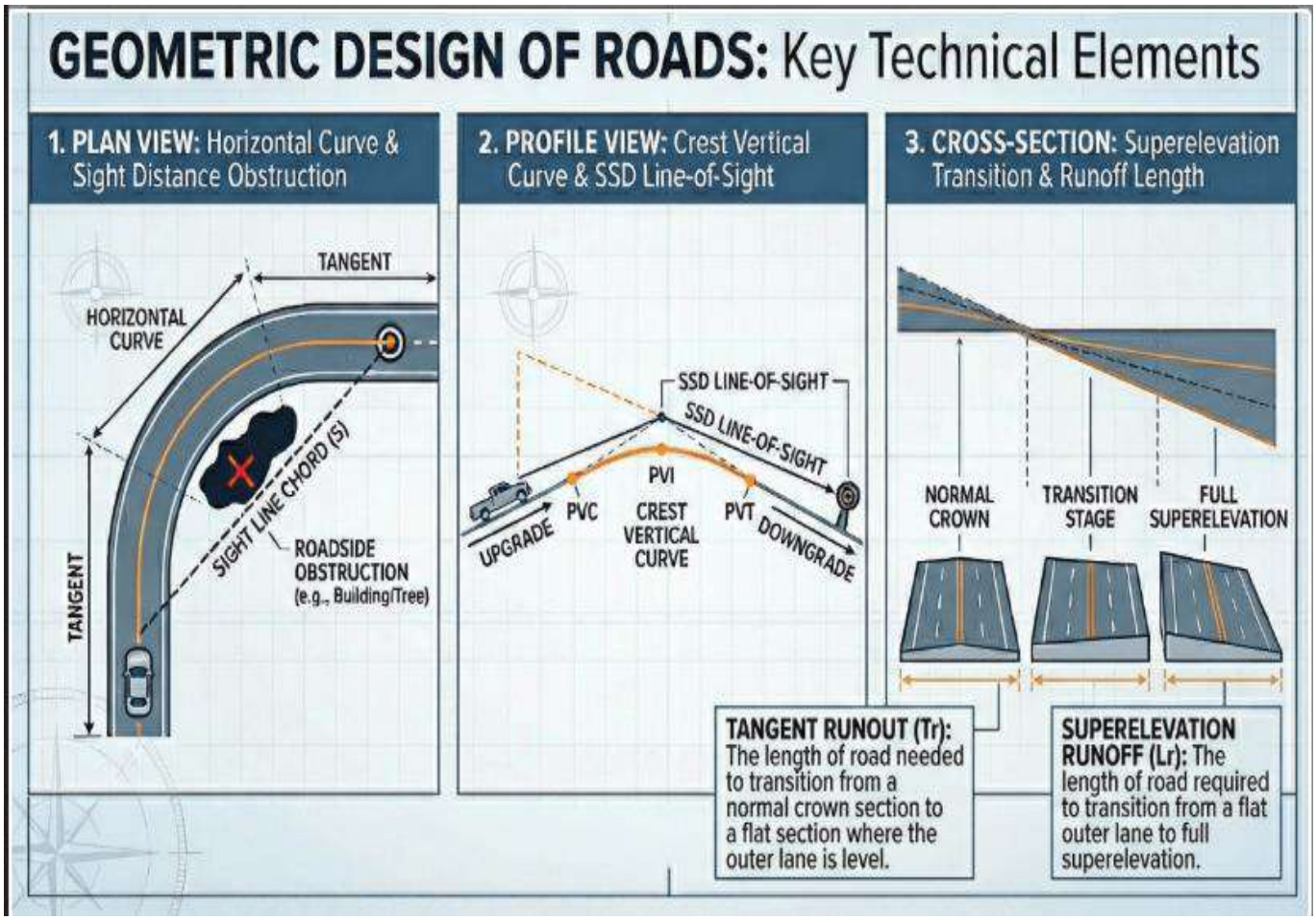
R.C.Patel College Of Engineering & Polytechnic, Shirpur

Department of Civil Engineering

Course Title- Highway Engineering **Course Code -** 313323

Programme Name -Civil Engineering **Semester-**Third

Unit	Title	COs	Learning hours	R Level	U Level	A Level	Total Marks
II	Geometric Elements of Highway	CO2	15	6	8	8	22



2.1. Definition:

1) Permanent Way / Right of Way (ROW)

- Permanent Way is the total width which acquired for road along with alignment, for construction, maintenance, future expansion, and operation of a road.

2) Road Formation:

- Formation width is the top width of the prepared embankment or cutting on which the pavement structure rests.
- It supports pavement layers also provides stability to roadway.

3) Carriageway width:

- It is the portion of Roadway used by vehicle for movement.
- Provides smooth vehicle travel, determines traffic capacity. Ensures safe overtaking and crossing.

Sr. No	class of Road	Width of carriageway
1	Single lane	3.75 m
2	Two lanes, Without Raised kerbs	7.0 m
3	Two lanes, with Raised kerbs	7.5 m
4	Intermediate Carriageway	5.5 m
5	Multi-Lane Pavements	3.5m per lane

4) Road Margin:

Road margin is the portion beyond the carriageway that includes shoulders, footpaths, side drains and slopes.

- Gives lateral support to pavement & improve safety.
- The minimum shoulder width recommended by the IRC is 2.5 m.

5) Side slopes

side slopes are inclined surfaces provided on embankments and cuttings.

- Prevent soil erosion, maintain slope stability.

1. Embankment → 2:1
2. Cutting → 1:1 to $\frac{1}{2}$:1

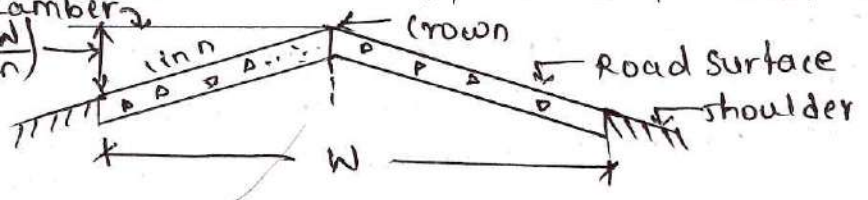
6) Side Gutter / side drain :

A side gutter is a channel constructed along the road edge to collect and carry rainwater.

- Prevent water accumulation, protect pavement from damage.

7) Camber :

- Camber is the transverse slope provided on the road surface to drain rainwater quickly.
- Removes surface water, prevents pavement deterioration.

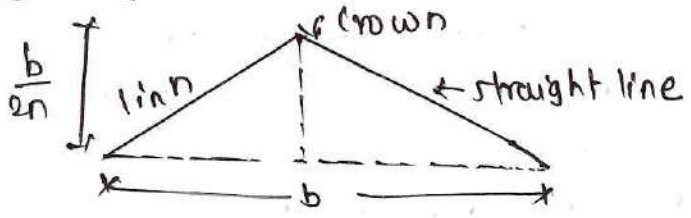


- Types of camber;

1. Straight or sloped camber
2. Two straight line camber
3. Barrel camber
   a) Parabolic barrel camber
   b) Elliptical barrel camber
4. Composite camber.

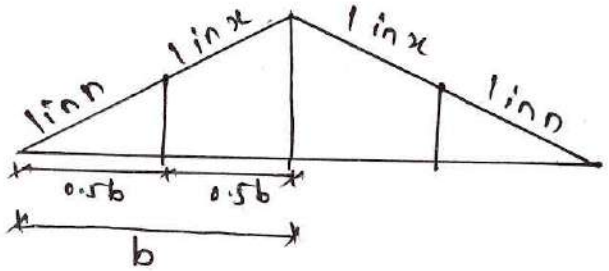
1. straight or sloped camber:

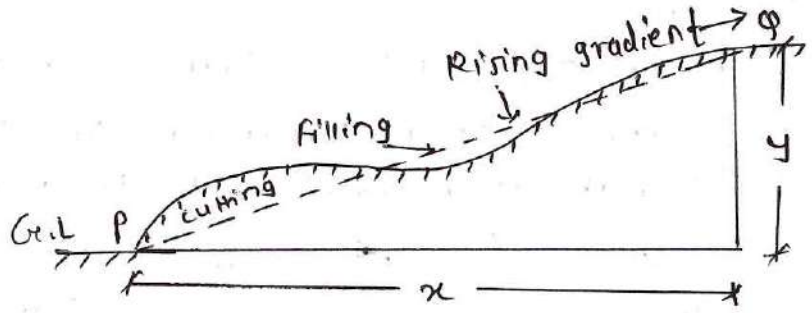
When two straight slope lines joins at edges at centre of carriageway then it known as straight line camber.



2. Two straight line camber.

When camber consits of two straight line near to steeper the edge and flatter near the crown.





$$\text{Gradient} = \frac{\text{Vertical distance}}{\text{Horizontal distance}} = \frac{y}{x}$$

$$\text{Gradient} = \frac{y}{x} \times 100\ \%$$

Purpose of Gradient:

1) To connect roads at different elevations
2) To provide proper drainage of water.
3) To reduce cutting and filling of soil.
4) To ensure safe vehicle movement on slopes.
5) To maintain comfort and fuel efficiency.

Types of Gradient:

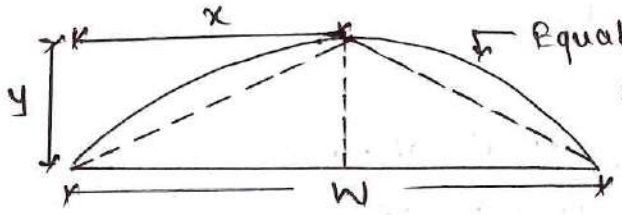
a) Ruling Gradient:
b) Limiting Gradient:
c) Exceptional Gradient:
d) Average Gradient:
e) Floating Gradient:
f) Minimum Gradient:

a) Ruling Gradient:

- Ruling gradient is the maximum gradient in which designer attempts design, it adopted as normal course in design of vertical profile road.
- Ruling gradient also called as design gradient.

3. Barrel Camber :

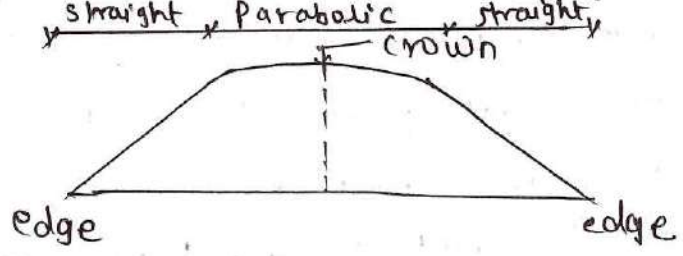
- It is the special type of Road surface shape where continuous curve either parabolic or elliptic so at profile is flat at middle and steeper at edges.



Equation of parabolic shape = $\frac{2x^2}{nw}$

4. Composite Camber :

- Composite camber is a type of road surface camber in which combined camber with parabolic central portion and straight line camber at the edges.



Sr No.	Types of Road surface	Range (Rainfall)
		Heavy to Light
1	Cement Conc. & High bituminous	1 in 50 (2.0%) to 1 to 60 (1.7%)
2	Thin bituminous Surface	1 in 40 (2.5%) to 1 in 60 (2.0%)
3	Water bound macadam & gravel	1 in 33 (3.0%) to 1 in 40 (2.5%)
4	Earth Road	1 in 25 (4.0%) to 1 in 33 (3.0%)

Gradient :

- The rate of rise or fall along the length of a road with respect to horizontal is called as gradient.
- Rising gradient is known as positive gradient.
  Falling gradient is known as negative gradient.

b) Limiting gradient:

- A limiting gradient is steeper than the ruling gradient and is adopted where it is difficult or uneconomical to provide ruling gradient.
- Used in – Hilly terrain, difficult topography.

c) Exceptional gradient:

- It is more steeper than limiting gradient. In some extra ordinary situations, for very short distances.
- Used only when Terrain is extremely difficult.

d) Average gradient:

- The average gradient is the average slope between two on a road or highway.
- It is calculated by dividing the total vertical Rise or fall by the total horizontal distance.

$$\text{Average Gradient} = \frac{\text{Total vertical Rise or Fall}}{\text{Total Horizontal Distance.}}$$

e) Floating gradient:

- The gradient on which vehicle moving with constant speed, with acceleration (Increasing speed) or deceleration (decreasing speed) without any application of power or brakes is called as floating gradient.

f) Minimum gradient:

The minimum gradient is the smallest slope provided mainly for drainage purposes.

- Prevent Water from stoping (stagnation)
- Provided generally to side drains.
- Kerbed pavements exist.

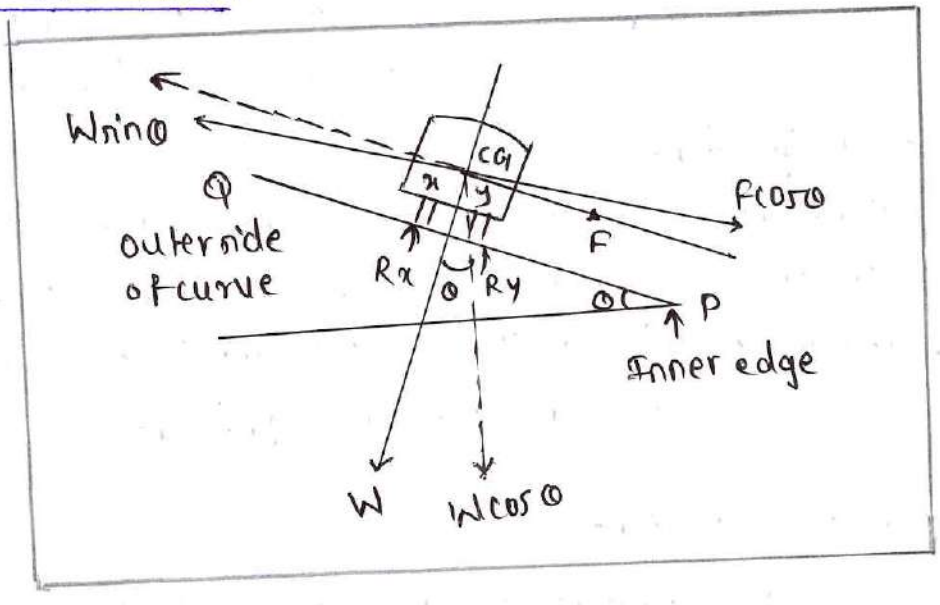
Superelevation :-

Superelevation means raising the outer edge of road curve to inner edge, so vehicle can turn safely without skidding or overturning.

objective/Purpose of Superelevation:

1) To prevent skidding - avoids slipping outward.
2) To prevent overturning.
3) To provide safe turning.
4) To increase comfort. feel less side jerk.
5) Reduces side friction. Reduces friction between tyres and road surface.

Formula for Calculating Minimum and Maximum Superelevation:



Consider, equilibrium.

$$F\cos\theta = W\sin\theta + Rx + Ry$$
$$F\cos\theta = W\sin\theta + fRx + FRy$$
$$F\cos\theta = W\sin\theta + f(W\cos\theta + F\sin\theta)$$

$$F(\cos\theta - f\sin\theta) = W\sin\theta + fW\cos\theta$$

a) V kmph

Then, $e + f = \frac{(0.278V)^2}{9.81 \times R}$

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

If friction f is neglected or assumed equal to zero,

$$e = \frac{V^2}{9R}$$

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

V = Speed, kmph

R = Radius of Curvature

f = Coefficient of lateral Fraction.

Q. Calculate the design speed of a vehicle on a horizontal curve having radius of 100m. with permissible super-elevation of 7%. consider coefficient of friction 0.18.

→ Given data:

horizontal curve having radius = 100m

e = 7%.

coefficient of friction = 0.18

Find design speed = ?

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

$$0.07 + 0.18 = \frac{V^2}{127(100)}$$

$$V^2 = 3175$$

$$\boxed{V = 56.4 \text{ KM/hr}}$$

Divinding by $W\cos\theta$ we get,

$$\frac{F}{W}\left(\frac{\cos\theta}{\cos\theta} - \frac{f\sin\theta}{\cos\theta}\right) = \frac{W\sin\theta}{W\cos\theta} + \frac{fW\cos\theta}{W\cos\theta}$$

$$\frac{F}{W}(1 - f\tan\theta) = \tan\theta + f$$

The value of coefficient of lateral friction 'f' is taken as 0.15 for design. Purpose and $\tan\theta$ hardly exceed 0.07,

$$(1 - f\tan\theta) = (1 - 0.15 \times 0.07) \simeq 0.989 \approx \underline{\underline{1.0}}$$

$$\frac{F}{W} = \tan\theta + f$$

$$F = W(\tan\theta + f)$$

$$F = W(e + f) \quad \{\tan\theta = e\} \quad \text{--- (1)}$$

We know,

$$F = \frac{WV^2}{gR}$$ — centrifugal force eqn.

where centrifugal force,

$$= \frac{mV^2}{R}, \quad m = \frac{W}{g}$$

$$\left\{F = \frac{\left(\frac{W}{g}\right)V^2}{R} = \frac{WV^2}{gR}\right\}$$

From (1)

$$\frac{WV^2}{gR} = W(e + f)$$

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

$$\boxed{e + f = \frac{V^2}{gR}}$$

Curves :-

- A curve is a gradual change in the direction or change in alignment or gradient or slope of road provided to ensure smooth, safe and comfortable movement of vehicle.
- The alignment changes may be horizontally and vertically.

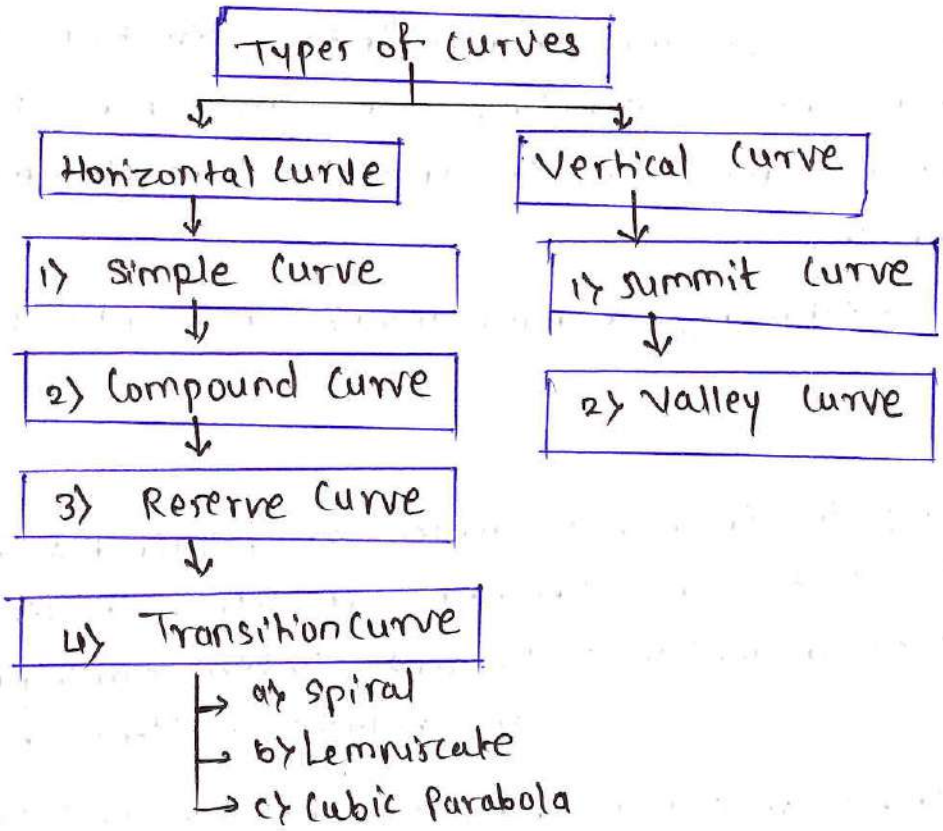
Necessity of curve:

1) Change in direction : Curves are required to smoothly connect two roads meeting at different directions.
2) Safety of vehicle : Prevents sudden turning movements and reduces accident chances.
3) Marshy lands : Marshy or unstable land can be avoided by curves.
4) Comfortable driving : Provides smooth movement without jerks or discomfort to passengers.
5) Better visibility : Properly designed curves improve sight distance for drivers.
6) Terrain Adjustment : Curve helps road pass through hills, valleys, rivers & obstacles economically.
7) Aesthetic Appearance : Gives a smooth and pleasant alignment to the roadway.

Functions of curves in Road :

1) For gradual change in gradient
2) gradual change in alignment
3) For smooth traffic flow
4) Curves are provided for smooth and comfort for passengers
5) Reduce cost of construction by balancing earthwork.

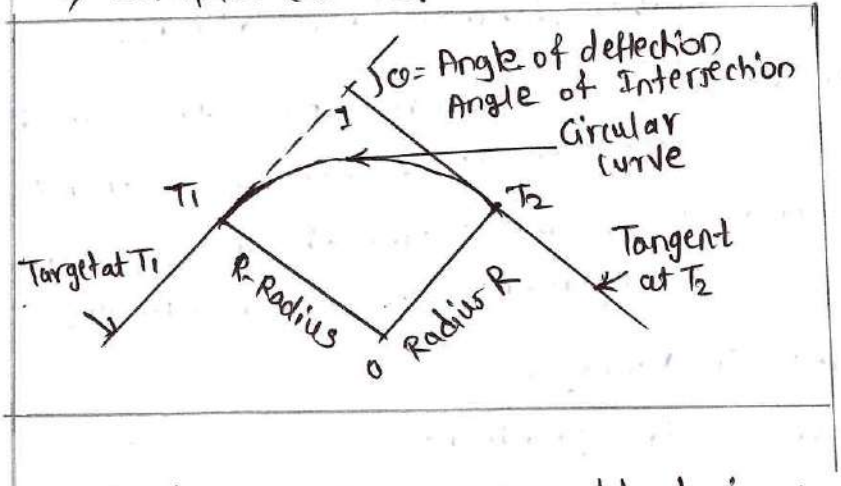
Types of curves.



Horizontal curve.

These curves are provided in the horizontal plane to change road direction left to right.

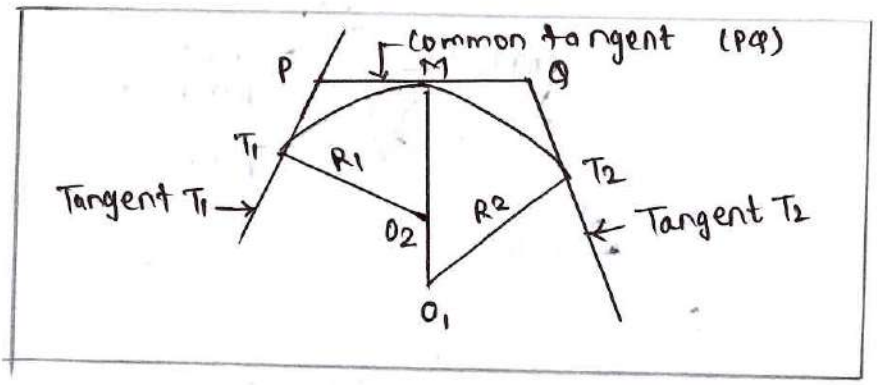
1) Simple curve:



- Single arc of a circle
- Most commonly used curve.

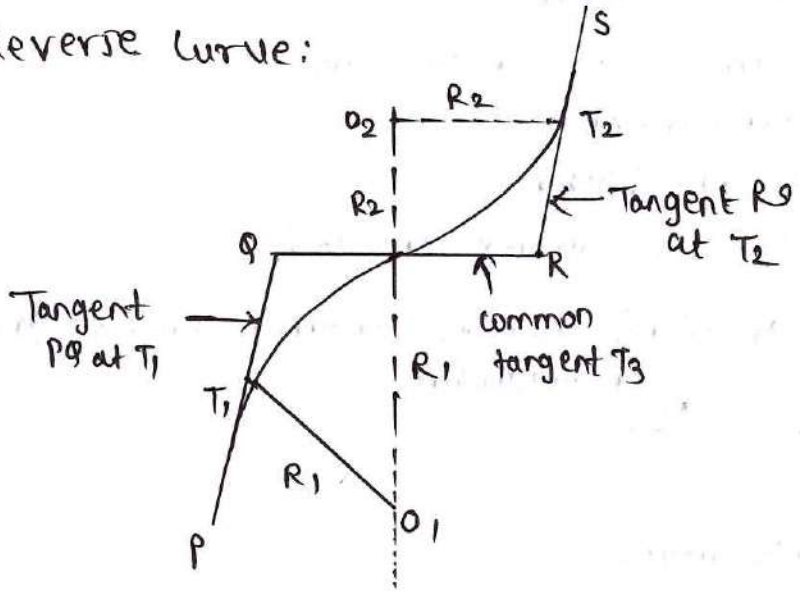
- simple curve are provided in at alignment or gradient in plain & in hilly area.

2) Compound curve:



- Two or more circular curves with different radii.
- Used in hilly areas.
- T_1M & MT_2 are two adjacent simple curves of Radius R_1 & R_2 respectively. common tangent at M.

3) Reverse curve:

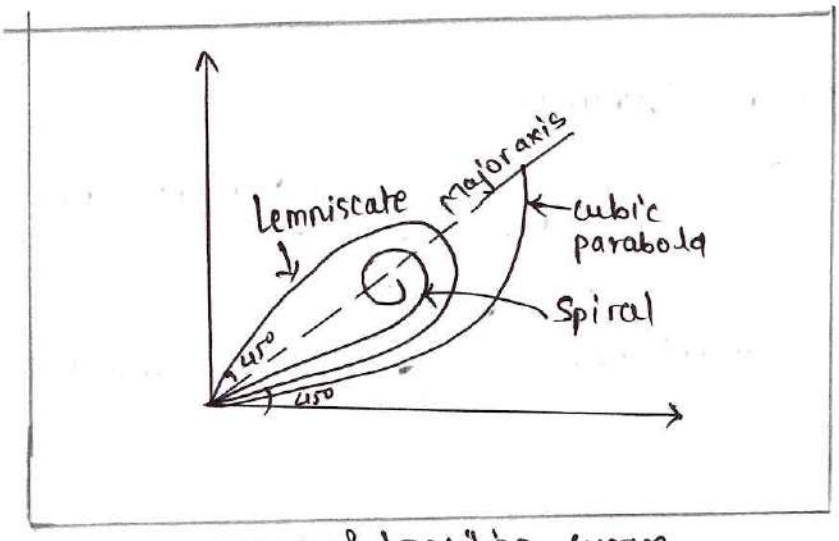


- Two curves bending in opponite directions.
- shape similar to 's'
- Common Tangent.

4) Transition Curve:

- Radius gradually changes from straight to circular.
- Provides smooth entry to the curve.

Examples: - spiral curve.
- Cubic parabola.
- Lemiscate.



Type of transition curve

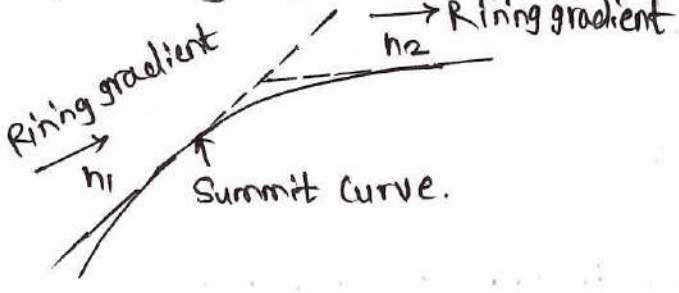
Vertical Curve:

These curves are provided in the vertical plane to connect two different slope (gradients).

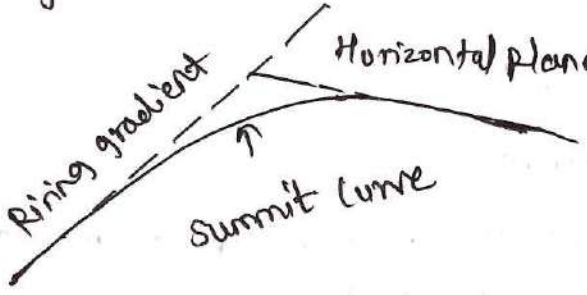
Types of Vertical Curve:

1) Summit curve or crest curves.
- convex upward shape.
- Provided at hilltops.
- The curve is convex upward.

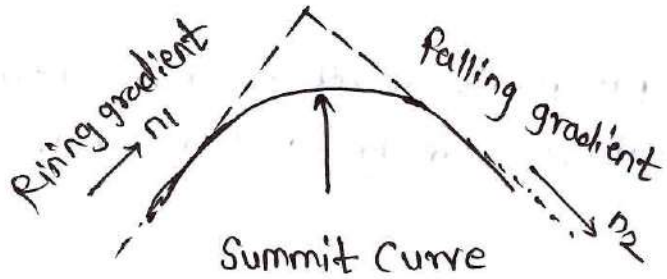
i) Rising gradient meets another Rising gradient.



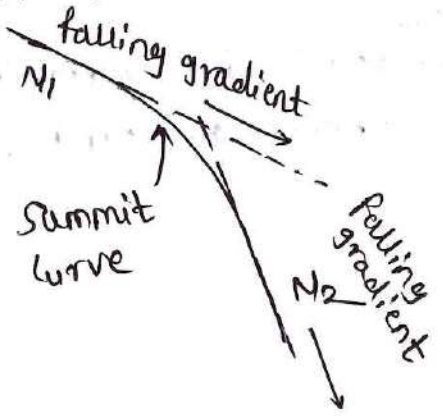
ii) Rising gradient meets Horizontal plane.



iii) Rising gradient meets falling gradient



iv) Falling gradient meets another falling gradient.

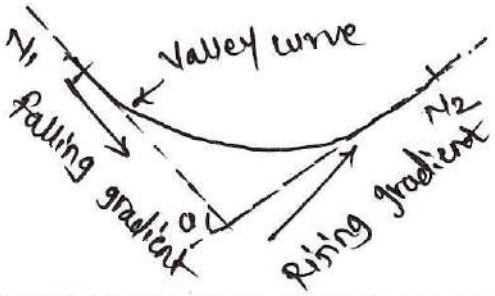


2) Valley curve.

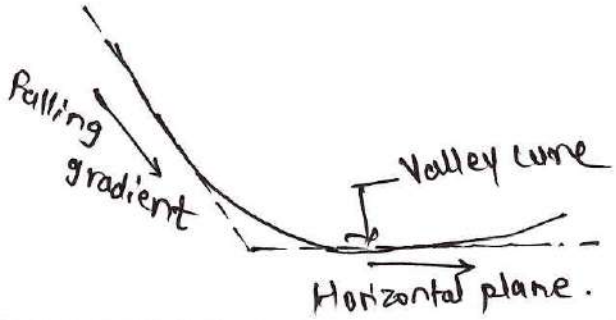
⇒ A valley curve is formed when a descending gradient meets an ascending gradient.

- It is concave upward like a valley.

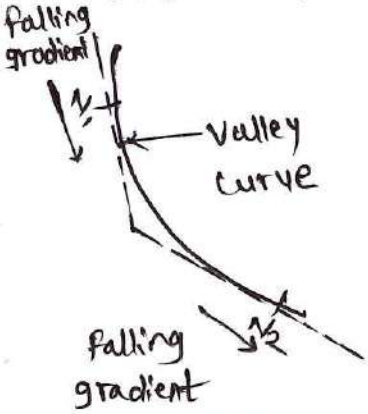
i) When falling gradient meets Rising gradient.



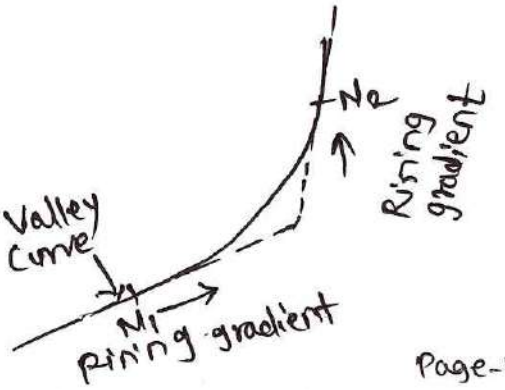
ii) When falling gradient meets horizontal plane.



iii) When falling gradient meets another falling gradient



iv) Rising gradient meeting another Rising gradient.



Road Widening:

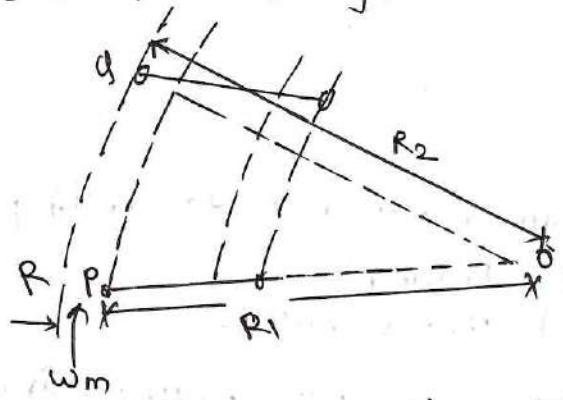
To provision of extra pavement width to horizontal curve to allow vehicles to move safely and smoothly.

Purpose of Road Widening:

- To reduce traffic congection.
- To avoid accidents.
- To provide more space for overtaking.
- To improve vehicle speed and safety.

Types of o Widening:

1. Mechanical Widening.



(mechanical widening)

R_1 = Radius path of outer rear wheel, m.

R_2 = Radius of path by outer front wheel, m

l = Length of wheelbase m.

$W_m = OR - OP = OB - OA = R_2 - R_1$

From, $\triangle OPQ$ $\quad OP^2 = OB^2 = QP^2$

$$R_1^2 = R_2^2 - l^2$$

$$PQ^2 \; R_1 = R_2 - W_m$$

$$(R_2 - W_m)^2 = R_2^2 - l^2$$

$$R_2^2 - 2R_2 W_m + W_m^2 = R_2^2 - l^2$$

$$l^2 = W_m (2R_2 - W_m)$$

$$W_m = \frac{l^2}{2R_2 - W_m}$$

$$W_m = \frac{l^2}{2R_2} \quad \text{or} \quad \boxed{W_m = \frac{n l^2}{2R_2}}$$

n = number of traffic lanes.

2. Psychological Widening:

- Psychological widening is the extra width provided because drivers feel unsafe while driving at high speed.
- Reduces fear during overtaking.
- Improves driving comfort.

$$Wps = \frac{V}{9.5\sqrt{R}}$$

Where, Wps = Psychological widening

R = Radius of curve

V = design speed.

Total widening = We = Wm + Wps = $\frac{n l^2}{2R} + \frac{V^2}{2.5\sqrt{R}}$

Sight distance:

stopping sight distance is the minimum distance required by a driver to stop the vehicle safely after seeing an obstacle.

- The sight distance available on a road to a driver at any instance depends on,

1) Features of the road surface

2) Height of the driver's eye above the road surface.

factors: a) Total reaction time of driver.

b) Speed of vehicle

c) Efficiency of brakes

d) Frictional resistance between

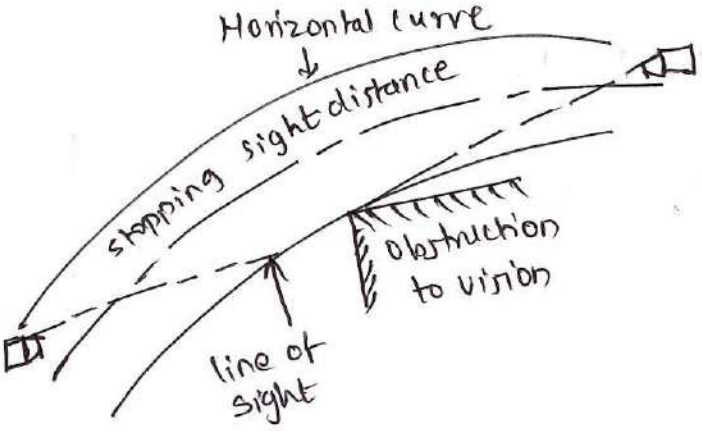
e) Gradient of the road.

Types of Sight

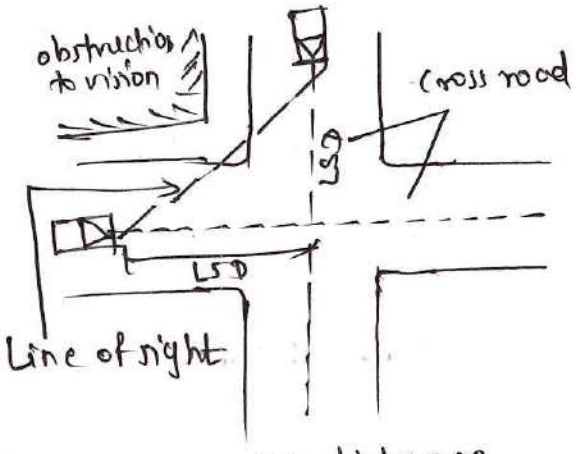
As per IRC in highway design.

1. Stopping Sight distance (SSD)
2. Overtaking Sight distance (OSD)
3. Intermediate sight distance
4. Lateral Sight distance
5. Head light Sight distance.

1. Stopping sight distance (SSD)



SSD at horizontal curve



Lateral sight distance at intersection

Lag distance →

If the design speed is V kmph then the lag distance work out to,

$$V \times \frac{1000}{60 \times 60} t = 0.278\ V.t \text{ meters.}$$

The K.E at the design speed of V m/sec will be,

$$\frac{1}{2} m v^2 = \frac{W v^2}{2g}$$

$$f W l = \frac{W v^2}{2g}$$

$$l = \frac{V^2}{2gf}$$

l = braking distance, m V = Speed of vehicle m/s

f = design coefficient of friction, g = acceleration due to gravity

Stopping distance = leg distance + braking distance

$$SD(meter) = Vt + \frac{V^2}{29f}$$

If speed is V kmph, stopping distance

$$SD(meter) = 0.278\,Vt + \frac{V^2}{254f}$$

Stopping sight distance at slope:

When the gradient is ascending to be +n.%. the gravity breaking distance is decreased.

- The component of gravity acting parallel to the surface which adds to the braking force is equal to,

$$W\sin\alpha = \frac{Wn}{100}$$

Equating K.E & Work done,

$$\left[fw + \frac{Wn}{100}\right] l = \frac{1}{2}\frac{WV^2}{g}$$

$$l = \frac{V^2}{2g\left(f + \frac{n}{100}\right)}$$

Similarly, descending gradient $-n.\% \rightarrow$ distance increases.

$$\left[fw + \frac{Wn}{100}\right] l = \frac{WV^2}{g}$$

$$l = \frac{V^2}{2g\left(f + \frac{n}{100}\right)}$$

So, $$SD(meter) = \left[Vt + \frac{V^2}{2g(f \pm 0.01n)}\right]$$

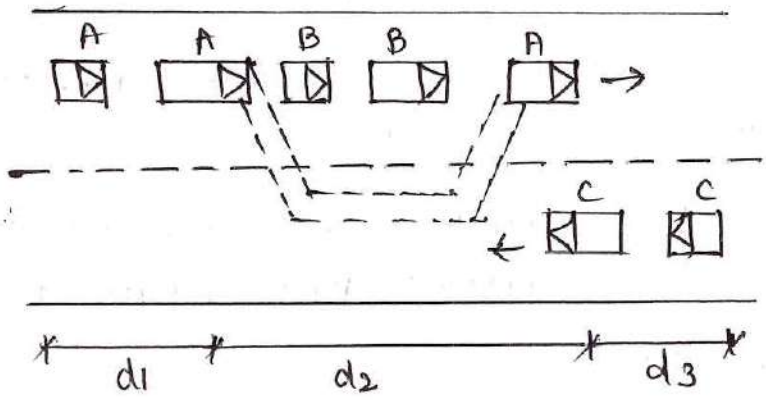
in V kmph,

$$SD(meter) = 0.278\,Vt + \frac{V^2}{254(f \pm 0.01n)}$$

2. Overtaking Sight Distance (OSD)

Overtaking sight distance is the minimum distance required for one vehicle to safely overtake another vehicle without causing accident with opposite traffic.

- Required on,
  - Two lane highways
  - Roads with fast moving traffic.



- Some factors for minimum overtaking sight distance required for safe overtaking,

a) Speed of,
  i) Vehicle overtaking
  ii) Vehicle overtaken
  iii) Vehicle coming from opposite direction.

b) Distance between the overtaking and o

c) Rate of acceleration of overtaking vehicle.

e) Gradient of the road,

Length of OSD = $d_1 + d_2 + d_3$

$d_1 = V_A \cdot t$, $d_2 = (V_A T + 25)$ m, $d_3 = VT$

$$OSD = d_1 + d_2 + d_3$$

$$OSD = V_A t + V_A T + 25 + VT$$

V_A = Speed of overtaking vehicle km/hr

t = Reaction time of driver = 2 sec.

V = Design speed kmph

$$T = \sqrt{\frac{4 \times 3.65}{A}} = \sqrt{\frac{14.45}{A}}$$

Where,

S = Spacing of vehicles

$S = (0.7 V_{bt} + 6)m$

A = Acceleration, kmph/sec.

3. Intermediate sight Distance (ISD)

The distance which affords reasonable opportunities to drivers to overtake the vehicle ahead with caution is known as intermediate.

- Intermediate sight distance visible to the driver which is equal to twice the Stop.

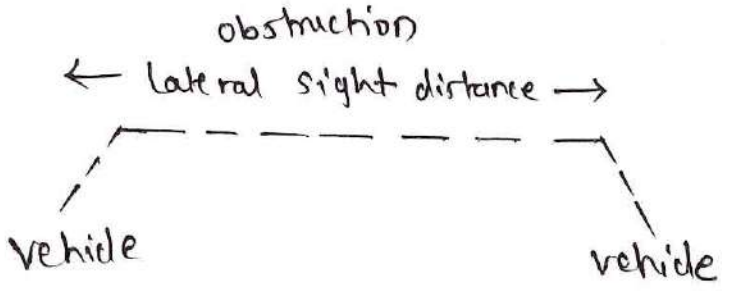
$$ISD = 2SSD$$

4. Lateral sight distance:

Lateral Sight distance is the clear side distance provided on the inner side of a horizontal curve so that the driver can see the road ahead clearly.

Purpose of Lateral Sight distance

- To improve visibility on curves
- To avoid accidents
- To help drivers see vehicles or obstacles ahead.
- To provide safe driving on horizontal curves.



5. Head light Sight distance

- Head light sight distance is the distance visible to a driver at night with the help of vehicle headlights.
- The visible length of road ahead is called Head light sight distance.

Purpose →
- To drive safety at night
- To avoid accidents
- To see obstacles clearly
- To stop the vehicle safely in darkness

Design Speed:

- Design speed is the maximum safe speed selected for designing a road.

or,

- It is the speed at which vehicles can move safely on the road under good conditions.

Purpose:

design speed affects many road features are given below:

1) Width of road
2) Radius of curve
3) Super elevation
4) Sight distance
5) Gradient & slopes.

Factors Affecting design Speed.

As per class of the road and terrain,

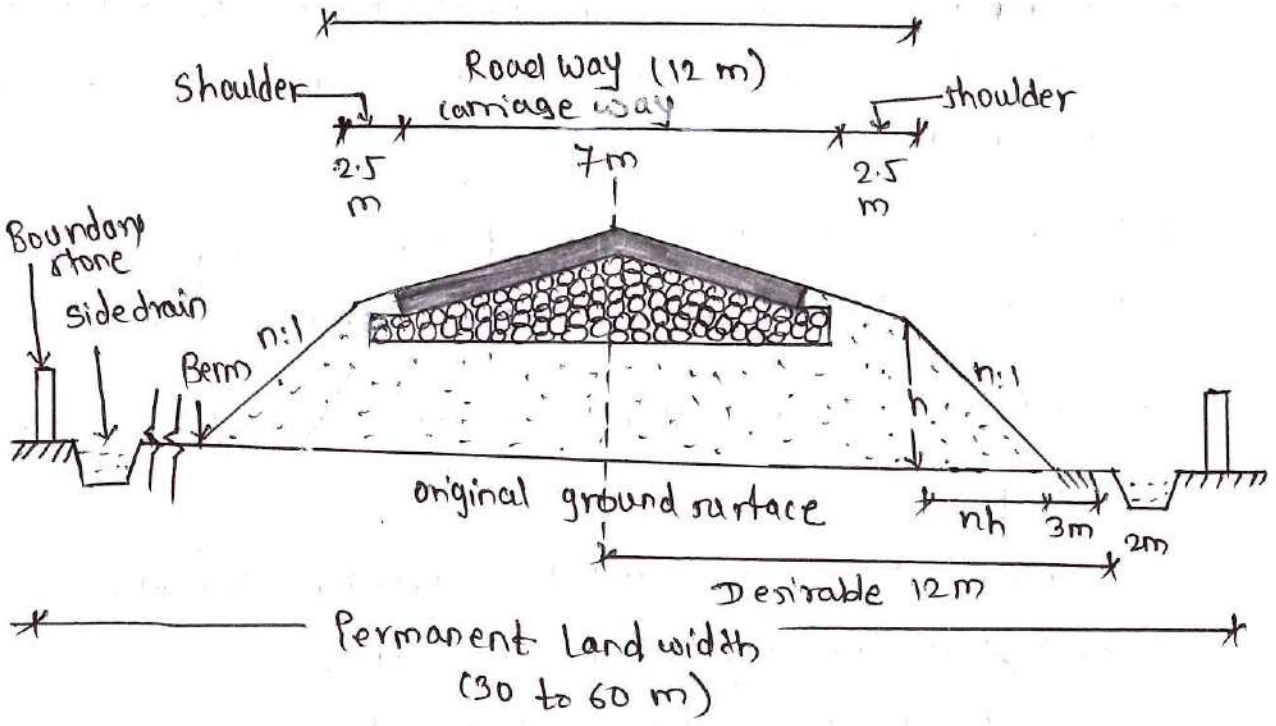
- classification of the terrain through which it passes depending on cross slope of the country the terrain is classified.

1. Plain: when cross slope of the country is 0-10 %.
2. Rolling: when slope of the country 10-25 %.
3. Mountainous: when slope of the country 25-60 %.
4. Steep:
   a) When slope of country is greater than 60.
   b) Nature, intensity & type of traffic.
   c) Type of curve along alignment.
   d) Structure of road.
   e) Sight distance required.

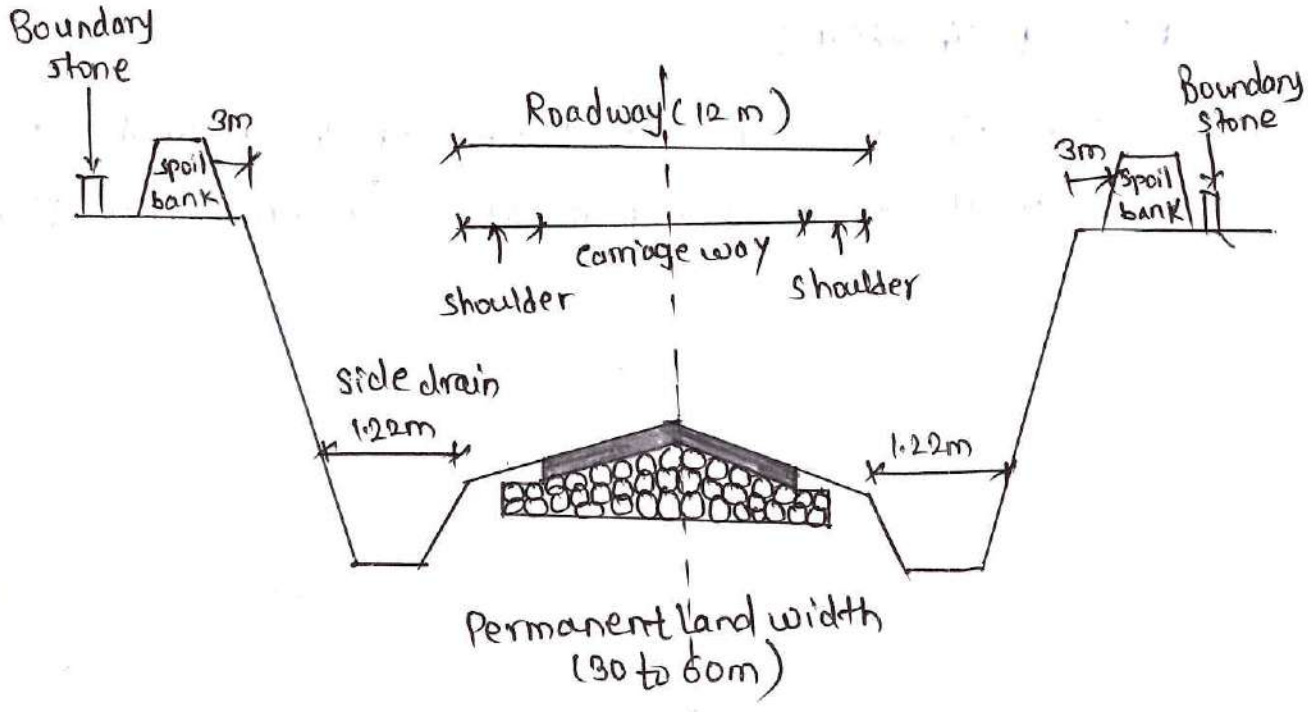
IRC Specification:

The maximum safe speed of vehicle assumed for geometrical design of a highway is known as Speed limit.

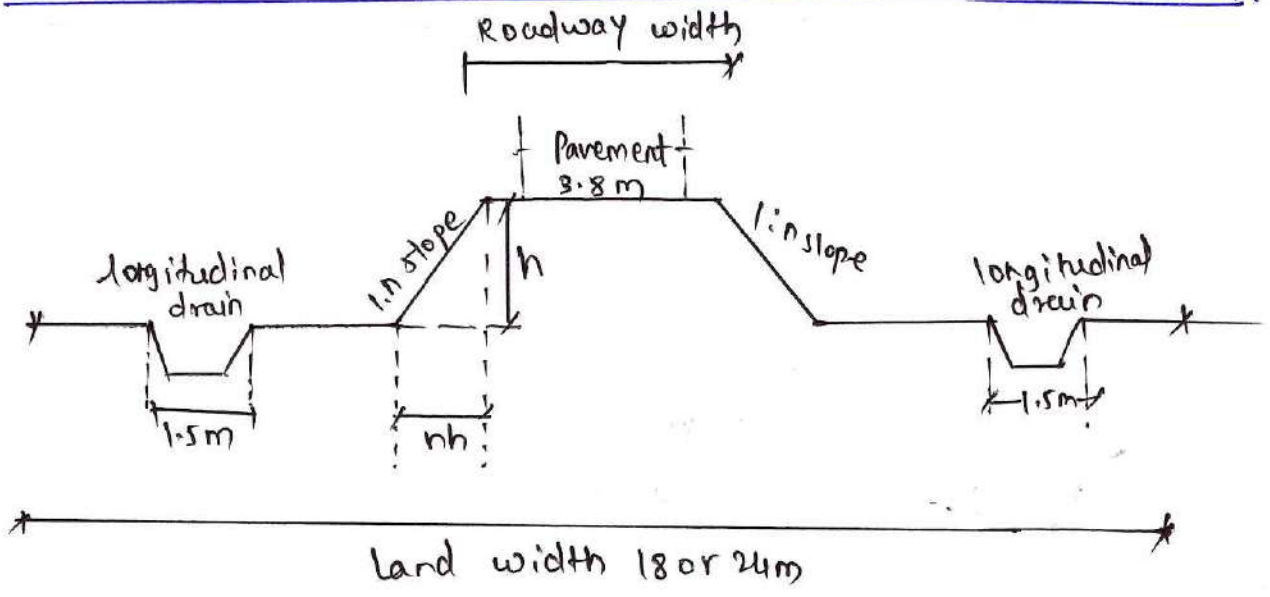
2.2 Standards cross-sections NH in Embankment & cutting



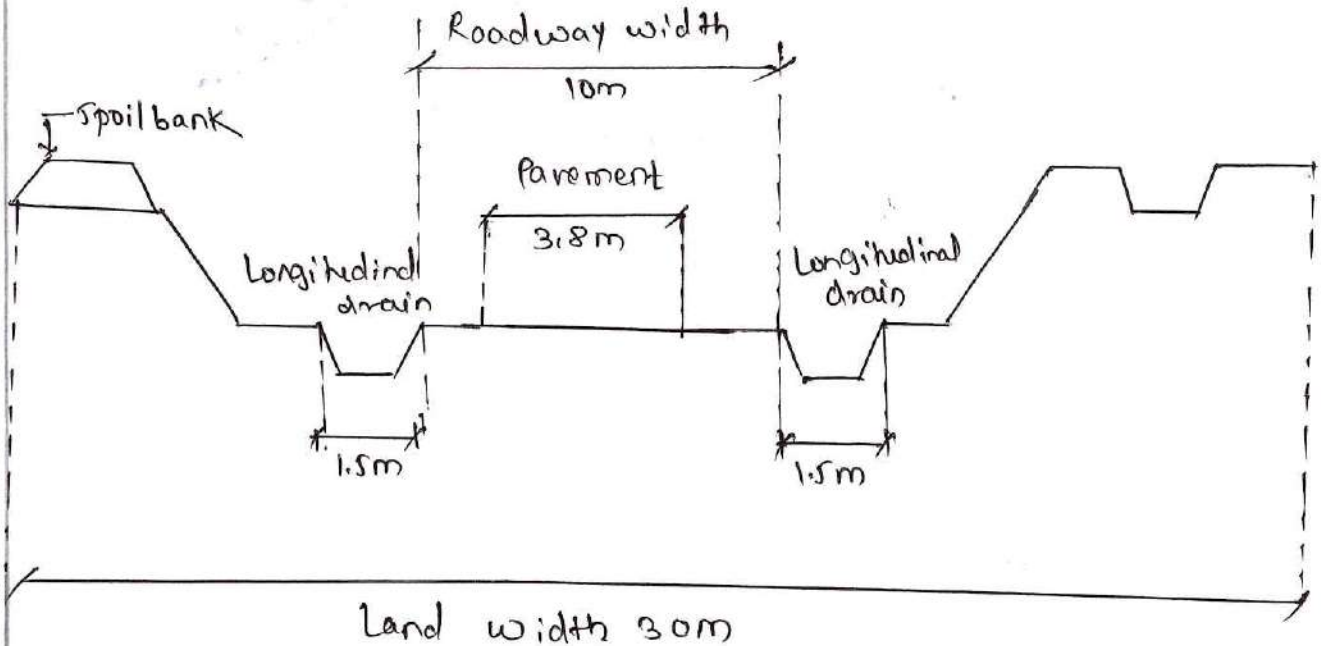
Standard cross section of State highway in cutting:



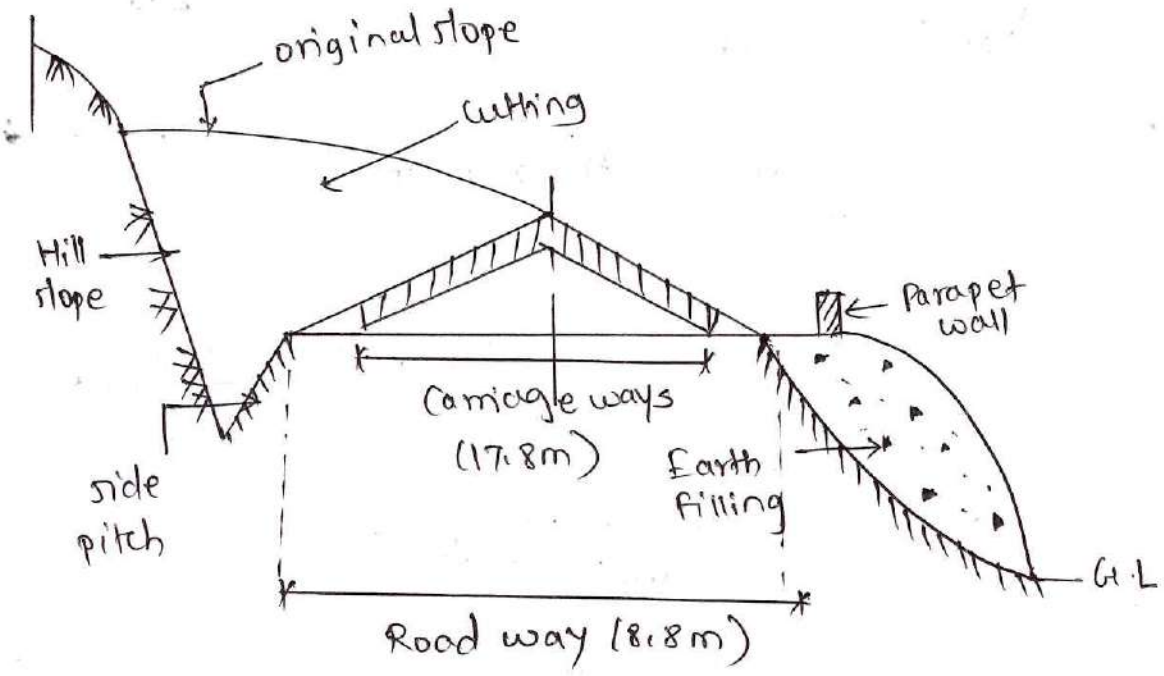
Cross section of VR or ODR in embankment in rural area:



Cross section of MDR in cutting in rural area.



Cross section of National or State Highway in Hilly Areas.



Unit - II Geometric Elements of Highway

1. Define the following terms : (i) Carriageway (ii) Shoulder (iii) Stopping Sight Distance (iv) Gradient
2. Define sight distance.
3. Name / state any two National highways passing through Maharashtra.
4. Draw and label standard cross-section of National highway in embankment.
5. State factors affecting gradient of a road.
6. Define design speed and super-elevation provided for a road.
7. State factors affecting camber of a given road.
8. State the purpose of providing permanent way or right of way, side slopes, road margin, side gutter, berms, temporary land in road construction.
9. i) Draw neat labelled diagram explaining overtaking sight distance.
   ii) State purpose of providing transition curve with diagram.
10. Explain vertical curve with purpose and explain types of vertical curves.
11. State Super Elevation with a neat labelled sketch.
12. Define Camber and enlist any four types of Camber.
13. Draw a neat labelled cross section of National Highway in embankment showing clearly the land width formation, pavement width, location of side drains, trees etc.
14. Classify the roads according to the Nagpur Road Plan.
15. Calculate the stopping sight distance for a road having design speed of 60 kmph. The break efficiency is 50% and the reaction time of the driver is 2.5 seconds.
16. Design super elevation for a 7 m wide road with design speed 80 kmph on a curve of radius 160 m. Consider co-efficient of friction 0.15.
17. Explain the following road curves with neat sketch : (i) Horizontal Curves (ii) Vertical Curves.