x) Hair pin bends:

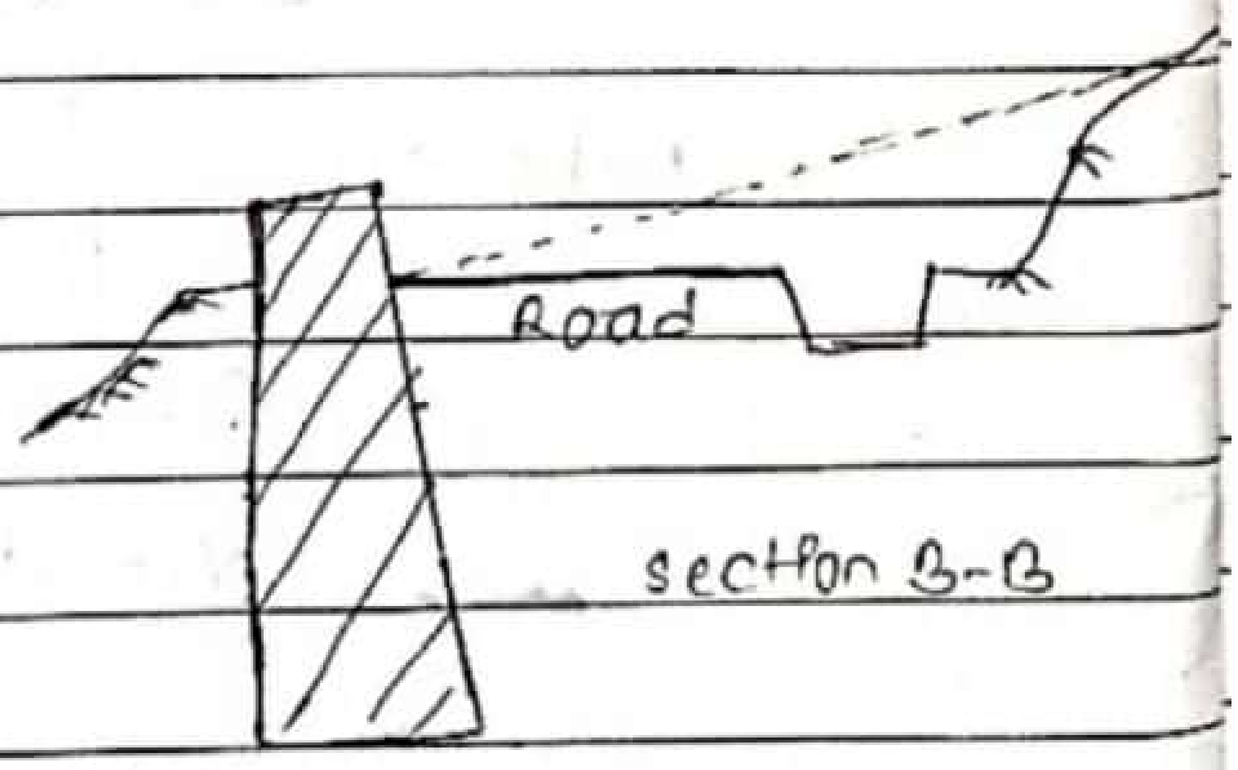
→ In aligning a hill roads, it becomes necessary to attain height at a particular location without substantial covering of horizontal distance. In such case hair pin bends is provided. When developing a route in hilly area, it is frequently necessary to insert sharp turning angle, within which it is very difficult and sometimes even impossible to layout curves following normal geometric standard of design.

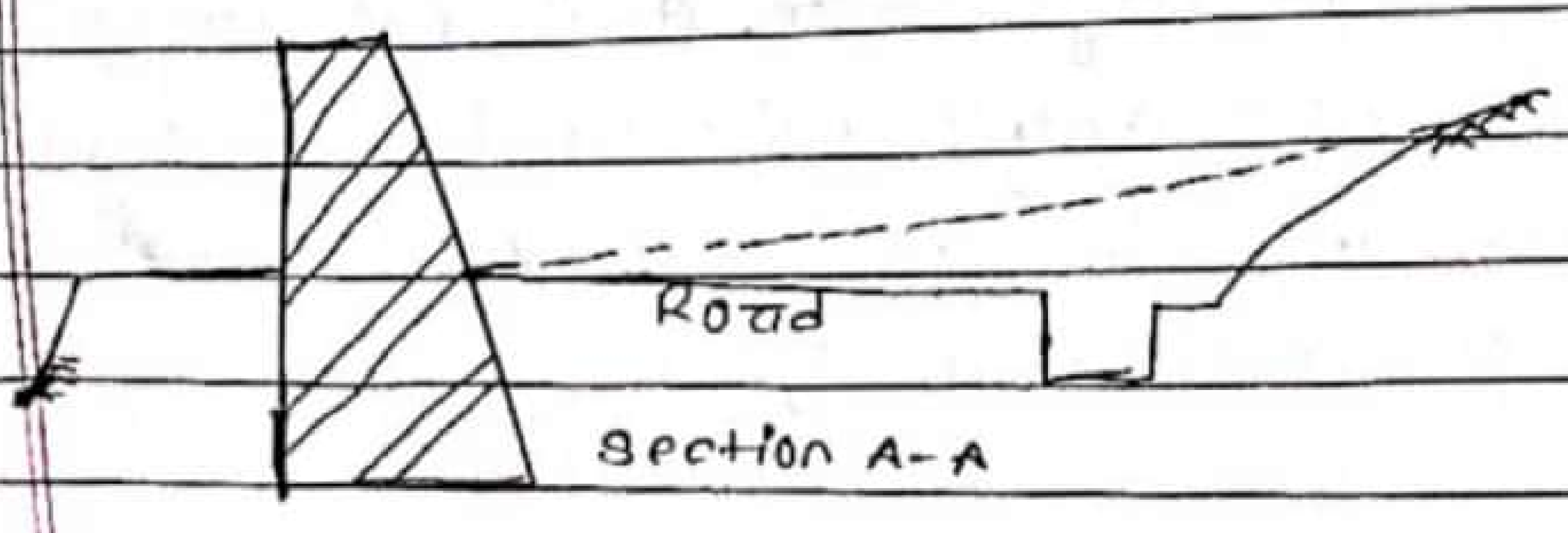
4) When inscribing a curve inside a turning angle the length of route will be substantially reduced, which result in steep gradients, In such circumstances it is preferable to round off the route not by inscribing but by circumscribing the curve around the turning point. Such compound curves are called hair pin bends or reverse loops.

* Design criteria for hair pin bends:

(i) Minimum design speed = 20 kmph.
(ii) Minimum radius of inner curve = 14m.
(iii) Minimum radius of transition curve = 15m.
(iv) Gradient → maximum 1 in 40, min - 1 in 200
(v) Super elevation → 1 in 10.







Imp Importance of hill roads:

- More service to people of hilly area.
- Provide easy access to agriculture, industrial and other production and service centers.
- Provide support to the development of other social and economic infrastructure.
- For economical development of country.
- For industrial development
- To meet need of strategic consideration of country in hilly area of country.
- Development of tourism
- To establish other project such as: hydropower, Hill Irrigation etc.
- In mountainous terrain, navigation and rail traffic are not possible which automatically demands hill roads.

Imp Typical cross-section of hill roads:

(i) Partly in cutting and partly in fillings:

- When cross-slope of the hill is not very steep, the best section of the road shall be partly in cuttings and partly in filling. Usually in this type of formation, the best section of the road shall be 2/3 in cutting and 1/3 in filling.

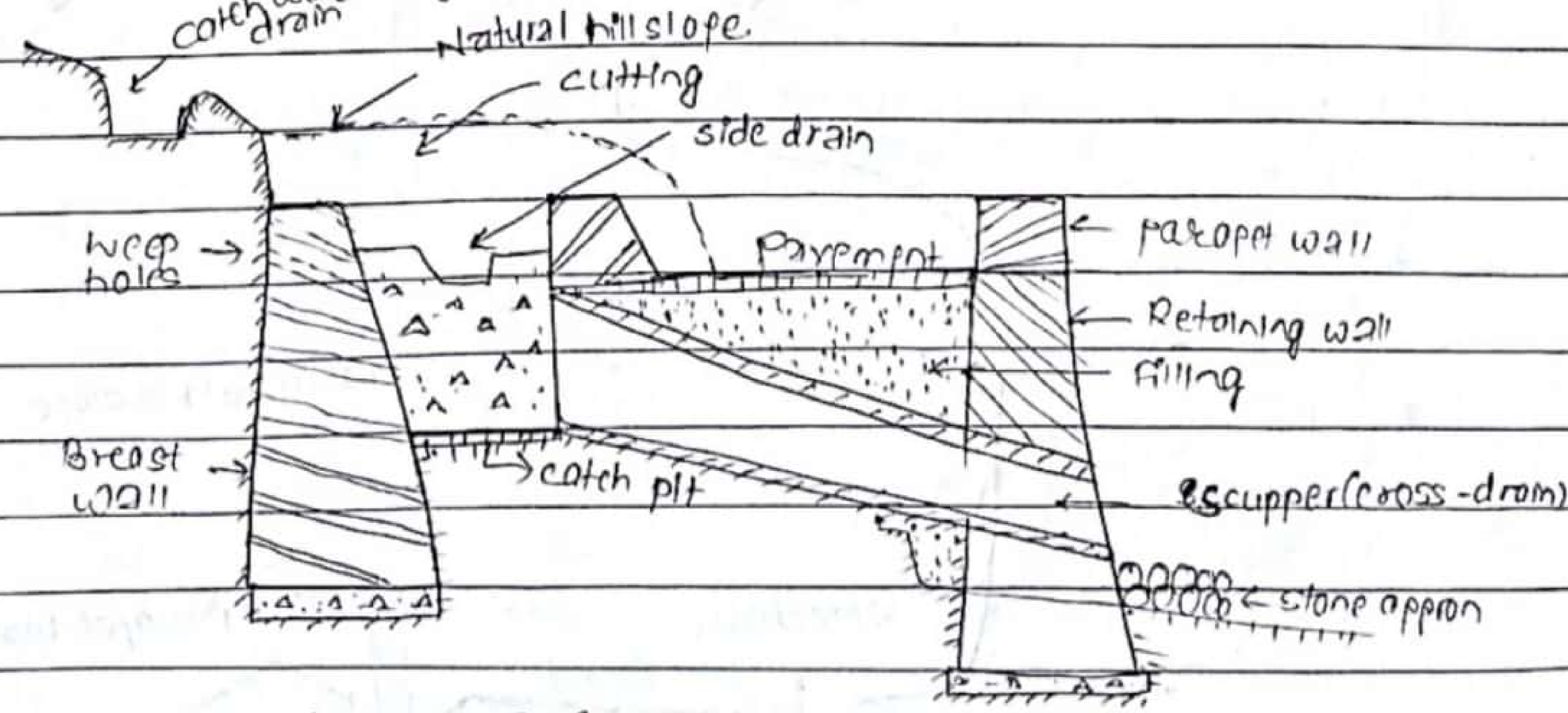


Figure: Typical hill roads section partly in cutting and partly in filling showing its components

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(ii) Road completely in cuttings:

↳ The section of a hill road completely in cuttings is shown in figure. when the cross-slope of the hill is very steep, the road is located in fully cuttings.

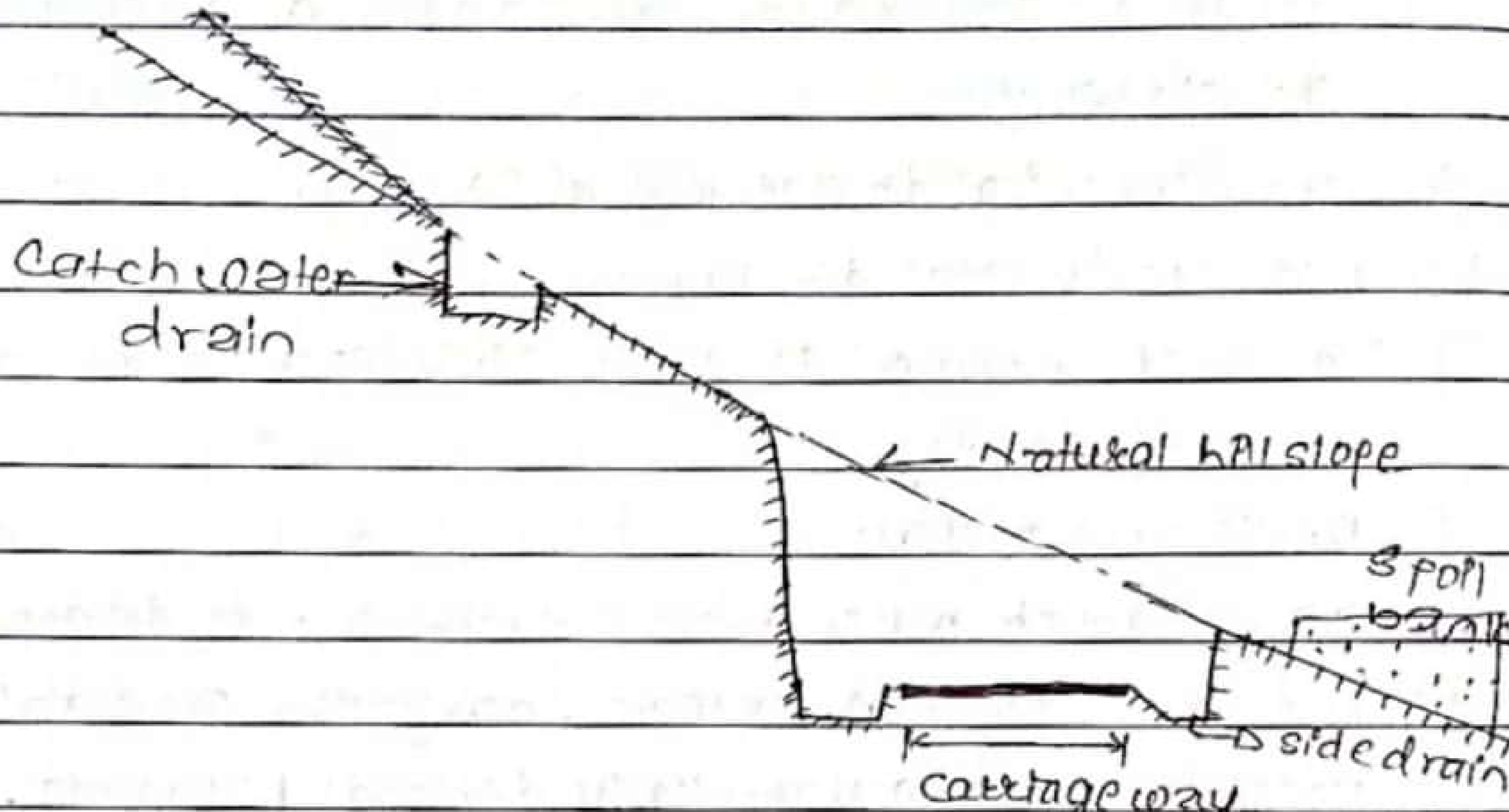

Figure: Section of hill roads completely in cutting.

(iii) Road in Half tunnellings:

↳ The section of hill road in half tunnellings is shown in figure. If along with steep slope hill side is sound and solid road can be constructed in half tunnellings.

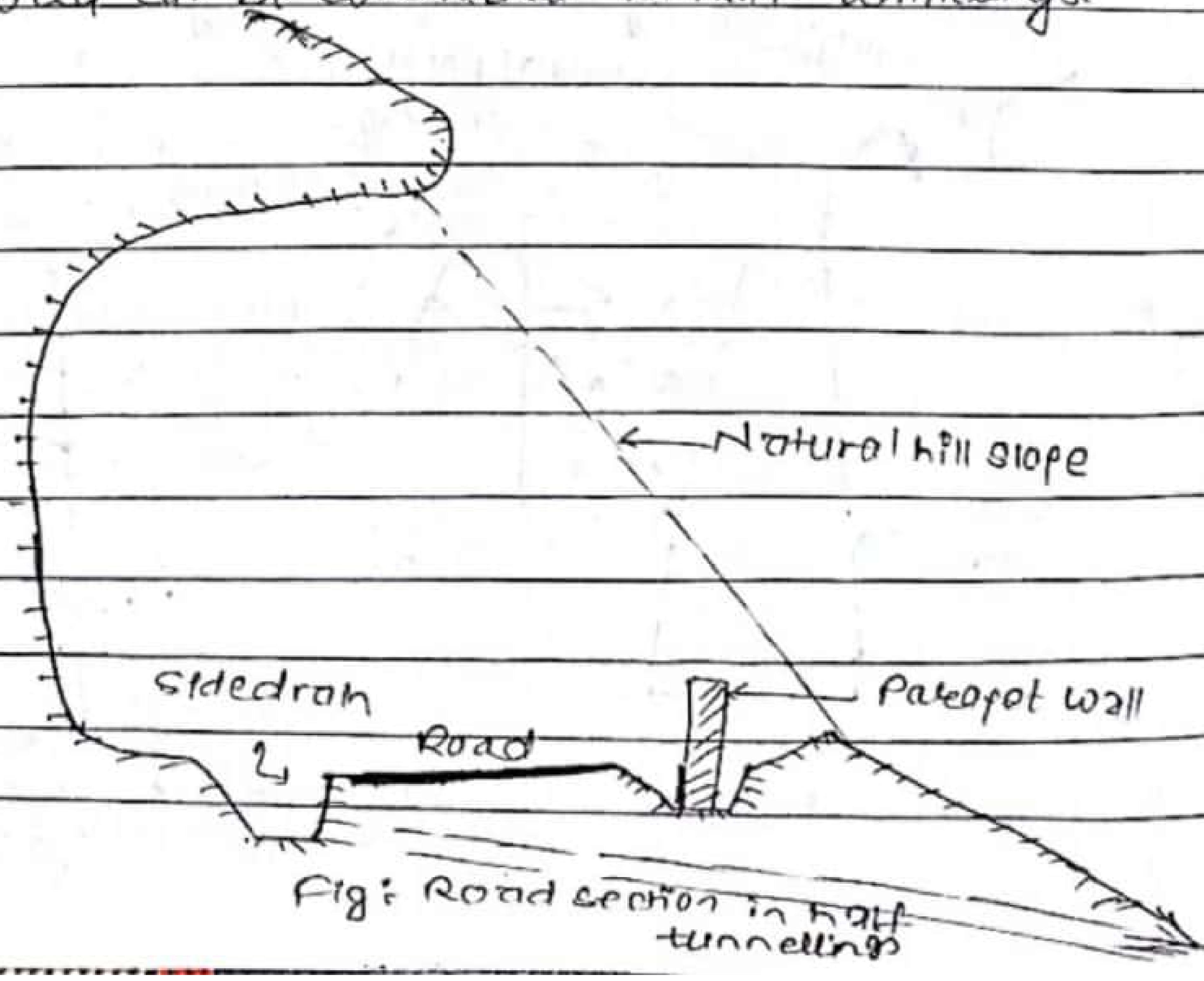

Fig: Road section in half tunnellings

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(iv) Road in fully tunnellings:

→ The section of hill roads in full tunnellings is shown in figure. This is constructed when there is no other alternatives for the economy of the hill road project.

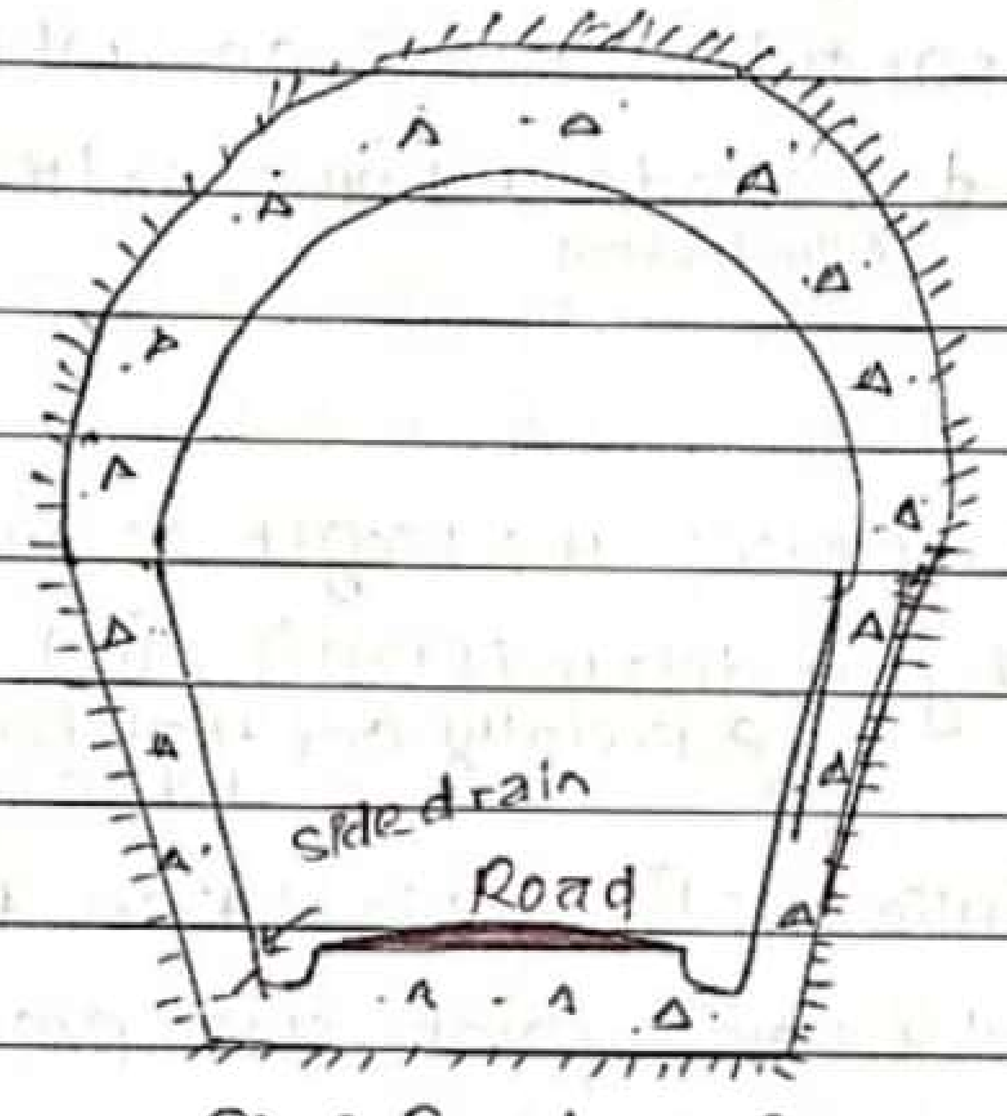

Fig:- Road section of full tunnellings.

(v) Road fully in embankment:

→ The road section fully in embankment is shown in figure. This type of construction is done when cross-slope of a hill is very small. In case of heavy filling retaining walls are constructed on both sides of the road.

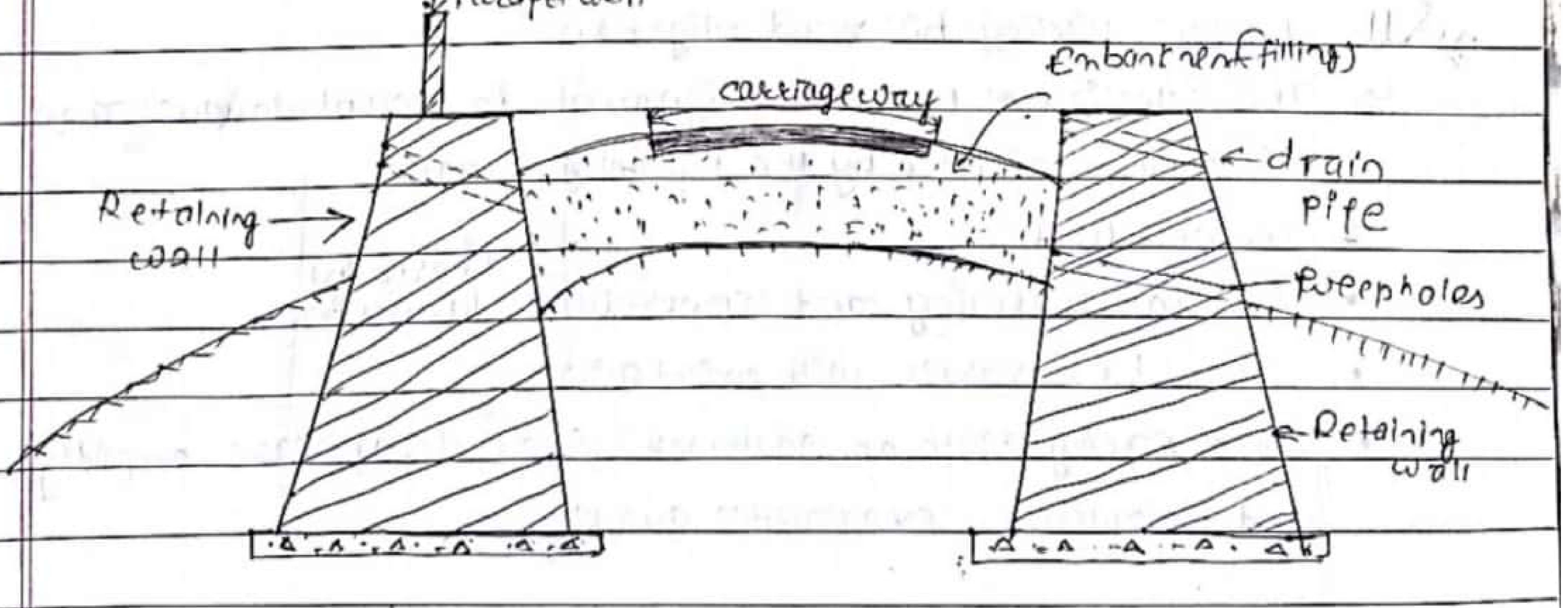

Fig:- Road section fully in embankment

Chapter 2.

HILL ROAD ALIGNMENT

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Introduction:

obligatory (boundary)

- The hill road alignment should link up the obligatory and control points fitting well in the landscape and satisfying and the geometric requirements.

- The best alignments for a hill road is one where in the total sum of ascends (climb up) and descends (climb down) between extreme points is the least.

- It is permissible to increases the length as much as 50 times the height saved by a detour. (घुमाउरो बाटो) especially one that is used temporarily while a hair

- preliminary investigation should start from the origin high obligatory or control summit points and proceeds downwards for better exploration

- The route should avoid the introduction of hair pin bends as far as possible.

- The bends location in valley should be avoided.

Factors affecting hill road alignment:

↳ The selection of the road alignment in mountainous and hill area is affected by the following factors

1. Temperature:

- Unequal warming and temperature fluctuation. (variation)
- Solar heat varies with orientation.
- slopes facing south or southwest snow disappears rapidly and rainwater evaporates quickly.

critical.

2. Rainfall :

- As the elevation increases rainfall also increases upto certain height
- In summer, very heavy storm occurs and about 15 to 20% of annual rainfall may occur in one stream.
- Effects of such heavy rainfalls on the construction and maintenance of hill roads are serious.
- At many locations in hill roads, the landslides and slips occur blocking traffic during heavy rainfall.
- A large number of streams cross the road and hence suitable and large facility for cross drainage is needed.

3. Atmospheric pressure:

- Atmospheric pressure decrease with increase in elevation

~~4.~~

4. Geological conditions:

- Follow the stable slope with no ground water and the alignment should pass through the area where the dip of the strata is as small as possible.

Reconnaissance

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Survey methods:

→ The alignment of hill road is fixed in the three stages:

(i) Reconnaissance: The general route for the alignment is selected during the reconnaissance, first the topographical geological and metrological maps of the area and aerial photographs (if available) are studied. This may be followed by aerial reconnaissance where it is necessary and feasible. ~~Sequen~~ Subsequently the ground reconnaissance and detailed study of difficult stretches are carried out.

(ii) Trace out: The route selected during the reconnaissance is translated on the ground during the trace out so as to provide an access for subsequent detailed surveys. 1.0 to 1.2 m wide track is constructed with easier gradients than the specified gradients. Instead of cutting into hard rock access is achieved by means of dry rubble filling or walls.

(iii) Detailed surveys: During the detailed surveys, bench marks are fixed and the Longitudinal and cross-sections are obtained. A strip covering about 15 m on either side on straights and 30m at sharp curves may be Surveyed. Necessary adjustments are made in the alignment to suit the design of horizontal curves and hair pins bends. The centre line is marked by stakes and reference point or pillars. Hydrological and soil investigation are carried out for the route.

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Hill road route location process:

→ There are mainly two route location possibilities in case of hill roads namely river route and ridge route.

(1) River route:

- Location along a river valley.
- Gentle gradient and numerous horizontal curves.
- Low vehicle operation cost.
- Construction of large number of cross-drainage structures.
- Extensive earthwork, protection of wall on the hillsides.
- Massive river training and protection works.
- construction of special retaining structure and protection of walls on the hill side is required

(2) Ridge route:

- very steep gradient
- Extensive rock works
- Large number of sharp curves including hair pin bends.
- construction of special structure.
- Ecologically stable and comparatively mild slope should be selected.
- Necessity of long length away from the air route

Unit 3.

GEOMETRIC DESIGN OF HILL ROADS

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3.1 Introduction:

- The geometric design of a hill roads deals with the dimensions and layout of visible features of hill roads such as alignment, sight distance and intersections, gradients etc.

- The geometric standards for gradient, super elevations and radius of curves etc on hill roads are different from those in plains. The main reasons for the difference are the topography and the other problems in alignment of hill roads.

(i) Cross-sectional elements.
(ii) sight distance considerations.
(iii) Hill road alignment details. (i.e Horizontal alignment)
(iv) vertical alignment details.
(v) width of pavements, formation and land, cross slope and surface characteristics of pavements.

3.2. Design speed:

- The design speed is the most important factor controlling the geometric design elements of highways. The design speed is decided taking into account of the overall requirements of the road.

- It will not be economical and safe to design all roads for very high speeds. A hill road has to be designed for a specific speed known as "design speed". It is also defined as the maximum approximately uniform speed that will be adopted by the majority of the drivers.

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- Design speed standards are modified depending the terrain or topography.
- Based on topography IRC (Indian Road congress) recommends the design speed for mountainous and steep terrains are:

Road classification	Mountains		Steep	
	Ruling.	Minimum	Ruling	minimum
National Highway	50	40	40	30
District roads	30	25	25	20
village roads	25	20	25	20

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3.3 Design of cross-sectional elements:

3.3.1 Road width:

- Road width is that portion of a road which is constructed for vehicular traffic.
- The recommended widths of pavements or carriage way, formation and land for hill roads.

The recommended widths of pavements or carriage way, formation and land for hill roads are given in table below:

Table: width of pavements, formation and land.

Highway classification	Pavements width 'm'	Roadway width, m (excluding side drains and parapets)	Right of way width, (m)	
NH & SH			Normal	Exceptional
Two-lane	7.00	8.80	24	18
single lane	3.75	6.25		
MDR	3.75	4.75	18	15
ODR	3.75	4.75	15	12
VR	3.00	4.00	9	9

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where,

NH = National Highway, SH = state highway.
MDR = Main District Road, VR = village Road.
ODR = other district Road.

3.3.2 Camber or cross-fall:

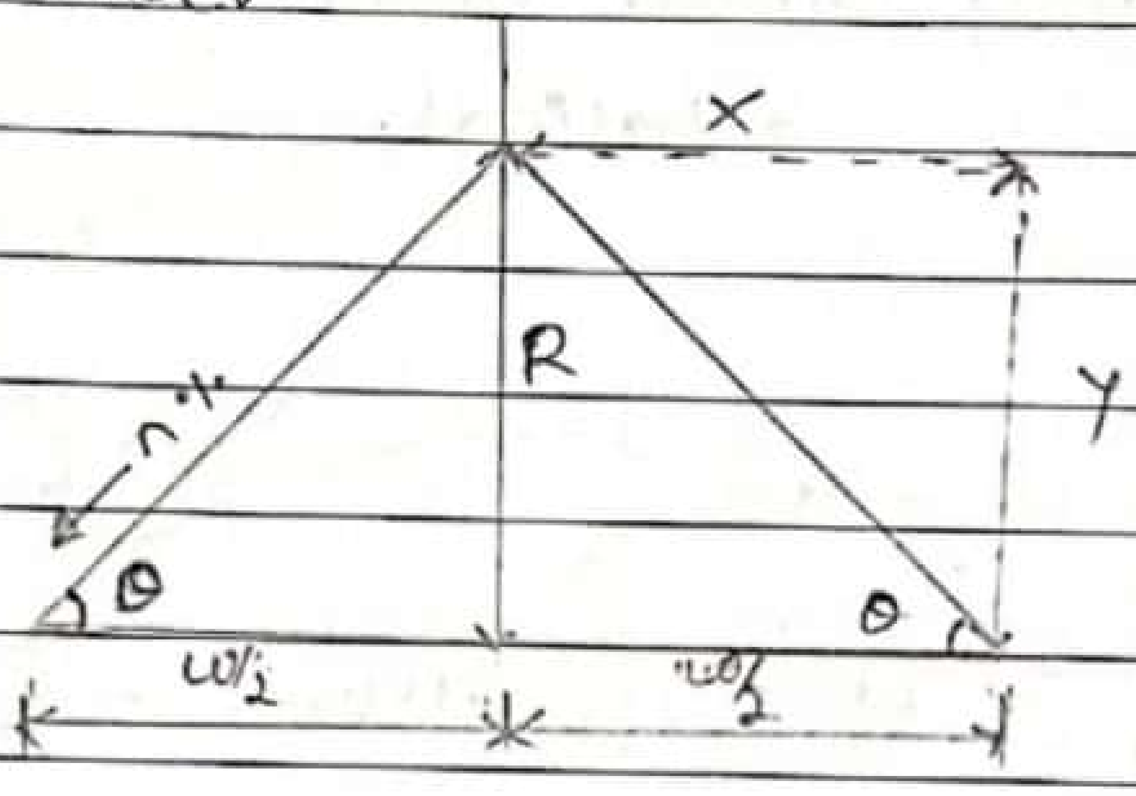
↳ Camber is a transverse slope given to the road surface.
It is provided for:
(i) To drain rain water from the road surface as quickly as possible.
(ii) To prevent percolation of rainwater from pavements surface. "The slow passage of a liquid through a filtering medium."
(iii) To segregating (separate) to traffic stream. (i.e. lane divide)
(iv) To provide aesthetic (beauty) appearance.

↳ Camber is the convexity provided to the cross-section of the carriage way to drain out surface water. Cambers are provided on the straight roads by raising the centre of the carriage way with respect to edges, forming a crown on the centre-line.

Design of camber of depends on:
(i) Amount of rail (horizontal bar and supports)
(ii) Types of road surface
(iii) Nature of soil
(iv) Hydrological analysis.
(v) Rainfall intensity.

Types of camber:
(i) Straight Line camber
(ii) Parabolic camber.
(iii) composite camber.

(i) Straight Line camber:
↳ A camber made of two equal straight lines is called straight line camber.



∴ W = width of the pavements
∴ n = camber (in percent %)
∴ R = Maximum thickness and pavements (at crown)
Now, From the figure.

$\therefore$ slope $= \tan\theta = \frac{R}{w/2} = \frac{2R}{w}$

i.e $n = \frac{2R}{w}$

As θ is very small

$\tan\theta \to \theta = n$ (says)

Also, $\tan\theta = n = y/x$

$\therefore \quad y/x = \frac{2R}{w}$

$\therefore \quad y = nx = \frac{2R}{w} \cdot x$

$\boxed{y = nx}$

This type of camber is adopted for very flat surface with cement concrete pavements.

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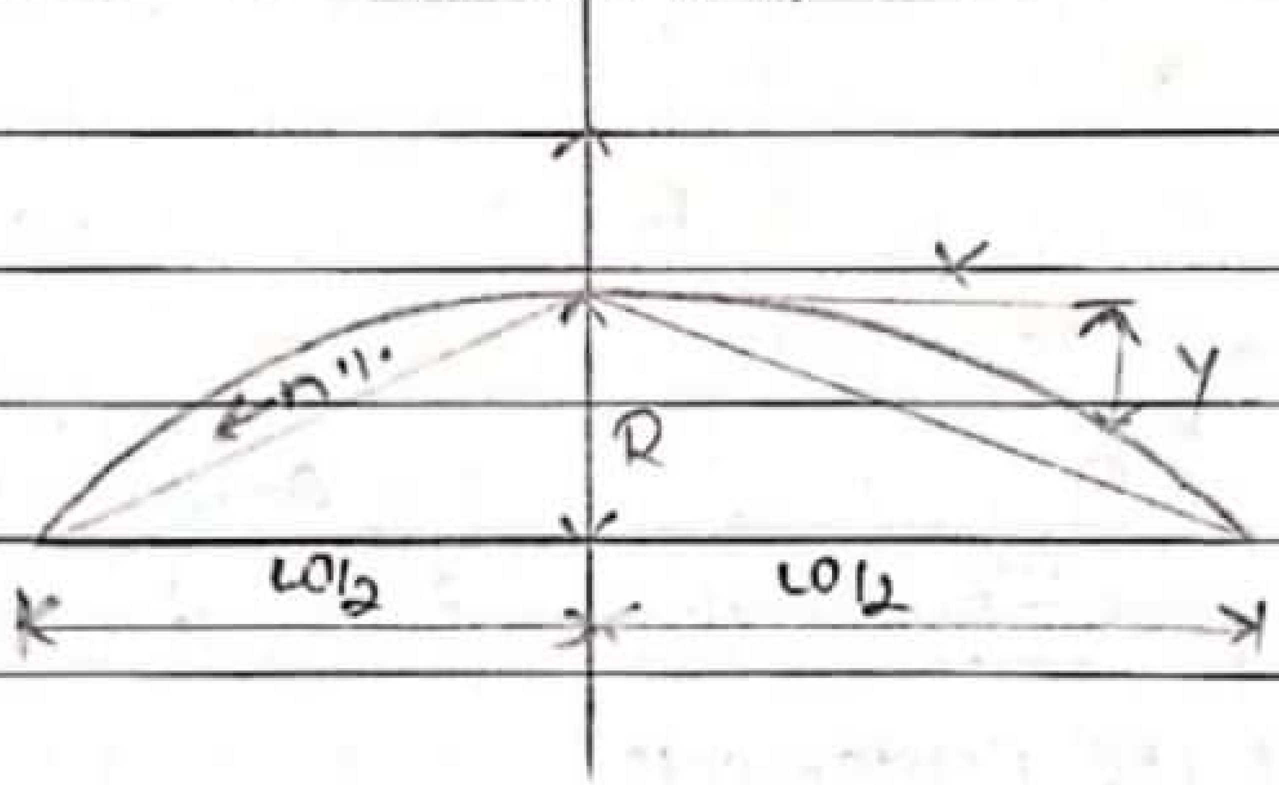
(iii) Parabolic camber:

→ A camber with the shape of a simple quadratic parabolic may be defined as a parabolic camber. It is provided in a low cost road and single lane or double lane roads.

In parabolic camber, ordinate 'y' varies as the square of abscissa 'x' (अनु)

For parabolic camber, we have parabolic relation:



$(R/w/_2 = n)$

$$\frac{y}{x^2} = \frac{R}{(w/_2)^2}$$

or, $$\frac{y}{x^2} = \frac{4R}{w^2}$$

or, $$y = \frac{4R}{w^2} * x^2 = 2/_w * \frac{2R}{w} * x^2$$

$$\therefore \boxed{y = \frac{2n}{w} * x^2} \qquad \left[\because n = \frac{2R}{w}\right]$$

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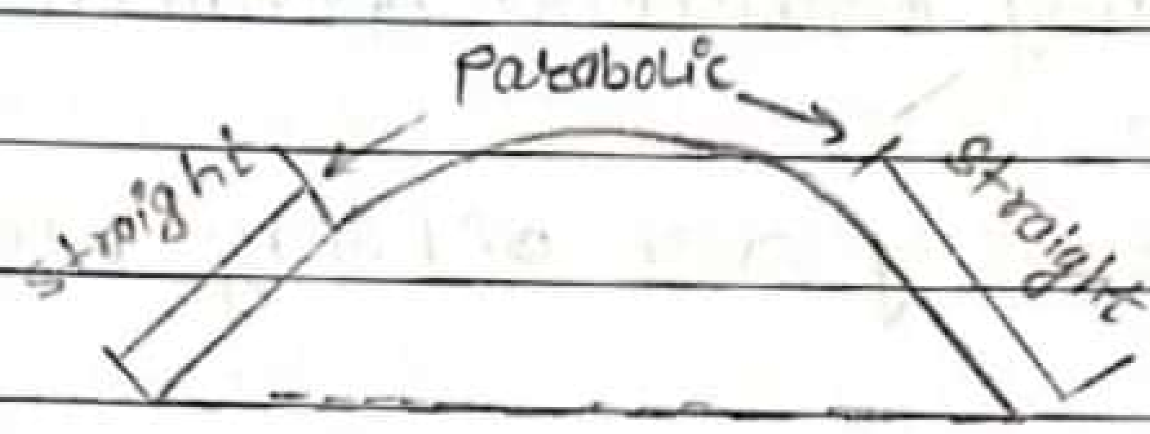
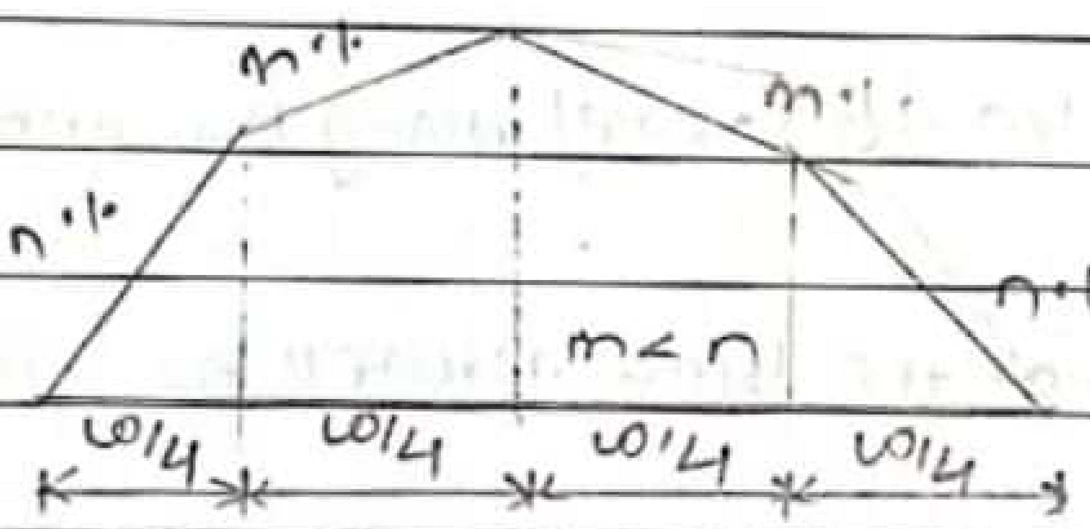
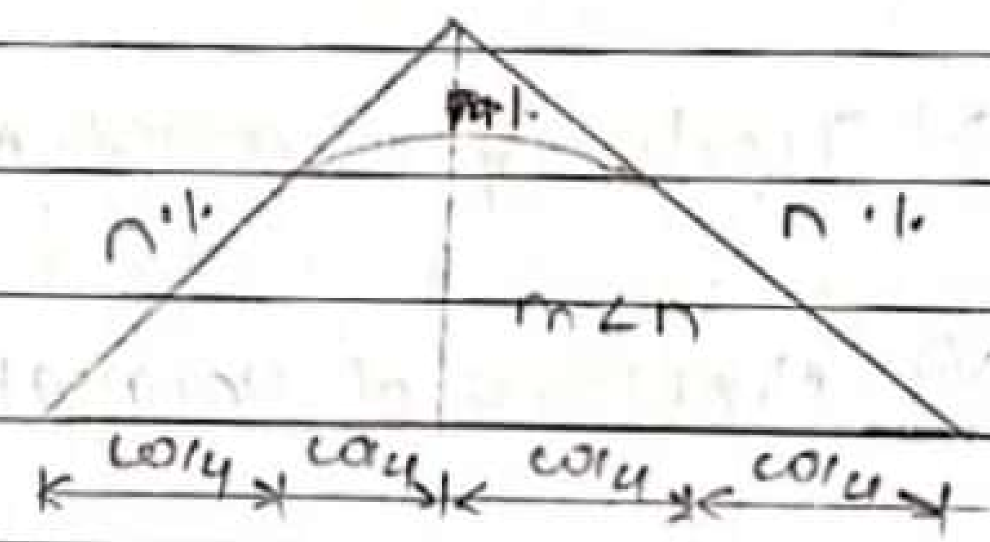
(iii) Composite camber:

→ It may be composed of partly parabola and partly straight or two straight lines having different slopes. Composite camber are used for slow moving vehicles.





Composite camber with two straight slopes.



Composite camber partly parabolic and partly straight.

Disadvantages of heavy camber:

(i) Low quality (earthen and WBM) road erode easily during rainy season.

(ii) chances of skidding and overturning of vehicles.

(iii) Most of the vehicles use centre part of road, so chances of damage in the centre part of the road easily and also the road capacity is affected.

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(i) Heavy camber leads to transverse tilting of vehicles which causes uncomfortable side thrust and a drag on the steering of automobiles.

(ii) Discomfort causing the throw of vehicles when crossing the crown during overtaking operation.

(iii) Problems of toppling over of highly loaded trucks.

(iv) Formation of cross cuts due to rapid flow of water.

(v) Tendency of most of vehicles to travel along the centre line.

(vi) Problems of unequal wear of the tyres as well as road surface.

- Steeper cross-slope or camber is adopted for hills roads and recommended values are given in table below:

when the road has longitudinal gradients greater than 1 in 20, flatter camber may be provided.

Table : Recommended values of camber:

Types of surface	Camber, percent
Sub grades, earth roads and shoulder.	3.0 to 4.0
Gravel and W.B.M surface	2.5 to 3.0
Bituminous surfacing	2.5
High type bituminous surface	2.0

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3.3.3 Superelevation:

- The super elevations to be provided at horizontal curves of hill roads is calculated from the formula:

$$\text{i.e. } e = \frac{v^2}{225R}$$

- It is the process of raising outer edge of the pavements with respect to inner edge along the curve in order to balance effects of centrifugal force. It is also known as "cant or banking". It is provided to balance centrifugal force.

objectives of superelevations:

- To counteract the effect of centrifugal force acting on moving vehicles to pull out the outward on horizontal curves.

- To helps the fast moving vehicles to negotiate a curve path without overturning and skidding.

IRC specifies that the superelevation should not exceed 7 percent in sections of hill roads which get snow bound and 10 % in other places.

Radius of Horizontal curve:

- The minimum radius of horizontal curves in hill roads, R(min) is calculate from the formula:

$$R_{(min)} = \frac{0.008V^2}{e+f} = \frac{0.008V^2}{e+f}$$

Reverse curves are designed to have a minimum radius of 80 m for the compound curves and a straight distance of 9 m between their transitional ends. In exceptional cases, the radius can be reduced to 22.5 m and the straight distance is dispensed with.

3.4. Horizontal Alignment:

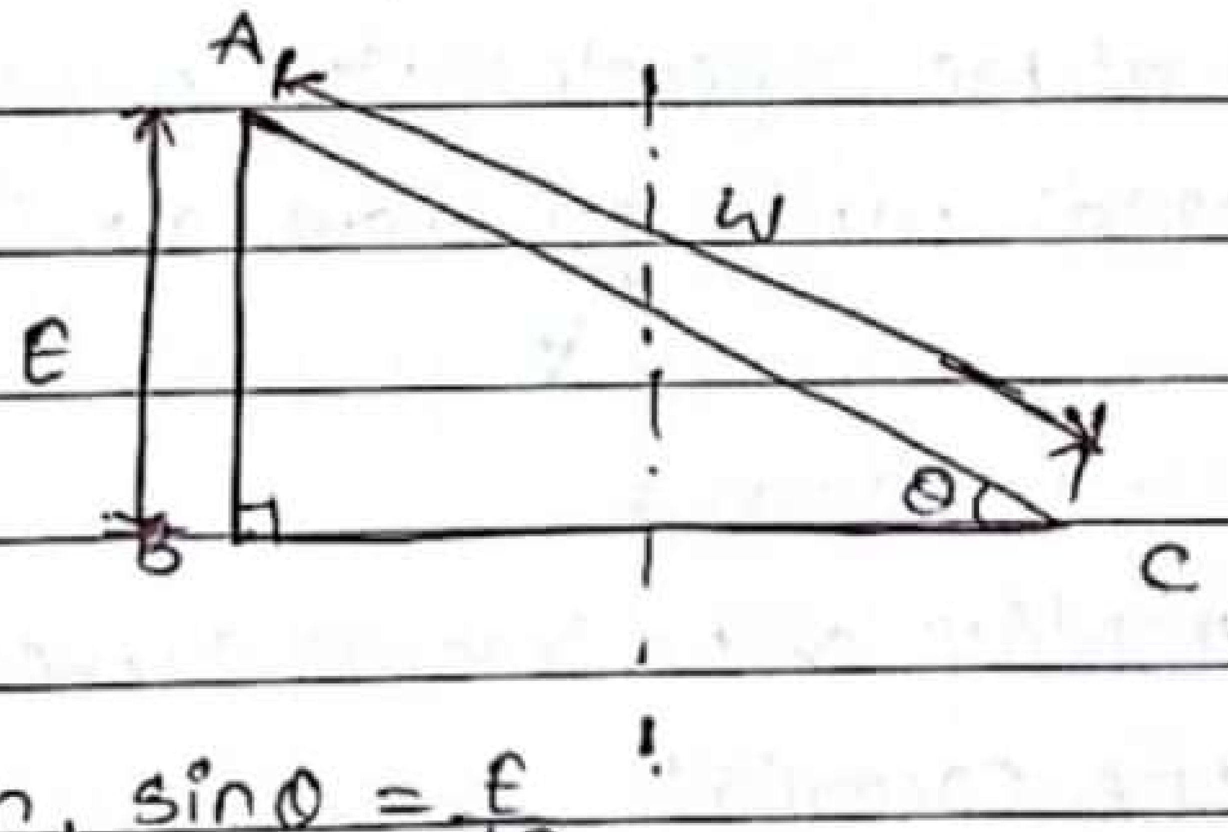
3.4.1 Super Elevation:

To reduce the tendency of the vehicle to topple or skid, the outer edges of the road pavements is raised with respect to the inner edge, thus tiltings the road surface from outer edge towards the inner edge. This lateral inclination of the road surface is known as super elevations.

It is denoted by 'e'

[If super elevation is not provided at horizontal curves the Load on outer wheel shall be more than Load on inner wheel]

Here, the centrifugal force always acts to horizontal even vehicle run on to super elevated track. And the super elevation is expressed as the ratio of the height of outer edge with respect to horizontal width of pavements.



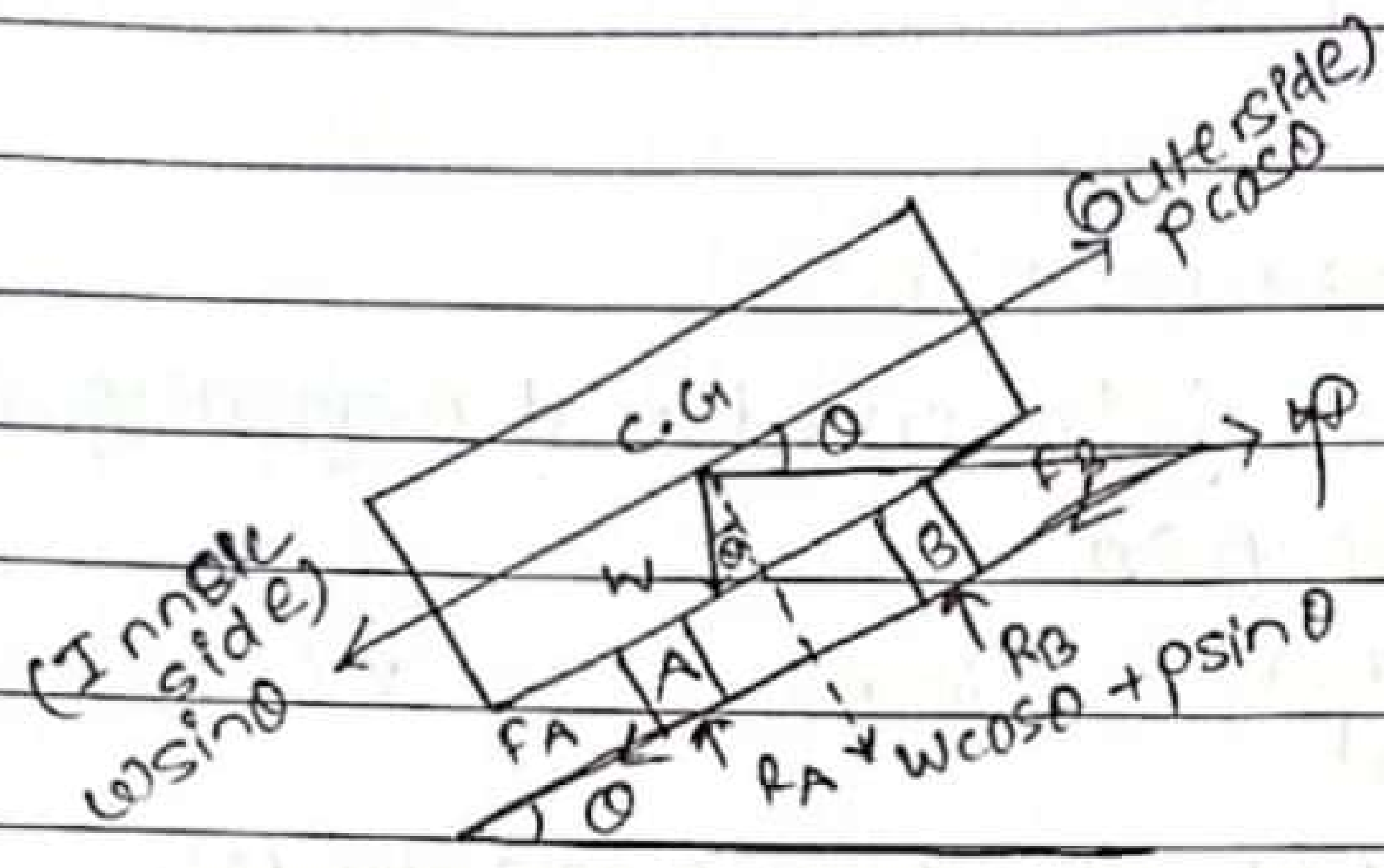
W = width, $\sin\theta = \frac{E}{W}$

For small θ, $\sin\theta = \tan\theta$

so, $\tan\theta = \frac{E}{W} = e$

or, $\boxed{e = \frac{E}{W}}$ [∵ where maximum value of $e = 7\%$]

Analysis of super-elevation:



Considering equilibrium:

$$P\cos\theta = W\sin\theta + F$$

or, $P\cos\theta = W\sin\theta + F_A + F_B \quad [\because F = F_A + F_B = f(R_A + R_B)]$

or, $P\cos\theta = W\sin\theta + f(R_A + R_B)$

or, $P\cos\theta = W\sin\theta + f(W\cos\theta + P\sin\theta)$

$[\because R_A + R_B = W\cos\theta + P\sin\theta]$

or, $P\cos\theta = W\sin\theta + fW\cos\theta + fP\sin\theta$

or, $P\cos\theta - fP\sin\theta = W\sin\theta + fW\cos\theta$

Dividing both side by '$W\cos\theta$' then,

or, $\frac{P}{W} - f\frac{P}{W}\tan\theta = \tan\theta + f \quad [\because \text{but } e = \tan\theta]$

or, $\frac{P}{W} - f\frac{P}{W}e = e + f$

or, $\frac{P}{W}(1 - ef) = e + f$

$$\therefore P/W = \frac{e+f}{1-ef}$$

Here, consider, $e = 7\% = 0.07$ and $f = 0.15$, then

$$1 - ef \simeq 1$$

so, $\frac{v^2}{gR} = \frac{e+f}{1} \quad (\because P/W = \frac{v^2}{gR})$

$$\therefore R = \frac{v^2}{g(e+f)}$$

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or, $e+f = \frac{v^2}{127R}$, v in km/hr.

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

Design steps for super Elevations:

1. Considering 75% of design speed and neglecting coefficient of Lateral friction(f) so,

$$e = \frac{(0.75V)^2}{gR}, \text{ V in m/s } \left[\because \text{for V in km/hr } e = \frac{(0.75V)^2}{127R}\right]$$

If $e \leq 0.07$, ok otherwise goto step (2).

2. If $e < 0.07$ from step (1) then take $e = 0.07$ and obtain 'f' by

$$f = \frac{V^2}{gR} - e \quad (\text{V in m/s})$$

3. If $f > 0.15$ from step (2), calculated restricted velocity 'V_a' by taking $e = 0.07$ and $f = 0.15$.

$$V_a = \sqrt{gR(e+f)} \text{ in m/s}$$ where, V_a = restricted velocity.

$$\therefore V_a = \sqrt{0.22 * 127R}, \text{ kmph}$$

$$\therefore \; \therefore V_{design} \geq V_{allowable\,(Restriction)}$$

Attainment of super-elevation (methods and providing super elevation):

It can be done by two methods:

(i) Elimination of crown of the cambered section.

(ii) Rotation of Road pavement to acquire full super elevation.

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1. Elimination of crown of cambered section:

It can be done by two methods:

(i) In first method outer half and width of the cross-slope is brought to level or made horizontal at the start of transition curve.

The disadvantages here is that has drainage problem in outer half and small length of road cross slope less than camber.

(ii) In second method, crown is shifted slowly outwards. The disadvantages are:

(i) Large negative super elevation on outer half.

(ii) Drivers have the tendency to run the vehicles along shifted curve.

2. (a) By rotating the outer edge about crown.

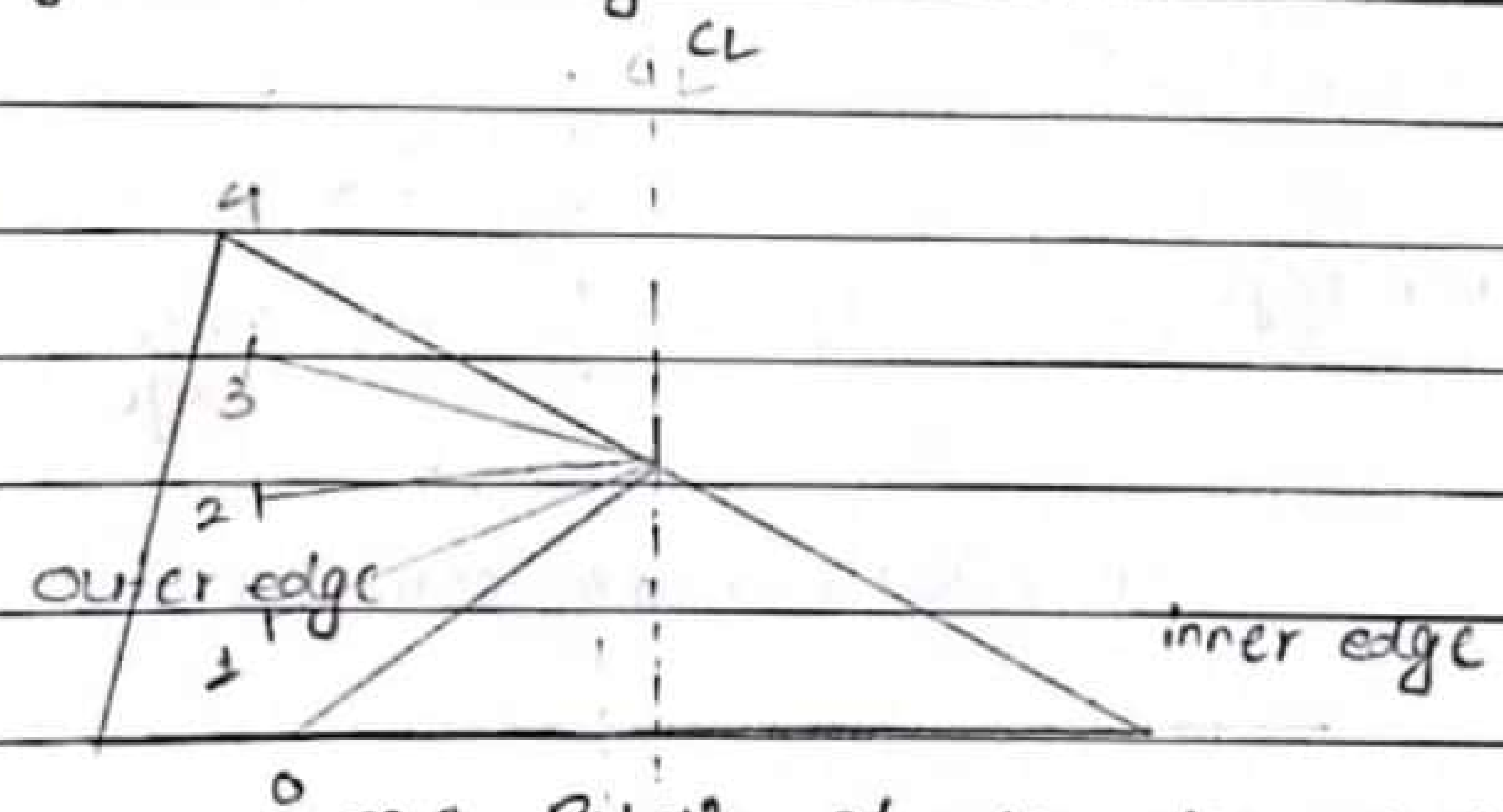


Fig: Rotation of outer edge about crown.

(b) By shifting of position of crown:

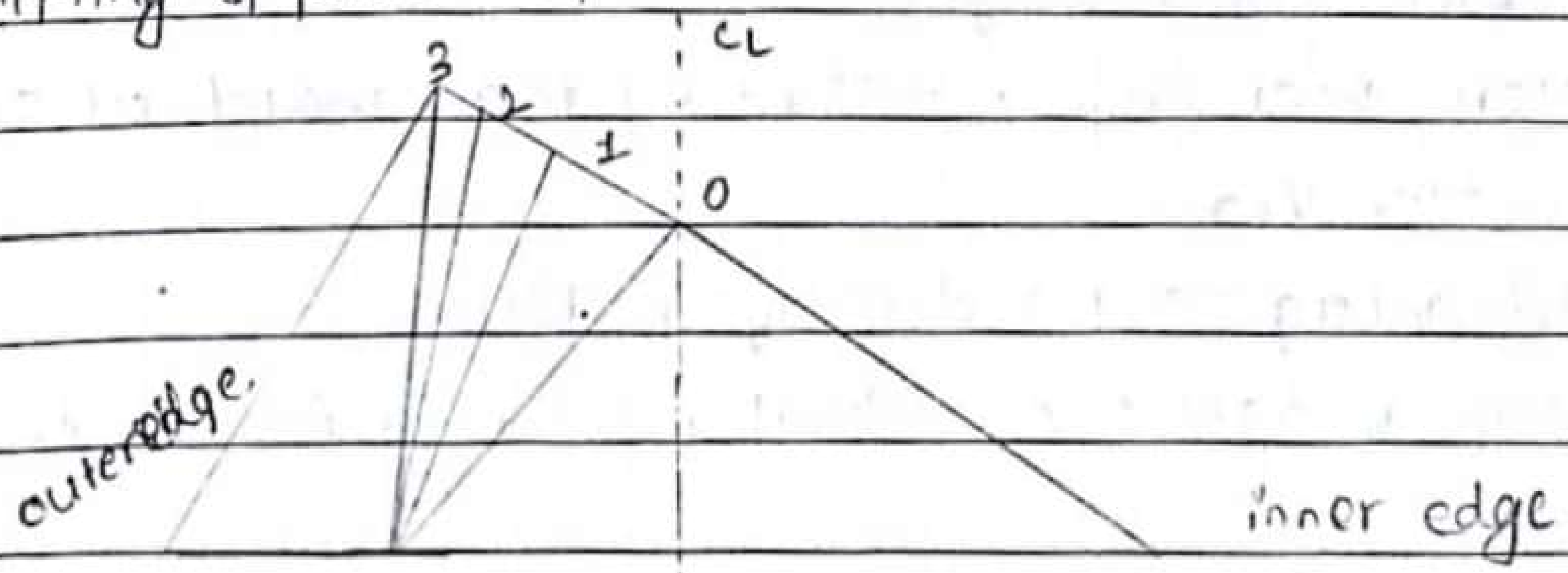


Fig: By shifting of position of crown.

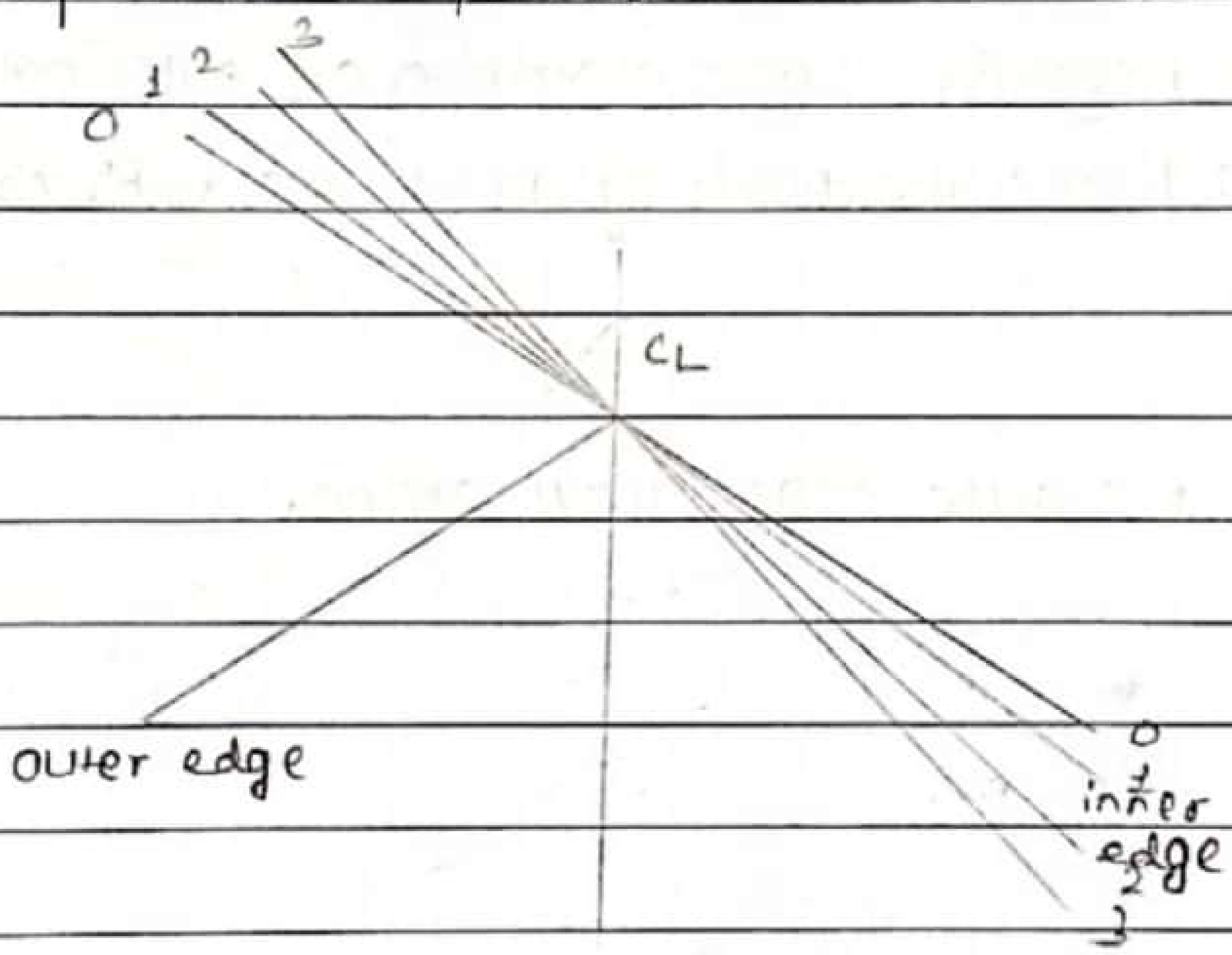
2. Rotation of pavement to attain full elevation:

1st method: Rotation about centre line (depressing the inner edge and raising the outer edge each by half the total sum of super elevation).

The advantages are:

- Earthwork is balanced.
- vertical profile to the centre lines remains unchanged

Disadvantages: Drainage problem as inner edges shall be depressed in position.



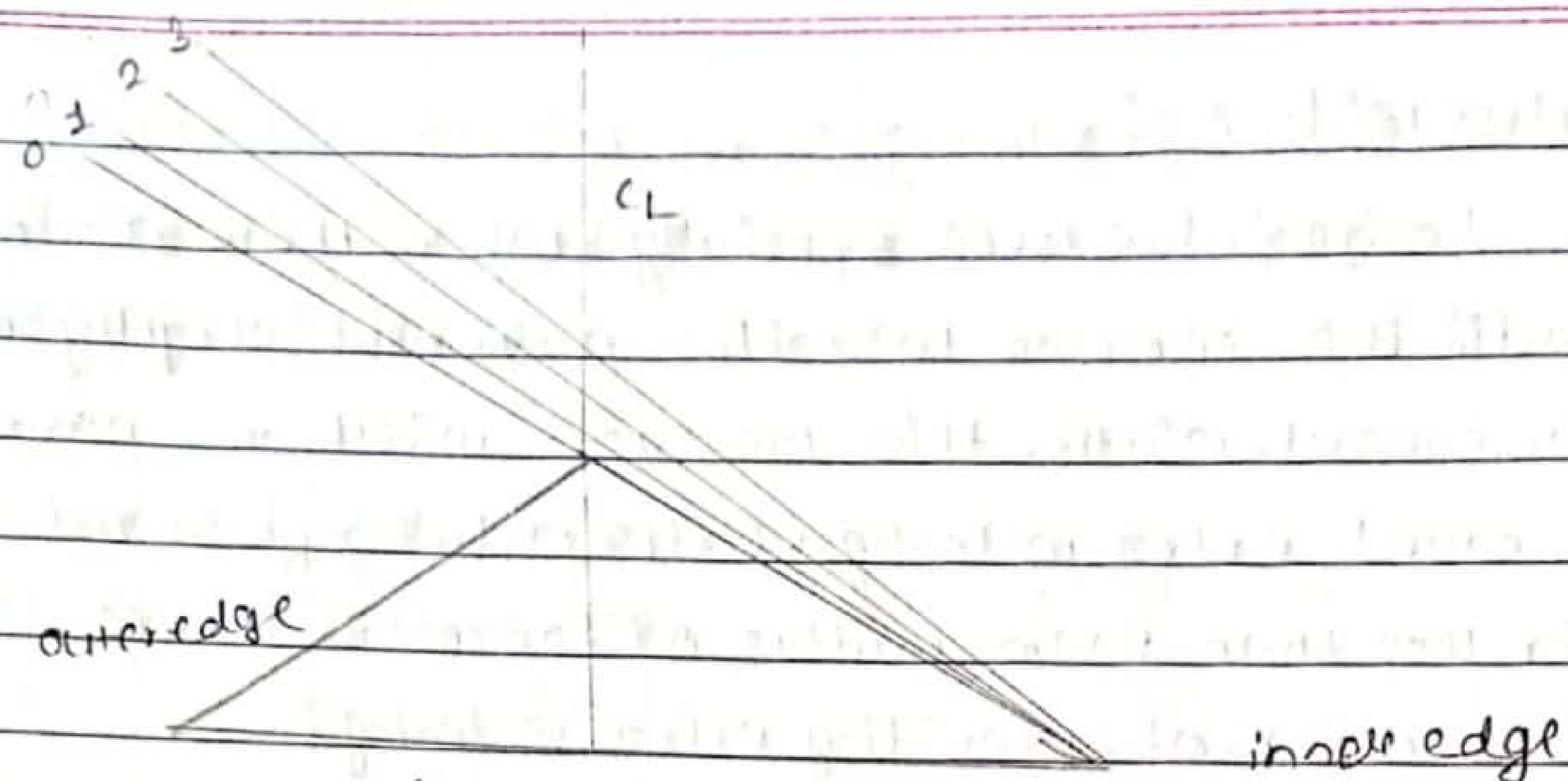
(a) Rotation about center line

2nd method: Rotation about inner edges (Raising both centre as well as outer edge)

Here outer edge is raised by total amount of super elevation.

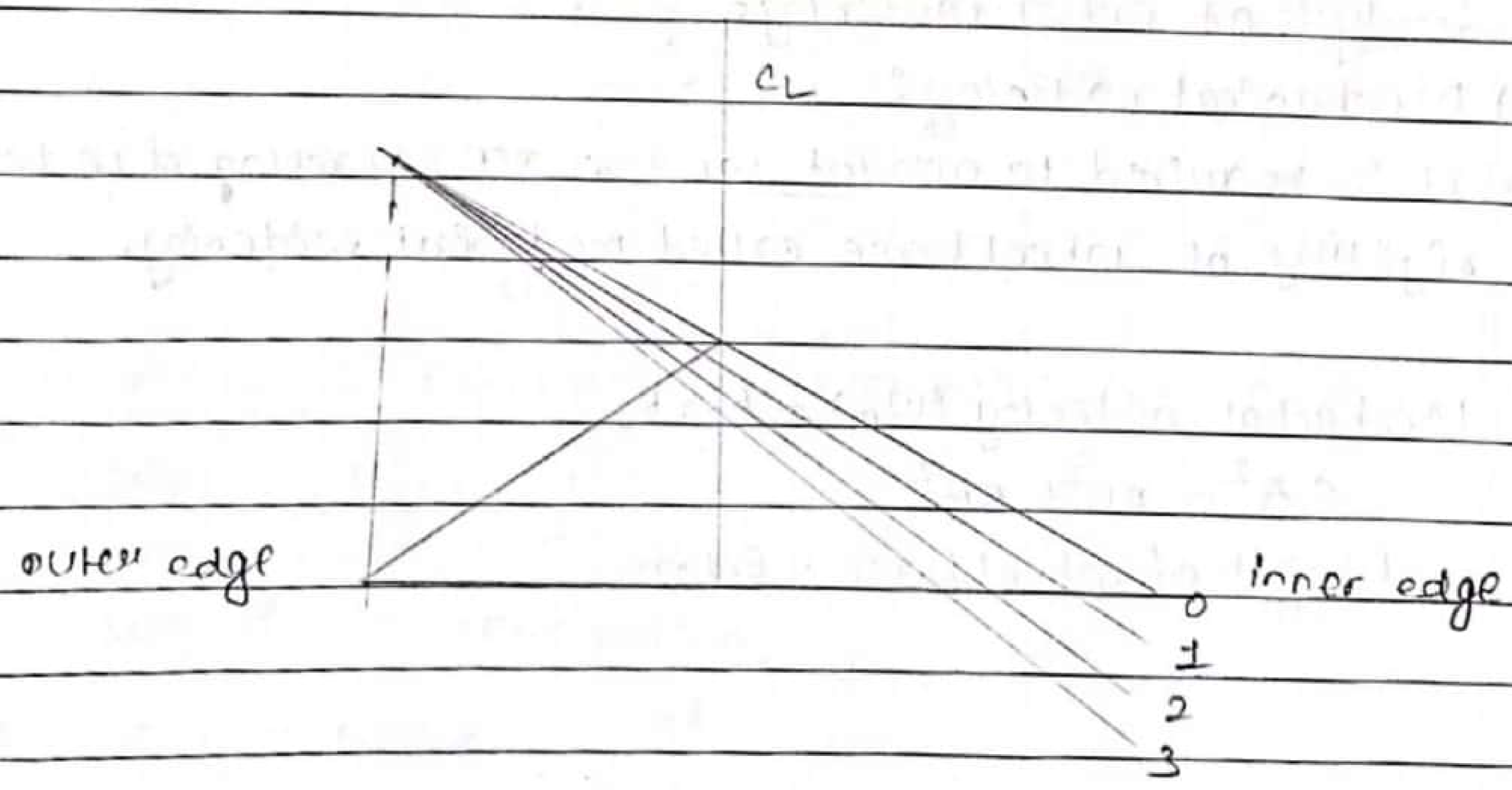
Advantages: No drainage problem

Disadvantages: Additional earthwork involved.



(b) Rotation about the inner edges

3rd method : Rotation about outer edge. (Depressing the inner edges as well as the centre such that inner edge in depressed by Full amount of super elevation.



(c) Rotation about the outer edge.

3.4.3 Extra widening:

In horizontal curves specially when there are not very radii it is common to widen pavement slightly more than the normal width, this increased width of pavement is called extra widening. Extra widening is required for less than 300m radius of horizontal curves.

Reason for of providing extra widening:

(i) Rigidity of wheel base
(ii) Excessive speed
(iii) visibility
(iv) Safety clearance
(v) Turning of Larger vehicle.

Analysis of extra widening:

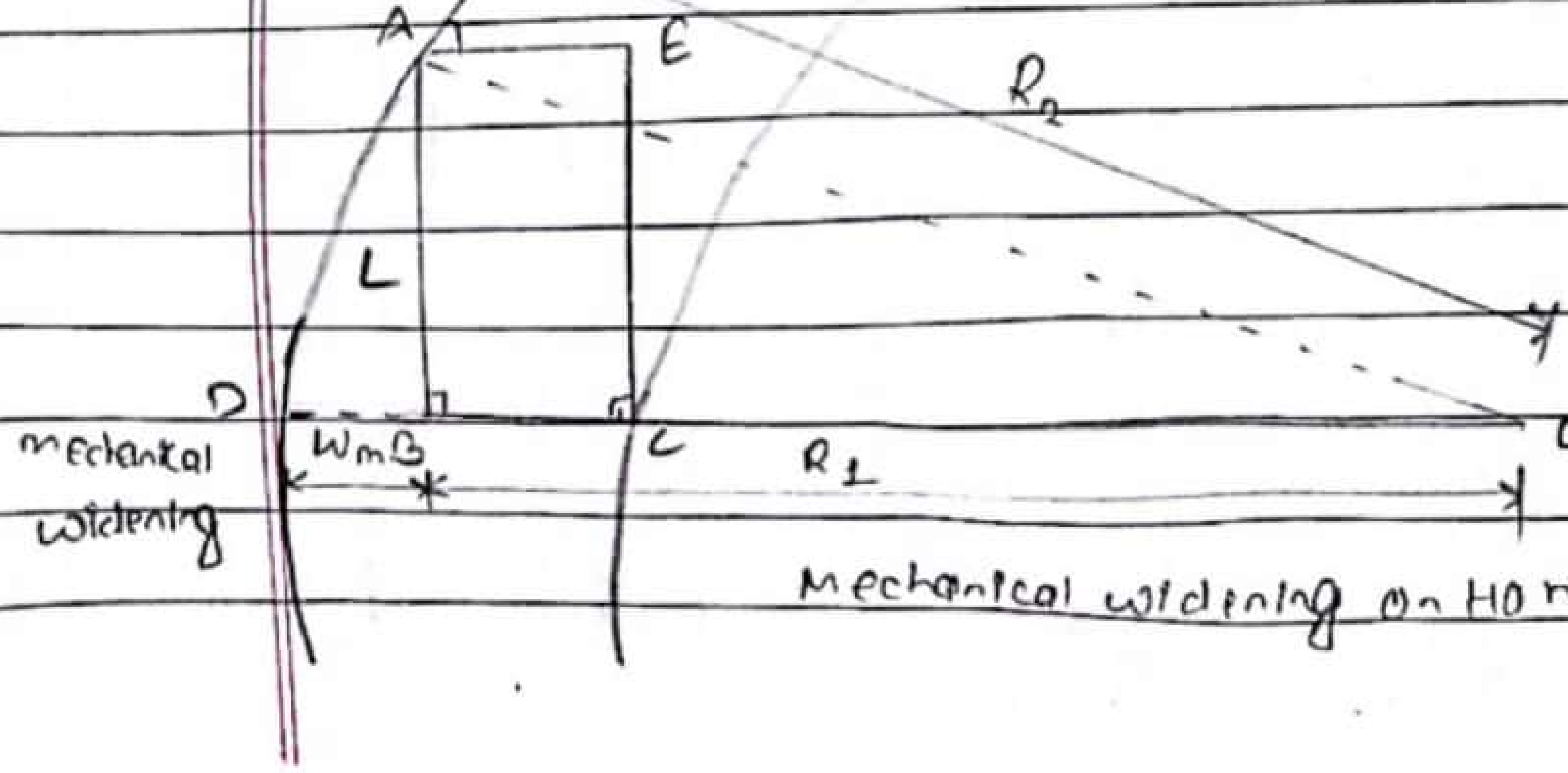
1) Mechanical widening:

→ It is required to account for the off-tracking due to the rigidity of wheel base called mechanical widening.

Mechanical widening $(W_m) = R_2 - R_1$

$OA^2 = OB^2 + AB^2$

Length of wheel base = 6.1 m



Mechanical widening on Horizontal curves.

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R_1 = Radius of outer track line of the rear wheel

R_2 = Radius of outer track line of the front wheel

L = Distance between rear and front wheel

n = no. of lane.

W_m = mechanical widening.

From figure:

mechanical widening $(W_m) = \cancel{OA-OB}$
$= R_2 - R_1$

$$\therefore \boxed{R_1 = R_2 - W_m} \quad --(i)$$

In triangle OAB,

$$R_2^2 = R_1^2 + L^2$$

or, $R_2^2 = (R_2 - W_m)^2 + L^2$

or, $R_2^2 = R_2^2 - 2R_2 W_m + W_m^2 + L^2$ {∵ using (i)}

or, $2R_2 W_m = W_m^2 + L^2$

or, $2R_2 W_m - W_m^2 = L^2$

or, $W_m (2R_2 - W_m) = L^2$

$$\therefore W_m = \frac{L^2}{(2R_2 - W_m)}$$

Neglecting W_m^2 [square of smaller value becomes more smaller]

$$W_m = \frac{L^2}{2R_2} = \frac{L^2}{2R}$$

where, R = mean radius.

For single lane, $= \frac{L^2}{2R}$

For no. of lane $= \frac{nL^2}{2R}$

where,
∴ n = no. of lane

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(2) Psychological widening:

→ The widening required due to psychological tendency to maintain greater clearance between vehicles is called psychological widening.

$$W_{psy} = \frac{V}{9.5\sqrt{R}} \quad V \text{ if in } \cancel{m/s} \text{ Kmph}$$

where, $= \frac{v}{2.64\sqrt{R}}$ in m/s

V = Design speed in Kmph

R = Horizontal radius

Therefore, total extra widening $= W_m + W_{psy}$

$$= \frac{nl^2}{2R} + \frac{V}{9.5\sqrt{R}}, \text{ if V Kmph}$$

For Hill road:

- Extra width of carriageway 'We' at horizontal curves is calculated from the relation.

$$W_e = \frac{18n}{R} + \frac{0.1V}{\sqrt{R}}, \text{ for } l = 6m$$

where n is the number of lanes.

The recommended values of extra widening on single and two-lane pavements at curves are given below for various speeds.

Radius of curve, m	14-20	20-30	30-60	60-150	above 150
Extra width of single-lane roads 'm'	1.5	1.2	0.9	0.6	Nill
Radius of curve, m	30-40	40-60	60-100	100-150	above 150
Extra width of two-lane roads, 'm'	1.5	1.2	0.9	0.6	Nill

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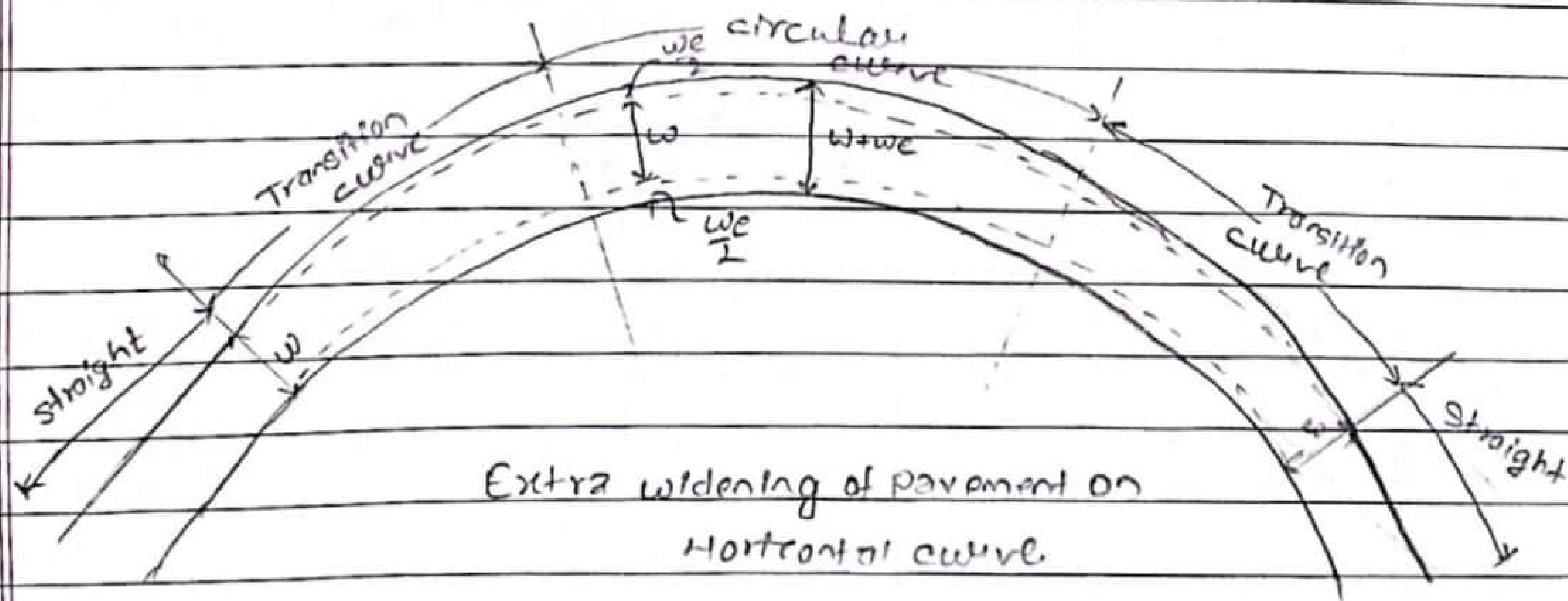
The formation of roadway width also should be increased at the horizontal curves. On single Lane National and state highways the extra width of the roadways is taken equal to the extra width of carriage way itself. In all other cases the roadway width is suitably increased so as to provide a shoulder width of at least 0.5m on either side after the carriageway has been widened.

Methods of Introducing extra widening:

1. Widening on curve with spiral form:
   - If horizontal radius = 60 - 300m, extra widening is provide both side of road.
   - If horizontal radius = 30 - 60m in multiple lane or less than 150m in single lane, extra widening provide only inner side of curve.



Extra widening of pavement on Horizontal curve.

- Horizontal radius = 20 - 30m in mountains region | Hill road Extra widening is provide only outer side of the road.

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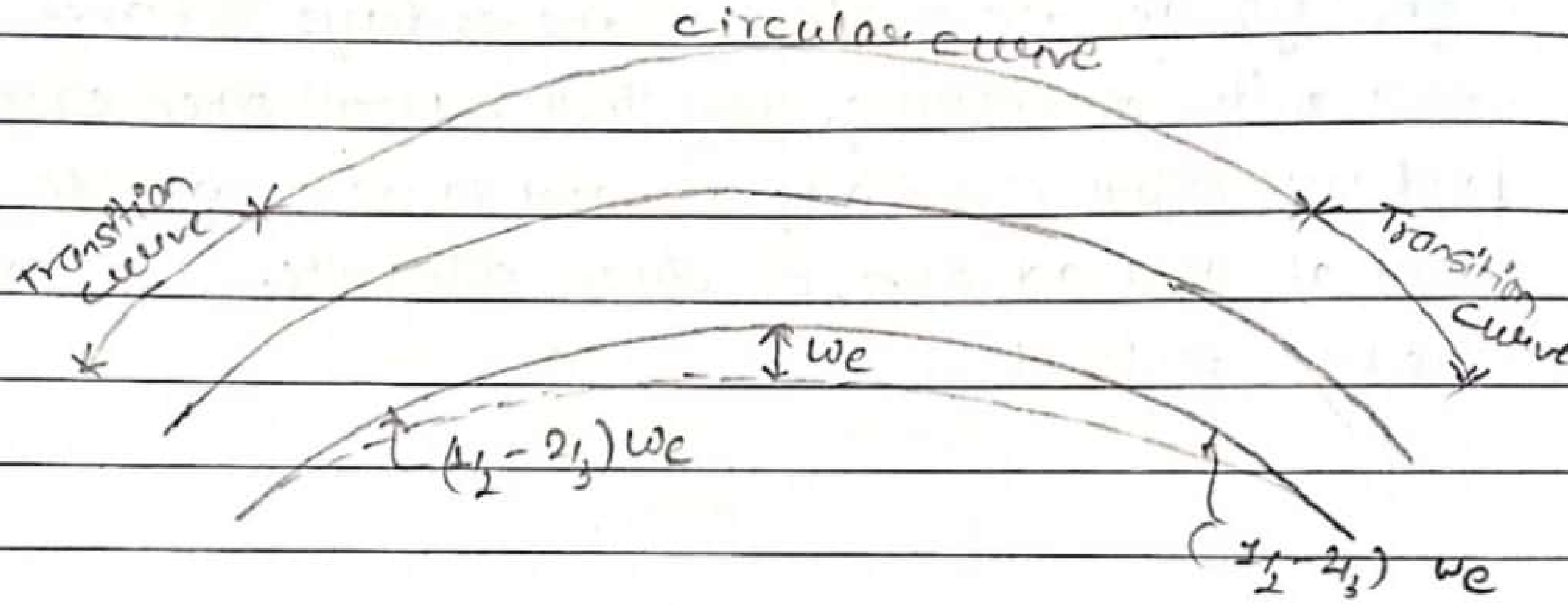
(2) widening on curve without spiral :-

↳ widening is provided only inner side of road.



Hence, the designed amount of extra widening is introduce gradually starting from beginning of transition curve and increases at uniform rate till the full value of widening is reached at the end of transition curve and confined throughout circular curve and decrease along the length of transition curve.

3.4.3 Set back Distance:

→ The distance required from the center line of the horizontal curve to the obstruction on inner side of the curve to provide adequate sight is called clearance distance or set back distance.

It depends on:

(i) Required sight distance (S)
(ii) Radius of the horizontal curve (R)
(iii) Length of the curve (Lc)

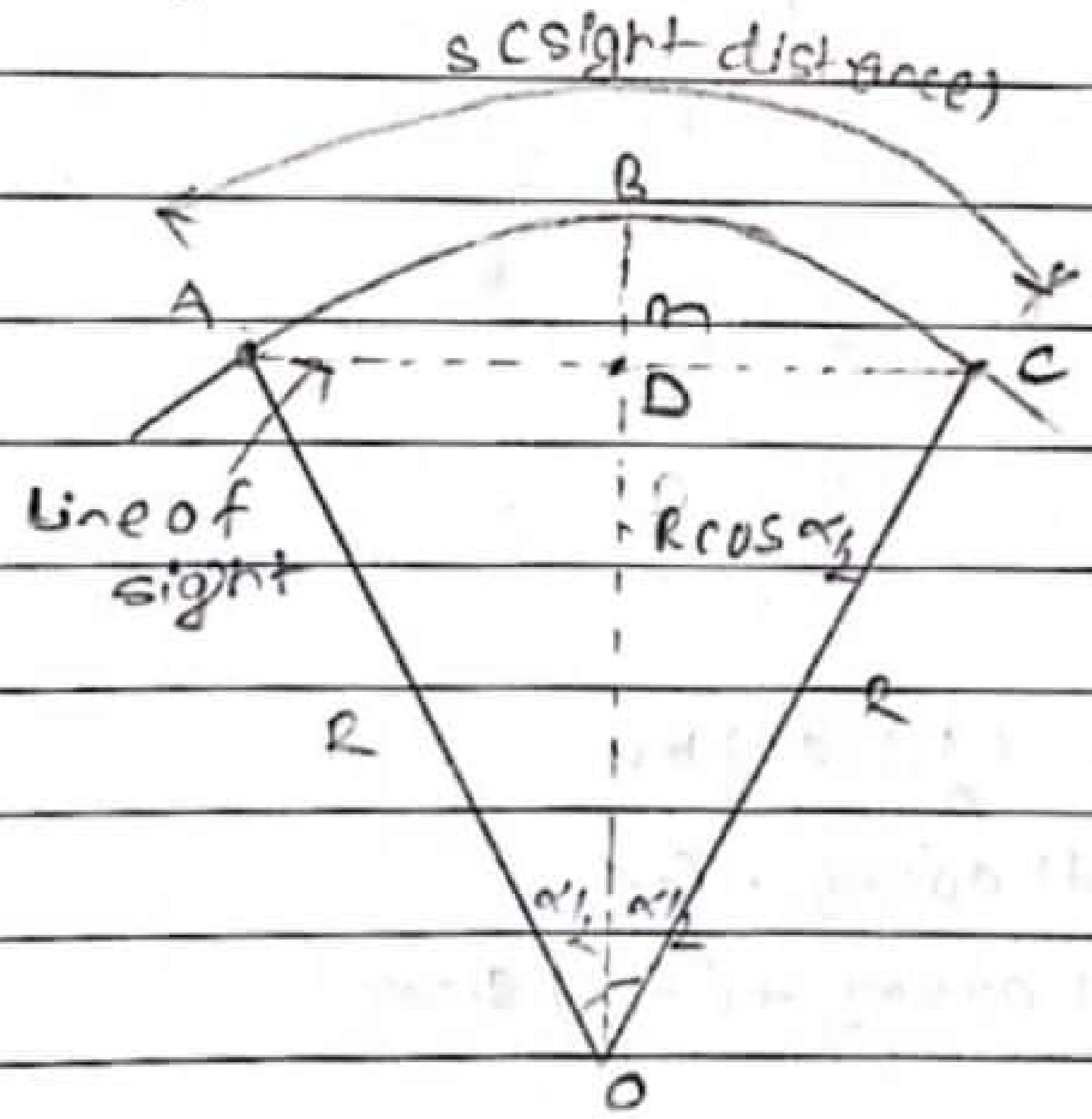
This may be greater or lesser than sight distance (S)

Case I.

(1) $Lc > S$

sight distance = ABC

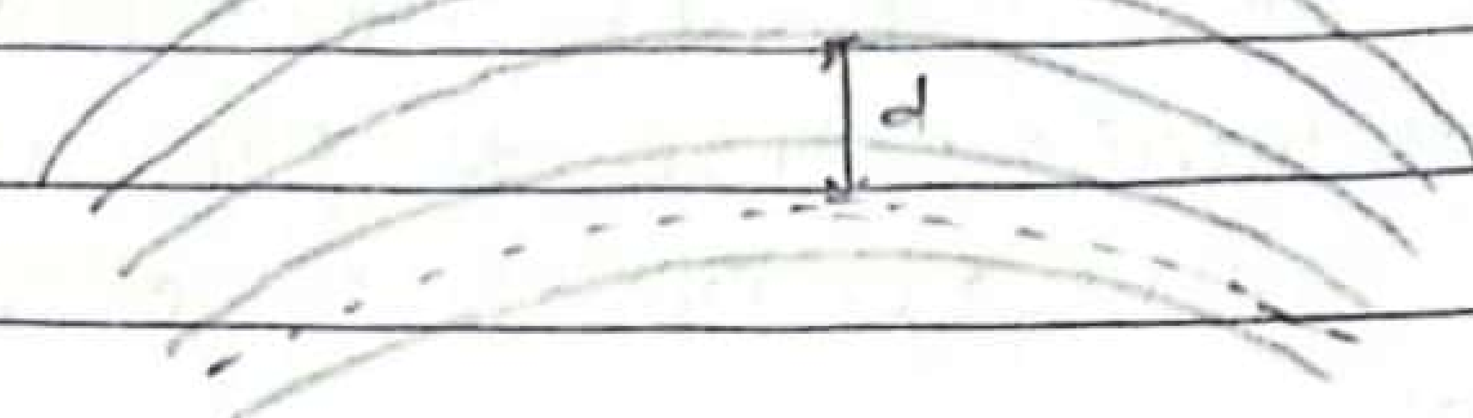
from geometry



$\alpha = S/R$ radian $= S/R \times \frac{180}{\pi}$ degree

$\therefore \alpha/2 = \frac{S}{2R} \times \frac{180}{\pi}$ degree

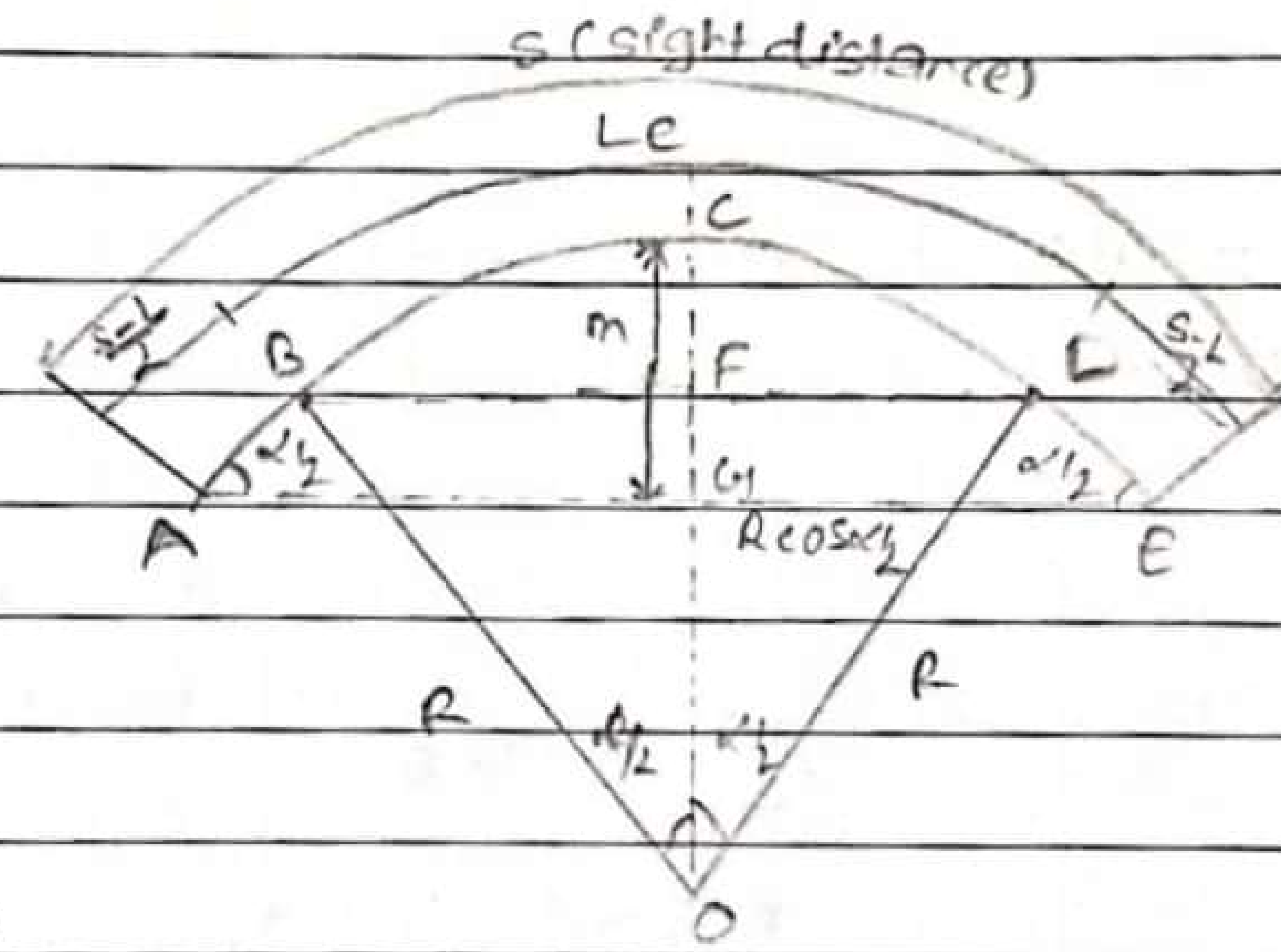
$\because$ d = distance between center line of a carriage way and center line of inner lane



$$M = R - (R-d)\cos\alpha/_2$$

For single lane $d=0$

CASE II



$Le < S$

From Geometry,

$$\alpha/_2 = \frac{Le}{2(R-d)} * \frac{180}{\pi} \text{ degree}$$

$$M = R - (R-d)\cos\alpha/_2 + G.F$$

$$= R - (R-d)\cos\alpha/_2 + \left(\frac{S-L}{2}\right)\sin\alpha/_2$$

For Hill roads;

As it is not practicable to provide visibility corresponding to overtaking sight distance all along the hill road, the alignment is made so as to provide at least the safe stopping sight distance. Accordingly the minimum set back distance on the inner side of horizontal curves for various speeds and radii of curves have been specified by the Indian Roads Congress.

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3.4 Transition curve:

→ The length of transition curve is to be calculated from the formula:

$$L_s = \frac{0.215 V^4}{CR}$$

Here, $C = \frac{80}{V+75}$

(maximum values of 0.76 for speeds less than 80 kmph)

L_s = Length of transition, 'metre'

R = Radius 'metre'

V = Design speed, kmph

The minimum lengths of transition recommended by I.R.C are 10m for design speed upto 40 kmph and 20m for design speed 40 to 50 kmph.

Numericals:

Imp 1. The radius of circular curve is 140m. The designed speed is 60 kmph and designed coefficient of lateral friction is 0.15.

(a) Calculate the super elevation required if lateral friction is assumed to develop.

(b) Calculate the coefficient of friction needed if no super elevation is provided.

c) Calculate the equilibrium super elevation if the pressure on inner and outer wheels should be equal.

→ Soln:

Given,

Radius of circular curve (R) = 140m

Design speed (V) = 60 km/hr.

(a) For $f = 0.15$

Super elevation $(e) = \frac{V^2}{127R} - f$

$$= \frac{(60)^2}{127 \times 140} - 0.15 = 0.0525 = 5.25\%$$

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(b) For no super elevations:

$$e+f = \frac{v^2}{127R}$$

or, Coefficient of friction (f) = $\frac{v^2}{127R}$

$$= \frac{(60)^2}{127 \times 140}$$

$$= 0.2025$$

$\therefore$ $f = 0.2025 = 20.25\% > 15\%$

so, adopt $f = 0.15 = 15\%$

(c) For equilibrium super elevation, when the pressure on inner and outer ~~which~~ wheels is same, Thus $f = 0$

$$\therefore e = \frac{v^2}{127R} - f$$

$$= \frac{(60)^2}{127 \times 140} \cancel{= 0.2025}$$

$$= 0.2025 > 0.07$$

So, provide super elevation (e) = 0.07
= 7 %

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$e = \frac{1}{f}$

Q.No. 2) The design speed of a highway is 80 kmph. There is a horizontal curve of radius 100 m on a certain locality. Calculate the super elevation needed to maintain this speed. If maximum super elevation of 1 in 15 is not to be exceeded, calculate the maximum allowable speed on this horizontal curve.

Imp

Soln:

Given:

Design velocity (V) = 80 kmph

Radius of horizontal curve (R) = 100 m

To maintain the speed of 80 kmph the needed super elevation to be provided is calculated without considering the frictional coefficient.

$$\simeq \frac{V^2}{225R} = \frac{(80)^2}{225 \times 100} = 0.284.$$

$$\text{Super elevation } (e) = \frac{V^2}{225R} = \frac{(80)^2}{(225 \times 100)} = 0.284 > 0.067$$

But, the super elevation cannot exceed 1:15. Therefore, the maximum super elevation that can be provided = 1:15 = 0.067

Adopt $e = 0.067$

Check for coefficient of lateral friction:

$$f = \frac{V^2}{127R} - e$$

$$= \left(\frac{(80)^2}{127 \times 100}\right) - 0.067 = 0.434 > 0.15$$

Therefore take $f = 0.15$

We know,

$$e + f = \frac{V_a^2}{127R}$$

$$\text{or, } 0.067 + 0.15 = \frac{(V_a)^2}{127 \times 100}$$

$$\text{or, } V_a^2 = (0.067 + 0.15) \times 127 \times 100$$

$$\text{or, } V_a = \sqrt{(0.067 + 0.15) \times 127 \times 100}$$

$$\therefore V_a = 52.50 \text{ kmph}$$

∴ Maximum allowable speed (V_a) = 52.50 kmph.

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V.Imp

Hair pin bends:

→ Because of precipitous rock, deep valley, steep ascends to obligatory points and presence of innumerable gorges, hair pins bends are unavoidable on hill roads. Within limits of the available turnings angle, it is often very difficult and sometimes even impossible to lay out curves following normal geometric standards of design. A hair pen bend is located on a hill side having the minimum slope and maximum stability. It must also be safe from view points of landslides and ground water.

→ Hair pins bends with long arms and further spacing should be preferred. This will be reduce construction problems and expensive protective works. The following design criteria are adopted for planning hair pin bends.

(a) Straight length between two successive hair pins bends should be minimum of 60m excluding the length of circular and transition curves. This length further depends upon the hill slopes to avoid costly protective measures between the upper and lower arms of the bends.

(b) minimum design speed = 20 kmph

(c) Minimum radius of the inner curve = 14m

(d) minimum length of transition = 15m

(e) Super elevation in circular portion of the curve = 1 in 10.

(f) Minimum width of carriage way at the apex of the curve are respectively 11.5 and 9.0m for two-lane and single-lane lane pavement of National and state Highway. The minimum width of MDR and ODR is 7.5m.

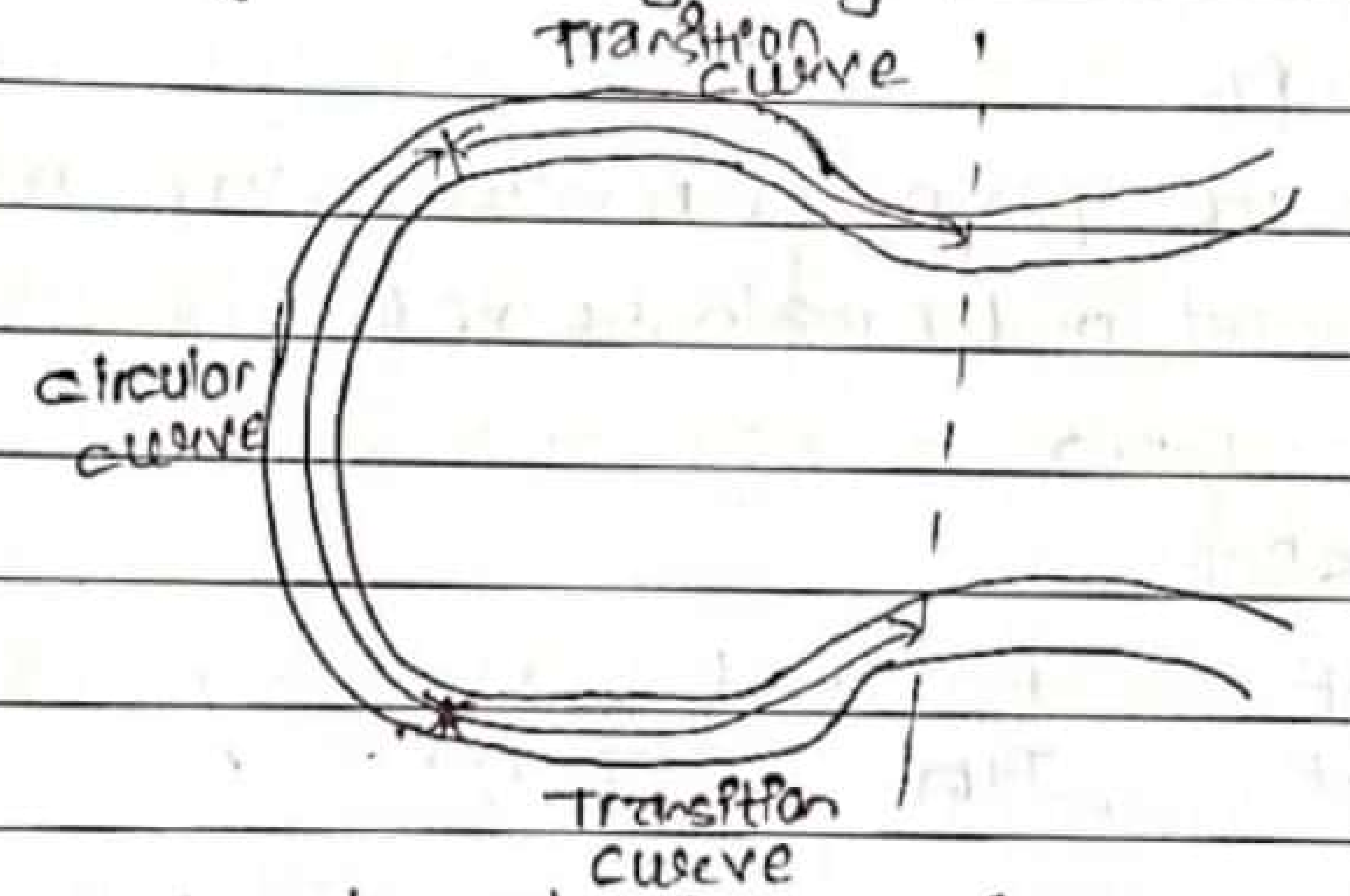
(g) The maximum and minimum gradients are 1 in 40 and 1 in 200 respectively at the curve

(h) Approach gradients should not be steeper than 2.5 % for 40 metre.

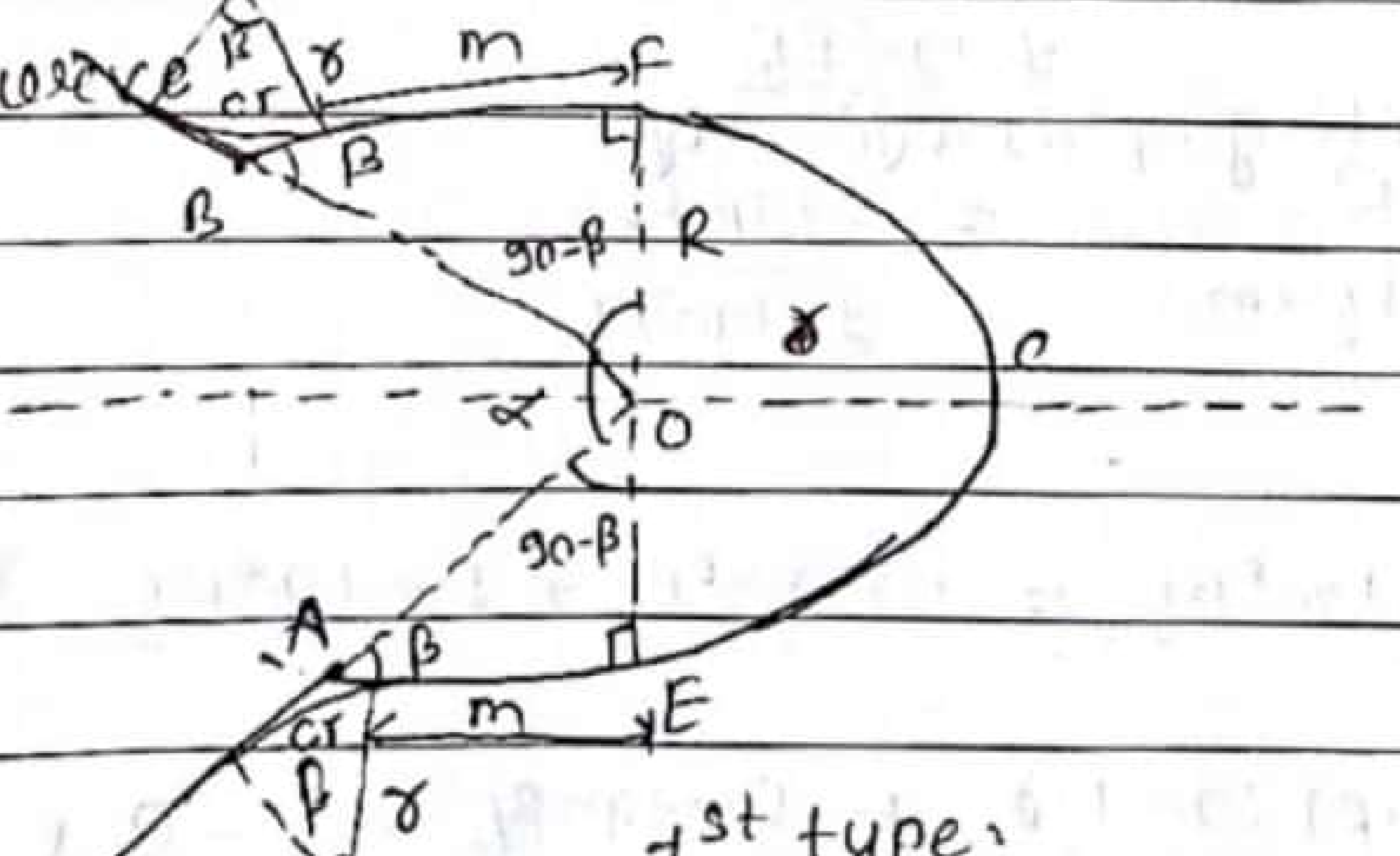
(i) For good visibility at the hair-pin bends, the island portion shall be cleared of all the ~~the~~ trees etc.

Design of Hair pin bends:

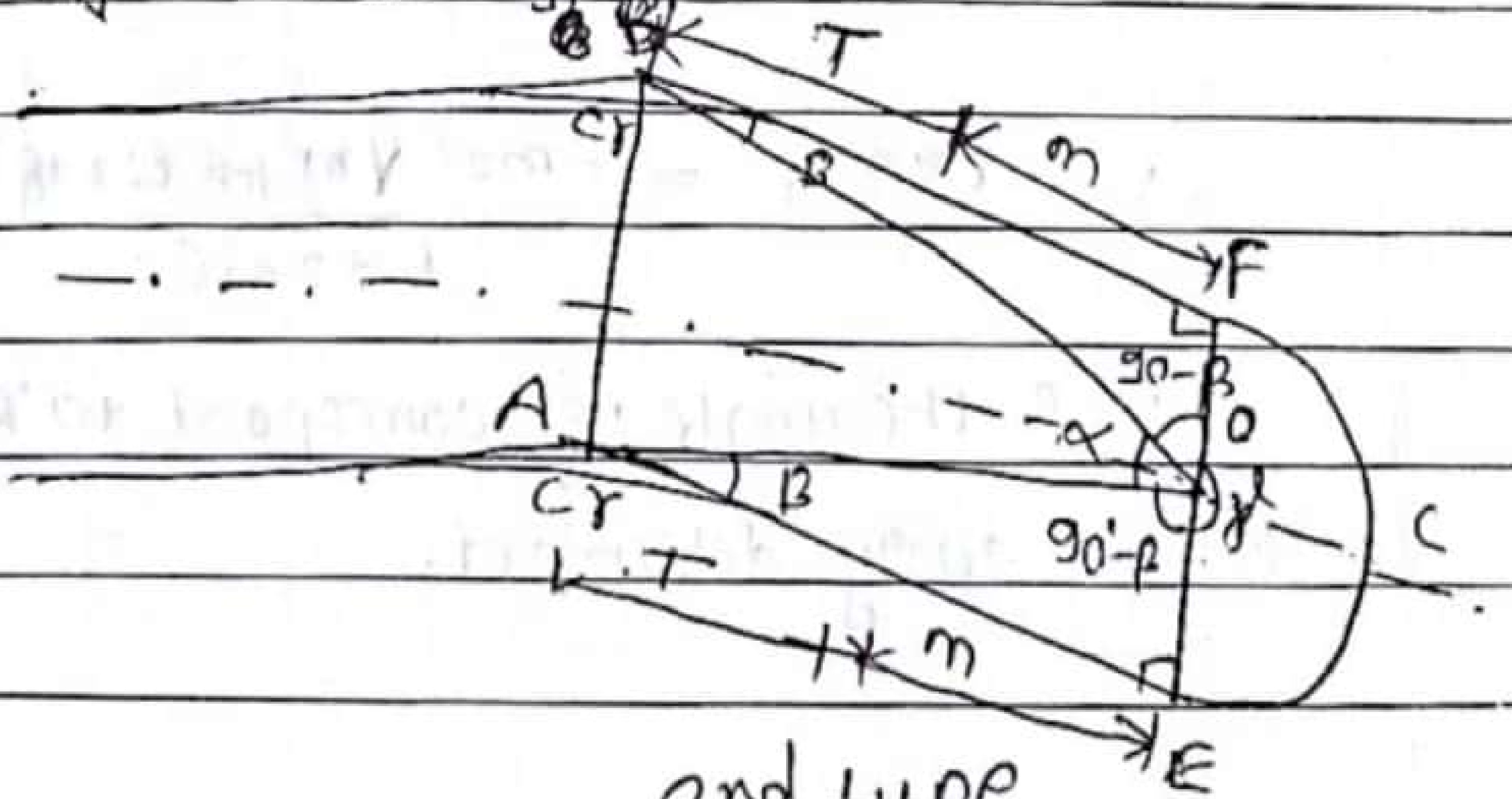
↳ In hilly regions it may become difficult to avoid bends where direction of the road reverses, precipitous rock, deep valley and obligatory points.



Hair pin bends where unavoidable may be designed either as a circular curve with transition at each end or as a compound circular curve



1st type.



2nd type

Hair pins bends consisting of:

a = main curve

C_r = reverse curves

M = tangent, α = acute angle of bend, r = radius of reverse curve

R = Radius of main curve.

C = total length subtends an angle 'β' (Deflection angle)

A and B = are ~~apices~~ apexs of the reverse curves.

Tangent length of reverse curve:

$$T = r\tan\beta/2$$

Distance from the apex of the reverse curve angle to the commencement of the main curve is:

$$AE = BF = T + m$$

From ΔAOE or ΔBOF,

$$\tan\beta = \frac{OE}{AE} = \frac{R}{T+m} = \frac{R}{r\tan\beta/2 + m} \quad \text{---(i)}$$

From ~~trigonometry~~:

$$\tan\beta = \frac{2\tan\beta/2}{1-\tan^2\beta/2} \quad \text{---(ii)}$$

Equating eqn (i) & (ii), we get

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

$$\text{or, } R - R\tan^2\beta/2 = 2r\tan^2\beta/2 + 2m\tan\beta/2$$

$$\text{or, } (2r+R)\tan^2\beta/2 + 2m\tan\beta/2 - R = 0$$

$\{\because ax^2+bx+c=0\}$ Quadratic equation $= \frac{-b\pm\sqrt{b^2-4ac}}{2a}$

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

Hence, the angle 'β' correspond to 'R', 'r' and 'm' can be easily determined.

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

$$AO = OB = \frac{T+m}{\cos\beta} = \frac{R}{\sin\beta}$$

The centre angle 'γ' corresponding to the main curve of the road is

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

And

the Length of the main curve is 'c' $= \frac{\pi R \gamma}{180}$

Hence, the total Length of the bends is:

$$L = 2(CT+m) + C$$

The expression above is for symmetrical hair pin bends having reverse curve with equal angles and equal radii.

Short Note

3.6 Sight distance:

↳ The sight distance is defined as the actual distance along the road surface which a driver sittings at a specified height in a vehicles can see object either moving or stationary on the road surfaces.

On straight plane road there is no problem or restriction to visibility. But sight distance may have been obstructed due to following reasons:

(i) Due to sharpness of horizontal curves.

(ii) Some object at the inner side of the road curve, obstructing the visibility.

(iii) Due to summit of vertical curve.

(iv) At road intersection building and other obstructing the centre line.

The stopping sight distance is calculated from the relation:

$$SSD = 0.278Vt + \frac{V^2}{254f}$$

where,

V = Design speed, kmph

t = reaction time, take as 3 seconds.

f = coefficient of friction, assumed as 0.4

Safe stopping sight distances for various speeds given by IRC, are given below:

Speed, kmph	20	25	30	40	50
SSD, m	20	30	35	50	70

The overtaking sight distance is calculated from the relation:

$$OSD = 0.556V_b + 2S + 0.278 V_bT + 0.278VT$$

where,

V = speed of overtaking vehicles, kmph

V_b = speed of overtaken vehicles = $(V-16)$ kmph

S = spacing of moving vehicles = $(0.2V_b+6)$ m

T = overtaking time = $\sqrt{\frac{14.4}{A}}$ secs.

A = acceleration in kmph/sec, taken as 4.72, 4.45, 4.00 for speeds of 30, 40 and 50 kmph respectively.

Minimum overtaking sight distance specified are:

Speed, kmph	30	40	50
OSD, m	90	145	210

classification:

a. stopping sight distance (SSD)
b. overtaking sight distace (OSD)
c. sight distance at intersection

SSD : stopping sight distance:

It is the minimum distance required within which a vehicles moving at designed speed can be stopped without colloiding with a stationary object on the road surface.

It is also called non-passing sight distance.

[∵ The sight distance ~~at~~ any spot is never less than the stopping sight distance]

Factors influencing stopping sight distance:

1. perception /Reaction time of driver.
2. Speed of vehicles
3. Efficiency of braikes.
4. Frictional resistance between road and wheels of vehicles.
5. Longitudinal gradient of Road.

• 1. Perception/Reaction time of driver:

↳ Perception is the process gathering information from environment and the reaction time is time taken from the instant of the object is visible to the driver to the when the brakes are applied. Total reaction time = perception time + break reaction time.

It depends on character of driver, characteristics of obstacles, speeds, characteristics of vehicles etc.

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(2) Speed of vehicles:

↳ Higher speed, requires more stopping sight distance. so if design speed increase, SSD is also increases.

i.e $s = v * t$

(3) Efficiency of brakes:

↳ Efficiency of brakes depends upon age of vehicles. If efficiency is more the vehicles stop at the moments of the brakes are applied. 100% breaking efficiency is not desired.

(4) Frictional resistance between road and wheels of vehicles.

↳ For high frictional resistance, less stopping distance required.

(5) Longitudinal gradient of road:

↳ Gradient of road also affect SSD. while climbing up a gradient, vehicle stops immediately so SSD required is less but while in descending on gradient, more SSD required.

Calculation of stopping sight distance (SSD):

SSD = Lag distance + breaking distance ---- (i)

where,

Lag distance → distance covered during the reaction time

and Lag distance = $v*t$, v = design speed of vehicles in m/s

= $0.278\,vt$, V = in kmph.

Breaking distance → distance covered by vehicles to come to stop after the brake application.

Workdone by vehicle = kinetic energy.

$$F*l = \frac{1}{2} mv^2$$

or, $$wf*l = \frac{1}{2} \frac{w}{g} v^2,$$ where,

w = weight of vehicle

f = coefficient of longitudinal friction.

= (0.3 to 0.4)

For n = 0

$$wfl = \frac{1}{2}\frac{mv^2}{g}$$

$$\therefore \boxed{l = \frac{v^2}{2gf}}$$, V = speed vehicles m/s

So, from equation (i)

$$\boxed{S.S.D = v*t + \frac{v^2}{2gf}}$$

If we consider gradient of n%.

$$\boxed{SSD = vt + \frac{v^2}{2g(f \pm n)*\eta}}$$ where, n = gradient

(V, m/s)

η = efficiency of brake

$$\therefore S.S.D = 0.278\,vt + \frac{v^2}{254f} \quad (V = \text{kmph})$$

$$= 0.278\,vt + \frac{v^2}{254(f \pm n\%)\eta} \quad (\text{Lt.})$$

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⇒ If the same speed vehicles coming from opposite direction in single Lane road.

Then, • Two way traffic in single Lane.

$$\text{Actual SSD} = SSD_1 + SSD_2 = 2SSD \quad [SSD_1 = SSD_2 = SSD]$$

Overtaking sight distance (OSD):

↳ The minimum distance on a highway required by a vehicles / driver to overtake slow moving vehicles ahead i.e travelling in same direction safely against approaching traffic in the opposite direction.

Factors affecting the OSD:

↳ (i) speed of overtaking, overtaken and vehicle coming from opposite direction.

(ii) spacing between vehicles.

(iii) skill and reaction time of the driver.

(iv) Rate of acceleration of the overtaking vehicles.

(v) Gradient of the road.

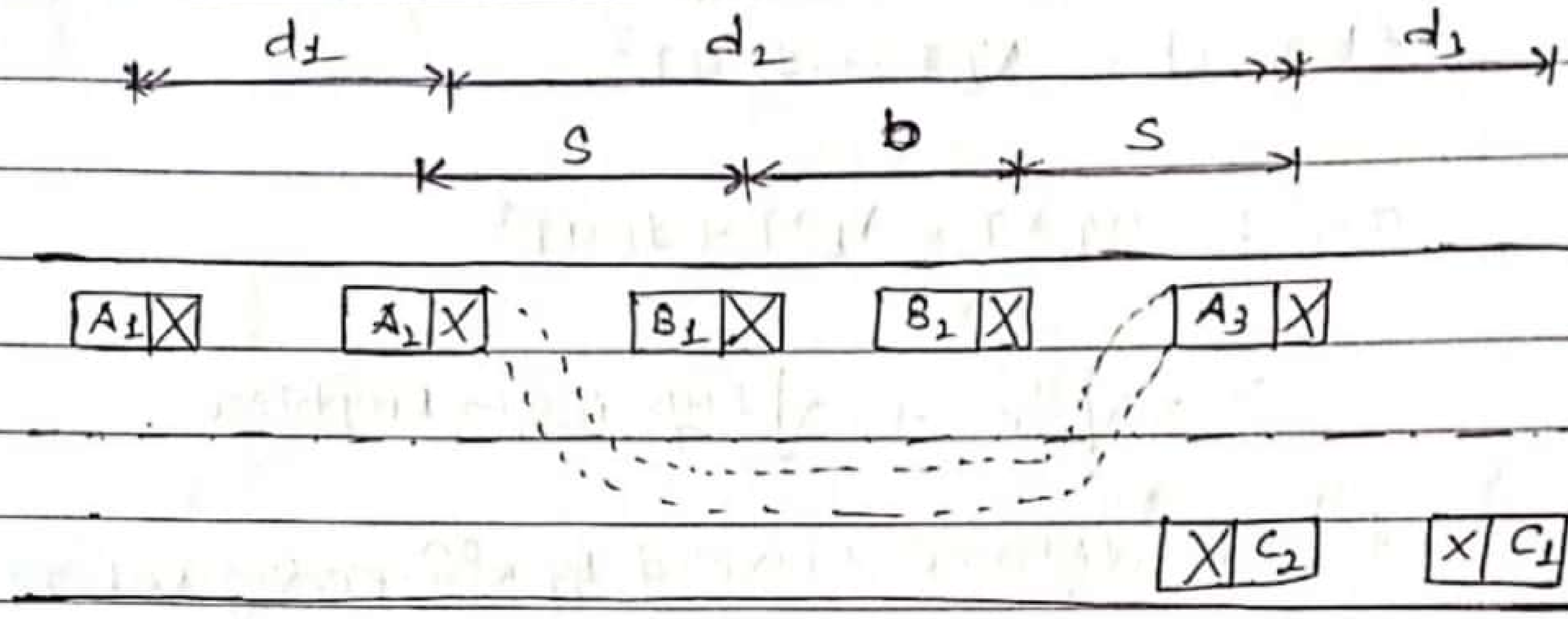
Assumption:

(i) slow moving vehicle travels at uniform speed.

(ii) Fast moving vehicle reduce its speed and follows the slow moving vehicles. (अनुसरण गर्ने)

(iii) Perceive, react and start acceleration time is 2sec.

Analysis of OSD :



where,

A_1, A_2 and A_3 = position of fast moving vehicle at different time interval.

B_1 and B_2 are the the position of slow moving vehicle

C_1 and C_2 are the position of opposite direction vehicle

V_b = speed of slow moving vehicles.

V = Design speed.

Approx, $V_b = (V-16)$ in kmph, (If not given in Numerical)

From Figure:

$$OSD = d_1 + d_2 + d_3$$

where, $d_1 = V_b * t$

V_b = speed at slow moving vehicle ~~after~~ before overtaking

t = 2sec

d_1 = distance travel by the overtaking vehicle 'A' during reaction time

S = spacing = $(0.69V_b + 6.1)$m

$b = V_b * T$

T = overtaking time from A_2 to A_3

d_2 is the distance travel by the vehicle 'A' during in actual overtaking operation.

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$d_2 = 2S + V_b * T$ $\quad S = \{2(0.7V_b+6)\}$

$= 2(0.69V_b + 6.1) + V_b * T$

Also, $d_2 = V_b T + \frac{1}{2} a T^2$

or, $2S + V_b * T = V_b * T + \frac{1}{2} a T^2$

$T = \sqrt{\frac{4S}{a}}$ & $\sqrt{\frac{14.4S}{a}}$ if a in kmph/sec

d_3 is the distance traveled by on-coming vehicle 'c' during overtaking operation 'T'

$d_3 = VT$

$\therefore OSD = d_1 + d_2 + d_3$

$= V_b t + V_b T + \frac{1}{2} a \left(\sqrt{\frac{4S}{a}}\right)^2 + VT$

$\therefore OSD = V_b t + V_b T + 2S + VT$ (If V in m/s)

For single lane road, neglecting 'd_3'

$\therefore OSD = d_1 + d_2$

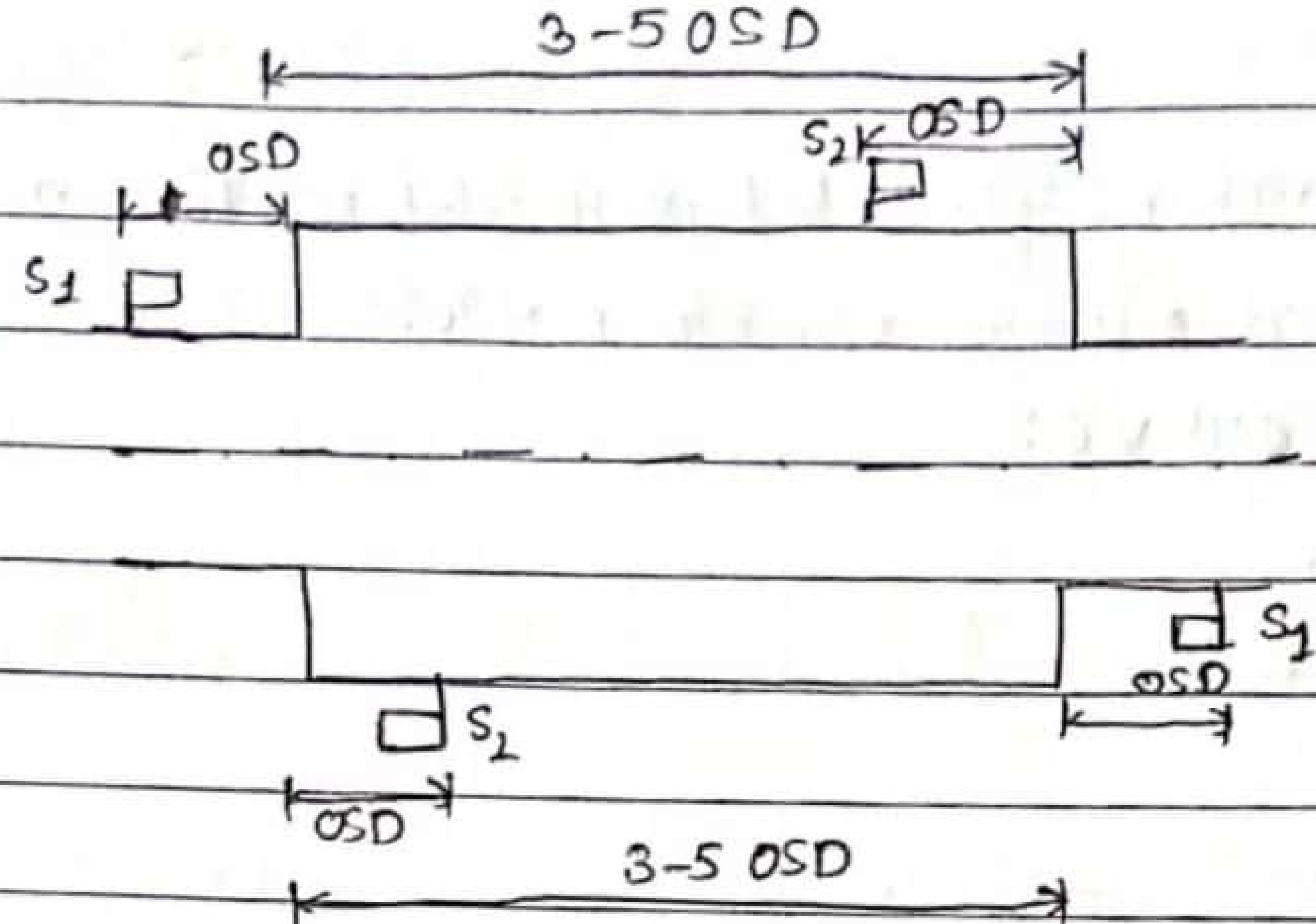
minimum length of overtaking zone = 3 * OSD

But desirable length of overtaking zone = 5 * OSD

also,

$\therefore OSD = 0.278 V_b t + 0.278 V_b T + 2[0.7 + 0.278 V_b + 6] + 0.278 VT$

"if V in kmph"



S_1 = Overtaking zone begin
S_2 = End of overtaking zone

3.7 Gradients:-

→ The ruling and limiting gradients in moutainous terrain in steep terrain over 3000m height above mean sea level are 5 and 6 %. respectively. The ruling and limiting gradients in steep terrain upto 3000m height above MSL (mean sea level) are 6 and 7 %. At high altitudes (>3000m) as the pulling power of engines decrease due to reduction in oxygen supply, the design values of steeper gradients should be lower. Exceptional gradients steeper than the limiting gradient may be sparingly used, separated by a minimum length of 100 m. At horizontal curves, the percentage compensation in gradient may be provided using formula $\frac{30+R}{R}$ with a maximum of $\frac{75}{R}$. The compound gradients may not however be flatter than 4 percent.

$$\text{Gradients} = \frac{\text{Difference in elevation}}{\text{Horizontal distance}}$$

8) Vertical curves:

→ These are the curves provided at the intersection of different grades to smoothen out the vertical profile.

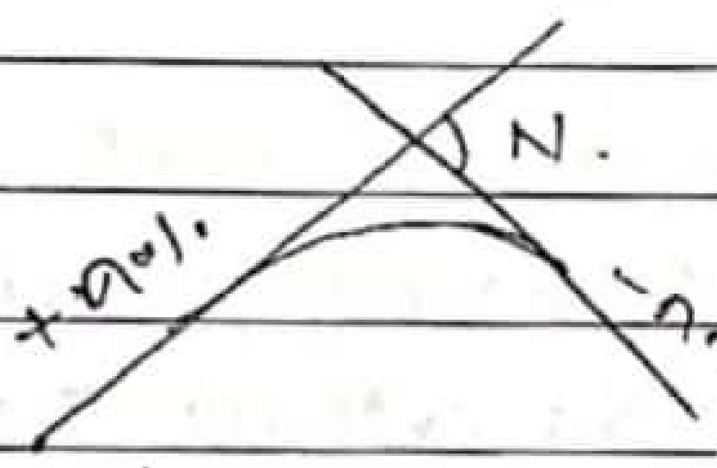
Types of vertical curves

(i) Summit curve

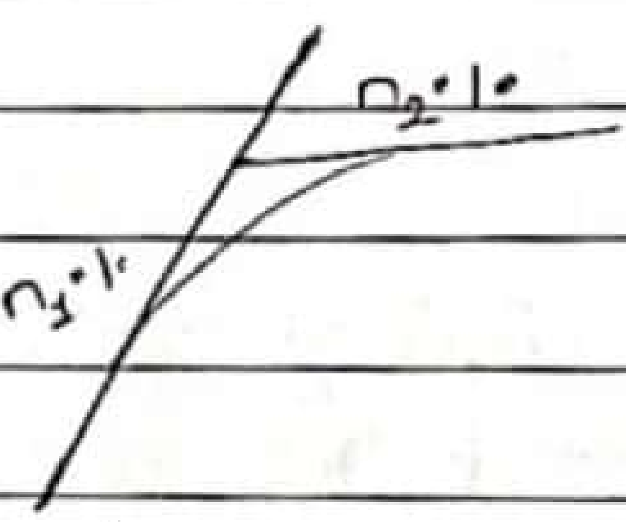
(ii) Valley curve

(i) Summit curve:

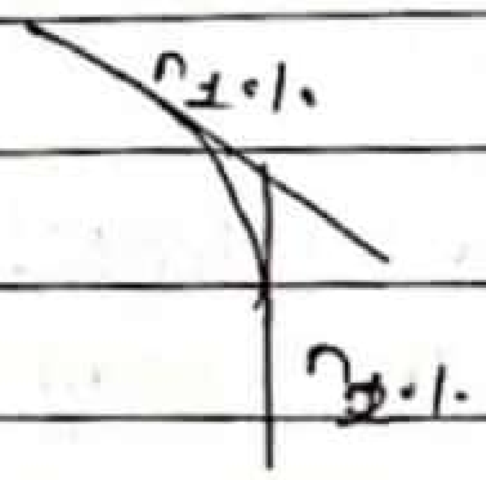
→ Summit curve with convexity upwards are formed in any one of the following.



$N = n_1 - (-n_2)$
$= (n_1 + n_2)$



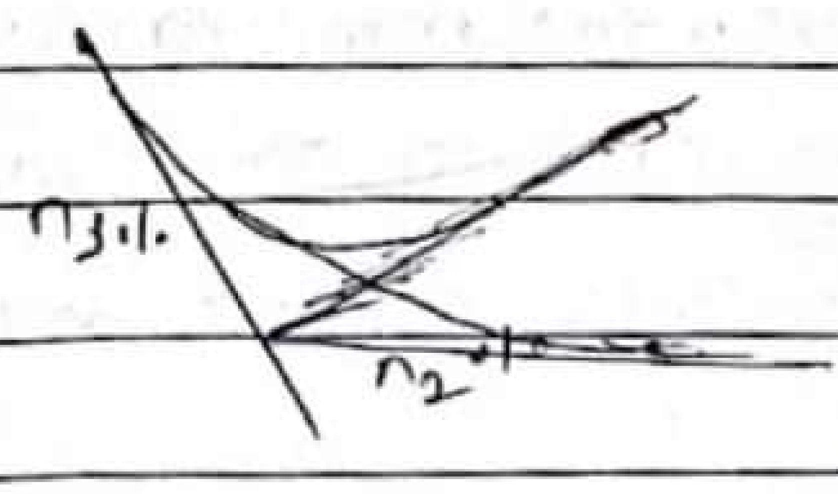
$N = n_1 - n_2$



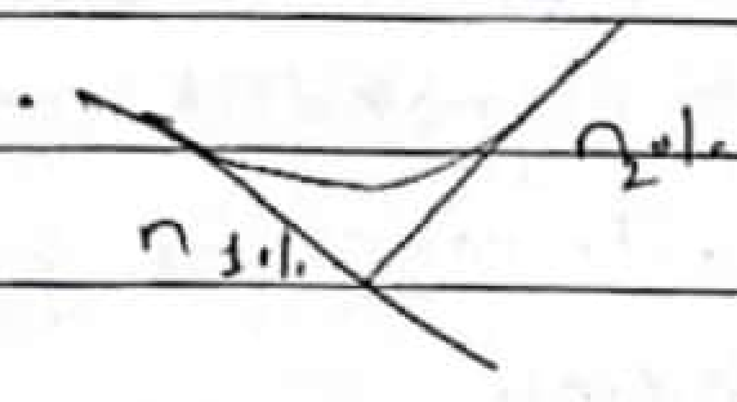
$N = n_1 - (-n_2)$
$= n_2 - n_1$

(ii) Valley curve:

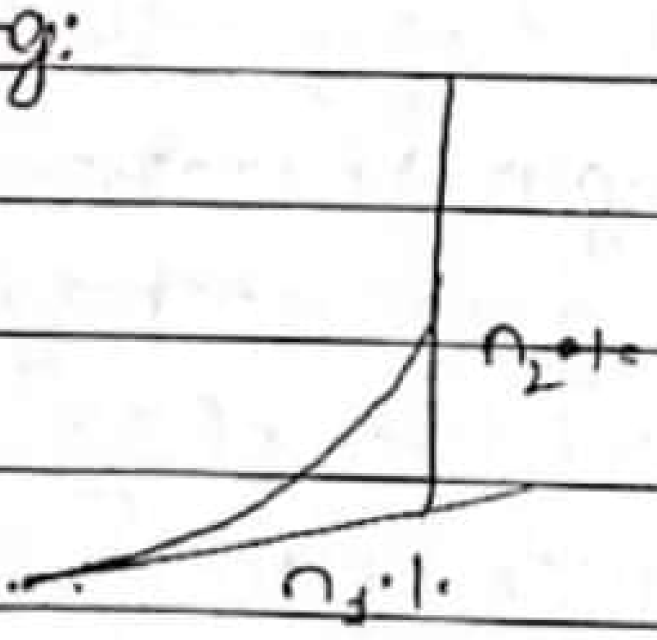
→ Valley curve or sag curve with convexity downwards are formed. In any one of the following:



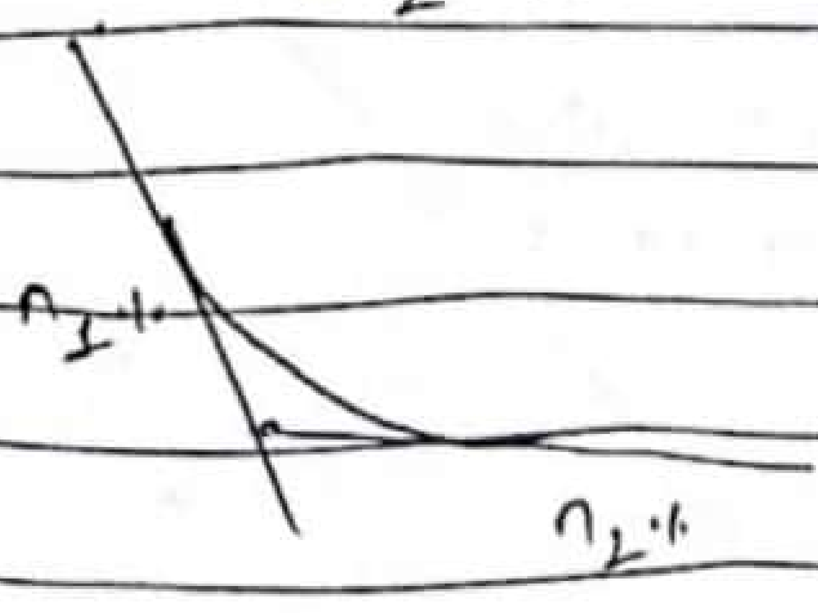
$N = -n_1 - (-n_2)$
$= n_2 - n_1$



$N = -n_1 - n_2$



$N = n_1 - n_2$



$N = n_2 - n_1$

3.8) Design of vertical summit curve:

→ The Length of summit curve can be obtain from two considerations

(1) Stopping sight distance (SSD)

(a) $L > SSD$

$$L = \frac{NS^2}{(\sqrt{2H} + \sqrt{2h})^2}$$

where,

L = Length of summit curve

N = Deflection angle (3.1.)

S = stopping sight distance (without considering grade if not given)

H = Height of driver eyelevel from road surface = 1.2 m

h = Height of the object from the road surface = 0.15 m

Substituting these value:

$$L = \frac{NS^2}{4.4 m}$$

(b) $L < SSD$

$$L = 2S - \frac{(\sqrt{2H} + \sqrt{2h})^2}{N}$$

$$\therefore L = 2S - \frac{4.4}{N}$$

(ii) Overtaking sight distance (OSD) or Intermediate sight distance (ISD):

$L >$ OSD or ISD

$$L = \frac{NS^2}{(\sqrt{2H} + \sqrt{2h})^2}$$

where, H = h = 1.2m in OSD or ISD

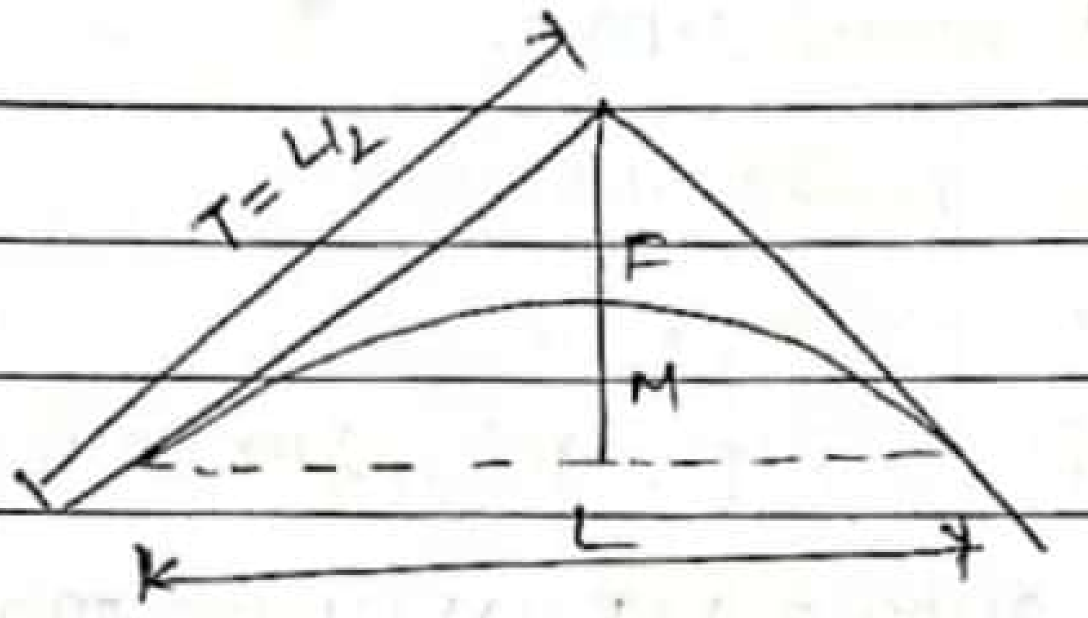
$$\therefore L = \frac{NS^2}{9.6}$$

(ii) L < OSD or ISD

$$L = 2S - \frac{(\sqrt{2H} + \sqrt{2h})^2}{N}$$

$$\therefore L = 2S - \frac{9.6}{N}$$

Element of vertical curve:



Tangent Length (T) = $L/_2$

Length (L) = 2T

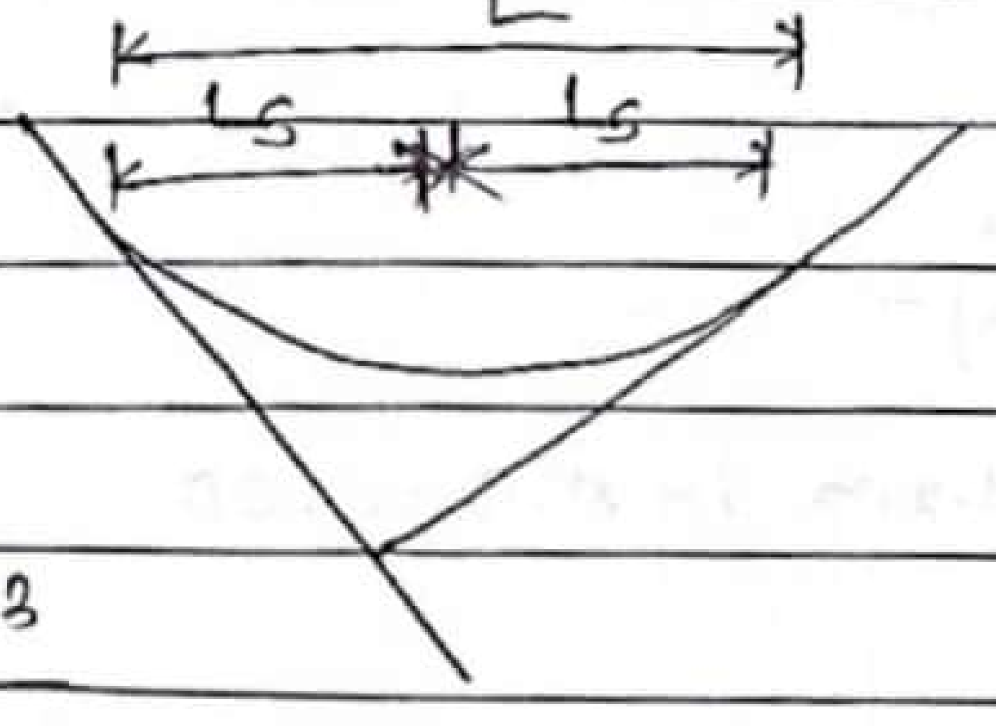
Apex distance (E) = $\frac{T^2}{2R}$

Mid-ordinate (M) = $R\left[1 - \cos\left(\frac{180N}{2\pi}\right)\right]$

3.8.2 Design of vertical valley curve:-

The length of valley transition curve is designed base on the two criteria

(1) By allowable rate of change of allowable centrifugal acceleration (0.6 m^3/sec) OR comfort condition.



$$L_S = \frac{v^3}{CR}$$

$$R = \frac{L_S}{N} = \frac{L}{2N}$$

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$$L_s = \frac{V^3}{C\frac{L_s}{N}}$$

or, $L_s^2 = \frac{NV^3}{C}$

, $l = \left(\frac{NV^3}{C}\right)^{1/2}$

$\therefore L = 2l_s = \left(\frac{NV^3}{C}\right)^{1/2}$

For $C = 0.6$

$$L = 0.38\,(NV^3)^{1/2}$$

where, V in kmph

(2) Head Light sight distance condition:-

Head Light sight distance = stopping sight distance

(a) $L > SSD$

$$L = \frac{NS^2}{(2h + 2S\tan\alpha)}$$

h = height of Head Light From road surface = 0.75m

α = beam angle of head light = 1°

$$\therefore L = \frac{NS^2}{1.5 + 0.35S}$$

(b) $L < SSD$

$$L = 2S - \frac{(2h + 2S\tan\alpha)}{N}$$

$$= 2S - \frac{(1.5 + 0.035S)}{N}$$

Adopt maximum value in design

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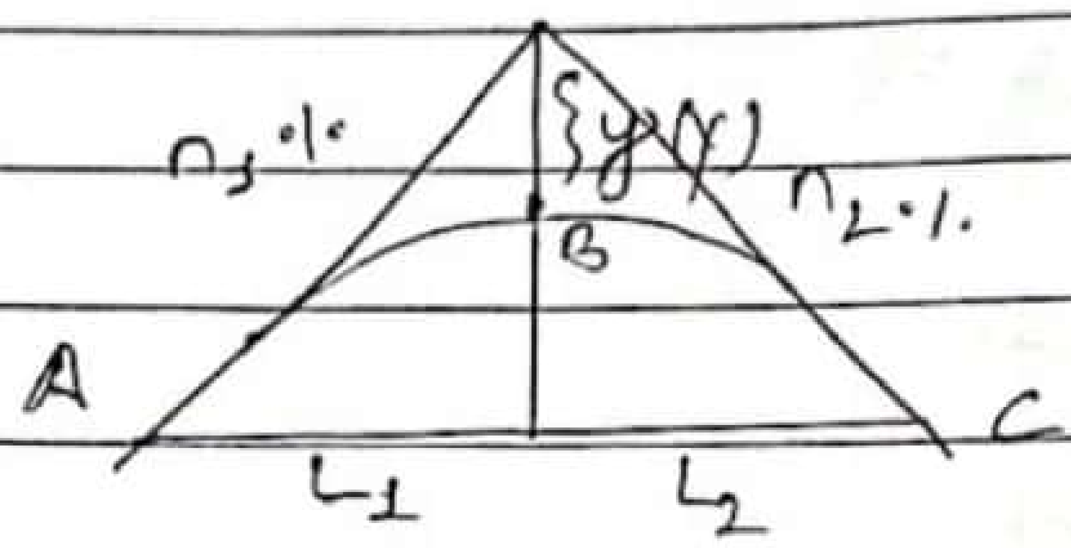
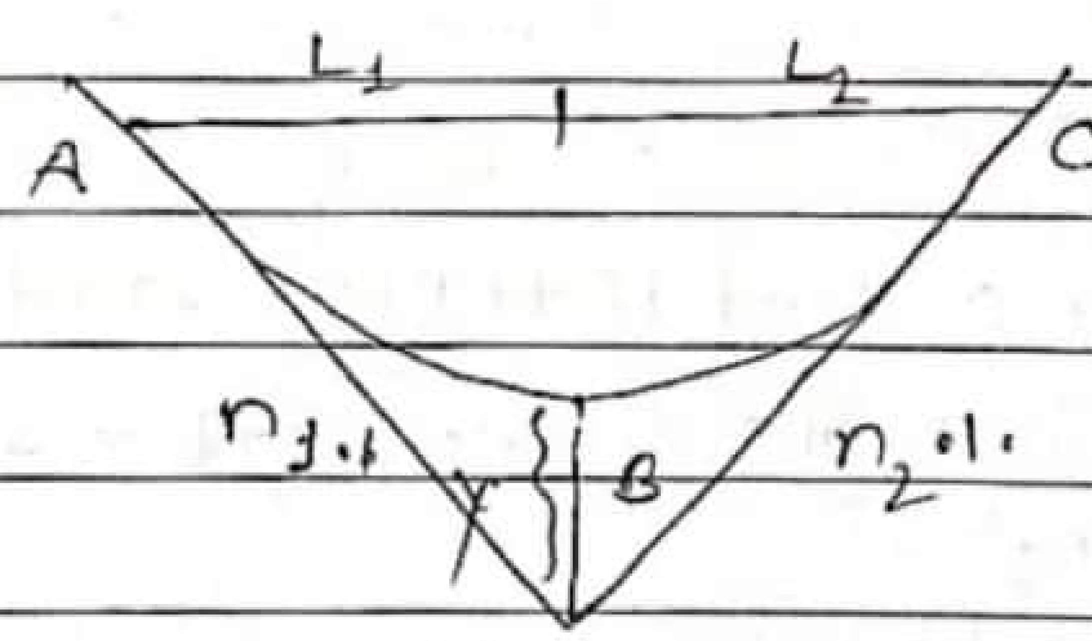
3.8.3 Lowest and Highest point of vertical curve:

Heighest point of summit curve and Lowest point on valley curve. Lowest & heighest point lies in flatter slope.



i.e if $n_1\% > n_2\%$, heighest point lies on $n_2\%$ side, if not lies $n_1\%$ side. Distance of the highest point of curve from BVC and EVC are given:



$$L_1 = n_1 R = n_1 \frac{L}{N}$$

$$L_2 = n_2 R = n_2 \frac{L}{N}$$

Elevation of the corresponding point on tangent line

$$= EVC \pm \frac{n_2 * L_2}{100}$$

$$= BVC \pm \frac{n_1}{100} * L_1$$

$$Y = \frac{L^2}{2R}, \quad L = L_1 \text{ or } L_2$$

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3.9. Typical cross-sections of hill roads:

Various types of road cross-sections includes.

(1) Box cutting
(2) Cut and fill
(3) Bench type
(4) Embankment with retaining walls.
(5) Semi bridge
(6) Semi - tunnel
(7) platforms.

(1) Box cutting:

It is needed when location of road bed is unstable or unsuitable along the hill side due to any reasons, the road is designed as a trench type of cross-section.

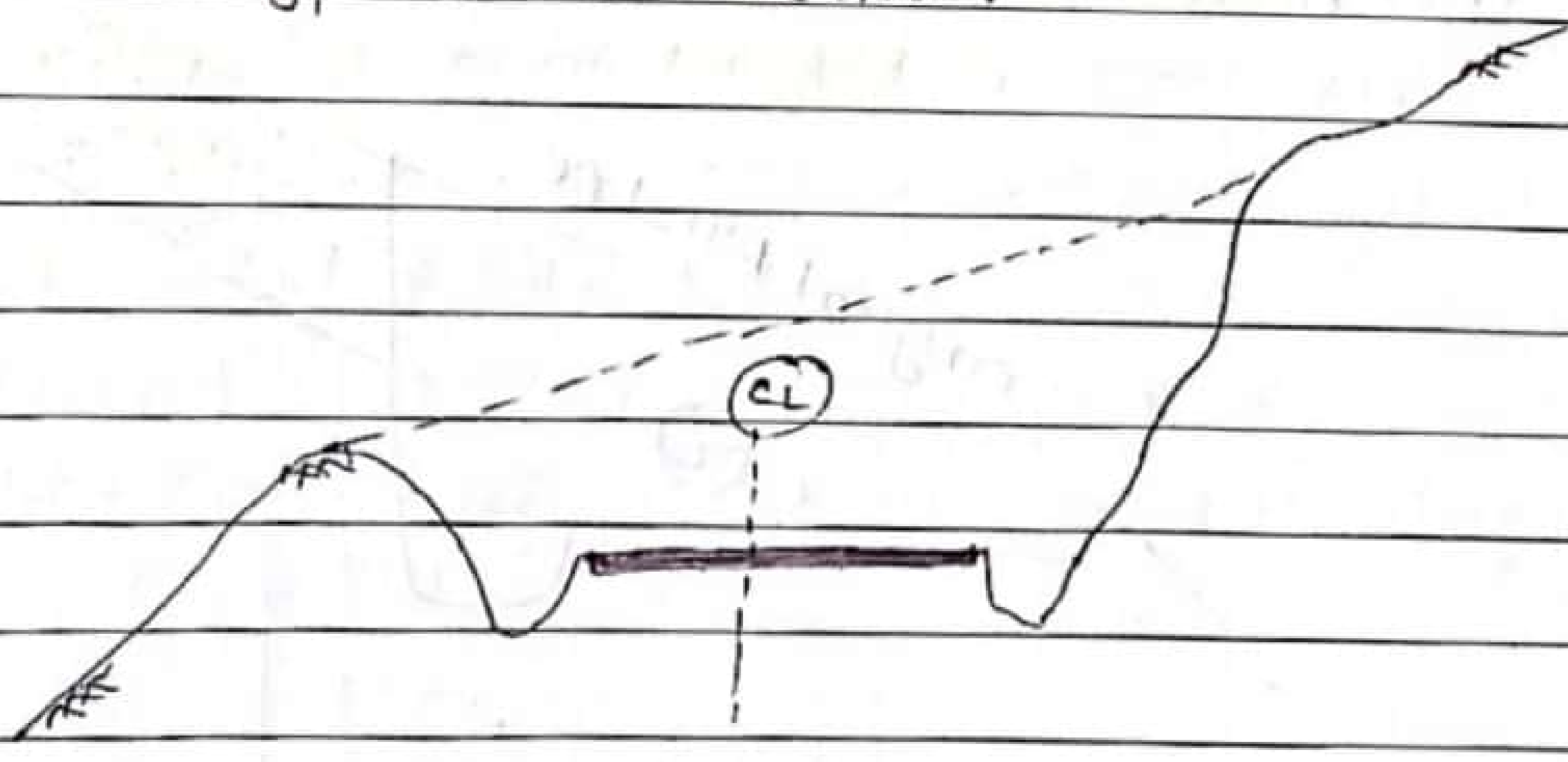

Fig: Box cutting.

(2) Cut and Fill:

If the hill side slope is more than 2%, cut and fill road bed is cheaper and environment friendly. The fill mass is obtained from cut materials at the same location.

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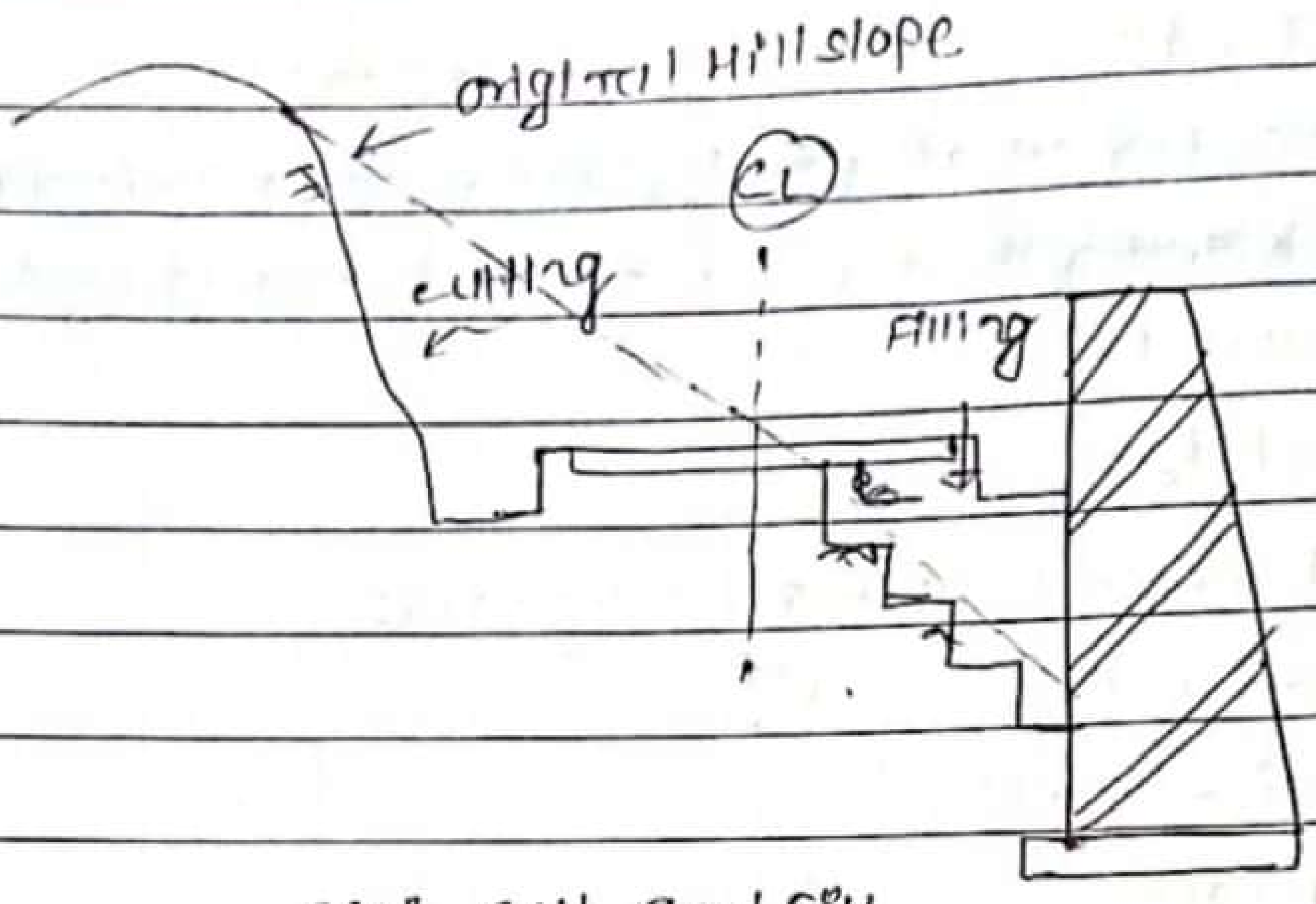

Fig:- cut and fill.

(3) Bench type:-
with increase in earthwork ensures the complete stability of the road bed, if hill side itself is stable.

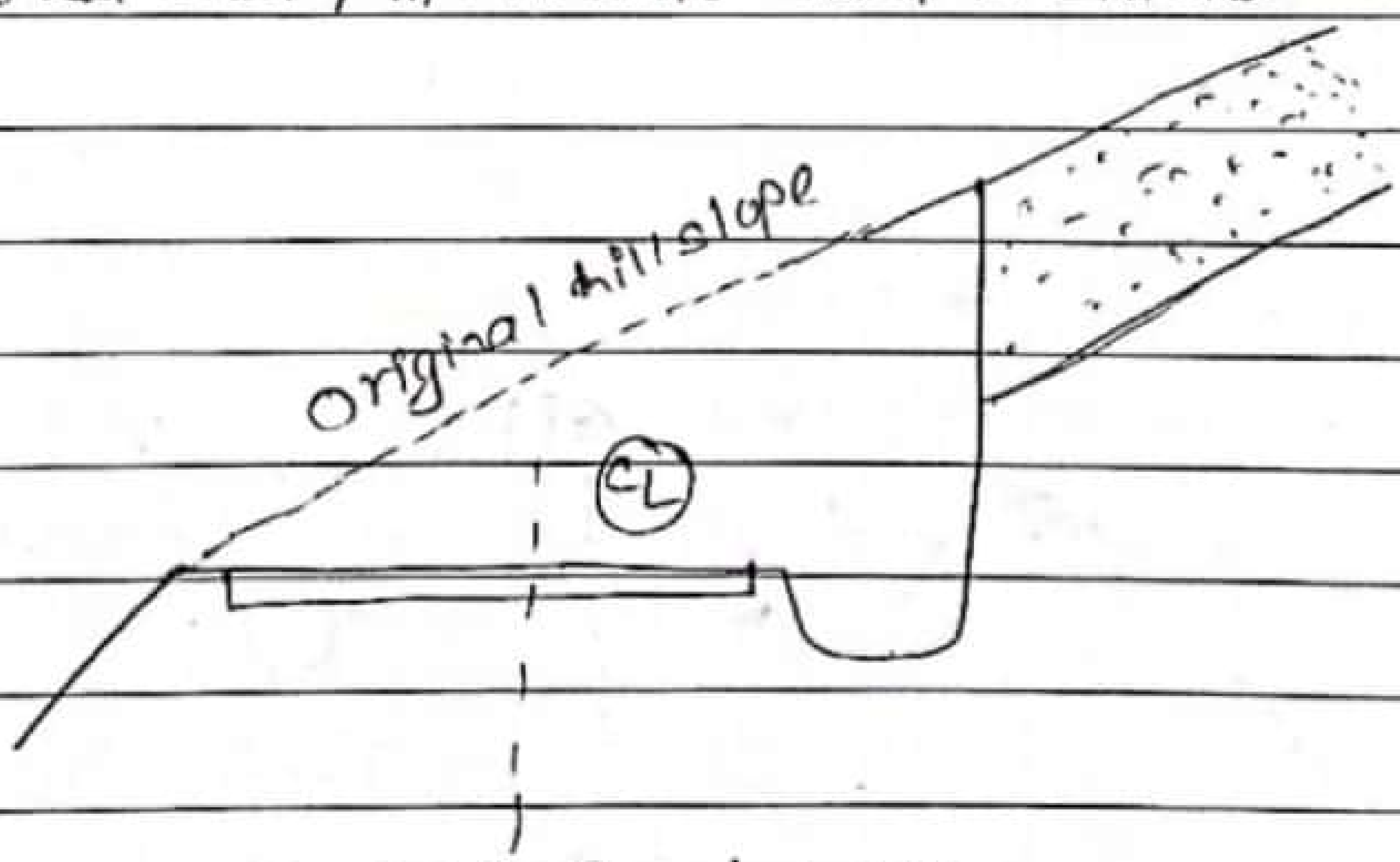

Figure:- Bench type

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(4) Embankment with retaining walls:

LD On steep-slopes over 30-35°, the earthwork involved in constructing the embankment increase substantially. Retaining wall provides the reduction in cost of earthwork and increase in stability of embankment and road bed.

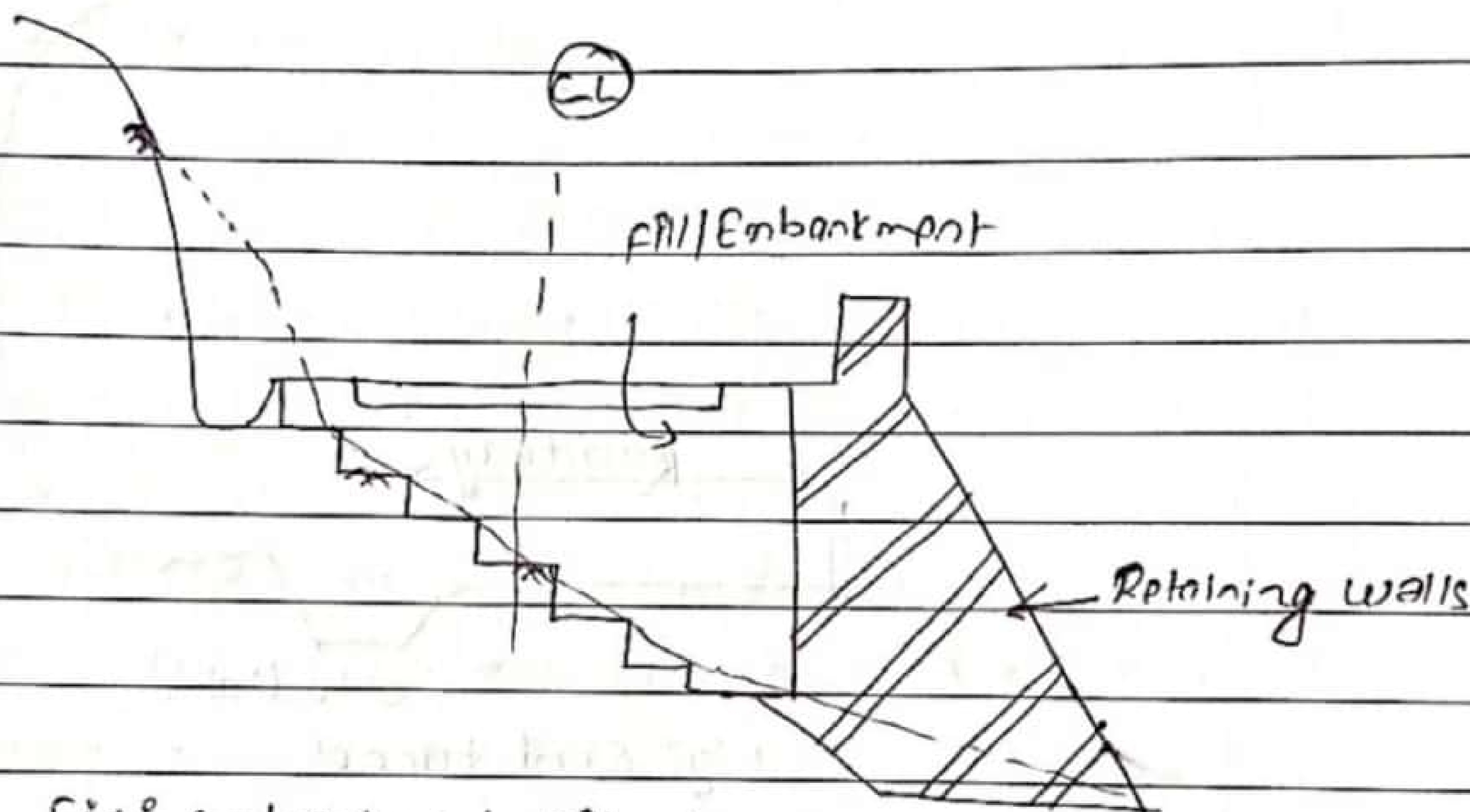

Fig: embankment with retaining walls.

(5) Semi-Bridge:

- Suitable in steep hill slope
- Reduce the quantity of works.
- part of road way is bench cut and part on the semi-bridge

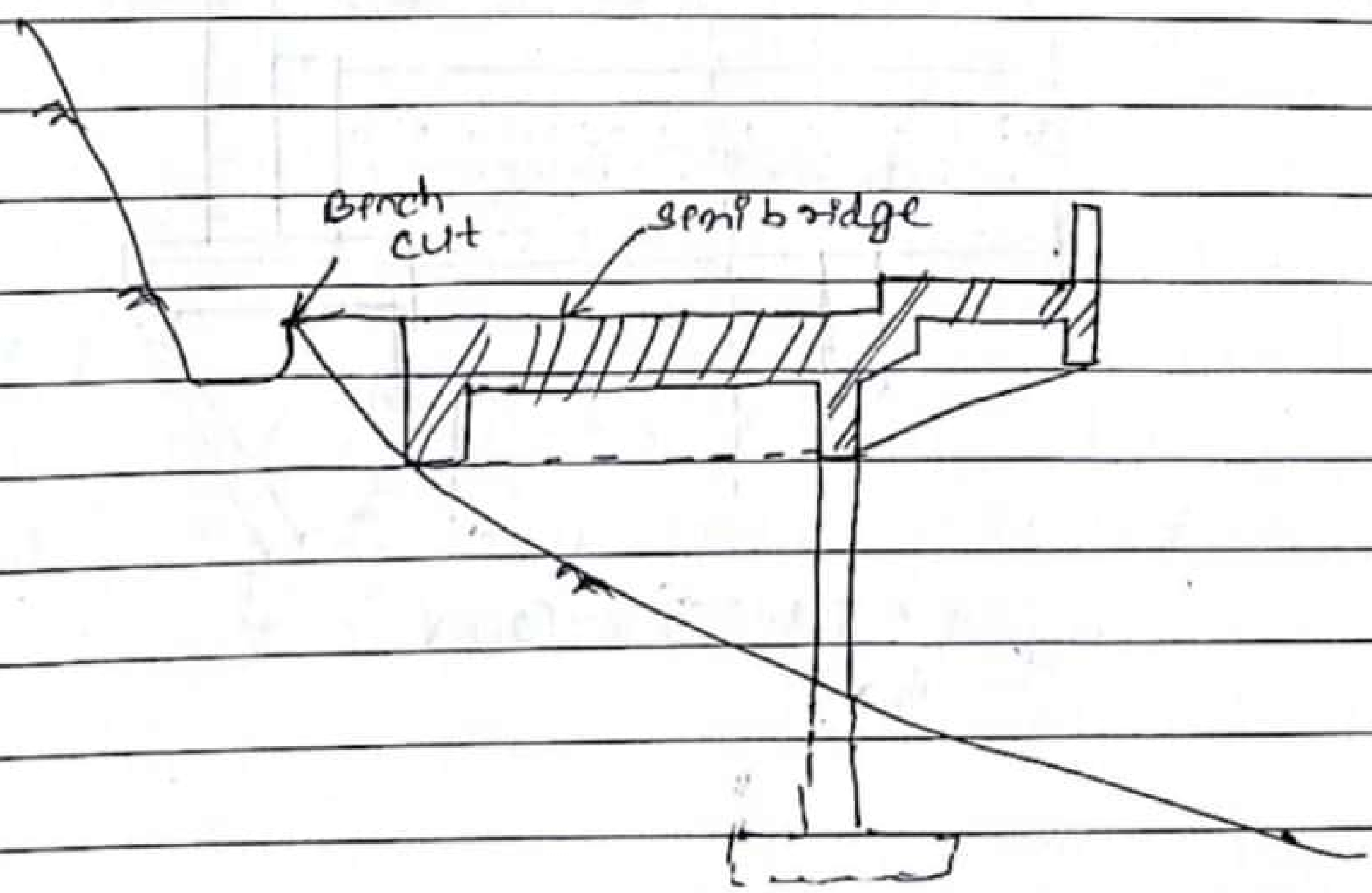

Fig: Semi-Bridge

(6) Semi-tunnel:

→ when inscribing cutting into steephills instable rock faces the rock maybe permitted to overhang the road.

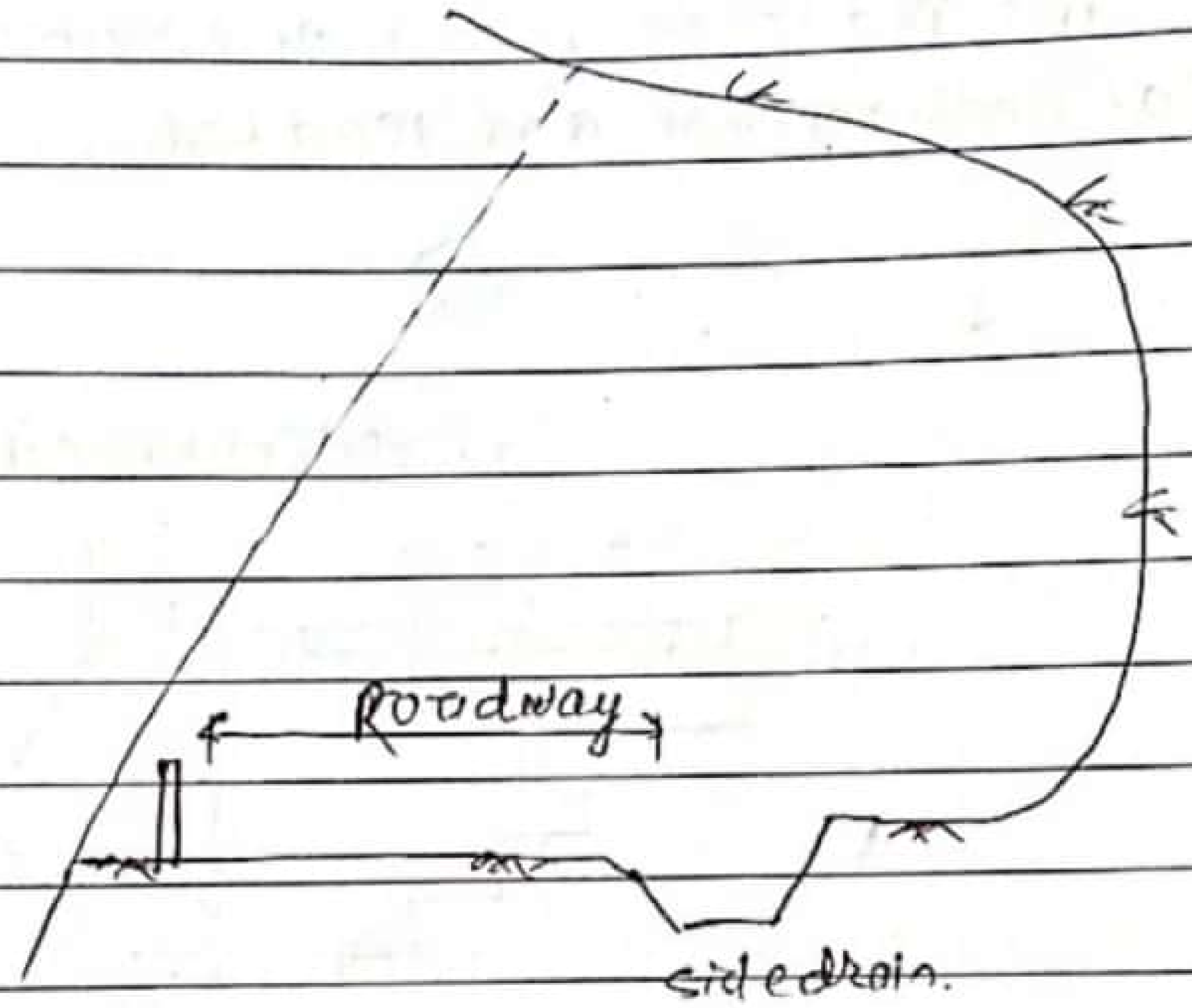

Fig: Semi-tunnel

(7) Platform:

→ platforms are usually cantilevered out of the rock on which road way is partially located. It is suitable where the enormous rock work is not feasible.

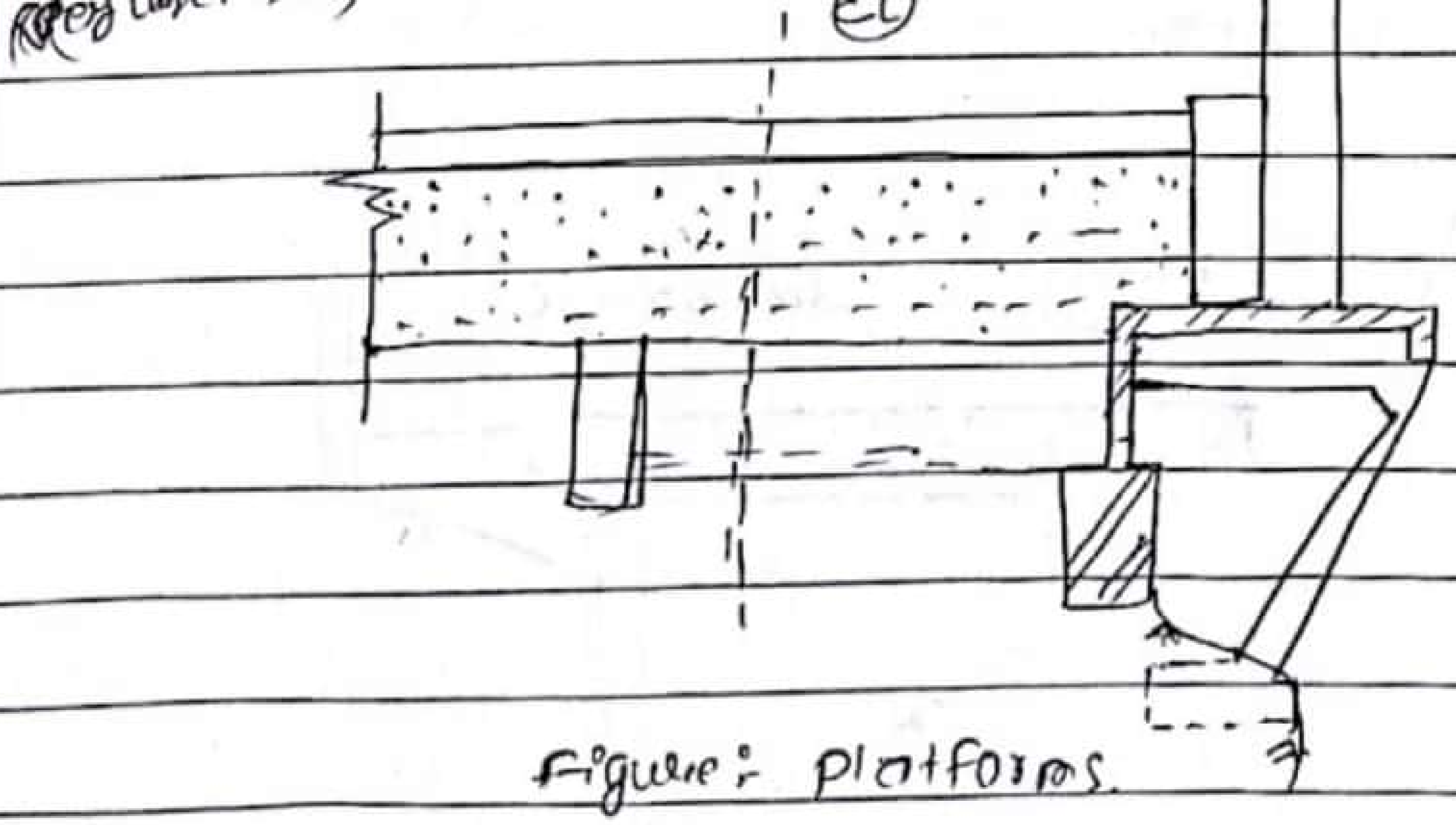

Figure: platforms.

Chapter 4. Formation works:

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4.1 Trace cut:

Imp → A party consisting of the following personnel (force), should carry out the trace out along the selected alignment and follow the pegging party:

(a) Junior Engineer - 1 NO.
(b) Surveyor / overseer - 1 NO.
(c) Helper - 2 NO
(d) labour - as required.

→ Trace cut will be about 1.0 metere to 1.2m wide track cut along the selected alignment to facilitate access to the area for inspection (review) and survey.

→ It may not be possible to cut a trace (cover) where the pegged route traverses precipices (very steep cliff) and may, therefore be detoured (घुमाउरो बाटो) by cutting the trace either along the top or bottom periphery of these areas.

4.2 Jungle clearance:

Imp → The alignment of hill road generally passes through dense vegetation except for barren (बाँझो), snow cloud (बादल) areas and cultivated habitations.

→ clearance of vegetation / jungle along the proposed alignment is the first activity in actual construction of the road.

→ As clearance of jungle results in reducation of green cover and is harmful to environment and ecology and upsets eco-balance, when done on a large scale, it is essential that alignment is so choosen to minimize jungle clearance.

↳ jungle clearance is generally done in two stages as under

(a) clearance of undergrowth, shrubs, bushes, creepers, and ballies (unculturable) upto 30cm girth (length).

(b) cutting down trees exceeding 30cm girth.

(4.3) Earthwork in excavation :-

↳ The earthwork for formation of hill road involves mostly side cut excavation to achieve designed formation width.

↳ For the purpose of excavation the soil is classified in three broad categories as under.

(a) ~~Type~~ Ordinary / Heavy soil :-

↳ This comprises (consists) of organic soil, clay, sand, ~~mo~~ and stiff clay which can be excavated manually by pick axes and or shovels or with dozers / excavators with normal efforts. This can be cut to side slopes of 1:1 to 1/2 : 1 (H:V). soil mixed with boulders is also deemed (kept / মানা) to come under this category.

(b) Soft rock :-

↳ This consist of soft (red soil) varieties of rocks such as lime stone, sand stone, laterite, conglomerate (composite rock) or other disintegrated rocks, which can be excavated by crow bars (heavy iron lever) and pick axes without blasting or with casual blasting. This can be cut to side slope of 1/4 : 1 to 1/8 : 1 (H:V).

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(c) Hard rock:

↳ This covers maybe any hard rock, excavation of which involves intensive drilling and blasting. This can stand vertical or even overhanging cut depending on the type/mass and dip of rock. Normally, the cut may vary from 80°-90° to horizontal.

4.4. Rock cutting, drilling, blasting, clearing:

Imp # Rock cutting:

↳ Rock cutting involves drilling with specialist equipments, blasting with explosives and the clearance of blasted debris with dozers. These being very expensive and risky operations, call for thoughtful planning and careful execution by personnel having through knowledge and extensive practical experience in rock cutting work and use of drilling and blasting and equipments and explosives.

↳ The planning of rock cutting work consists of:

(a) Determination of resources/stores required based on estimated quantum of work, output norms and target time for completion of the work

(b) Location of most advantages points/faces to commence the work based on detailed ground reconnaissance

(c) Working out the drilling patterns most suitable to the particular Location, assessing the quantum of individuals charge and sequence of blasting

(d) Special precautions for wet/under-water/cold weather blasting and dealing with figures.

(e) The effort should be to collect and store as much blasted rock as possible to use the same for subsequent protective, drainage and pavement works.

Drilling:

→ The first step after detailed planning is drilling operation. The main points pertaining (related) to drilling are:

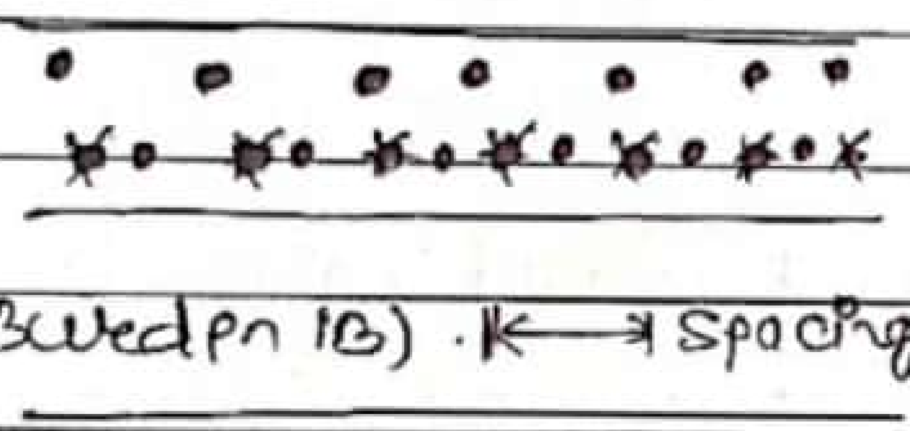
(a) In forward locations where compressors cannot be taken light, portable, mechanically operated drills are used.

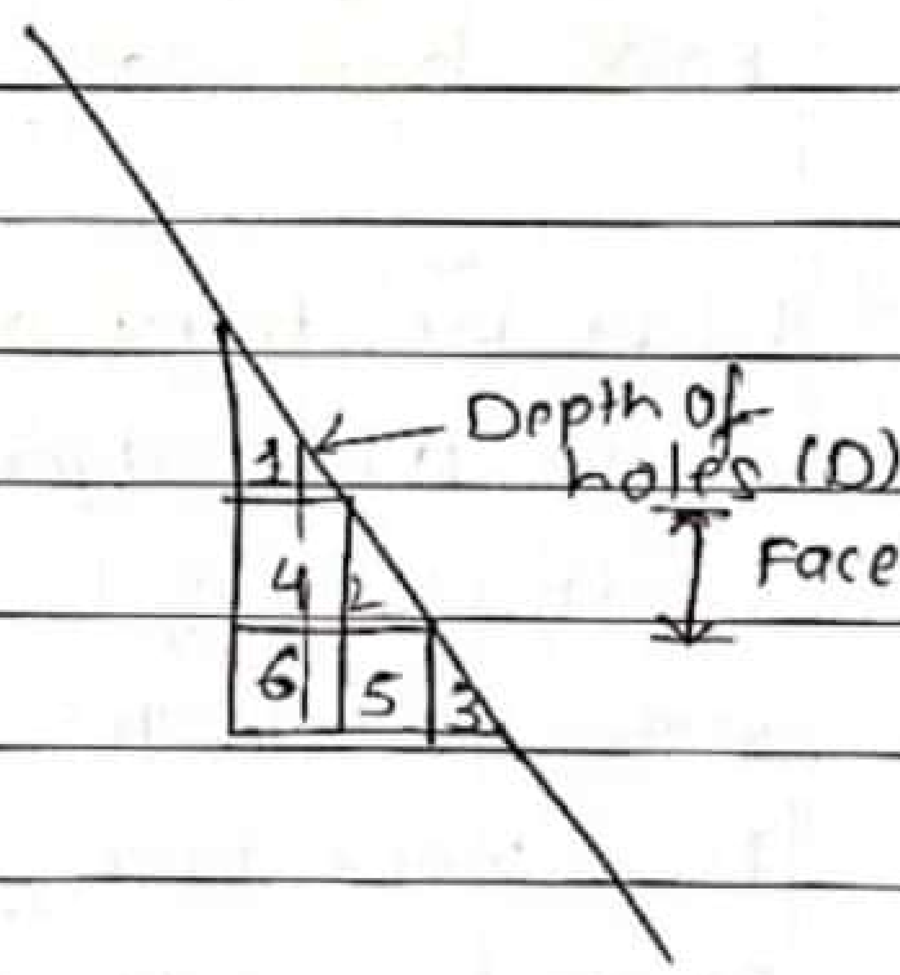
(b) The most commonly used drilling equipments is pneumatically operated rock hammer capable of drilling about 40 mm dia. holes upto 3 meters in depth. Generally the maximum depth of holes for blasting in continuous rock is restricted to 1m.

(c) In very exceptional cases where deeper holes are essential to be drilled, in order to avoid the drills rods getting stuck (fixed), the first 1m of the holes is drilled with 42 mm dia. rods and the the next 1m with 38 mm dia. rods.

(d) For cutting fresh / initial formation, hillslope is cut into benches of 1 to 1.5 m vertical face. These benches are brought down to trace cut level in stages by drilling vertical holes of depth equal to or slightly more than the face height. The burden (Load) distance of the nearest row of holes from the face to the face) is kept two thirds of the depths of the holes and spacing is equal to the burden. The successive rows of holes are drilled by in zig-zag pattern.

(e) For widening of the initial cut or widening an existing road, One row of holes about 1.25 to 1.5 m deep are drilled 1 m apart and 1 m above road level on the vertical face at a slope of about 45° to the face dipping downwards. The holes is taken about 10 to 15 cm below the formation level, so that toes and (compact mass) lumps are not left after the blast. The second row is drilled horizontally with about 1 to 1.25 m spacing in zig-zag pattern with relation to lower row. The typical pattern and layout of holes are shown in figure.





$D = $ For $1.25\,F$

$B = S = 0.67\,D$

$F = 1$ to $1.5\,m$

Fig: Drilling for fresh / Initial cut

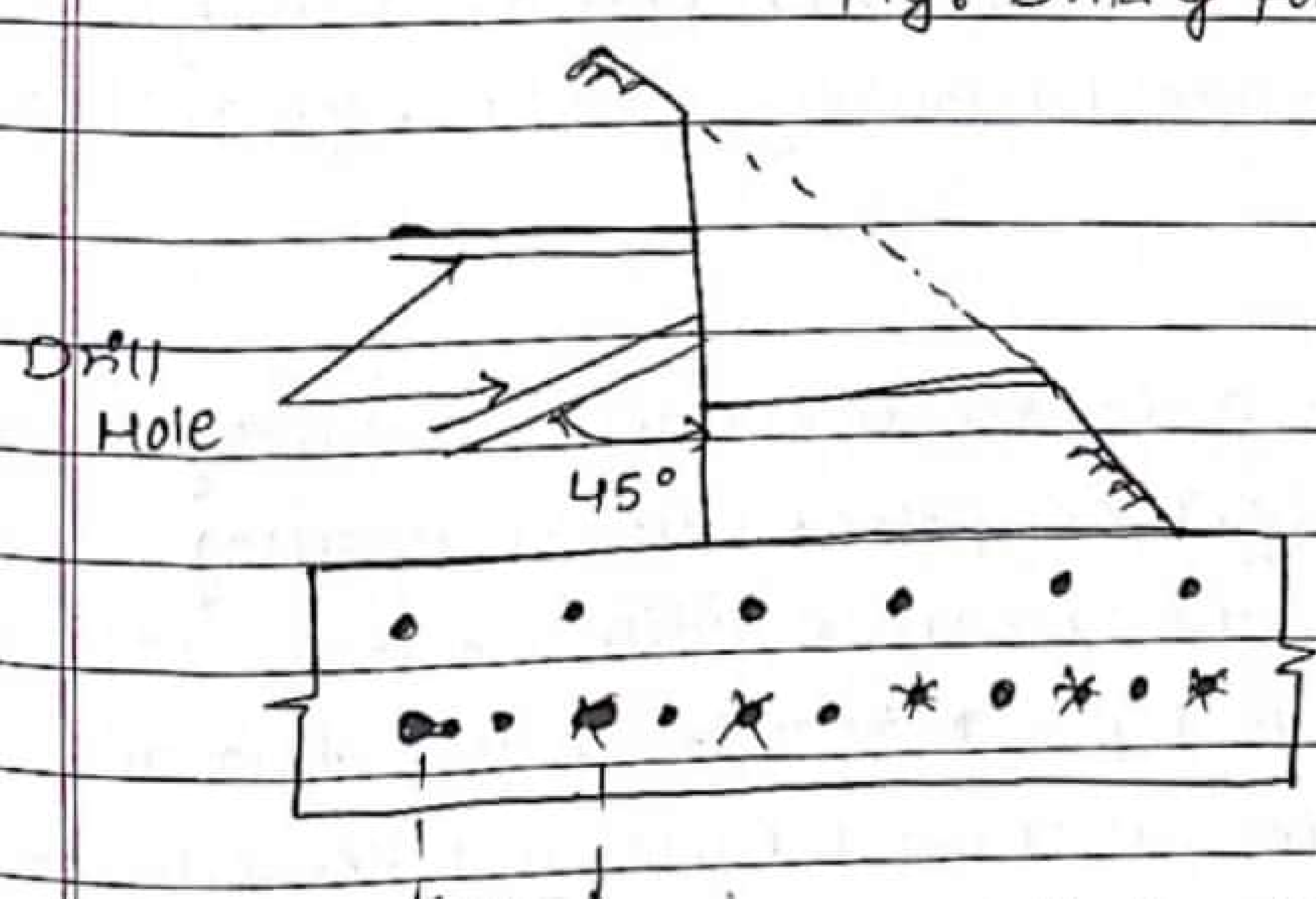


Fig: Drilling for widening.

(f) In heavy rock cut areas, wagons drills capable of drilling approximate 10 cm dia. holes and depth up to 10 to 15 m are used.

Blasting:

↳ After drilling the holes, their charging for blasting is taken up. The charge per hole depends on the type of explosive used and blasting ratio expected.

↳ Special gelatine 60% and 80% is the most commonly used explosive (Theatrical lighting) and blasting or firing is done normally with detonating fuse (shock compression) initiated by ordinary detonator (explosive device) and safety fuse or electric detonators.

↳ The main points to be observed in charging and blasting are:

(a) The charging of holes is commenced after the drilled holes has cooled down.

(b) Lower ~~are~~ one third or half of the hole is filled with explosives (gelatine) by light tamping with wooden rod. The last cartridge of gelatine is primed with knotted detonating fuse or detonator and safety fuse or electric detonator. The upper empty space in the hole is filled with suitable stemming materials, preferably ~~as~~ clay by proper tamping with wooden rod. The other end of safety fuse / electric detonator / detonating fuse is kept outside the hole for firing.

(c) The holes primed with ordinary detonator and safety fuse are fired individually. Those primed with detonating fuse are connected to each other with another detonating fuse on the surface and fired with ordinary detonator or connected in series to a lead cable and fired by an exploder dynamo. The continuity of the connection and whether the number of holes are within the capacity of the exploder dynamo is tested with ohmmeter or circuit tester.

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(d) Blasting may be done at fixed timing, either just before lunch break or evening break. So that there is no work immediately after blasting and loose stones if any are allowed to fall on their own.

(e) Warning / precautions should be taken by whistle, red flags or any other effective signals.

(f) While working in extreme cold weather, the explosives get frozen and dangerous. No forcing, rolling of explosives should be done to soften them.

(g) In wet weather conditions, firing is done with detonating fuse by a single detonator placed at dry location.

(h) Blasting, specially with electric detonators, should be stopped during thunder, storm (आंधी) and workers should leave the site to safe distance.

(i) Careful day to day account of explosives drawn from stores, consumed at site and returned to store, unconsumed should be maintained.

Clearing:

- After blasting, sufficient time should be allowed to elapse to allow for any loose stone to fall.

- The site is inspected for any dangerous overhanging or loose stone. These are removed carefully to avoid accidents.

- The clearance of blasted debris is then up either normally manually or with dozers under proper supervision.

- During the clearing of debris, maximum possible stone should retrieved (regain) and stocked / shifted to suitable locations for use in protective, drainage, pavement works etc. subsequently.

Earthwork in embankment:

- In hill roads, heavy embankment work is very limited. The ratio of cut and fill method can vary with the slope and terrain of hill.

- There is requirement for adopting cut and fill method at ~~few~~ places in mountaineous region except where valleys are to be negotiated (succeed in passing through) between hill features or mountain region.

- The area where the embankment / fill is to come is cleared of all organic matter.

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precipitous
precipices

↳ Selected materials for new embankment is spread and consolidated in layers with roller.

↳ In case of cut and fill with dozer, the consolidations is normally achieved under dozer operation.

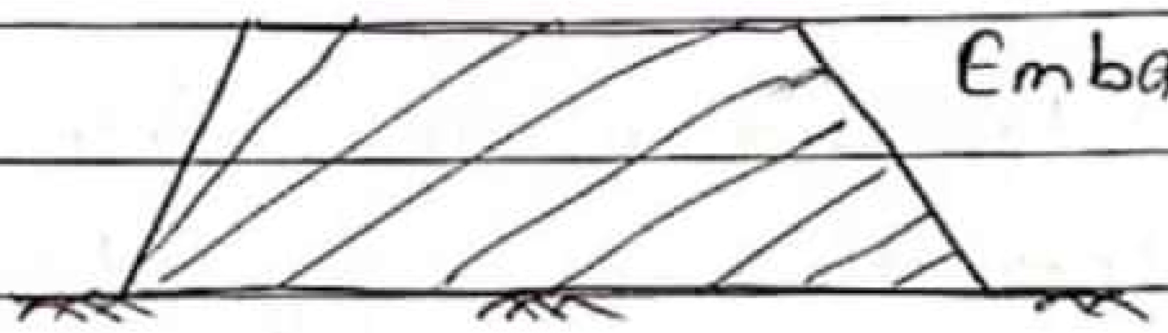

Fig :- Embankment

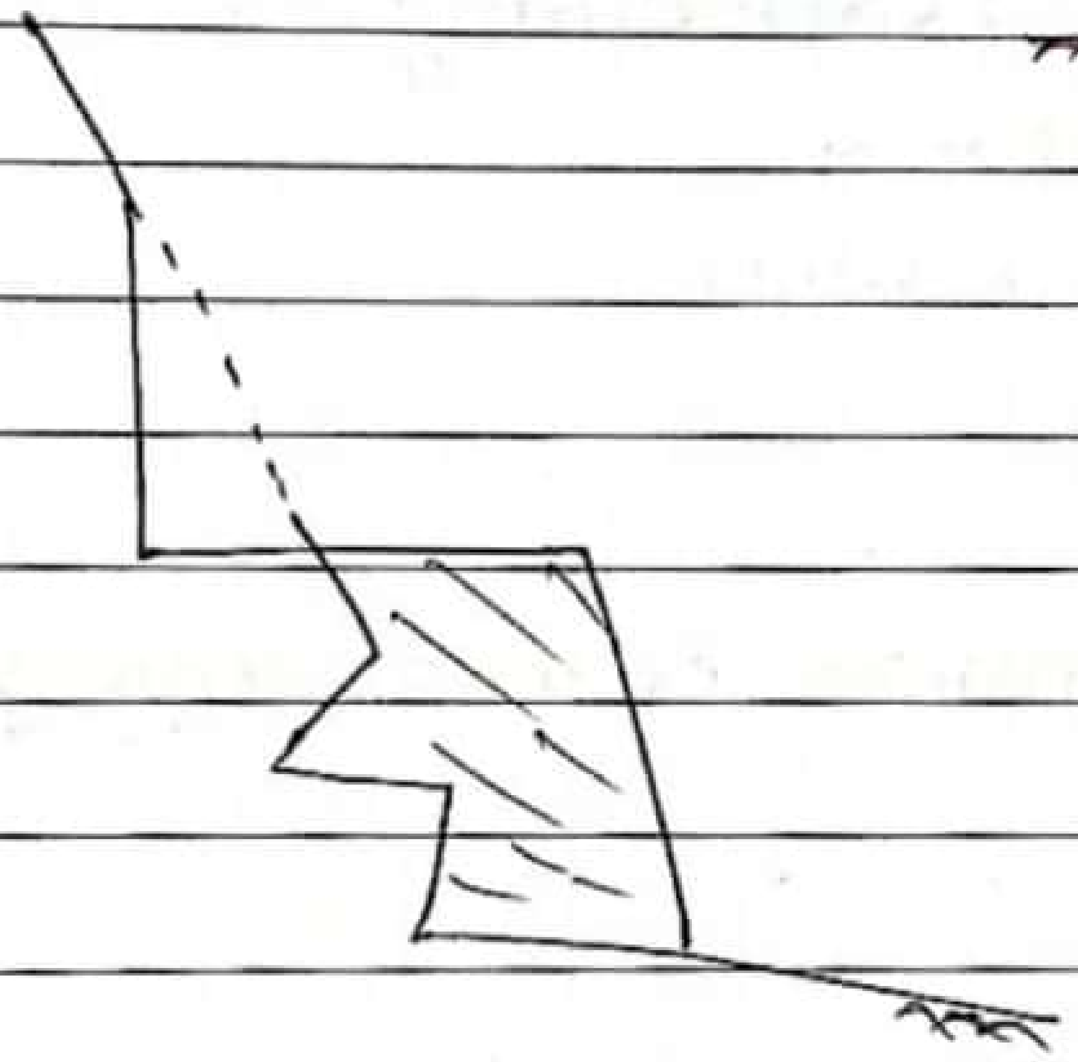

Fig : Embankment / cut & fill

4.6 Tools required for manual method of road construction.

Imp

1. Hand shovel
2. chisel (छिनो)
3. peak
4. spade (कोदालो)
5. Hand rammer.
6. Brushes
7. Trowel
8. wheel barrows
9. plumb bob
10. Hock shaw
11. Fork.

1-7) Plants and equipments required for mechanized method of road constructions.

3m

↳ In road construction project different machinery is required for different types of jobs. The sequence of job operations can be as follows:

(i) Clearing ~~the~~ site, trace out
(ii) Formation of subgrade: Rock cutting, Excavation drilling, blasting, embankment.
(iii) Spreading of construction materials.
(iv) Rolling or compaction.
(v) Surfacing
(vi) Plants for materials preparation (such as aggregate, bitumen, etc).

1. Equipments used for clearing the site:
(a) Dozer - bulldozer, angle dozer, treedozer etc
(b) Rooter or Ripper.
(c) Tractor
(d) Scraper

2. Equipment used for formation of subgrade:
(a) Tractor
(b) Shovel
(c) Dozer
(d) Dragline
(e) Grader
(f) Clam shell.
(g) Trucks
(h) Rollers: smooth wheeled, Pneumatic tyred, sheeps footed, rammer, vibrator etc.
(i) Hoe

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3. Manufacturing and spreading of materials.

(a) Crushers
(b) Trucks
(c) Gravel and aggregates distributors.

4. For surfacing:

(i) For Bituminous surfacing:

(a) Bitumen boiler.
(b) Bitumen sprayer.
(c) Aggregate spreader.
(d) Bitumen mixing machine
(e) Grouting machine
(f) Roller.

(ii) For concrete surfacing:

(a) ~~Central~~ concrete batching and mixing plant
(b) concrete mixers
(c) Concrete pavers
(d) concrete spreader (Screeds)
e) concrete vibrator
(f) concrete finisher

5. Plants:

(a) Cement concrete plant
(b) Aggregate crusher plant
(c) cold premix mixing plant
(d) screening plant
e) sand blowing plant.

Chapter 5 →

Pavement and maintenance.

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Road pavement:

→ Road pavement is a specified space, required for the movement of traffic / vehicle below at or above the ground level. The space required by the road pavement is considered in Longitudinal as well as transverse direction to enable the fast moving vehicles to move safely and comfortable at the design speed.

→ The main function of pavement is to support and transfer the wheel load of vehicles over a wider area on the underlying the sub-grade soil.

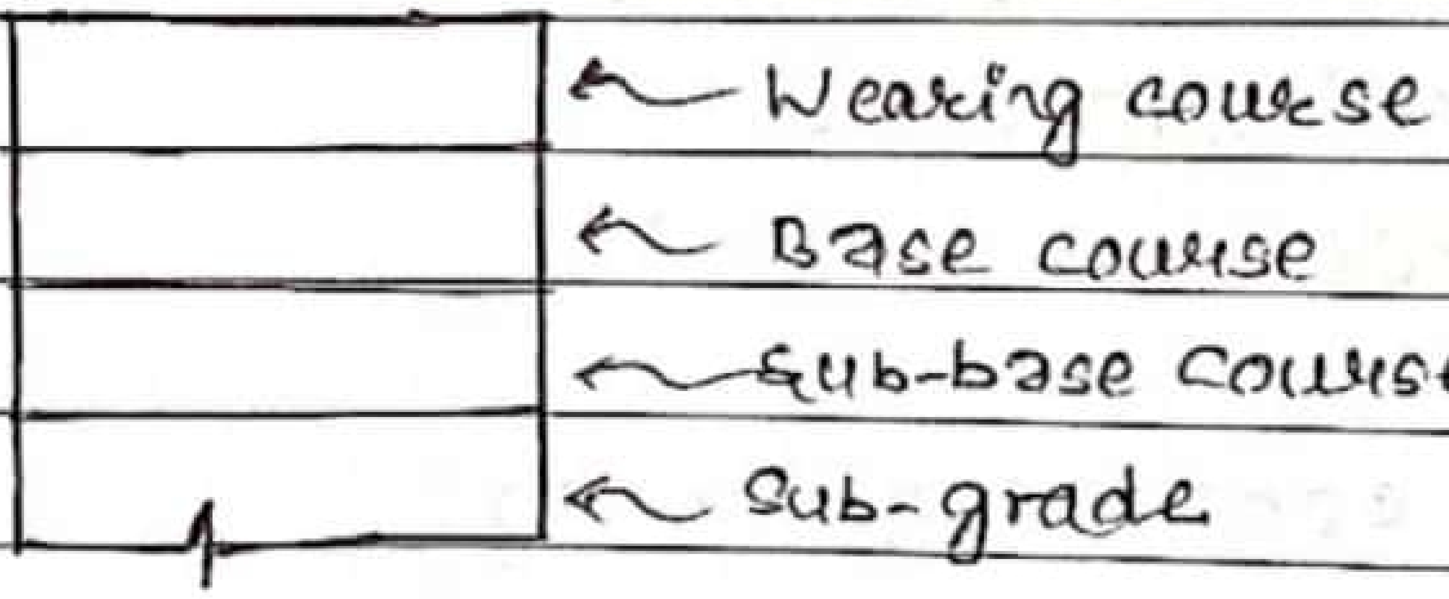

Fig: Layers of pavement!

Types of pavement:

Imp → Based on the structural behaviours, the road pavement are generally classified following types:

(i) Flexible pavements:

→ The pavements, which have negligible flexural strength but flexible ~~pavement~~ in their structural action under the Loads, are known as flexible pavements.

→ The lower Layers of flexible pavements reflect the deformation up to the surface of the layer. So if their is undulations in sub-grade flexible pavement also get undulated.

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- The flexible pavement layers, transmit the vertical compressive stresses to the lower layers by grain to grain transfer through the points of contact.

- The vertical compressive stress is maximum on the pavements surface directly under the wheel loads and decrease successively to lower layers.

- Therefore, quality of materials from top layer to bottom layers also decrease corresponding to resulting stress to minimize the cost of road. It is made of local soil, gravel and bituminous materials.

(ii) Rigid pavements:

- The pavements, which have worthy flexural strength, are known as rigid pavements. The rigid pavements are made of plain, reinforced or prestressed concrete.

- Rigid pavements structure consists of a cement concrete slab, below which a granular sub-base or base course over sub-grade soil.

- The rigid pavements are normally analyzed, and designed based on elastic theory assuming the pavements as an elastic plate resting over an elastic or a viscous foundation

- The plain cement concrete are expected to take up about $40 kg/cm^3$ flexural stresses.

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(iii) Semi-rigid pavements:

↳ The pavements, which have flexural strength in between rigid and flexible pavements, are known as semi-rigid pavements.

↳ It is made of lean cement concrete, soil cement or or pozzolanic concrete.

↳ The semi-rigid pavements have low resistance to impact and abrasion. The semi-rigid pavements can also be constructed by using intermediate class of materials as sub-base or base course.

Imp
4.3 Factors governing pavement design:

↳ The various factors to be considered for the design of pavements are given below:

(i) Design wheel load:

↳ The thickness design of pavement primarily depends upon the design wheel load. Higher wheel load obviously need thicker pavement, provided other design factors are the same.

(ii) Subgrade soil:

↳ The properties of the soil sub-grade are important in deciding the thickness requirements of pavements. A sub-grade with lower stability requires thicker pavement to protect it from traffic loads. The variation in stability and volume of the sub-grade soil with moisture changes are to be studied as these properties are dependent on the soil characteristics.

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(iii) climatic resources:

- Among the climatic factors, rainfall affects the moisture conditions in the sub-grade and the pavements layers

- The daily and seasonal variations in temperature has significance in the design and performance of rigid pavements and bituminous pavement. where freezing temperature are prevalent (प्रचलित) during winter, the possibility of Frost action in the sub-grade and damaging effects should be considered at the design stage itself.

(iv) Pavement component materials:

- The stress distribution characteristics of the pavements component layers depend on characteristics of the materials used.

- The ~~failure~~ Fatigue (Temporary loss of strength) behaviours of the these materials and their durability under adverse conditions of weather should also be given consideration.

(v) Environmental factors:

- The environmental factors such as height of embankment and its foundation details, depth of cutting, depth of sub-surface water table, etc. effect the performance of the pavements.

- The choice of the bitumen binder and performance of bituminous pavements depends on the variations in pavement temperature with the seasons in the regions.
- The warping stresses in rigid pavements depends on the daily variations in temperature in the region and in the maximum difference in temperature between the top and bottom of the pavements slab.

Date

5.4 Introduction and necessity of maintenance:

Introduction:

- Road maintenance is one of the importance components of the entire road system. The maintenance operations involve the assessment of road condition, Diagnosis (identification) of the problem and adopting the most appropriate maintenance steps.
- The process of preserving the serviceable condition of road or highway as normal as possible is called highway maintenance.

classification of maintenance works:

- Routine maintenance.
- periodic maintenance
- special maintenance

Necessity of maintenance:

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- Maintenance work is necessary to due to following failures causes:

(i) Defects in the quality of materials used.

(ii) Defects in construction method and quality control during construction.

(iii) Inadequate surface or subsurface drainage in the Locality resulting in the stagnation of water in the subgrade or in any of the pavement Layers.

(iv) Increase in the magnitude of wheel loads and the number of load repitions due to increase in traffic volume.

(v) Settlement of foundations of embankment of the fill materials itself.

(vi) Environmental factors including heavy rainfall, soil erosion, high water table, snowfall, frost action etc

~~Maintenance and repairs works~~

5.5 Component of maintenance activities:

→ In hill road, bituminous surface is mostly used due to economic and environmental considerations. Maintenance of bituminous surfacing consists of:

(i) Patch repairs
(ii) Pot holes repairs works.
(iii) surface treatments
(iv) Re- surfacing.

(i) Patch repairs:

→ Patch repairs are carried out on the damaged or improper road surface, Localised depression and pot holes may be formed in the surface layers due to defects in materials and constructions.

(ii) Pot holes repairs works:

→ Pot holes are cut to rectangular shape and the affected materials are in the section is removed until the sound materials are encountered.

→ The excavated patches are cleaned and painted with bituminous binder.

→ A premixed materials is then placed in the sections, Generally, cut back or emulsion is used as binder.

→ Compaction with properly.

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(iii) Surface treatment:

↳ Excess of bitumen in the surface materials bleeds and the pavement becomes patchy and slippery. corrugations or rutting or shoving develop in such pavement surface.

↳ It is customary to spread blotting materials such as aggregates chips of maximum size of about 10mm or coarse sand during summer.

↳ Necessary rolling is done to develop permanent bond between the existing surface and the new materials, after heating the surface if necessary.

(iv) Re-surfacing:

↳ Re-surfacing is carried out only, when the existing pavement surface is totally worn out and develops a poor riding surface. It may be more economical to provide an additional surface coarse on the existing surface.

↳ In case of, pavements is ~~of~~ inadequate thickness due to increases in traffic loads and strengthening is necessary then an overlay of adequate thickness should be designed and constructed.

5.3 Pavement design methods:

- IRC recommends the use of bitumen with penetration grade 175/225 for ground macadam in very cold regions.

- A higher viscosity bitumen, through can be sprayed to or mixed with aggregates by heating at the required temperature will become brittle in very cold regions.
  (भंगुर)

- Out of various flexible pavement design methods available the following are used in hill road design and discussed here;
  (i) Group Index method.
  (ii) California Bearing Ratio method (CBR method)
  (iii) Triaxial test method.
  (iv) Burmister method.

(i) Group Index method:

- Group Index values is an arbitrary index assigned to the soil types in numerical equation based on the percent fines, liquid limit and plasticity index.

- The GI value of soil vary in the range of 0 to 20.

$$GI = 0.2a + 0.005ac + 0.01bd$$

where,

a = that portion of materials passing 75 μ sieve greater than 35% but not exceeding 75%.

b = That portion materials passing 75 μ sieve greater than 15% but not exceeding 55% (0 to 40)

c = The values of liquid limit in excess of 40% but not exceeding 60% (0 to 20)

d = The value of plasticity index exceeding 10% but not more than 30% (0 to 20)

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(*) classification of traffic :

1. Light (< 50 vehicles/days)
2. medium (50-300 vehicles/days)
3. Heavy (>300 vehicles/days)

→ In this method, first the GI value of the soil is determined. The anticipated traffic is estimated and is designated as light, medium or heavy as indicated.

→ The appropriate design wave is choosen and the total thickness of pavement is found from the group index design chart, corresponding the GI values of soil.

(ii) California bearing ratio method (CBR):

→ Pavement thickness Determination:

→ In order to design a pavement by CBR method, first the soaked CBR value of the soil subgrade is evaluated. Then, the appropriate design curve is choosen by taking the anticipated traffic into considerations (as given in Fig. below). Thus the total thickness of flexible pavement needed to cover the sub grade of the known CBR value is obtained.

→ In case there is a materials superior than the soil sub-grade, such that it may be used as sub-base course then the thickness of construction over this materials could be obtained from the design chart knowing the CBR value of the sub-base. Thickness of the sub-base course is the total thickness minus the thickness over the sub-base.

→ Thus CBR method of flexible pavement design ~~is~~ is based on strength parameter of sub-grade soil and subsequent pavement materials.

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(iii) Triaxial method :-

→ L. A. Palmer and E.S Barber in 1940 proposed the design method based on Boussinesq's displacement equation for homogeneous elastic single layer:

$$\Delta = \frac{3pa^2}{2E(a^2+z^2)^{1/2}} \quad \ldots \text{(a)}$$

Here, $p = \frac{P}{\pi a^2}$

$$\therefore \Delta = \frac{3P}{2\pi E(a^2+z^2)^{1/2}}$$

or, $(a^2+z^2)^{1/2} = \frac{3P}{2\pi E\Delta}$

or, $a^2+z^2 = \left(\frac{3P}{2\pi E\Delta}\right)^2$

$$\therefore z = \sqrt{\left(\frac{3P}{2\pi E\Delta}\right)^2 - a^2}$$

Assuming that the pavement is incompressible,

z becomes T, the thickness of pavement

$$T = \sqrt{\left(\frac{3P}{2\pi E_S\Delta}\right)^2 - a^2} \quad \ldots \text{(b)}$$

Here,

T = pavement thickness 'cm'

P = wheel load, kg

E_S = modulus of elasticity of subgrade from triaxial test results, kg/cm^2.

a = radius of contact area, cm

Δ = Design deflection (0.25 cm)

In the above analysis the pavement and the sub-grade are assumed to have the same E-value

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(iv) Burmister's (Layered system) method:

↳ Donald M. Burmister developed the layered system analysis. As known the flexible pavement sections are composed of layers and the elastic modulus of the top layer is the heighest.

↳ The total mass of pavement and sub-grade does not possess a constant 'E' value as assumed by Boussinesq in his analysis.

↳ However, Boussinesq analysis can be considered as a special case of Burmister's layered system analysis. If layers of soil sub-grade, sub-base & base course are assigned elastic moduli of E_s, E_{sb}, E_b then as per Bousinesq's analysis.

↳ It is considered $E_s = E_{sb} = E_b$ where as in layered analysis, it is taken that $E_b > E_{sb} > E_s$. The effectiveness of the reinforcing action of the pavement layers is logically utilized in Burmister's approach. Following are the assumptions made in this approach.

↳ (i) The materials, in the pavement layers are isotropic, homogeneous and elastic. The pavement forms a stiffer reinforcing layer having modulus of elasticity higher than that of the underlying sub-grade in the two layer system.

(ii) The surface layer is infinite in horizontal direction and finite in vertical direction, the underlying layer in two layered system is considered infinite in both directions.

(iii) The layers are in continuous contact the top layer is free of shearing and normal stresses outside the loaded area.

chapter 6.

Drainage and cross Drainage:

6.1 Introduction:

↳ Highway drainage may be defined as the process of interception and removal of water from over, under and vicinity (particular area) of the road surface.

↳ Surface water flowing from the hill slope towards the road way is one of the main problems in drainage of hill roads.

↳ Drainage of surface water is more important in hill roads. For efficient diversion and disposal of water flowing down the hill slope, the shape is carefully choosen and numerous intercepting catch water drains should be provided.

↳ If the drainage system in hill road is not adequate and efficient it will result in complex maintenance problems.

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6.2 Hydrological study (empirical formula for runoff calculation):

↳ The main objectives of hydrological analysis is to estimate the maximum quantity of water expected to reach the element of the drainage system under consideration.

↳ A portion of the precipitation during the rain fall infiltrates into the ground as ground water and a small portion gets evaporated

↳ The remaining portion of water which flows over the surface is termed as runoff. various factors affecting the run-off are rate of rainfall, type of soil and moisture condition topography of the area, type of ground cover like vegetation etc.

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↳ Rational formula is widely used to estimate the peak run-off water for highway drainage, The rational formula in its simplest form is given by:-

$$Q = \frac{C I A_d}{360} \quad -(i)$$

where,

Q = Run-off m^3/sec.

C = run-off coefficient, expressed as a ratio of run-off to rate of rainfall.

I = Intensity of rainfall, mm/sec

A_d = Drainage area in $1000 m^2$

↳ The value of 'C' may be taken as 0.8 to 0.9 for bituminous and cement concrete pavements, 0.35 to 0.70 for gravel and WBM pavements, 0.40 to 0.65 for impervious soils.

↳ When the drainage area 'A_d' consists of several types of surface with run-off coefficients C_1, C_2, C_3 with their respective area A_1, A_2, A_3, the weighted value of run-off coefficient 'C' is determined from.

$$C = \frac{A_1C_1 + A_2C_2 + A_3C_3 + \cdots}{A_1 + A_2 + A_3 + \cdots} \quad -- (ii)$$

(4) Hydraulic Design:-

↳ Once the design runoff 'Q' is determined, the next step is the hydraulic design of drains. The side drains and partially filled culverts are designed based on the principles of flow through open channels.

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↳ If 'Q' is the quantity of surface water (m^3/sec) to be removed by a side drain and 'v' is the allowable velocity of flow (m/sec) on the side drain, the area of cross-section 'A' of the channel (m^2) is found from the relation:

$$Q = Av \quad -(iii)$$

↳ The allowable velocity of flow depends on the soil type for sand and silt it is 0.3 to 0.5 m/s, Loam 0.6 to 0.9 and clay 0.9 to 1.5 and gravel 1.2 to 1.5 m/sec.

↳ For good, soil covered with well established grass 1.5 to 1.8 m/sec may be allowed.

↳ Assuming uniform and steady flow through channel of uniform cross-section and slope, manning's formula is used for determining the velocity of flow or the Longitudinal slope which is given by:

$$V = \frac{1}{n} R^{2/3} S^{1/2} \quad -- (iv)$$

where,

V = average velocity m/sec

n = Manning's roughness coefficient.

R = Hydraulic radius 'm' (cross section area of flow divided by wetted perimeter)

S = Longitudinal slope of channel.

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> The roughness coefficient values depends on the type of soil in inclined channels. For ordinary earth, the value of $n = 0.02$, whereas for earth with heavy vegetation or grass the value is of $n = 0.05$ to 0.1 in lined channels, the roughness coefficient depends on the type of lining. For well finished concrete, the value of $n = 0.013$ but, for rough rubble and riprap, $n = 0.04$.

3# Design of side drains:

↳ Data for drainage Design:

The following data are to be collected for the design of road side drain.

(i) Total road length and width of land from where water is expected to flow on the stretch of the side drain.

(ii) Run-off coefficients of different types of surfaces in the drainage area and their respective areas (such as paved area, road shoulder area, turf surfaces etc.

(iii) Distance from farthest point in the drainage area to the inlet of the side drain along the steepest gradient and the average values of the slope.

(iv) Type of soil of the side drain, roughness coefficient allowable velocity of flow in the drain.

(v) Rainfall data including average intensity and frequency of recurrence of flood.

Design Steps:

↳ Simplified steps for design of longitudinal drains of a road to drain off the surface water are given below:

(i) The frequency of return period such as 10 years, 25 years etc is decided based on finances available and desired margin of safety, for the design of the drainage system.

(ii) The values of coefficients of run-off C_1, C_2, C_3 etc from drainage areas A_1, A_2, A_3 etc. are found and the weighted value of 'C' is computed.

(iii) Inlet time T_1 for the flow of storm water from the farthest point in the drainage area to be drain inlet along the steepest path of flow is estimated from the distance, slope of the ground and type of the cover.

(iv) Time of flow along the longitudinal drain 'T_2' is determined for the estimated length of longitudinal drain 'L' upto the nearest cross drainage or a water course and for the allowable velocity of flow 'V' in the drain i.e.

$$T_2 = \frac{L}{V}$$

(v) The total time 'T' for inlet flow and flow along the drain is taken as the time of concentration or the design value of rainfall duration $T = T_1 + T_2$.

(vi) From the rainfall intensity duration, frequency curves the rainfall intensity 'i' is found in mm/sec. corresponding to duration 'T' and frequency of return period.

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(vii) The total area of drainage Ad is found in units of $10\,000m^2$.

(viii) The run-off quantity 'Q' is computed $= \frac{CIAd}{360}$

(ix) The cross-sectional area of flow 'A' of the drain is calculated $= Q/V$, where 'V' is the allowable speed of flow in the drain.

(x) The required depth of flow in the drain is calculated for a convenient bottom width and side slope of the drain. The actual depth of the open channel drain may be increased. Slightly to give a free board. The hydraulic mean radius of flow 'R' is determined.

(xi) The required longitudinal slope 's' of the drain is calculated using manning's formula adopting suitable value of roughness coefficient 'n'.

6.4 # Intercepting drains / catch water drains:

↳ Such drains are provided on hill slopes to intercept water flowing from upper reaches and guide such flow into culverts.

↳ Catch drains or intercepting drain is constructed ~~and~~ maintained if the slope's is more.

↳ The main purpose of catch drain is collection of surface water due to rainfall / spring ~~and~~ safe ~~surface~~ discharge to the nearest natural drainage.

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Cross-drain:

↳ As far as possible cross-drainage should be taken under the road and at right angle to it. At the head of small cross drains catch pits must be provided to collect the stones and rubbish and to prevent scour.

Chutes:

↳ It is an inclined channel or vertical passage down which water may be dropped.

Ford:

↳ A Ford is a shallow place with good footing where a river or stream may be crossed by wading or inside a vehicle its wheels wet.

Causeway:

↳ A causeway is of course, a raised road, usually built on an embankment often running across water.

Sub surface drainage:

↳ The seepage flow of water on hill roads is one of the major problems during and after the monsoons.

↳ The seepage water may cut across the hill side slope above at or below the road level depending upon several factors, such as depth of hard stratum and its inclination, quantity of under ground flow of water etc.

↳ Collection and disposal of sub-surface water is termed as sub-surface drainage.

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Q.N(1) The surface water from road side is drained to the longitudinal side drains from across one half a bituminous pavement surface of total width 7m. shoulders and adjoining land of width 8 m on one side of the side drains. On the other side of longitudinal drain, water flows across from reserve land with grass and 2% cross-slope towards the side drains, the width of this strip of land being 25 m. The run-off coefficients of the pavements shoulder and reserve land with grass surface are 0.8, 0.25 and 0.35 respectively. The length of the stretch of land parallel to the road from where water is expected to flow to the side drains is about 400m. Estimate the quantity of run-off flowing in the drain assuming 25 year period of frequency. Design the cross-section and slope of the side drain in loamy soil with manning's roughness coefficient = 0.022 and suitable speed of flow = 0.8 m/sec.

LD Soln:

(i) Quantity of Run-off

Pavement area $(A_1) = \frac{1}{2} * 7 * 400 = 1400 m^2$

Area of shoulder and adjoining land $(A_2) = 8 * 400 = 3200 m^2$

Area of land on the other side of the drain

$(A_3) = 25 * 400 = 10,000 m^2$

$\therefore C_1 = 0.8$

$\therefore C_2 = 0.25$

$\therefore C_3 = 0.35$

Total drainage area ~~At~~ $= 1400 + 3200 + 10,000 = 14600 m^2$

$$A_t = \frac{14600}{1000} = 14.6 m^2$$

Weighted value of run-off coefficient

$$C = \frac{C_1 A_1 + C_2 A_2 + C_3 A_3}{A_1 + A_2 + A_3}$$

or, $$C = \frac{0.8 * 1400 + 0.25 * 3200 + 0.35 * 10,000}{1400 + 3200 + 10,000}$$

$\therefore C = 0.371$

The maximum distance of flow across the land upto longitudinal drain is 25m along the reserve land with grass and cross-slope 2%. Therefore, inlet time.

T_1 from figure = 11 min

$$T_2 = \frac{L}{V} = \frac{400}{0.8 \times 60} = 8.33 \text{ min.}$$

Total duration of rainfall $= 11 + 8.33$
$= 19.33$ min.

From Figure, Typical rainfall intensity duration curve, corresponding to 19.11 min. duration and 25 years period, rainfall intensity $= 125$ mm/hr.

$$i = \frac{125}{60 \times 60} = 0.0347 \text{ mm/sec}$$

$\therefore \quad Q = CIA_d$
$= 0.371 \times 0.034 \times 14.6 = 0.188 \text{ m}^3/\text{sec}$

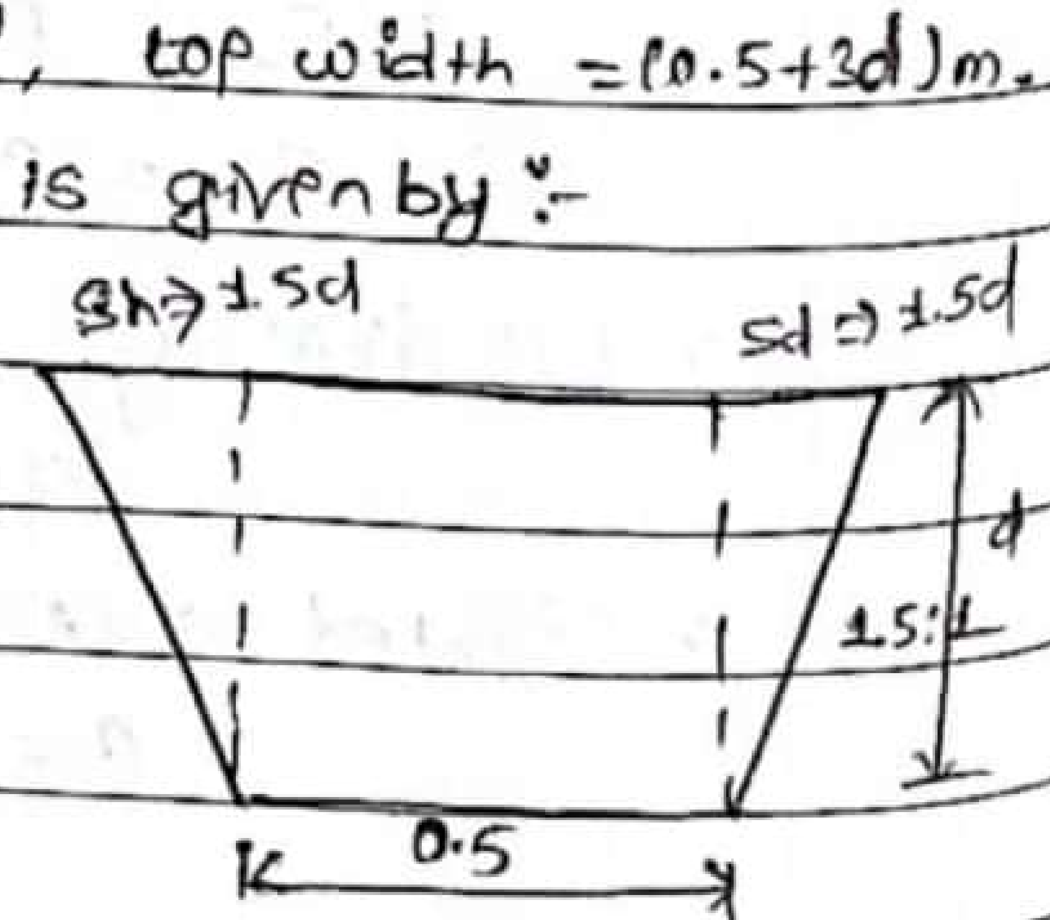
(ii) cross section:

Area of cross-section of flow in the drain is given as $A = Q/V = \frac{0.188}{0.8}$
$= 0.235 \text{ m}^2$

Assuming bottom width of drain as 0.5m, ~~side~~ slope 1 vertical to 1.5 horizontal and depth of flow as d', top width $= (0.5 + 3d)$ m.

$\therefore$ Area of cross-sections of flow in drain is given by:-

$0.235 = (0.5 + 0.5 + 3d) \times d/2$



or, $0.235 = d/2 + 1.5d^2$

or, $1.5d^2 + 0.5d - 0.235 = 0$

Solving the quadratic equation:

$$d = \frac{-0.5 \pm \sqrt{(0.5)^2 - 4 \times 1.5 \times (-0.235)}}{2 \times 1.5}$$

$\therefore d = 0.263$ m

Therefore, the average depth of drain may be taken as 0.40m after allowing a free board of about 14cm

(iii) Slope of drain :

When depth of flow in the trapezoidal drain is 0.263 m

wetted perimeter $= 0.5 + \left(\sqrt{0.263^2 + (1.5 * 0.263)^2}\right) * 2$

$= 1.448 m$

Hydraulic Radius (R) $= \frac{\text{Area}}{\text{wetted perimeter}}$

$= \frac{0.235}{1.447} = 0.162$

Now,

$V = \frac{1}{n} R^{2/3} S^{1/2}$

or $S^{1/2} = \frac{V * n}{R^{2/3}}$

or, $S^{1/2} = \frac{0.8 * (0.02)}{(0.162)^{2/3}}$

$\therefore S^{1/2} = 0.059$

or $S = 0.0035$ 1 in 250

Therefore, provide a longitudinal slope 1 in 250 Ans chapter 7

Special structures in Hill roads:

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7.1 slope protection structures:

Imp ↳ To protect the soil surface from (destructive) erosive forces and improve the stability of soil slopes that are subject to seepage or have poor soil structures is known as slope protection structure.

↳ slope protection structure are:

(i) Breast wall:

↳ The wall construction on the uphill side of roadway in order to retain earth from slippage is called breast wall.

↳ The top width of breast wall should be 600mm thick and should have number of weep holes to relieve the water pressure at the back of wall. This type of wall is constructed of stone masonary, brick masonary or cement concrete.

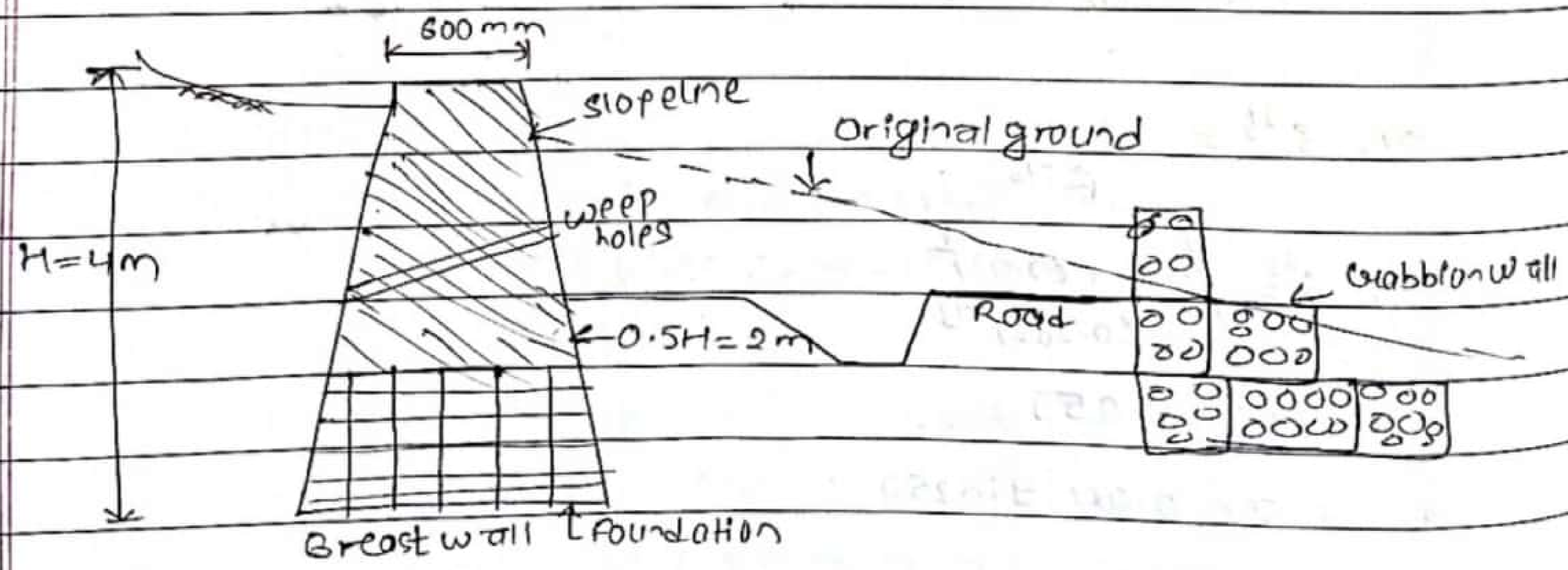

Fig: Breast wall

(ii) Revetment walls:-

↳ when the cutting slope is too steep and contain loose or scrabble soils, supper of slope in the form of wedge or any from many occur. To prevent this dry masonary is constructed to retain the soil on the cutting side.

↳ By this sippery action of the soils on slopes is prevented. These dry masonary provided on the cutting slope is called revetments wall.

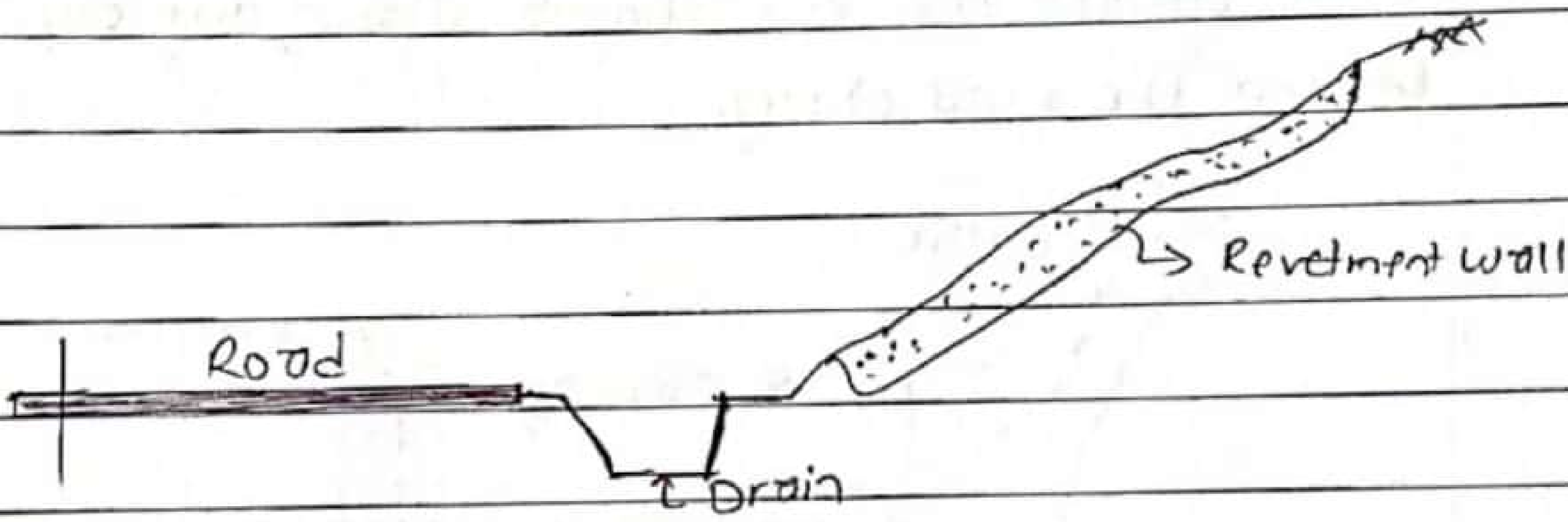

Fig: Revetment wall

(iii) Toe walls:-

↳ The embankment slopes are generally ported from the pitching above 30cm thick to avoid erosion due to flow of water.

↳ It sloping long ties to long then a wall is constructed from the base to support the embankment and slope which is called toe wall. It is provided in the base of embankment from toe of the road.

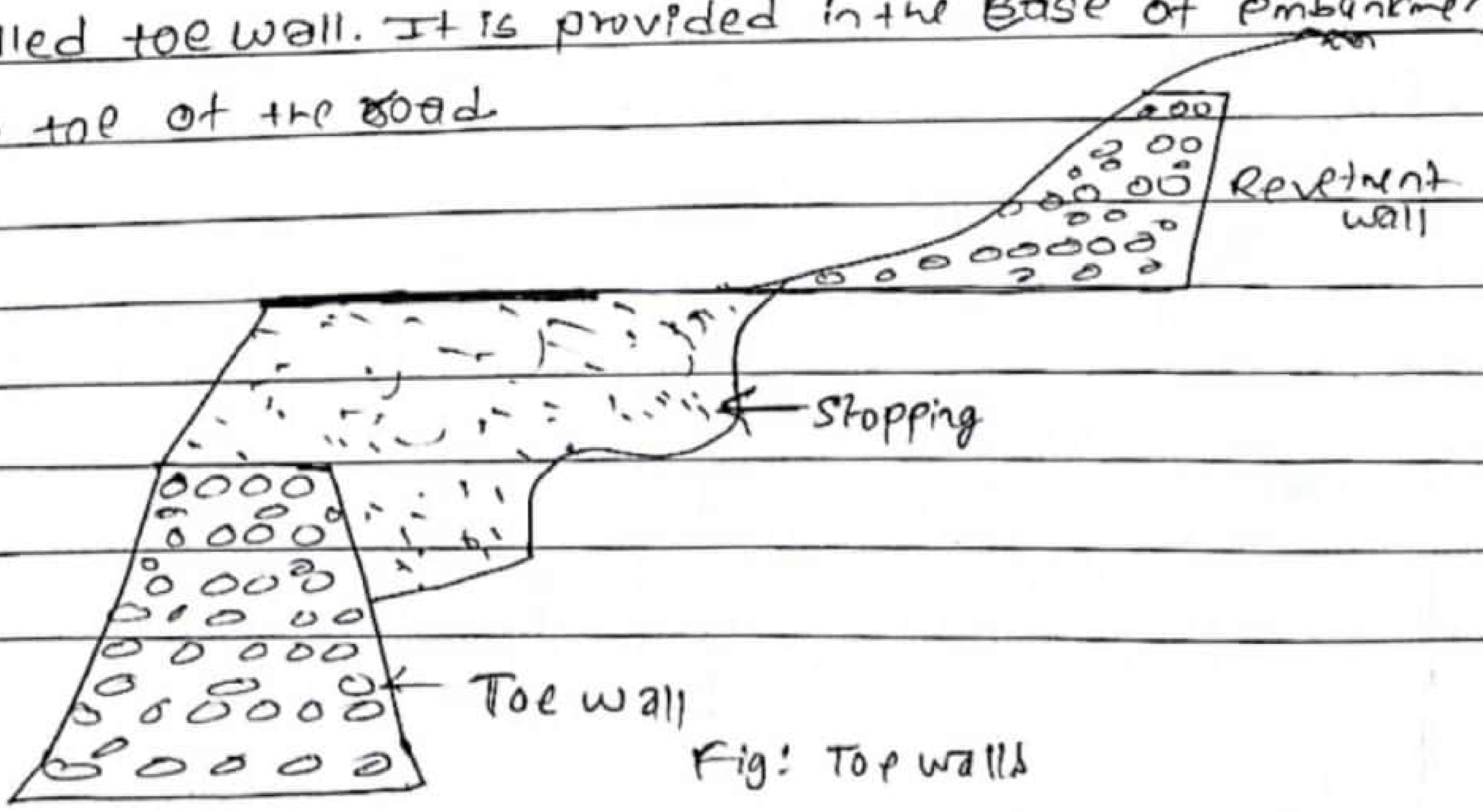

Fig: Toe walls

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7. classification of retaining wall:
5. (i) Retaining wall:
- Retaining wall are needed to retain the fill portion of highway.
- A retaining structure is usually a wall constructed for the purpose of supporting or retaining a vertical earth bank.
- It is constructed on the valley side of a road way also with hill side road.
- They are also provided retain earth for elevated and depressed road where the embankment slope, cut slope can't be extent beyond the road way.

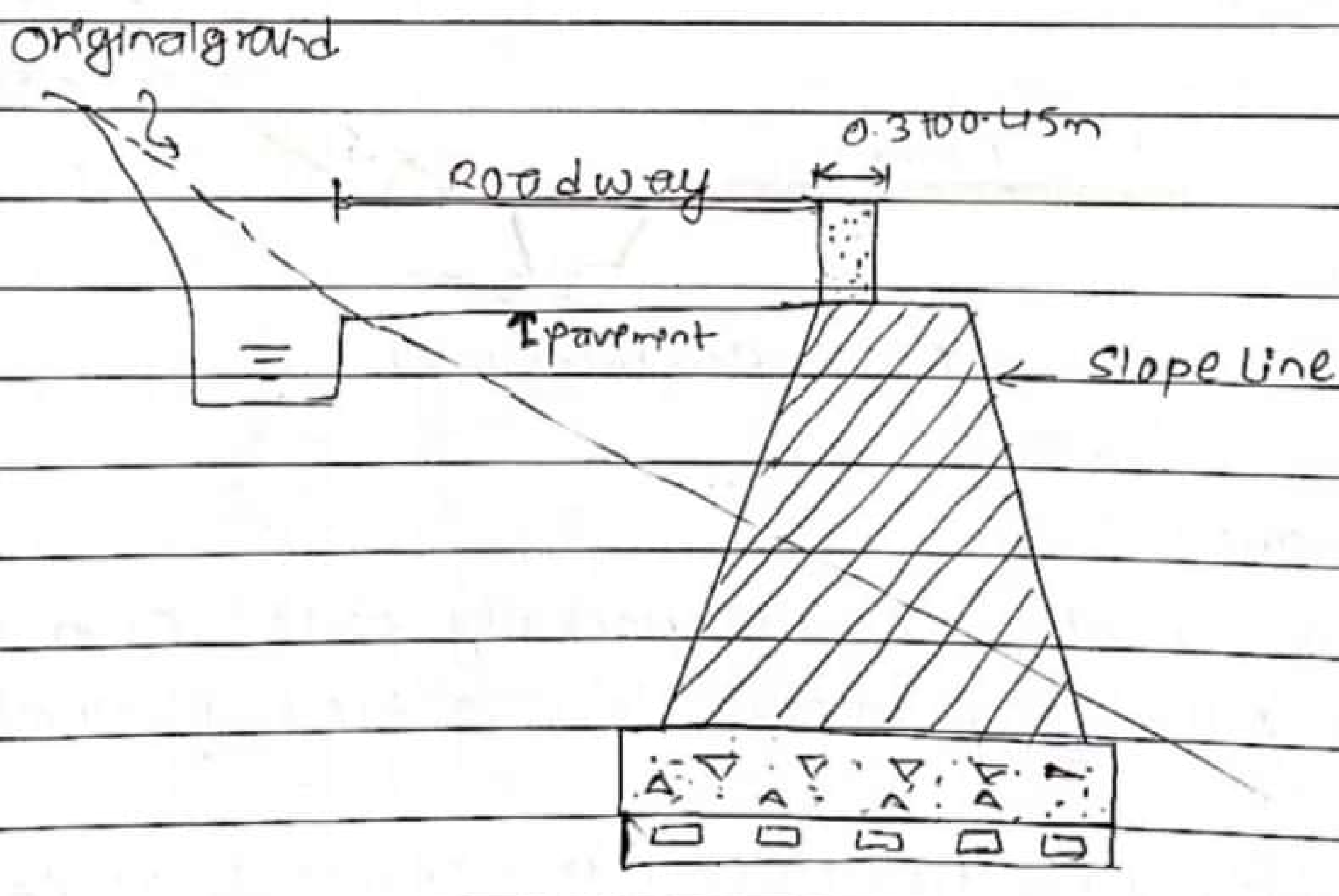


Fig: Retaining wall.

A. Based on materials used:

(i) Dry stone masonry
(ii) stone filled gabion wire.
(iii) Stone masonry with cement sand mortar.
(iv) composite retaining wall
(v) PCC retaining wall.
(vi) RCC retaining wall

B. Based on the Location:

(i) Hill or valley side
(ii) Toe wall
(iii) cut of wall
(iv) Revetment wall.

C. Based on structural scheme:

(i) Gravity wall
(ii) piling wall
(iii) cantilever wall
(iv) Anchored wall.
(v) semi-gravity walls
(vi) counter fort walls
(vii) Buttressed wall
(viii) crib walls
(ix) Reinforced soil walls

(i) Gravity wall:

Gravity wall depends on their mass (stone, concrete or other heavy materials) to resist pressure from behind and they may have a 'batter' (strike against forcefully) set back to improve stability by Leaning back toward the retained soil.
(tendency)

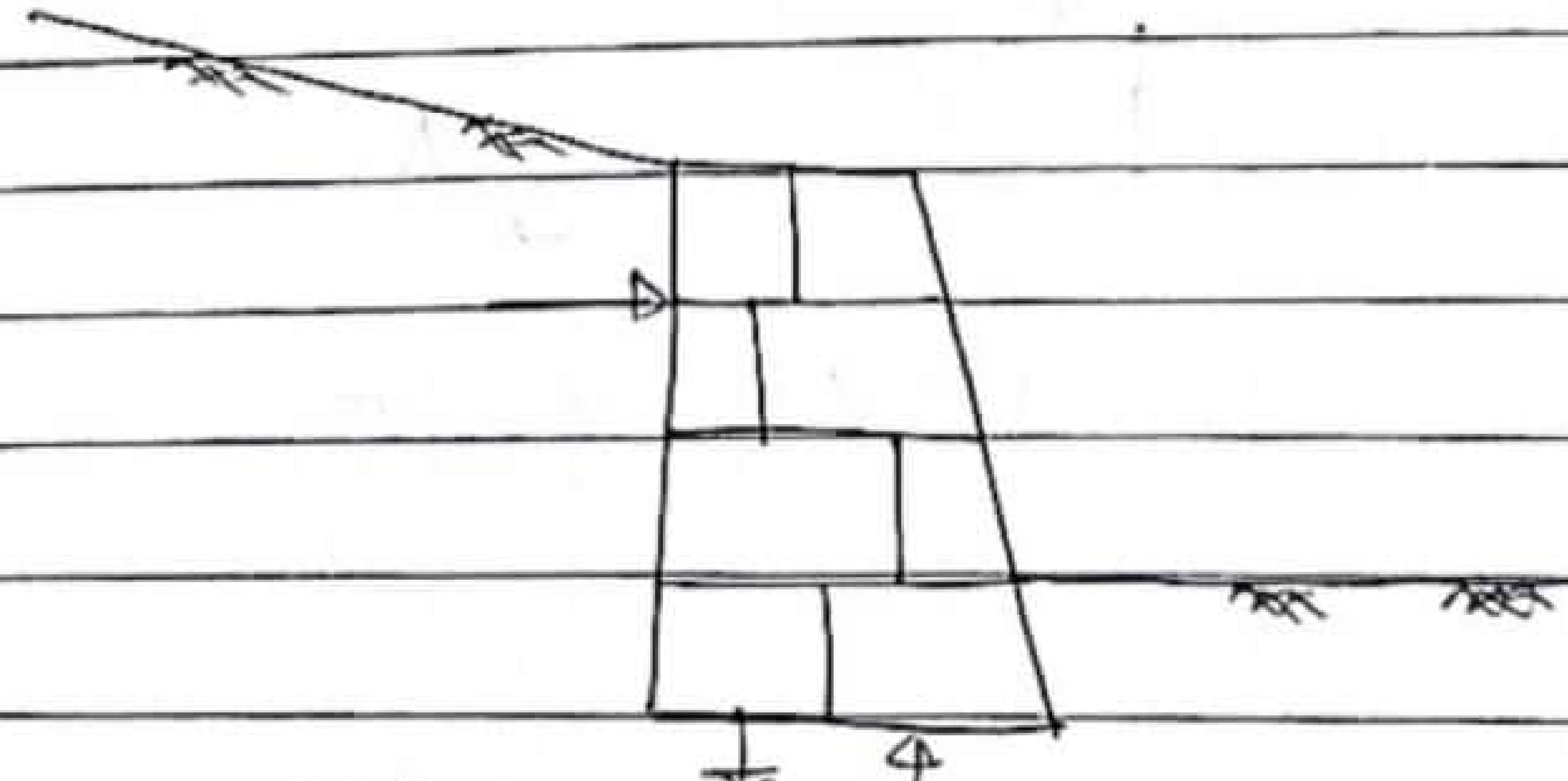


Fig: Gravity wall.

(ii) Pilling wall:

↳ Using long piles, this wall is fixed by soil on both sides of its lowest length, the piles themselves can resist the bending forces, this wall can take high loads.

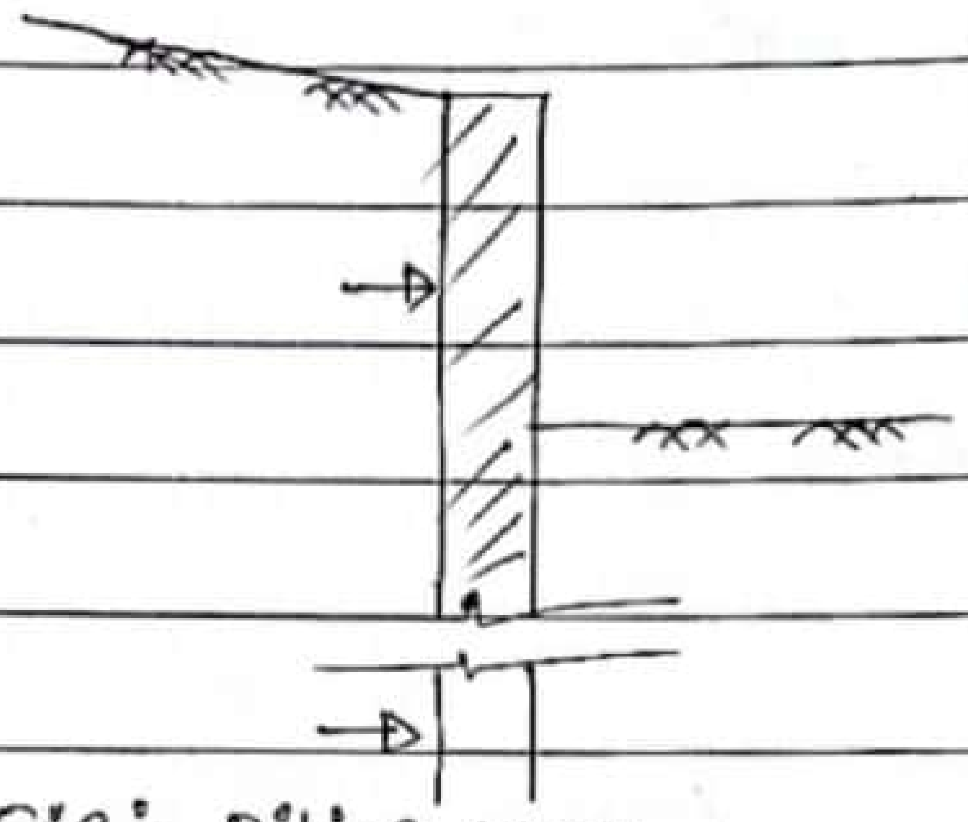
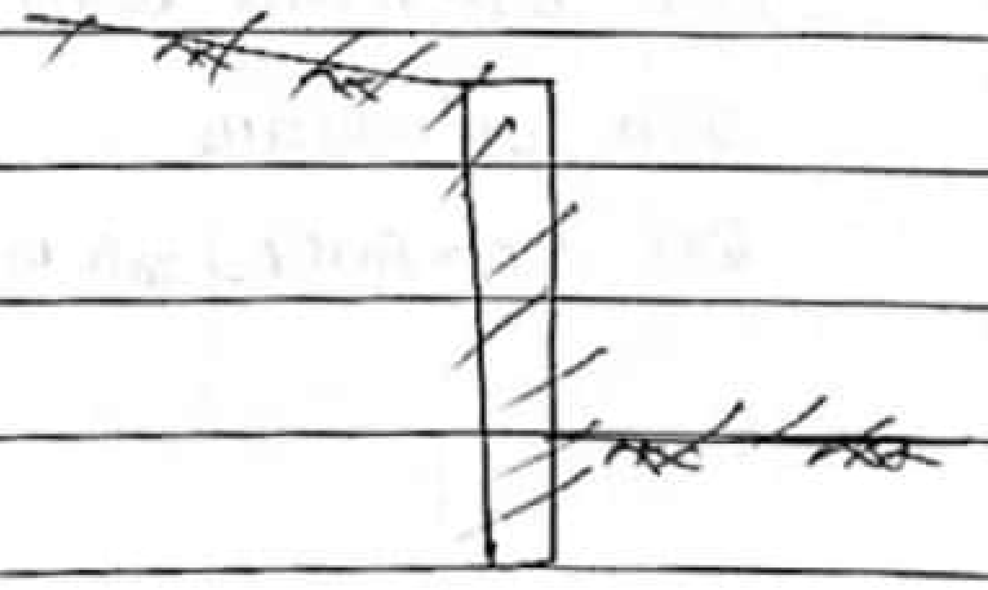


Fig: piling wall.

(iii) Cantilever wall:

↳ The cantilever wall (which may also extend in the other direction) uses the same earth pressure trying to topple it to stablize itself with a second lever arm.
↳ (push, overturn)



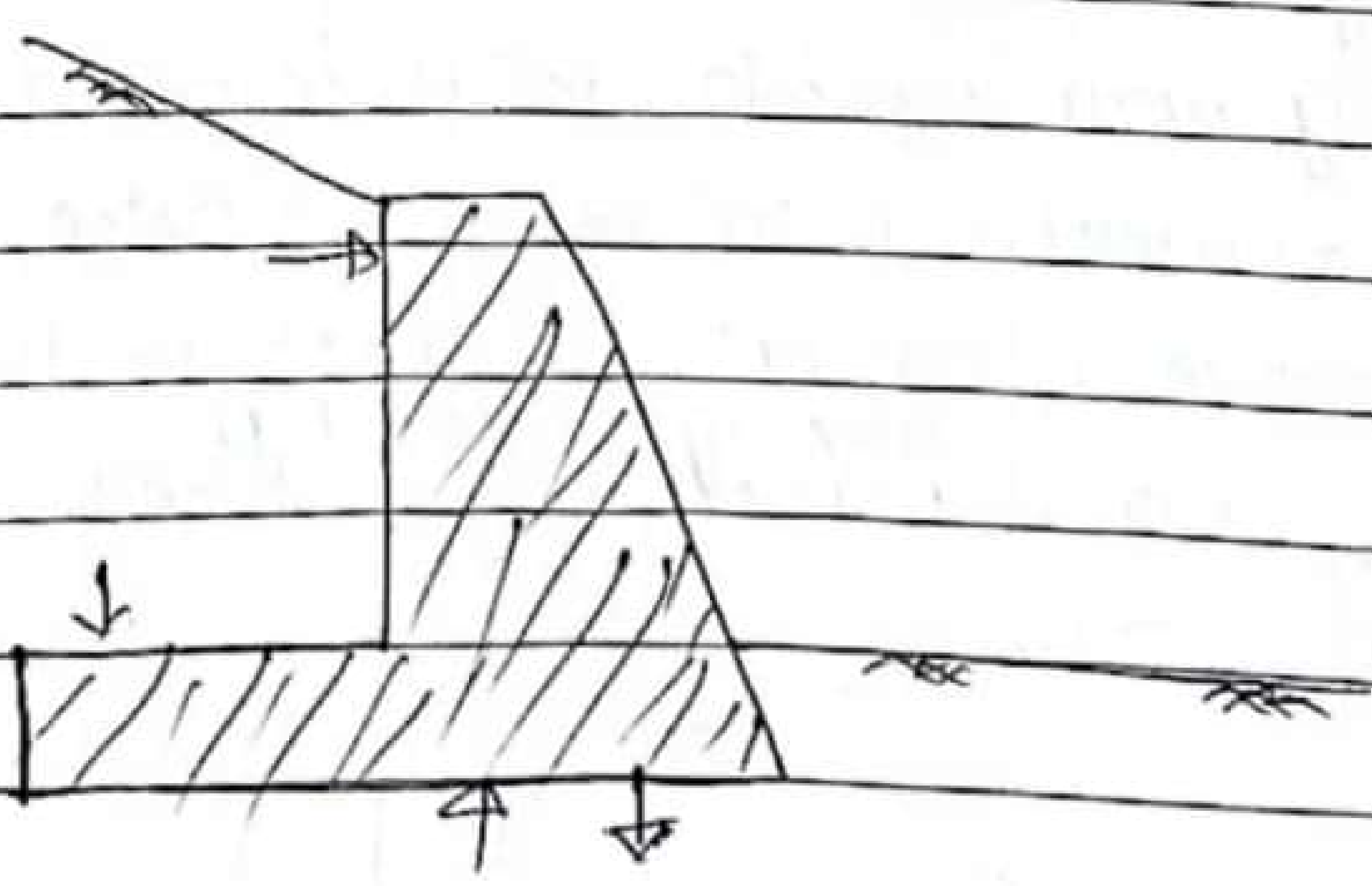


Fig: Cantilever arm

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(v) Anchored wall:

- An anchored retaining wall can be constructed in any of the aforementioned (previously mentioned) styles but also includes additional strength using cables or other stays anchored in the rock or soil behind it.
- This wall keeps itself from toppling (push) by having cables driven into the soil or rock.

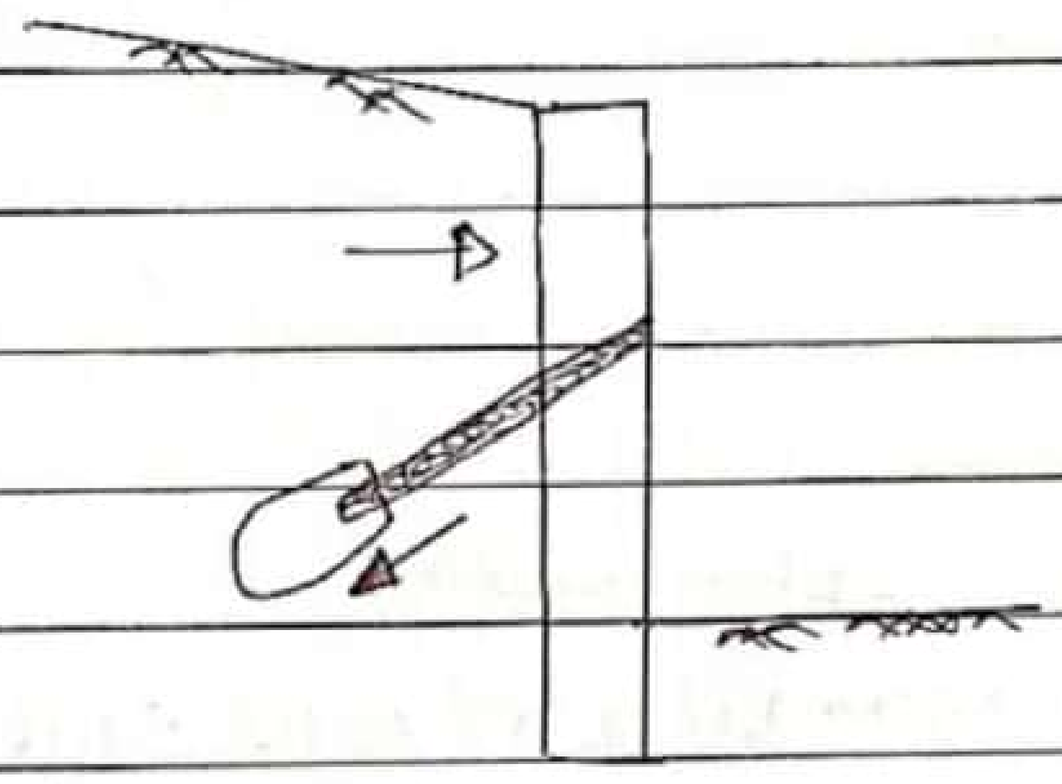

Fig: Anchored wall.

7.3. Parapet, railing and edge stones:

Parapet:

- Parapet walls are provided on the khud (show) side of the hill road all along the road except where the hill slope is very gentle.

- It serves the following purposes:

(i) Prevents the wheels of the vehicle from coming on the retaining wall.

(ii) Provides a sense of security to the driver and the passengers.

(iii) In the case of hard rocky strata the parapet is replaced by C.I. pipe railing.

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Railing:

- Railing are the safety barriers and safety fences. These are devices which physically prevent vehicles from running off the roadway.

- To protect vehicles from falling down a slope.
- To protect vehicles from hitting a roadside object.

Edge stones:

breakdown.

- It helps to prevent crumbling of road edge and deterioration of shoulders.

The process of making or growing worse!

imp

7.4. River training structures:

- River training refers to the structural measures which are to be taken to improve a river and its banks.

It can be classified into two types:

(1) Transversal protection structures.
(2) Longitudinal protection structure

(1) Transversal protection structure:

- They are installed perpendicular to the water course.

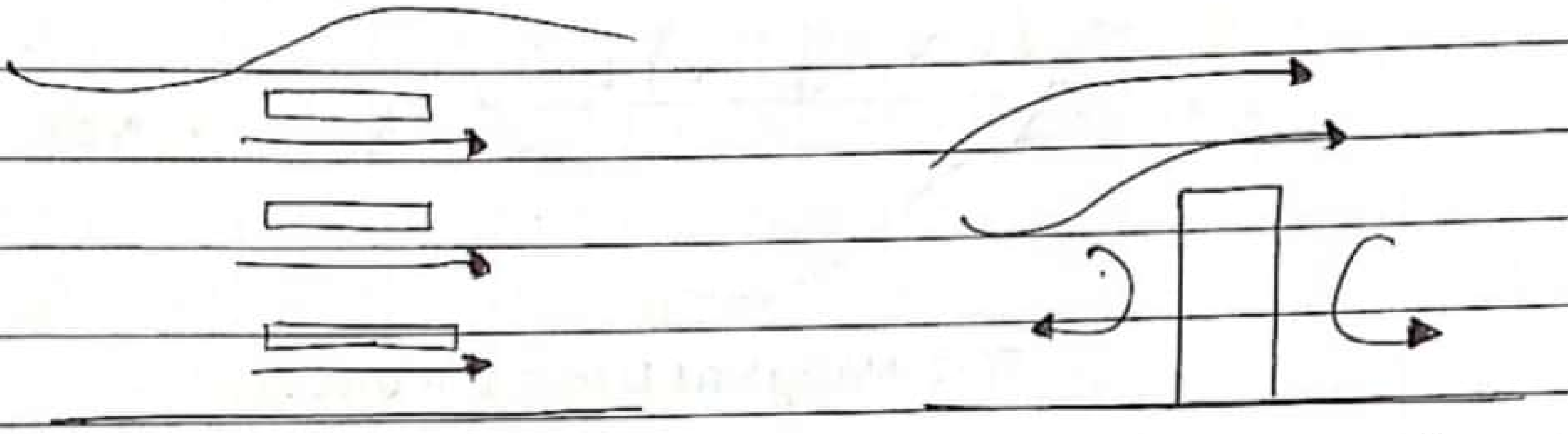
(a) check dams:

- They are made of gabions, concrete, Logs, bamboo etc. constructed to reduce ~~a~~ water velocity and reduce erosion and debris flow.

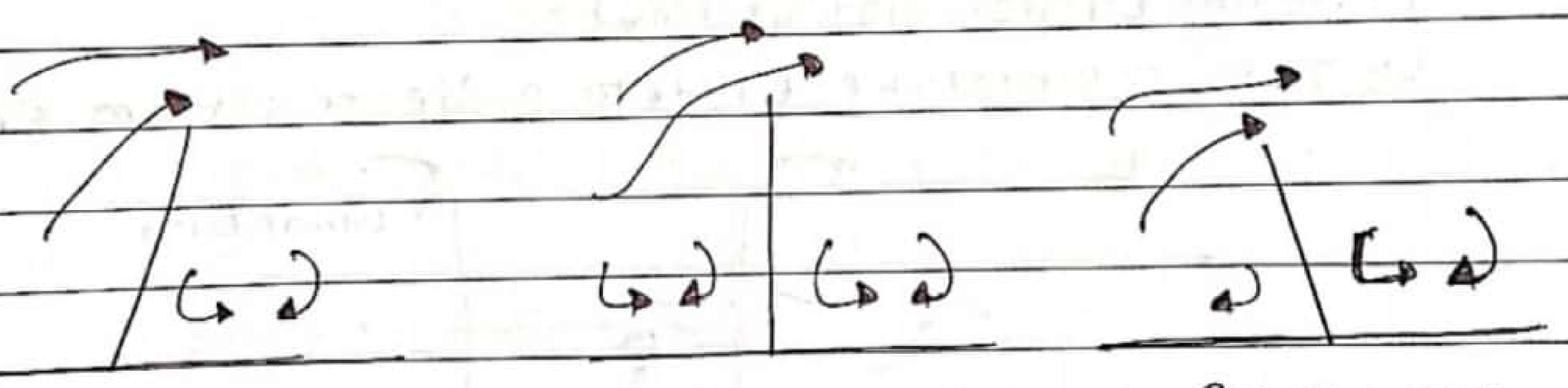
rubble, Junk, dust.

(b) Spurs :-

→ A spur is structure made to project flow from a river bank into a stream. The aim of construction of spur is attracting, deflecting, repelling, velocity reduction etc.



* Permeable spur * * Impermeable spur *



Attracting spur Deflecting spur Repelling spur

(c) Sill :-

→ It is a structure built across the bed of a river of stream to reduce bed erosion.

(d) Screen dams and beam dams :-

→ They are sediment retention structures, design to trap medium to large sediment.

(2) Longitudinal protection structures:

↳ They are installed parallel to the river course.

(a) Marginal bunds or Levees:

↳ They are dam like earthen structures constructed along a river in order to protect the surrounding side.

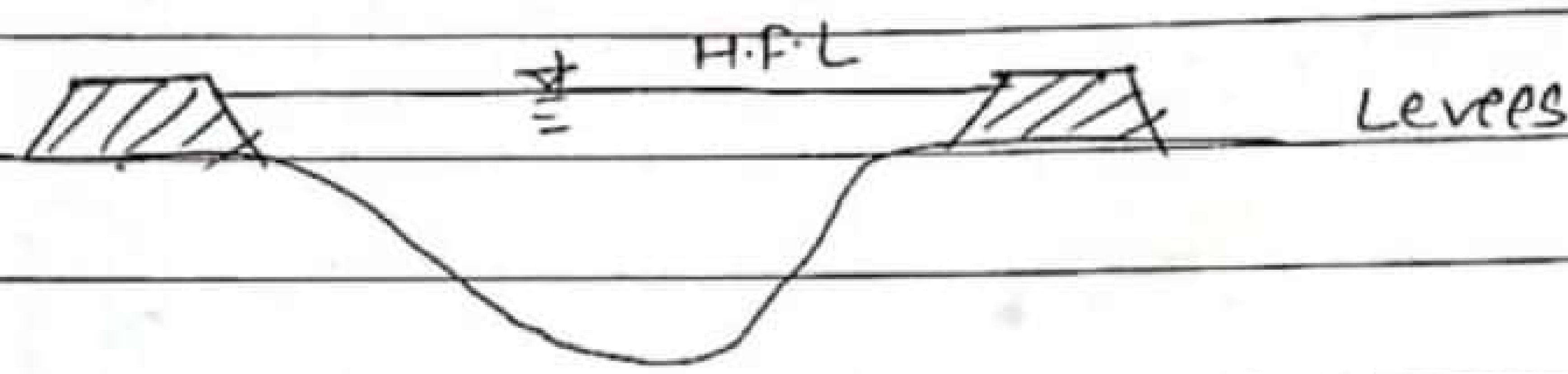
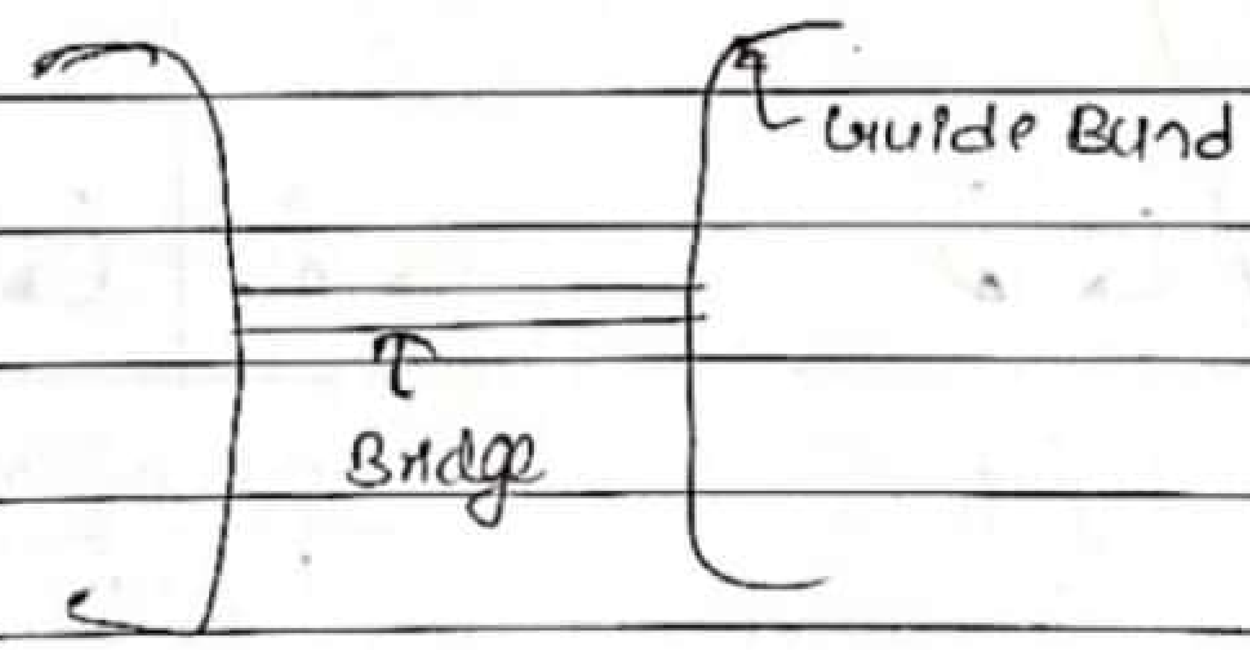


Fig: Marginal bunds or levees.

(b) Guide bunds: (Spell's bunds)

↳ It is a structure built to guide a stream of river.



↳ Other structures are:

* Revetments
* Rock riprap.
* Concrete embankment
* Filter blanket etc.

8 chapter

Road side facilities, safety and environment

aesthetic

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8.1 Introduction and Importance of Road side facilities:

Road side development deals with the development of aesthetic and other amenities of road and the abutting land or the right of way. Proper plannings is needed for the road side development right from the stages of preliminary surveys for highway alignment and during construction.

The following are some of the points to be considered for this:

(i) Consistent and smooth horizontal and vertical alignments.
(ii) wide right of way and shoulders in rural highway & wide right of way in urban areas to screen adjoining property by plantation.
(iii) Flat side slopes in embankment and cut, rounded to blend to original surface
(iv) Suitable planting of road side trees and shrubs and proper maintenance
(v) Turfing on side slopes and on shoulders on rural road.
(vi) Developing pleasant views and parking places.

In hill roads, road sides facility includes mainly, bio-engineering (i.e, arboriculture), parking facility, informatory and other traffic signal etc.

Importance of road side facilities are:

(i) Bio-engineering provide attractive Landscape of road sides.
(ii) Trees on the road side intercept the annoying sound waves and fumes from road vehicles.
(iii) To improves stability of roadside Land and control Landslide during rainy season.
(iv) To facilitate space for vehicles parking during emergency situations also permit the motorists to easily leave the roadways for recreational area.
(v) To provide information about road condition safety measures for road users, in advance
(vi) To enhance level of safety during travelling

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8.2 Tyes of Road side Facilities:

Road side facilities consists various types of services to provide prove the easy and comfort journey to road users.

Types of road side facilities are:

1. Gas filling stations or oil filling stations: Location and general design of gas or oil filling stations along the road and their spacing to be as per the guidelines published by department of roads.
2. Hotel, Highway motels, camping stations and Technical services centres. They should be provided preferably at 50-100km distances.
3. Telephone booths: They should be provided at least 20km distances but in case of hill road, it may not be feasible to establish telephone booths.
4. Highway police control rooms and medical service centers.
5. In order to permit the motorists to easily leave the roadways for vehicle inspection, scenic lookouts and rests, a number of lay-bys, parking lots and ~~recretional~~ recreational area should be provided on road. Recreational area should be located on the scenic sites. They should be provided with wash rooms, public toilets and drinking water facilities.
6. Bio-engineering, turfing etc. to improve stability of soil slopes and to enhance aesthetic appearance.

8.3 Introduction to Hill Road safety:

↳ Road safety has been a much neglected area in the design of roads, with an increasing number of accidents each years. Attention to road safety should be emphasized, while the road element is only one of the three groups of influences causing accidents, it is nonetheless the responsibility of the designer to provide as safe a road environment as possible.

↳ Thus the technique and various measures adopted during the design of hill road to provide optimum safety facility to minimize the road accidents is called hill road safety.

↳ In this aspects, the road design should be one with uniformly high standards applied consistently over a section. It should avoid discontinuities such as abrupt major changes in design speeds, transitions in roadway cross-sections, the introduction of a short radius curve in a series of longer radius curves, constructions in roadway width may by narrow bridges, intersection without adequate sight distances or other facilities to maintain consistency in the roadway design.

↳ The road should offers no surprises to the driver, in terms of either geometrics or traffic controls.

↳ A warning sign must provided on the road side, for inadequate geometric design to enhance hill road safety.

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8.4 Introduction and causes of accidents: Imp

Accident is an event occuring suddenly, unexpectedly and inadvertently under unforseen circumstances.

Causes of accident:

1. Driver: High speed, carelessness, violation of rules and regulations, Failure to see or understand situation of traffic, sign or signals, temporary effects due to sleep, fatigue, sickness, alcohol etc.

2. Pedestrian: In the case hill road, chance of accident due to pedestrain is very low. But it may sometimes occurred because of violating regulation, carelessness in using roadway meant for vehicular traffic.

3. Passenger: Alighting from or getting into moving vehicles.

4. Vehicle defects: vehicle defects consists failure of brakes, steering system, lighting system, tire burst etc. which are consequences of lack of regular maintenance by the users.

5. Road condition: slippery or skidding road surface, pot holes and ruts, inadequate road marking and unexpected obstructions such as road work, parked vehicles etc

6. Road design: Improper and defective design of road such as inadequate sight distance, improper curve design, presence of so many sharp bends, improper and inadequate traffic signals and controls devices.

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7. Weather: Unfavorable weather conditions like fog, snow, dust, smoke or heavy rainfall which distracts normal visibility of the vehicles users.

8. Natural calamities: Landslides after heavy rainfall, floods and soil movement, snow fall during winter etc.

9. Animals: Stray animals, wild animals on the road, route along forest area etc.

8.5 Safety measures: (Engineering, Enforcement and education)

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The various measures to decrease the accident rates may be divided into three groups:

(i) Engineering.
(ii) Enforcement.
(iii) Education.

These three measures are generally termed "3-Es". The details of these measures are given below:

~~(a) Road de~~

Engineering measures:

(a) Road design: The geometric design features of the road such as sight distance, width of pavement, horizontal and vertical alignment design details and intersections design elements are checked and corrected if necessary. The pavement surface characteristics including the skid resistance values are checked and suitable maintenance steps taken to bring them upto the design standards. Where necessary by-passes may be constructed to separate through traffic from local traffic. To minimize the delay and conflicts at the intersections, it may be essential to design and construct grade separated intersections or fly overs.

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(b) preventive maintenance of vehicles:- The braking system, steering and lighting arrangements of vehicles plying on the roads may be checked at suitable intervals and heavy penalties levied on defective vehicles. These measures are particularly necessary for public carriers.

(c) Before and after studies:-
↳ The record of accidents and their patterns for different locations are maintained by means of collision and condition diagrams. After making the necessary improvements in design and enforcing regulation, its design again, necessary to collect and maintain the record of accidents "Before and after" the introduction of preventive measures to study their efficiency.

(d) Road lighting:- Proper road lighting can decrease the rate of accidents during night, due to poor visibility, lighting is particularly desirable at intersections, bridge sites and at places where there are restrictions to traffic movements.

~~EER~~ Enforcement measures:
↳ The various measures of enforcements that may be useful to prevent accidents at spots, prone to accidents are enumerated here. The motor vehicles rules are revised from time to time to make them more comprehensive.

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(a) Speed control: To enable drivers of buses to develop correct speed habits tachometers may be fitted so as to give the record of speeds. Also surprise checks on spot speed of all fast moving vehicles should be done at selected locations and timings and legal actions on those who violate the speed limits should be taken.

(b) Traffic control devices: Signals may be re-designed or signal system be introduced if necessary. Similarly proper traffic control device like signs, markings or channelizing islands may be installed wherever found necessary.

(c) Training and supervision: The transport authorities should be strict in testing and issusing license to drivers of public services vehicles and taxis. Even the drivers who have passed the requisite tests should be kept under proper supervision and be trained in proper defensive driving. Driving license of the driver may be renewed after specified period, only after conducting some tests to check whether the driver is fit.

(d) Medical check: The drivers should be tested for vision and reaction time at prescribed intervals, say, once in three years.

(e) Special precautions for commercial vehicles: It may be insisted on having a conductor or attendant to help and give proper direction to drivers of heavy commercial vehicles.

(f) Observance of law and regulation: This is one of the most essential steps in enforcement for prevention of accidents. Traffic or transport authorities should send study groups of trained personnels, assisted by a police to different locations to check whether the traffic regulations are being followed by the road users and also to enforce the essential regulations. The study group can provide useful data for deciding about about the necessity of revision of certain traffic regulations.

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Educational measures:

(a) Education of road users: ~~Jt~~

It is very essential to educate the road users for the various precautionary measures to use the roadway facilities with safety. The passengers and pedestrains should be taughts the rules of the road, correct manner of crossing etc. This may be possible by introducing necessary instruction in the schools for the children. posters exhibiting the serious results due to carelessness of road users may be also be useful. The Indian Roads congress has recently prepared Highway safety code and the document on Road safety for school children and an instruction manual on Road safety Education is under preparation.

(b) Safety drive:

→ Imposing traffic safety week when the road users are properly directed by the helps of traffic police and transport staff is a common mean of training the ~~public~~ police an public these days. Roads users should be impressed on what should and what should not be done, with the helps of films and documentaries. Training courses may be conducted for drivers.

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8.6 Introduction to environment:

- While planning development of roads and transportation facilities, apart from aiming at operational efficiency, it is also necessary to consider the quality of the environment due to the development.

- It is important to prepare an environmental impacts statement at the planning stage itself. Good results could be achieved if the aesthetic aspects of the roads are given due consideration at the time of hill road planning.

- Other aspects which deserves attention are planning road side avenues, preservation of natural scenery and water sources, reservation of recreational areas and provision of various roadside amenities to the road users.

- The air pollution and noise pollution aspects are also considered.

- In order to ensure better environment on new road, environmental studies should be carried out considering all the above aspects. A multidisciplinary approach may be needed to make a cumulative assessment of land suitability for road development causing minimum adverse effects to the surroundings.

- On existing roads, an environmental evaluation study may be undertaken to assess the quality of the environment and also to quantify the functional and aesthetic components.

8.7 Impact of highway projects on environment:
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The environmental impacts of roads (both positive and negative) include the local effects of highway such as on noise, water pollution, habitat destruction and local air quality and wider effects which may include climate change from vehicle emission.

- A brief discussion of the anticipated impacts due to the construction of a new highway projects are to be discussed below taking into account the contribution of the people to that impact on different aspects:

1. Encorachment on Ecology:

→ The proposed routing of the highway encroaches upon the ecological resources of the construction area including green areas. At some point, these constructions may disturb the natural habitats and the life of creatures and animals. During this road construction, the vegetation on the land will be affected and changes in the eco-system will take place. In addition to that, during construction the works (operation noise) may be interruptions to the wildlife around the road.

2. Impact on ancient monuments:

→ During the construction of new highways, an emission of carbon dioxide and carbon monoxide is considered to be of high values released into the atmosphere. This may cause a threat on the line constructions which react with these gases in the presence of water.

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3. Impact on the quality of water:

↳ The development project of a highway may need the construction of Large bridges which will be constructed with deep foundations and shallow (hollow) piers. moreover, bored piles may be also be required for such constructions. These actions may deplete the quality of water in addition to the soil erosion that may be caused and the wastewater and potential pollution caused by Large construction sites. To sum up, hazardous materials such as fuel, oil, acids, etc may drain into streams and drainage areas. causing the pollution problem to surface and ground water which further causes the loss of lives due to the abstraction of the quality of water

4. Erosion:

↳ Large amounts of trees and plantation has to be removed from the construction site. On the other hand, wearing away and and transportation of soil from one place to another by the effect of wind erosions may be occuring. The embankment construction and road sections with enormous amounts of cut, fills and borrow, in addition to spoilage of certain sites taking place too.

5. Noise and vibration:

↳ High levels of noise and intensive effect of vibrations may be caused during the construction phase of a highway development project. The use of excavators, power shovels, dumpers, compacters, etc can cause a certain level of interruptions of the normal life of people and wildlife around the area of construction.

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6. Air pollution hazards:

↳ The main and most important gas that contributes to the most dangerous effects of the construction of highway projects is the carbon monoxide gas. This gas comes from various sources like machines and motor vehicles The air quality should be discussed by two stages which are the impacts on air quality during operation, and the impacts during the construction phase. Highway run-off pollution, surface run-off from highway may contain some toxic liquids and hazardous materials which will have an effect on the ecology in the region of construction.

7. Land acquisition:

↳ The highway project may causes an agricultural products loss due to the decreased farming lands. Adding to that, another extra Land will be needed beyond the construction of the highway such as access roads, borrow and spoil sites etc

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Mitigation measures of adverse environmental impacts:-

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a. All roads should be designed and constructed with proper assessment of all Environmental and Social aspects and their impacts.

b. Environment protection Acts and Rules of government of Nepal should be followed.

c. All design elements of highways should properly blend with the surrounding elements of nature.

d. Road alignments should avoid preserved zones like national parks, historical monuments and other sensitive to flora, fauna and people.

e. Highway should be located away from the populated areas so as to minimize the disturbance to people from construction activities and noise from moving vehicles.

f. As far as possible road alignments should be located on wind leeward (opposite to windward) side of the populated areas so as to minimize the effect of dust and smoke pollution during construction and vehicle movement.

(g) proper provisions of path should be made for migration of animals across the roads located in forest areas. In access controlled highway provisions of under/overpass bridges for movement of people should be made at required intervals.

(h) Provisions of sound barriers should be made on roads passing through populated areas.

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(i) Removal of top soil before road construction should be done and used for land recultivation, reclamation and road slope stabilizations.

(j) Bio-engineering techniques should be applied on road slope stabilization.

(k) Road side arboriculture should be implemented.

(l) Road embankments should be constructed using imported materials as far as possible. Road side excavation and borrow pits should not be encouraged especially on highly fertile lands.

(m.) Quarries for construction materials should be properly managed and provision for reinstatement to an acceptable condition should be made in the project.

(n) Dust / smoke producing pavement technology shall not be adopted near populated areas.

THE END