UPPSC-AE 2025

Uttar Pradesh
Public Service Commission

Combined State Engineering Services Examination

Assistant Engineer

Civil Engineering

Transportation Engineering

Well Illustrated **Theory** *with*
Solved Examples and **Practice Questions**

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Transportation Engineering

Contents

CHAPTER 2

Geometric Design of Highway

2.1 Introduction

This unit contents the principle of road layouts. A highway has many visible dimensions and the design of visible dimensions is known as Geometric Design. These visible dimensions are:

(i) Cross sectional elements
(ii) Sight distance considerations
(iii) Horizontal alignment
(iv) Vertical alignment

2.2 Factors Controlling Geometric Design

There are certain basic design controls and criteria which govern the geometric features of a highway.

(i) Topography
(ii) Design speed
(iii) Road user characteristics
(iv) Vehicle characteristics
(v) Traffic (its volume, directional distribution and composition including the future estimates)
(vi) Traffic capacity
(vii) Environmental considerations
(viii) Economy in construction, maintenance and operation of vehicles

2.2.1 Topography

The topography of the land, through which the road passes, also known as the terrain, controls the geometric design.

Table : Terrain classification

S.No.	1.	2.	3.	4.
Type of Terrain	Plain	Rolling	Mountain	Steep
Cross-slope of country(in %)	0 - 10	10 - 25	25 - 60	> 60

2.2.2 Design Speed

Most important factors for controlling the geometric design elements of highway.

- Factors considered in India for deciding design speeds are:
  (i) Importance of road (ii) Terrain or topography

For rural highway two types of design speeds

(i) **Ruling design speed:** The speed that should generally be considered as guiding extension for correlating the various design factures.

(ii) **Minimum design speed:** The speed that should be adopted in sections where site conditions or economics do not permit a design based on the ruling design speed.

Design speeds in kmph as per IRC (Ruling and minimum)

Table-: Ruling and minimum

Type of road	Plain	Rolling	Hilly	Steep
NH & SH	100 - 80	80 - 65	50 - 40	40 - 30
MDR	80 - 65	65 - 50	40 - 30	30 - 20
ODR	65 - 50	50 - 40	30 - 25	25 - 20
VR	50 - 40	40 - 35	25 - 20	25 - 20

2.3 Highway Cross-section Elements

These are the features of the cross-section of the pavement that affects the life of pavement, riding comfort and safety.

- Following are the cross-sectional elements of the pavement:
  - (i) Right of way
  - (ii) Width of formation
  - (iii) Road margins
  - (iv) Medians
  - (v) Kerbs
  - (vi) Width of pavement or carriageway
  - (vii) Camber or cross slope
  - (viii) Pavement characteristics

2.3.1 Pavement Characteristics

(a) **Friction:** Friction between wheel and pavement surface is a crucial factors in the design of horizontal curves and thus the safe operating speed. Further it also affects the acceleration and deceleration ability of vehicles.

(i) Longitudinal friction: Due to frictional force developed in horizontal direction.

- This friction supports movement of vehicles.
- As per IRC, f_{longi} = 0.35 – 0.4

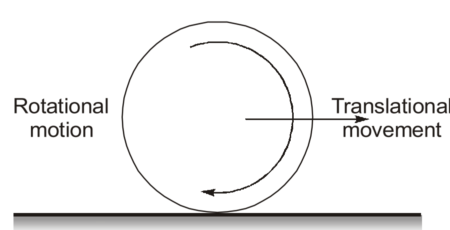
NOTE

- Higher the speed of vehicle, lower the coefficient of longitudinal friction due to less area of contact.
- On dry pavement old tyre generates more coefficient of friction than a new tyre due to large area of contact. However, on wet pavement condition is reversed because water acts as a lubricating agent.

(ii) **Lateral friction:** Frictional force developed in transverse direction to vehicle movement. This friction comes in picture only when there is a curve on road. As per IRC $f_{lateral}$ = 0.15.

(b) Skid and slip:

- Skid: During brake, (Rotational motion < Translations motion)
- Slip: During acceleration (Rotational motion > Translations motion)



Skid and Slip

(c) Pavement Unevenness:

- Measured by unevenness index which is the cumulative vertical undulations of the pavement surface per unit horizontal length of road (cm/km).

- It should be low.
- For good pavement: (150 cm/km)
- (250 cm/km) is satisfactory for design speed of 100 kmph.

NOTE: It is measured by using roughometer and bump integrator (developed by CRRI).

$BI = 630\ [IRI]^{1.12}$

IRI - (International : BI-Bump integrator roughness index)

(i) As per IRC, if bump integrator is more than 320 cm/km then road is considered as uncomfortable. In this case reconstruction of road required.

2.3.2 Camber

It is the cross slope provided to road by elevating the centre line in order to allow the flow of water from surface to drainage system.

Functions: To drain off the rain water from road surface.

- Better surface drainage is important from considerations of:
  (i) Prevention of entry of surface water into sub-grade soil through pavement.
  (ii) To make the surface dry soon after the rain so that skid resistance does not reduce.
  (iii) Designation:
  As 1 in n
  or (1V = nH) or as percentage (%)
  Ex: Camber = 4% = $\frac{4}{100}\left(\frac{1}{25}\right)$ or 1 in 25 or 1 V : 25 H or (0.04) or 1/25
- Factors:
  (i) Type of pavement surface
  (ii) Amount of rainfall

As per IRC

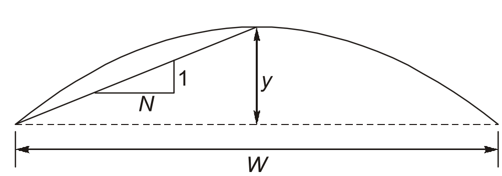
Table : Amount of rainfall

Surface type	Heavy rainfall	Light rainfall
High type bituminous surfacing or cement concrete	2%	1.7%
Thin bituminous surfacing	2.5%	2%
Water bound macadam	3%	2.5%
Earth	4%	3%

2.3.2.1 Types of Camber based on shape

(i) Parabolic Camber:

Equation $y = \frac{2x^2}{NW}$

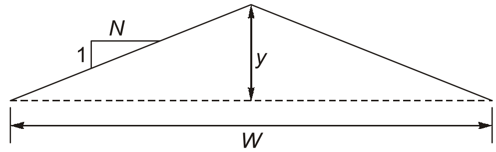


Parabolic Camber

Merits: Profile will be flat at the middle and steeper towards the edges. It is preferred for fast moving vehicles as then have to frequently cross the crown line during overtaking operation.

Demerits: Since steeper at edges slow moving vehicles have a tendency to overturn inside and hence try to occupy the central portion of the roadway, resulting in reduction of traffic capacities.

(ii) **Straight line camber:** Generally, in cement concrete pavements, the wheels does not have contact at centre when straight camber is provided or when vehicle is on a curved slope

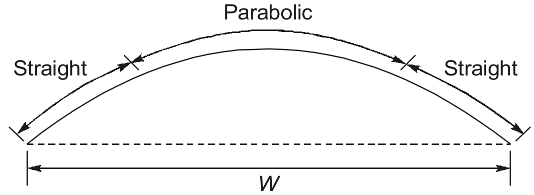


Straight line camber

Merits: Uniform cross slope on either side of centre, comfortable for slow moving vehicles.

Demerits: Discomfort for fast moving vehicles which have a tendency to overtake slow moving vehicles by crossing the centre line, which is a sharp point, resulting in jerk. Further the road is likely to get damaged at the centre, since stress intensity is high because of sharp point of negligible area.

(iii) **Combination of straight and parabolic:** This is particularly useful to increase the area of contact of the wheel and thus decrease the contact straight pressure in case of animal drawn vehicles with steel types occupying different lateral positions of the pavement



Combination of straight and parabolic

- It has the positive points of both parabolic and straight cambers. i.e. comfortable for both slow and fast moving vehicles and less damage to the road.

NOTE

- **Relation between longitudinal gradient and camber:** For better drainage and smooth flow of traffic, the camber(C) of the road should be approximately equal to half of longitudinal gradient (G) i.e. $G = 2C$.
- Superior the road flatter the camber
- The cross slope for shoulder should be 0.5% steeper than the cross slope of adjoints pavements, subject to an minimum of 3%.

Example - 2.1 In a district load where the rainfall is heavy major district of WBM pavement, 3.8 m wide and a state highway of bituminous concrete pavement 7.0 m wide are to be constructed, what should be the height of crown with respect to the edges in these two cases.

Solution:

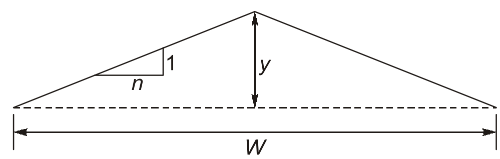
For WBM road,

As the rainfall is heavy, Camber = 3% (1 in 33)

$$\therefore \text{ Rise of camber with respect to edges } = \frac{W}{2n} = \frac{3.8}{2\times 33} = 0.058 \text{ m}$$

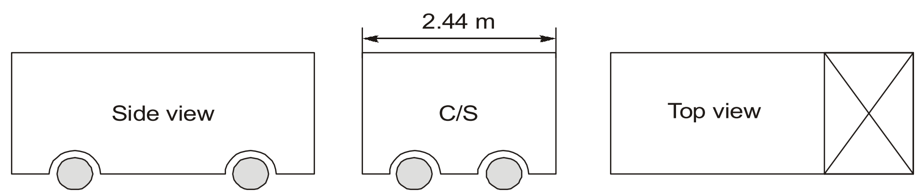
(For Bituminous concrete road): provide a cross slope of 2% (1 in 50)

$$\therefore \text{ Rise of crown with respect to edges } = \frac{W}{2n} = \frac{7}{2\times 50} = 0.07 \text{ m}$$



2.3.3 Width of Pavement or Carriage Way

The maximum width of vehicle as per IRC is 2.44 m.



Pavement and Carriage way

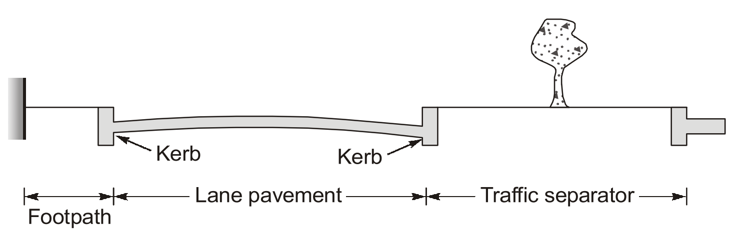
Table

S.No.	Classification	Width of carriageway
1.	Single lane	3.75 m for all roads
2.	Two lanes without raised kerb	7.0 m
3.	Two lanes with raised kerb	7.5 m
4.	Intermediate carriageway	5.5 m
5.	Multilane pavements	3.5 m per lane

NOTE: The width of pavement is increased on horizontal curves, to take care of off tracking and psychological effects called extra widening.

2.3.4 Traffic Separators or Medians/Kerb

Kerbs: Kerb is boundary between pavement and footpath. It provides lateral support to the pavement.



Kerbs

Medians: It separates road traffic moving in opposite direction so that chances of head on collision can be reduced. It also reduce the glaring effect due to head light of vehicle coming from opposite direction in night.

As per IRC: Minimum width of divider/medians required for highway is 5 m. When space is restricted than provide 3 m.

- On long bridges width of medians reduced upto 1.2 to 1.5 m

2.3.5 Road Margins

- Shoulders: Extra width provided adjacent to outer edge of pavement for emergency purpose (breakdown of vehicle/ambulance) called shoulder.
- The surface of shoulder should be rougher than the traffic lanes so that vehicles are discouraged to used the shoulder as a regular traffic lane.

As per IRC:

(i) Minimum width of shoulder should be 2.5 m in one direction.

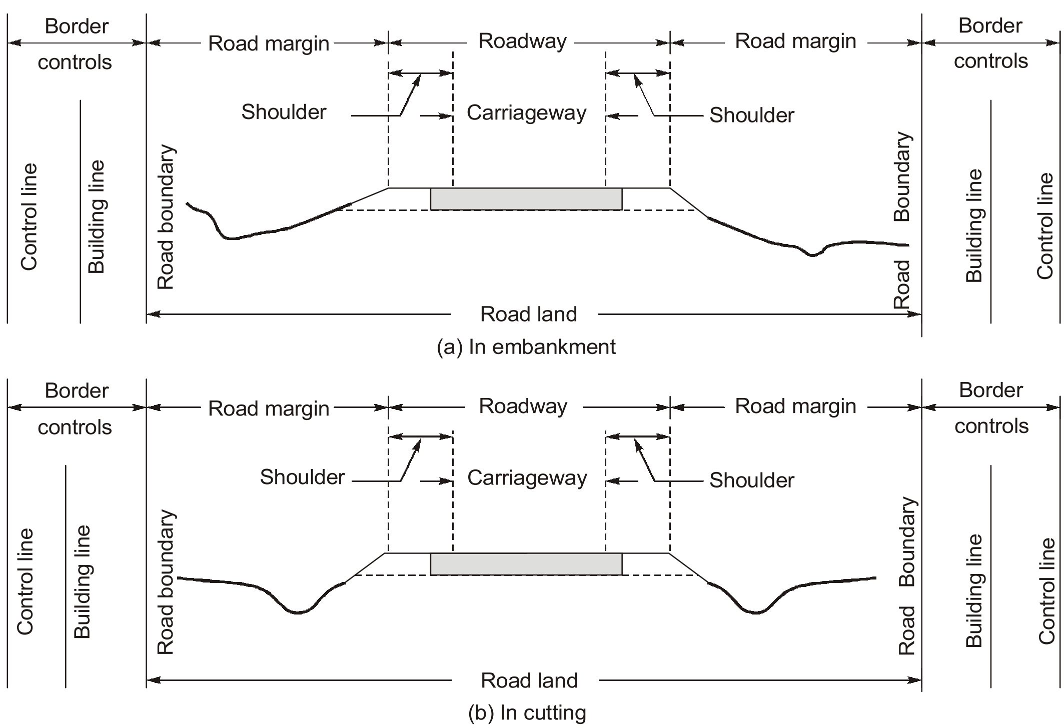
(ii) Camber of shoulder should be 0.5% steeper than camber of road.

(iii) Minimum camber for shoulder should be 3%.

(iv) For super-elevated section

Camber of road = Camber of shoulder

- Frontage roads: Are provided to give access to properties along an important highway with controlled access as expressway or freeway.
- Driveways: Connects the highway with commercial establishments like fuel stations, service stations etc.
- Guard rails: When embankment height is more than 3 m.



Cross section details

2.3.6 Width of roadway or formation

Formation width = Carriageway width (including separators) + Shoulders

- It is the top width of highway embankment (or) bottom width of highway cutting excluding side drains.

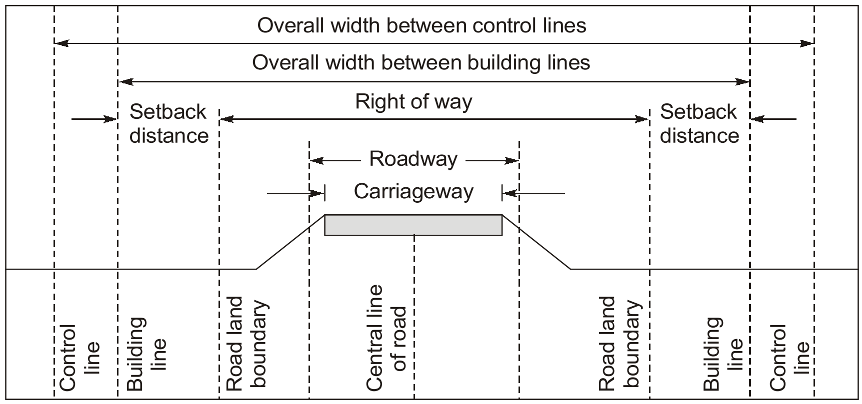
2.3.7 Right of Way

Area of land required for the road, along its alignment. The width of this acquired land is known as land width.

Right of way = Formation width + Road margins

- Building activities are to be disallowed upto building line with sufficient setback from road boundary. In addition to this it is desirable to exercise control on the nature of building upto control lines.

- Normal land width required for NH and SH is 45 m.
- Maximum land width required for NH and SH is 60 m.
- Corresponding distance between building lines is 80 m and between control lines is 150 m.



Road margins

2.4 Sight Distances

Geometric design of highway is done in such a way that from every point on highway the length of view available is sufficient so that the vehicle could be stopped in that visible distance 'or' operations like overtaking could be safely performed.

Various types of sight distances:

(i) SSD (Stopping sight distance): Also known as non-passing sight distance. It is provided for safety stopping the vehicle.

(ii) OSD (Overtaking sight distance): Also known as passing sight distance, provided for safe overtaking operation.

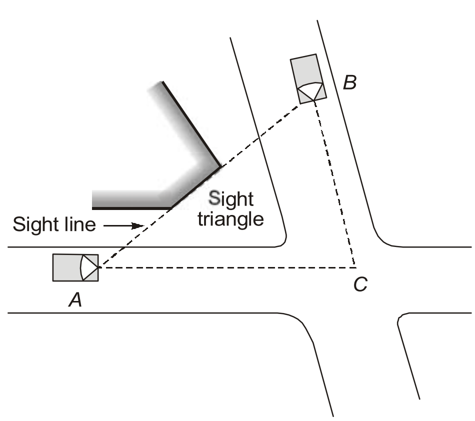
(ii) ISD (Intermediate sight distance): When OSD can't be provided, we provide ISD, so as to give some degree of overtaking opportunity

$$ISD = 2 \times SSD$$

(iv) Head light sight distance (HSSD): Distance visible to the driver at night under head light illumination.

Minimum value of HSSD $\simeq$ SSD

(v) Safe sight distance to enter into an intersection.



Sight distance at intersection

2.4.1 Stopping sight distance (SSD):

- It is also known as absolute minimum sight distance.
- It is the minimum sight distance that should be available at all spots on highway such that vehicles travelling at design speed could be safely stopped within that distance.

2.4.1.2 SSD depends upon

(i) Speed of vehicle

(ii) Reaction time of the driver (t_R)

- Reaction time of driver is the time taken from the instant the object is visible to the driver to the instant when the brakes are applied.
- The total reaction time may be split up into four components based on PIEV theory.

P. Perception time (Time lost in perceiving any object)

I. Intellection time (Time Lost in understanding the situation)

E - Emotion time (Time Lost due to anger or fear)

V - volition time (Time Lost in final action)

$\therefore \quad t_R = P + I + E + V$

Table

As per IRC	t_R
SSD	2.5
OSD/ISD	2
Minimum space heasway	0.7

(iii) Braking efficiency: IRC assumes a brakes efficiency of 50%. It has already being included in the longitudinal friction coefficient.

(iv) Friction coefficient, f = (0.35 – 0.4) As per IRC

Table

Speed (km/h)	Longitudinal coefficient of friction (f)
20 - 30	0.40
40	0.38
50	0.37
60	0.36
65	0.36
80	0.35
100	0.35

(v) Longitudinal gradient of road.

- Up gradient will lead to lower value of SSD.
- Down gradient will lead to higher value of SSD.

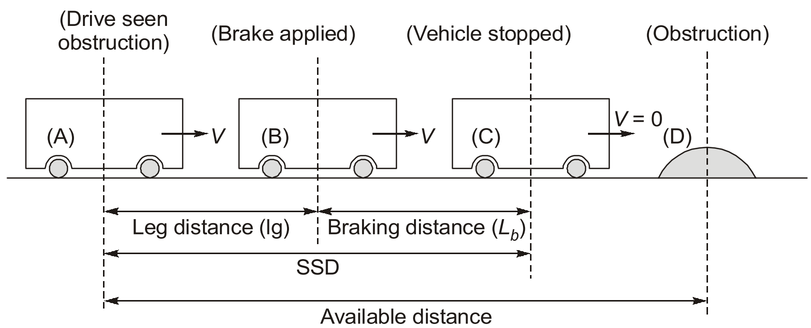
Calculation of SSD:

Case-1: When the vehicle is moving on level ground, i.e. no longitudinal gradient.

Assumptions: Height of obstruction = 0.15 m height of driver's eye = 1.2 m above carriageway.

- SSD = Lag distance + Braking distance

  SSD = $l_g + l_b$



Calculation of SSD

(a) Lag Distance: It is the distance travelled by vehicle during reaction time. It speed of vehicle V (in km/h) and rk^n time t_R (in sec)

$$\text{Lag distance (m)}, l_g = 0.278\, Vt_R$$

(b) Braking distance: It is the distance travelled by vehicle after application of brake before stopping

$$V^2 = u^2 + 2as \qquad (a = -f \cdot g)$$

$$0 = V^2 - 2(f \cdot g) \times l_b$$

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

If V (in km/h),

$$l_b = \frac{V^2}{254f}$$

∴ On level ground,

$$\text{SSD} = l_g + l_b$$

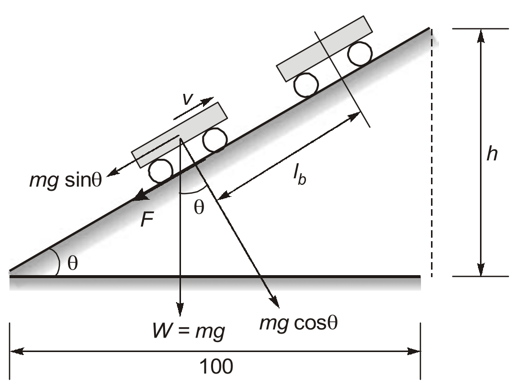
$$\text{SSD} = 0.278Vt_r + \frac{V^2}{254f}$$

Case-2: When the vehicle is moving on longitudinal gradient (say an upgradient of n%)

(a) Leg Distance:

$$\text{Lag distance}, l_g = 0.278\, Vt_R$$

(b) Braking distance:



Braking distance

f = Frictional force = f(mg)cosθ

$$\text{Total resistive force} = f(mg\cos\theta) + mg\sin\theta$$

$$a = \frac{-(mg\sin\theta + fmg\cos\theta)}{m} = -(g\sin\theta + fg\cos\theta)$$

$$V^2 = u^2 + 2as$$

$$0 = V^2 - 2(g\sin\theta + fg\cos\theta)l_b$$

$$l_b = \frac{V^2}{2g(\sin\theta + f\cos\theta)} = \frac{V^2}{2g\cos\theta(\tan\theta + f)}$$

For small angle $\cos\theta \simeq 1$

If V (in km/h), $$l_b = \frac{V^2}{2g(f + \tan\theta)}$$

$$\tan\theta = \frac{n}{100} = n\%$$

$$l_b = \frac{V^2}{2g(f + n\%)}$$

If V in km/h, $$l_b = \frac{V^2}{254(f + n\%)}$$

$\therefore$ $$\text{SSD} = l_g + l_b$$

$$\text{SSD} = 0.278Vt_r + \frac{V^2}{254(f + n\%)}$$

Similarly, for downgradient:

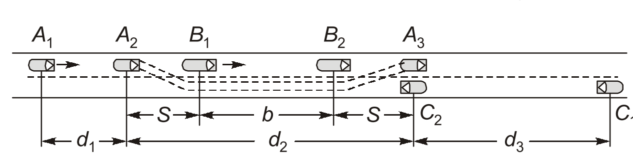
$$\text{SSD} = 0.278Vt_r + \frac{V^2}{254(f - n\%)}$$

2.4.1.3 IRC Recommendations

- For single lane, roads with two way traffic the minimum SSD should be equal to twice of SSD (for same speed).
- For two lane two way traffic.
  Minimum sight distance = SSD.
- For undivided highway two way traffic effect of gradient is not considered while calculating SSD. However, on divided highway effect of gradient should be considered.
- SSD on vertical curve is calculated along the centre line of the curve from which a driver with an eye level of 1.2 m above the ground surface can see an obstruction 0.15 m above ground.
- If SSD can't be provided on a road in a particular stretch, proper sign boards with speed restrictions should be provided.

2.4.2 OSD Calculation

- Provide for safe overtaking operation.
  Analysis:
  Let us suppose,
  Vehicle A = Travelling at the design speed of highway
  Vehicle B = Slow moving vehicle which is going to overtaken by vehicle A.
  Vehicle C = Travelling in the opposite direction of A and B.
- The whole process of overtaking is split into three parts d_1, d_2, d_3 as shown in figure.



Overtaking manoeuvre

d_1 = Distance travelled by overtaking vehicle A during the reaction time (t sec).

d_2 = Distance travelled by the vehicle A during the actual overtaking operation in time (t sec).

d_3 = Distance travelled by vehicle coming from the opposite direction

V_b = Speed of slow moving vehicle (Over taken vehicle)

V = Design speed = Speed of fast moving vehicle (overtaking vehicle)

$$\therefore \quad \text{OSD} = d_1 + d_2 + d_3$$

$$d_1 = 0.278\, V_b t_r \quad (V_b \text{ (in km/h)}, t_r \text{ (in sec)})$$

$$d_2 = b + 2s$$

$$b = 0.278\, V_b T$$

$$T = \sqrt{\frac{4s}{a}} \quad (a = \text{Acceleration in m/s}^2)$$

If acceleration (in kmph/sec),

$$T = \sqrt{\frac{14.4s}{A}}$$

$$S = 0.2V_b + l \quad \text{If } (V_b \text{ in km/h})$$

$$l = \text{Length of vehicle}$$

$V_b = V - 16$ If (V in km/h)

$= V - 4.5$ If (V in m/sec)

$$d_2 = 0.278VT$$

$$\therefore \quad OSD = 0.278V_b t_r + 2s + 0.278V_b T + 0.278VT$$

$$t_r = 2'' \text{ as per IRC}$$

2.4.2.1 IRC Recommendations

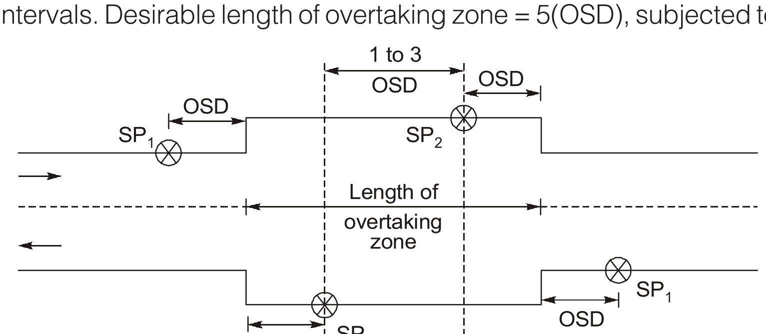
- For one way road,

$$\text{OSD} = d_1 + d_2$$

- Vehicle A and C both are considered as fast moving vehicle and vehicle B slow moving vehicle. If data not given we can consider

$$V_A = V_C$$

- For designing: $V_A = V_C$ = Design speed (V)
- IRC is not considered any effect of gradient for OSD calculation.
- Overtaking zone: If SSD can't be provided throughout the length of road we provide overtaking zone at certain intervals. Desirable length of overtaking zone = 5(OSD), subjected to a minimum of 3(OSD).

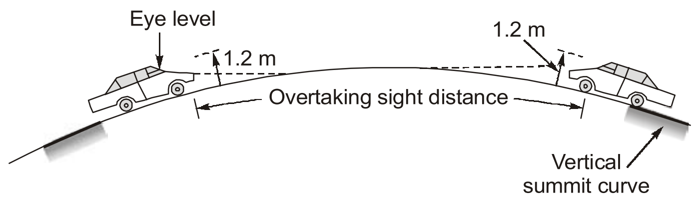


Overtaking zone

SP_1 - Overtaking zone ahead.

SP_2 -End of overtaking zone.

- On vertical curve OSD is calculated along the centre line of the road over which a driver with its eye level 1.2 m above the road surface can see the top of an object 1.2 m above road surface.



Measurement of overtaking sight distance

- ISD (Intermediate Sight Distance): ISD (Intermediate Sight Distance) is the substitute of OSD and it is provided only when OSD can't be provided.

  SSD < ISD < OSD

  Generally, ISD $\simeq 2 \times$ SSD

Example - 2.2 Calculate SSD for $V = 50$ kmph for

(a) Two-way traffic in a two lane road.
(b) Two-way traffic in a single lane road.
Use, $f = 0.37$, Reaction time of driver, $t_r = 2.5''$

Solution:

Given: $V = 50$ kmph, $f = 0.37$, $t_r = 2.5''$

$$\text{SSD} = l_g + l_b = 0.278Vt_r + \frac{V^2}{254f}$$

$$= 0.278 \times 50 \times 2.5 + \frac{50^2}{254 \times 0.37}$$

$$= 61.4 \text{ m}$$

(i) For two way traffic in a two lane road, SSD = 61.4 m

(ii) For two way traffic in a single lane road, SSD = (2 × 61.4) = 122.8 m

Example - 2.3 Find minimum sight distance to avoid head on collision of two cars approaching at 90 kmph and 60 kmph.

Use, reaction time of driver, $t_r = 2.5''$
Coefficient of longitudinal friction = 0.7
Brake efficiency = 50%

Solution:

Given: $V_1 = 90$ km/h, $V_2 = 60$ km/h, $f = 0.7$; $n_b = 50\%$, $f' = 0.35$

$$\text{SSD}_1 = 0.278V_1t_r + \frac{V_1^2}{254f'}$$

$$= 0.278 \times 90 \times 2.5 + \frac{90^2}{254 \times 0.35} = 153.6 \text{ m}$$

$$\text{SSD}_2 = 0.278V_2t_r + \frac{V_2^2}{254f'}$$

$$= 0.278 \times 60 \times 2.5 + \frac{60^2}{254 \times 0.35} = 82.2 \text{ m}$$

∴ Stopping sight distance to avoid head on collision of the two approaching cars (SSD)

$$= SSD_1 + SSD_2$$
$$= 153.6 + 82.2$$
$$= 235.8 \text{ m}$$

Example - 2.4 Find SSD for a descending gradient of 2% for a design speed of 80 kmph. Coefficient of friction = 0.35. Take other data required as per IRC.

Solution:

Given: $V = 80$ kmph, $t_r = 2.5''$(as per IRC)

$$\text{Down gradient} = 2\%$$
$$f = 0.35$$
$$SSD = 0.278Vt_r + \frac{V^2}{254(f - n\%)}$$
$$= 0.278 \times 80 \times 2.5 + \frac{80^2}{254(0.35 - 0.02)} = 131.95 \text{ m}$$

Example - 2.5 Find head light sight distance and intermediate sight distance for a design speed of 65 kmph.

Use, $f = 0.35$, $t_r = 2.5$ sec.

Solution:

$$\text{Design speed, } V = 65 \text{ kmph,}$$
$$t_r = 2.5''$$
$$f = 0.36$$
$$SSD = 0.278Vt_r + \frac{V^2}{254f}$$
$$= 0.278 \times 65 \times 2.5 + \frac{65^2}{254 \times 0.36} = 91.38 \text{ m}$$

∴ Head light sight distance (HSD) = SSD = 91.38 m

Intermediate sight distance (ISD) = 2 × SSD = 2 × 91.38

= 182.76 m

2.5 Horizontal Alignment Details

Design elements:

- Radius of circular curve.
- Design of super-elevation
- Extra widening at horizontal curves
- Design of transition curve
- Set back distance

$$N = \left|\frac{1}{20} - \frac{1}{30}\right| = 0.083$$

Now length of valley curve

$$L_v = 2\left[\frac{NV^3}{C}\right]^{1/2} = 2\left[\frac{0.083\times(22.22)^3}{0.61}\right]^{1/2} = 77.27 \text{ m}$$

Student's Assignments

Q.1 The centrifugal force one car moving on a horizontal circular curve is proportional

(a) $\frac{WV^2}{gR}$ (b) $\frac{WV}{gR}$

(c) $\frac{WV^2}{gR^2}$ (d) $\frac{WV}{gR^2}$

Q.2 Camber in the road is provided for:

(a) Coutneracting the centrifugal force.
(b) Effective drainage
(c) Having proper sight distance
(d) Avoiding overturning

Q.3 The shift of the transition curve of radius 300 m and length 48 m is_______.

(a) 0.32 m (b) 0.42 m
(c) 0.52 m (d) 0.62 m

Q.4 In highway construction on superelevated curves, the rolling shall proceed from

(a) sides towards the centre.
(b) center towards the side.
(c) lower edge towards the upper edge.
(d) upper edge towards the lower edge

Q.5 The ruling minimum radius of the curve for ruling design speed, V(m/sec), coefficient of friction, f acceleration due to gravity. g (m/sec^2) and superelevation e is given by:

(a) $\frac{V^2}{(e-f)g}$ (b) $\frac{V^2}{(f-e)g}$

(c) $\frac{V^2}{(e+f)g}$ (d) $\frac{V^2}{(e+f)2g}$

Q.6 The camber of hill roads in case of bituminous surfacing is adopted as_______.

(a) 2.0% (b) 2.5%
(c) 3.0% (d) 3.5%

Q.7 In plains the minimum length of transition curve is______.

(a) $\frac{V^2}{R}$ (b) $\frac{V^2}{1.5R}$

(c) $2.7\frac{V^2}{R}$ (d) $\frac{V^2}{24R}$

Q.8 The stopping sight distance depends upon

(a) total reaction time of the driver
(b) speed of the vehicle
(c) efficiency of brakes
(d) All of the above

Q.9 Right of way is the summation of the width of______.

(a) Carriageway and shoulder
(b) Carriageway shoulder and road margins
(c) Carriageway and road margins
(d) Road margins and shoulder

Q.10 Gradient one highway is 1 in 20. After grade compensation the grade to be provided should not be less than 4% calculate the grade compensation.

(a) 0.38% (b) 1.15%
(c) 4.63% (d) 5%

Q.11 Calcaulate the design rate of superelevation (%) one highway in plain terrian, if design speed of the highway is 80 kmph and radius of the curve is 400 m

(a) 7 (b) 7.11
(c) 8.2 (d) 12.6

Q.12 The ruling design speed one curve is 100 km/h and the superelevation on the curve is 7%. Calculate the ruling design radius (m) of the curve. Take coefficient of the lateral friction as 0.15
(a) 129 (b) 189
(c) 358 (d) 1668

Q.13 Which of the following are correct values for coefficient lateral and longitudinal friction as per IRC?
(a) 0.10, 0.15 (b) 0.15, 0.35
(c) 0.30, 0.10 (d) 0.35, 0.15

Q.14 The intermediate sight distance is equal to_____.
(a) overtaking sight distance
(b) stopping sight distance
(c) twice of stopping sight distance
(d) None of these

Q.15 Calculate the safe stopping sight distance for a design speed of 60 km/h for two way traffic on single lane road. The reaction time of driver is 2.5.
(a) 82.21 (b) 136.23
(c) 164.42 (d) 674.24

Q.16 Calculate the safe stopping sight distance for the descending gradient of 3% for a design speed of 80 km/h. Take coefficient of friction as 0.35 and total reaction time as 2 seconds.
(a) 110.82 m (b) 123.26 m
(c) 1018.41 m (d) 1092 m

Q.17 Pick up the incorrect statement from the following:
The width of right of way is decided to accomodates
(a) formation width (b) side slopes
(c) horizontal curve (d) vertical curve

Q.18 Which of the following statement is correct for cross slope of the shoulder?
(a) it is 1% flatter than the cross slope of pavement.
(b) Its minimum value is 2%.
(c) It is 0.5% steeper than the cross slope of the pavement.
(d) Its value is equal to cross slope of pavement.

Q.19 For water bound macadam roads in localities of heavy rainfall, the recommended value of camber is______.
(a) 1 in 30 (b) 1 in 33
(c) 1 in 48 (d) 1 in 60

Q.20 The equilibrium superelevation required to counteract the centrifugal force fully is given by
(a) $\dfrac{V^2}{27.5R}$ (b) $\dfrac{V^2}{75R}$
(c) $\dfrac{(0.75V)^2}{127R}$ (d) $\dfrac{V^2}{127R}$

Q.21 The attainment of superelevation by rotation of pavement about the inner edge of the pavement
(a) is preferable in steep terrain.
(b) results in balancing the earthwork.
(c) avoids the drainage problem in flat terrain.
(d) does not change the vertical alignment of road.

Q.22 The maximum width of vehicle as recommended by IRC is______.
(a) 1.85 m (b) 2.44 m
(c) 3.81 m (d) 4.72 m

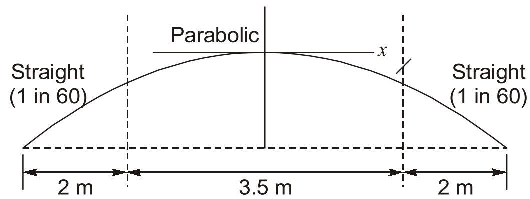
Q.23 The off-tracking of a vehicle having a wheel base of 6.0 and negotiating a curved path of mean radius 25 m is
(a) 0.82 m (b) 0.72 m
(c) 0.65 m (d) 1.44 m

Q.24 The important factor considered in the design of summit curves on highway is_______.
(a) comfort to passenger
(b) sight distance
(c) superelevation
(d) impact factor

Q.25 If an ascending gradient of 1 in 50 meets another ascending gradient of 1 in 30 then the deviation angle is ______.
(a) $\dfrac{1}{50}$ (b) $\dfrac{1}{75}$
(c) $\dfrac{1}{30}$ (d) $\dfrac{8}{150}$

Q.26 Width of carriageway for a single lane is recommended as______.
(a) 7.5 m (b) 7.0 m
(c) 3.7 m (d) 5.5 m

Q.27 A road camber given in the following figure



For designing this camber the equation to be used is______.
(a) $y=\frac{x^2}{60}$ (b) $y=\frac{x^2}{120}$
(c) $y=\frac{x^2}{210}$ (d) $y=\frac{x^2}{225}$

Q.28 The compensated gradient provided at the curve of radius 60 m with a ruling gradient of 6 percent is______
(a) 5.25% (b) 4.75%
(c) 4.5% (d) 3.75%

Q.29 If N is the algebraic difference of grades, S is the headlight sight distance (in meters), then the transmission length of a valley curve should be equal to
(a) $\frac{NS^2}{6}$ (b) $\frac{NS^2}{9.6}$
(c) $\frac{NS^2}{4}$ (d) $\frac{NS^2}{10}$

Q.30 For the load on inner and outer wheels to be equal for a vehicle moving at a speed of 50 kmph about a horizontal circular curve of radius 100 m the superelevation will be_____
(a) $\frac{25}{127}$ (b) $\frac{25}{225}$
(c) $\frac{25}{125}$ (d) $\frac{25}{227}$

Q.31 The rate of change of radial acceleration as per IRC recommendation for computing length of transition curve for a vehicle with design speed V (km/h) is given by
(a) $\frac{85}{75+V}$ m/ sec^3 (b) $\frac{65}{70+V}$ m/ sec^3
(c) $\frac{80}{75+V}$ m/ sec^3 (d) $\frac{72}{65+V}$ m/ sec^3

Q.32 The design speed of a highway is 80 kmph. Assuming other data as per IRC recommendations, which one of the following is the approximate leg distance?
(a) 55.5 m (b) 66.7 m
(c) 61.2 m (d) 44.5 m

Q.33 Roads provided to give access to properties along an important highway with controlled access as expressway of freeway are______.
(a) drive ways (b) access loads
(c) parking lanes (d) frontage roads

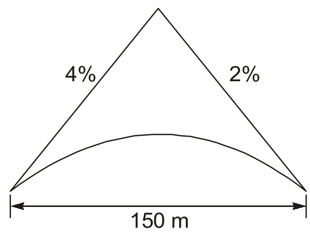
Q.34 Which one of the following is associated with 'limiting gradient' on highways
(a) Requirement of maximum tractive force for a short distance.
(b) Requirement of minimum tractive force for a short distance.
(c) Efficient drainage condition
(d) Alignment design in general.

Q.35 A valley curve is formed by a descending gradient of $\frac{1}{20}$ meets with an ascending gradient of $\frac{1}{30}$, design speed 80 kmph, allowable rate of change of centrifugal acceleration is 0.6 m/sec^3 length of valley curve for comforts is _____.
(a) 38.64 m (b) 77.28 m
(c) 42 m (d) 84 m

Q.36 A rising gradient of 1 in 50 meets a falling gradient of 1 in 100. The length of vertical curve if the rate of change of gradient is 1% per 100 m length is______.
(a) 100 m (b) 200 m
(c) 300 m (d) 600 m

Q.37 Set back distance
(a) to compensate for visibility.
(b) provided on hair pin bends only.
(c) essentially required on steep slopes.
(d) a part of transition curve.

Q.38 A parabolic curve is used to connect a upgrade 4% with a 2% downgrade as shown in figure. The highest point on the summit is at a distance of (measured horizontally from the first tangent)



(a) 50 m (b) 60 m
(c) 75 m (d) 100 m

Q.39 The extra widening required for a two-lane national highway at a horizontal curve of 300 m radius, considering a wheel base of 8 m and a design speed of 100 kmph is
(a) 0.42 m (b) 0.62 m
(c) 0.82 m (d) 0.92 m

Q.40 The centrifugal ratio for a vehicle is 0.25, width of vehicle is 2.4 m, height of vehicle to its CG is 4.2 m, lateral friction is 0.15 assuming no superelevation
(a) lateral skidding occurs first
(b) overturning occurs first
(c) Neither lateral skid nor overturning
(d) Both simultaneously

Q.41 The design speed of a highway is 80 km/hr and the radius of circular curve is 150 m in plain topography. Which one of the following is the minimum length of transition curve?
(a) 174 m (b) 85 m
(c) 140 m (d) 120 m

Q.42 A rising gradient of 1 in 50 meets a falling gradient of 1 in 30. Which one of the following is the length of vertical curve if the stopping sight distance is 120 m?
(a) 174 m (b) 158 m
(c) 140 m (d) 120 m

Q.43 Full amount of superelevation on a horizontal curve is provided at the
(a) beginning of the transition curve
(b) centre of the circular curve
(c) end of the transition curve
(d) centre of the transition curve

Q.44 A road is having a horizontal curve of 400 m radius on which a super elevation of 0.07 is provided. The coefficient of lateral friction coefficient mobilized on the curve when a vehicle is travelling at 100 km/h is:
(a) 0.07 (b) 0.13
(c) 0.15 (d) 0.4

Q.45 At a horizontal curve portion of a 4-lane undivided carriageway, a transition curve is to be introduced to attain required superelevation. The design speed is 60 kmph and radius of the curve is 245 m. Assume length of wheel base of a longest wheel is 6 m, superelevation rate as 5% and rate of introduction of this superelevation as 1 in 150. The length of the transition curve (m) required, if the pavement is rotated about inner edge is:
(a) 81.4 (b) 85.0
(c) 91.5 (d) 110.2

ANSWER KEY — STUDENT'S ASSIGNMENTS

1. (a)	**2.** (b)	**3.** (a)	**4.** (c)	**5.** (c)
6. (b)	**7.** (c)	**8.** (d)	**9.** (b)	**10.** (a)
11. (a)	**12.** (c)	**13.** (b)	**14.** (c)	**15.** (c)
16. (b)	**17.** (d)	**18.** (c)	**19.** (b)	**20.** (d)
21. (c)	**22.** (b)	**23.** (b)	**24.** (b)	**25.** (b)
26. (c)	**27.** (d)	**28.** (b)	**29.** (a)	**30.** (a)
31. (c)	**32.** (a)	**33.** (d)	**34.** (a)	**35.** (b)
36. (c)	**37.** (a)	**38.** (d)	**39.** (c)	**40.** (a)
41. (c)	**42.** (a)	**43.** (a)	**44.** (b)	**45.** (d)

HINTS & SOLUTIONS — STUDENT'S ASSIGNMENTS

3. (a)

$R = 300$ m, $L_T = 4$ m

$$S = \frac{L_T^2}{24R} = \frac{(48)^2}{24 \times 300} = 0.32 \text{ m}$$

10. (a)

$R = 200$ m

$$GC = \left(\frac{30+R}{R}\right)\% \ngtr \left(\frac{75}{R}\right)\%$$

$$= \left(\frac{30+200}{200}\right)\% \not> \left(\frac{75}{200}\right)\%$$

$$= 1.15\% \not> 0.375\%$$

$$\therefore \quad GC = 0.375\%$$

11. (a)

$$V = 80 \text{ kmph}, \quad R = 400 \text{ m}$$

$$e = \frac{V^2}{225R} = \frac{(80)^2}{225 \times 400}$$

$$= 0.0711 > 0.07$$

$$\therefore \quad f = \frac{V^2}{127R} - e = \frac{(80)^2}{127 \times 400} - 0.07$$

$$= 0.055 < 0.15 \text{ (OK)}$$

Provide $(e = 0.07) \simeq 7\%$

12. (c)

Given: $V = 100$ km/h, $e = 7\%$, $f = 0.15$

Ruling design radius

$$R = \frac{V^2}{127(e+f)} = \frac{(100)^2}{127(0.07+0.15)}$$

$$= 357.90 \simeq 358 \text{ m}$$

15. (c)

Given: $V = 60$ km/h; $t_r = 2.5''$

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

$$f = 0.36$$

$$= 0.278 \times 60 \times 2.5 + \frac{(60)^2}{254 \times 0.36} = 81.07 \text{ m}$$

SSD one single lane 2-way traffic = 2 × 81.07

= 162.14 m

16. (b)

Given: Downward gradient = 3%

Design speed (V) = 80 km/h

$$f = 0.35, \; t_r = 2''$$

$$\text{SSD} = 0.278Vt_r + \frac{V^2}{254(f - n\%)}$$

$$= 0.278 \times 80 \times 2 + \frac{(80)^2}{254(0.35 - 0.03)} = 123.22 \text{ m}$$

23. (b)

$$l = 6 \text{ m}$$

$$R = 25 \text{ m}$$

$$\text{Offtracking} = \frac{l^2}{2R} = \frac{36}{2 \times 25} = 0.72 \text{ m}$$

25. (b)

$$N = |n_1 - n_2| = \left|\frac{1}{50} - \frac{1}{30}\right|$$

$$= \left|\frac{3-5}{150}\right| = \left|-\frac{2}{150}\right| = \frac{1}{75}$$

27. (d)

$$y = \frac{2x^2}{nW} = \frac{2x^2}{60 \times 7.5} = \frac{x^2}{225}$$

28. (b)

$$R = 60 \text{ m}$$

$$\text{GC} = \frac{30+R}{R} \not> \frac{75}{R}\%$$

$$= \frac{30+60}{60} \not> \frac{75}{60}$$

$$= 1.5\% \not> 1.25\%$$

$$\therefore \quad \text{GC} = 1.25\%$$

∴ Compensated gradient = Ruling gradient – GC

= 6% – 1.25% = 4.75%

30. (a)

For load on outer and inner wheel equal,

$$\Rightarrow \quad f = 0$$

$$\therefore \quad e = \frac{V^2}{127R} = \frac{(50)^2}{127 \times 100} = \frac{25}{127}$$

32. (a)

$$l_g = 0.278\, Vt_r = 0.278 \times 80 \times 28 = 55.6 \text{ m}$$

35. (b)

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

$$N = \left|\left(-\frac{1}{20} - \frac{1}{30}\right)\right| = \frac{1}{2}$$

$$V = 80 \text{ km/h} = 80 \times \frac{5}{18} = 22.22 \text{ m/sec}$$

$$L_V = 2\left(\frac{1/12 \times (22.22)^3}{0.61}\right)^{1/2} = 77.42 \text{ m}$$