Pb-(42) W.B. Utility per unit length

lecture-② 16|04|19

For P = $\frac{100\times0.5+(150\times1)+(40\times2)+20(4)+3\times8+(150\times1)+20(5)}{500}$

= 1.253

For Q = 1.61

For R = 1.857

For S = 1.922

$\boxed{S > R > Q > P}$

Chapter-②
Geometric Design

[IRC 73-1980]

A = Cross-sectional element

B = Sight distance

C = Horizontal alignment

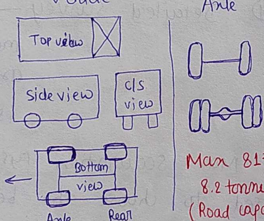
D = Vertical alignment

speed → km/h

length → m

time → sec

Vehicle



Max 8170 kg

8.2 tonne

(Road capacity)

(A) CROSS SECTIONAL ELEMENTS →

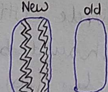
- Pavement characteristic

(a) Friction

Longitudinal friction ⇒

- this friction help or support movement of vehicle.
- this friction depend upon speed
- For more speed friction generated is less ($V \propto \frac{1}{F}$)
- As per IRC [$f_{Long.} = 0.35 - 0.40$] [Area of contact ∝ coeff. of friction]

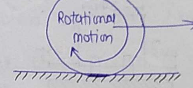
**Note On dry pavement old tyre generate max coefficient of friction than new tyre due to large area of contact, whereas on wet pavement condn is reverse because water act as a lubricating agent.



lateral friction → this friction comes only when there is a lateral force on vehicle.

As per IRC [$f_{lateral} = 0.15$]

[B] SKID AND SLIP



1 rotation = $2\pi R$

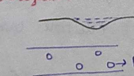
Uniform movement

Skid (during brake)	SLIP (during acc)
R.M < T.H	R.M > T.H
Pure skid	Pure slip
R.M = 0	R.M ≠ 0
T.H ≠ 0	T.H = 0

[C] Unevenness Index

It is define as cumulative undulation (sudden rise and sudden fall) per unit road length. It is measured by bump integrator (developed by CRRI)

Corrugation



Note the similar factor in other country (IRI) (International Roughness index)

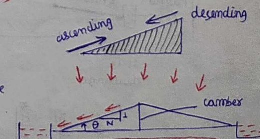
$\boxed{B.I = 630[IRI]^{1.12}}$ **

B.I (mm/km)	Type of Road
< 1500	Good
1500-2500	Satisfactory
2500-3200	Bad (Repair)
> 3200	Uncomfortable (Reconstruct)

2] CAMBER (gradient → longitudinal slope)

(elevation at the center of pavement)

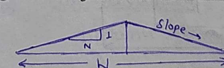
(cross-slope provided to road by elevating center line in order to allow the drainage from surface to drainage system)



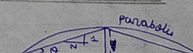
(camber = slope = tanθ) ***

Type of camber

(a) Straight line camber -



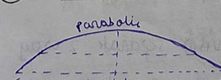
(b) Parabolic camber



Eqn of Parabolic camber

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

(c) Combination



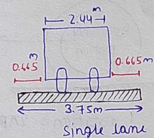
Camber as per IRC

	High rainfall	light rainfall
CC Pavement	2%	1.7%
High bitumen type		
thin bituminous type	2.5%	2%
WBM/Gravel Road	3%	2.5%
Earthen Road	4%	3%

Note: Parabolic camber is prefer → (When the road design for High speed due to flat center portion)

$\boxed{\text{Gradient} = 2 \times \text{camber}}$

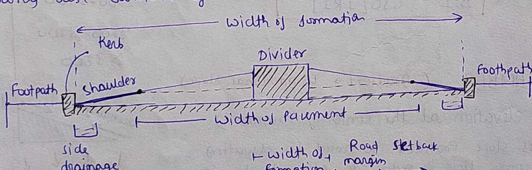
③ Width of Pavement :

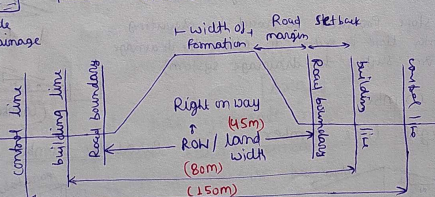


		[Lane width]
1.	Single lane	3.75 m
2.	two lane without Kerb	7 m
3.	two lane with Kerb	7.5 m
4.	Intermediate lane	5.5 m
5.	Multiple lane	3.5 m per lane

④ Shoulder : (An extra width is provided adjacent to edge of pavement is called shoulder)

- It is provided for emergency point of view like medical emergency break down of vehicle etc. as per IRC.
- Width of shoulder should be mini 2.5 m
- Camber of shoulder should be 0.5% stepper than camber of road.
- In any case camber of shoulder should not be less than 3 %.





⑤ KERB : Element provided as a separator b/w pavement and footpath. It provide lateral support to the pavement.

⑥ DIVISOR / Median / divisional island : Divisor separate 2 way traffic due to which head of collision can be avoided.

- It also reduce glaring due to head light of vehicle coming from opposite dirn
- As per IRC (mini width of divisor in highway is 5 m [When space is restricted then minimum width is 3 m]

Typical cross-section of road over embankment

[B] Sight distance

1. OSD
2. SSD
3. ISD

(43) P.b. camber of road = 2% = 1/50

N = 50
W = 7

$y = \frac{2x^2}{NW} = \frac{2 \times x^2}{50 \times 7} = \frac{x^2}{175}$

44 (Pb) camber shoulder of CC = 2%

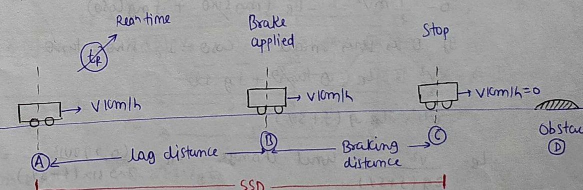
shoulder ⇒ 2 + 0.5 = 2.5%

Should ≮ 3%

3% Ans

① SSD (absolute mini sight distance / Non passing sight distance or stoping sight distance)

- It is min. sight distance available on a Highway at any spot having sufficient length to enamel the driver to stop the vehicle travelling without collision with any obstaction.



② Lag distance

Distance travelled by vehicle during reach time

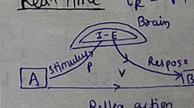
$L_L = V_{km/h} \times t_{R\,sec} = \left(\frac{1000}{3600}\right)_{m/s} t_{R\,sec} = 0.277 V t_R$

As per IRC

$\boxed{L_L = 0.278 V t_R}$

V → km/h
t_R → sec
L_L → m

Reach time $t_R = P + I + E + V$



	t_R (sec)
SSD →	2.5 sec
OSD →	2.0 sec
min space headway →	0.7 sec

(P) Perception → time lost in perceiving an object

(I) intellection → time lost in understanding the situation

(E) Emotion → time lost due to anger and fear

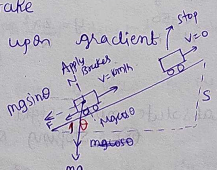
(V) Volition → time lost in final action

[B] Braking distance (L_B) Distance travelled by vehicle after application of brake

Main**

① braking distance depends upon gradient

case-① Ascending gradient



Gradient = $\tan\theta = \frac{S}{100} = S\% = 0.015$

total resistive force $= mg\sin\theta + F$

$= Mg\sin\theta + f \cancel{N}^{mg\cos\theta} = (Mg\sin\theta + f mg\cos\theta)$

$\Delta KE = W.D$

$0 - \frac{1}{2}mv^2 = -L_B\,(mg\sin\theta + f mg\cos\theta)$

If θ is very small, $\cos\theta = 1$, $\sin\theta = \tan\theta$

$\Rightarrow \frac{V^2}{2} = L_B\,(g\tan\theta + f.g.1)$

$\frac{V^2}{2} = L_B.g\,(f + S\%)$

$L_B = \frac{V^2}{2g\,(f+S\%)}$ unit change $L_B = \frac{(0.278V)^2}{2\times9.81\times(f+S\%)} = \frac{V^2}{253.86(f+S\%)}$

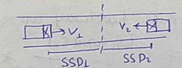
As per IRC $\boxed{L_B = \frac{V^2}{254(f+S\%)}}$

case ② Descending gradient $\boxed{L_B = \frac{V^2}{254(f-S\%)}}$

case ③ Flat gradient $S=0$ $\boxed{L_B = \frac{V^2}{254f}}$

$SSD = L_L + L_B = \boxed{0.278Vt_R + \frac{V^2}{254(f\pm S\%)}}$

Note: Single lane road 2 way traffic



$\boxed{SD = SSD_1 + SSD_2}$

Note: $\boxed{f_{obtain} = \eta_B f_{max}}$ If braking efficiency (η_B) and maxi friction is f_{max} then $f_{obtained}$ will be

Pb-④⑤ $SSD = SSD_1 + SSD_2$

$SSD = 0.278\times(60)(2.5) + \frac{(60)^2}{254(0.35+0.04)} + 0.278\times(60)(2.5) + \frac{(60)^2}{254(0.35-0.04)}$

$= 78.04 + 87.42 = 165.46\,m$

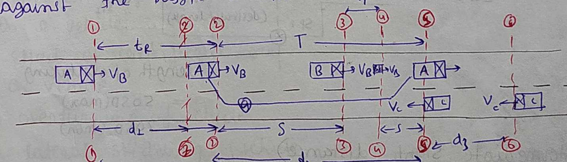
Pb-

$L_2 - L_1 = 9$

$\frac{V^2}{254(f-S)} - \frac{V^2}{254(f+S)} = 9$ [2.8 %] Ans

② OSD (overtaking sight distance) → (Passing sight distance)

mini sight distance open to the vision of a driver intending to overtake slow vehicle ahead safely against the traffic in opposite dirn.



distance (d_1) $= 0.278V_Bt_R$

distance (d_2) $= (2S+B) = V_BT + \frac{1}{2}aT^2$

$2S + \cancel{V_BT} = \cancel{V_BT} + \frac{1}{2}aT^2$

$\boxed{T = \sqrt{\frac{4S}{a}}}$ $\boxed{S = 0.2V_B + 6}$

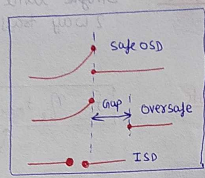
overtaking time

$d_2 = 0.278V_BT + 2S$

$\boxed{d_2 = 0.278V_BT + \frac{1}{2}aT^2}$ $\boxed{d_3 = 0.278V_CT}$

Note! If space headway are different (S_1 and S_2)

then $T = \sqrt{\dfrac{2(S_1+S_2)}{a}}$ *** आ सकता है।



$OSD = d_1 + d_2 + d_3$

***

$$\boxed{OSD = 0.278 V_B t_R + \left(0.278 V_B T + \tfrac{1}{2} a T^2\right) + (0.278 \times V_C T)}$$

Some Imp Point

1. For 1 way traffic $OSD = D_1 + D_2$
2. If data not given then speed of vehicle A and vehicle C can be considered same ($V_A = V_C$)
3. For design if design speed is V km/h

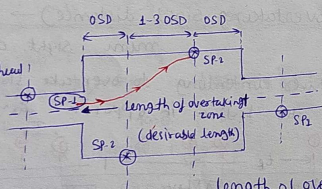
Design speed = V kmph $V_A = V$ kmph, $V_B = (V-16)$ kmph, $V_C = V$ kmph

*** 4. IRC has not consider effect of gradient for OSD calculation

Overtaking zone

SP-1 overtaking zone ahead!

SP-2 End of overtaking zone



length of overtaking = 5 OSD (max)
= 3 OSD (min)

ISD (Intermediate Sight distance) is the substitute of OSD & it is provided only when OSD can't be provided

$\boxed{SSD < ISD < OSD}$ Generally $\boxed{ISD \approx 2\,SSD}$

- Height of driver eye (H) for SSD = 1.2 m
  Height of obstruction (h) for SSD = 0.15 m
- Height of driver eye (H) for OSD = 1.2 m
  height of obstruction (h) for OSD = 1.2 m

Pb-(47) $V_A = 85$ km/h, $V_B = 60$ km/h

$OSD = (0.278 V_B t_R + 0.278 V_B T + \frac{1}{2} a T^2 + 0.278 V_C T)$

$= 0.278 \times (60)(2) + (0.278 \times 60 \times 8.84) + \frac{1}{2}(0.92 \times 8.84^2) + (0.278 \times 85 \times 8.84)$

$= 425.64$ m

b] Desirable length of overtaking zone

$= 5 \times OSD = 5 \times (425.64) = \boxed{2128.2\text{ m}}$ Ans

(N) Horizontal Alignment

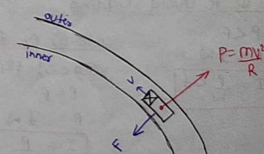
Terrain classification

	Cross slope
Plain terrain	0-10%
Rolling terrain	10-25%
mountaneous terrain	25-60%
Steep terrain	> 60%

Design speed **

	Plain terrain		Rolling terrain	
	Ruling	min	Rule	min
Express highway	120	100	100	80
NH & SH	100	80	80	65
MDR	80	65	65	50

- **Horizontal curve** When a vehicle negociate a horizontal curve then centrifugal force act at outward dirn which is laterally on a vehicle
- Effect of centrifugal force on vehicle



(A) overturning of vehicle
(B) lateral skidding of vehicle

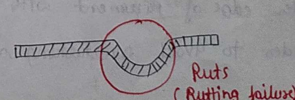
(A) **O.T.V** (overturning of vehicle)

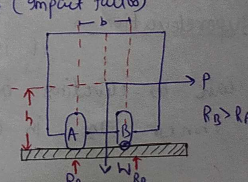
$P =$ centrifugal force $= \dfrac{mv^2}{R}$

$F =$ friction $= f.mg$

$W =$ Weight of vehicle $= mg$

$I = \left(\dfrac{P}{W}\right) =$ centrifugal Ratio (Impact factor)





M_o = overturning moment $= P \times h$

M_R = Resistive moment $= W \times \frac{b}{2}$

case-① To avoid overturning $M_o < M_R$

$P \times h < W \times \frac{b}{2}$

$$\boxed{I = \frac{P}{W} < \frac{b}{2h}}$$

case-② on the verge of overturning

$M_o = M_R$

$P \times h = W \times \frac{b}{2}$

$$\boxed{I = \frac{P}{W} = \frac{b}{2h}}$$

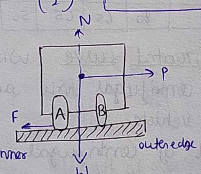
case-③ unsafe case $M_o > M_R$

$P \times h > W \times \left(\frac{b}{2}\right)$

$$\boxed{I = \frac{P}{W} > \frac{b}{2h}}$$

Skidding force = P

Resistive force = $F = f.W$



case-① to avoid skidding

$P < F$

$P < f.W$

$$\boxed{I = \frac{P}{W} < f}$$

case-② on the verge of skidding

$P = F$

$P = f.W$

$$\boxed{I = \frac{P}{W} = f}$$

case-③ unsafe case

$P > F$

$P > f.W$

$$\boxed{I = \frac{P}{W} > f}$$

Imp**

Note To avoid both overturning and skidding

$$I < \min\left\{\frac{b}{2h},\ f\right\}$$

- Superelevation → it is cross slope provided to horizontal curve by elevating outer edge of pavement with respect to inner edge. in order to avoid overturning and skidding

due to effect of centrifugal force

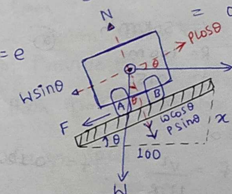
Type ①
Pb - ㉓

$e = 7\%$, $f = 0.15$, $I = \left(\frac{e+f}{1-ef}\right) = \left(\frac{0.07+0.15}{1-0.07\times0.15}\right) = 0.22$

$V = 65$, $R = 1400$, $I = \frac{P}{W} = \frac{\frac{Mv^2}{R}}{mg} = \frac{V^2}{Rg} = \frac{(0.278\times65)^2}{1400\times9.81}$

$= 0.023$ Ans

Superelevation $= \tan\theta = \frac{x}{100} = x\% = e$



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

force balance along inclined

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

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

$P(1 - f\,\cancel{\tan\theta}^{\,e}) = W(f + \cancel{\tan\theta}^{\,e})$

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

centrifugal ratio

$\frac{\frac{mv^2}{R}}{mg} = \left(\frac{e+f}{1-ef}\right)$; $\frac{V^2}{Rg} = \frac{e+f}{1-ef}$

As per IRC → $(ef <<< 1)$ (Only for Indian road)
(ef will include in track, superfast etc)

$\Rightarrow \frac{V^2}{Rg} = e+f$

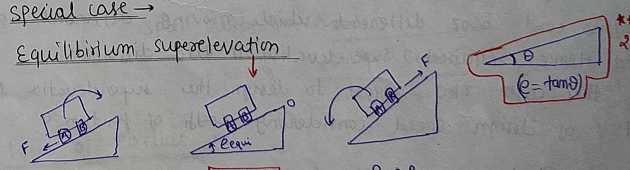
$e + f = \frac{(0.278V)^2}{9.81\times R} = \frac{V^2}{126.93R}$

As per IRC

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

Special case →

Equilibrium superelevation



$R_B > R_A$ $\boxed{R_A = R_B}$ $R_A > R_B$

Superelevation corresponding to which pressure under inner tyre and outer tyre will same is called equilibrium superelevation in this case friction=0

$f=0$ $\boxed{e_{equi} = \frac{V^2}{127R}}$ ***

Ques (48) (Pb) $V = 50$ km/h, $R = 100$ m, $f = 0.15$

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

$e+0.15 = \frac{(50)^2}{127(100)}$ $e = 0.0468$ $= 4.68\%$

(b) $e=0$

$\cancel{e}+f = \frac{V^2}{127R}$ $f = 0.1968$

(c) e_{eq}. $f=0$

$e_{eq} = \frac{V^2}{127R} = \frac{(50)^2}{127\times100} = 0.196$

Ques-(15) W.B $I = \frac{e+f}{1-ef} = \frac{V^2}{gR}$

$e = \tan\theta = \tan 33$
$V = 320$ km/h
$R = 335$ m

$I = \frac{\tan 33 + 0.15}{1-\tan 33 \times 0.15} = \frac{(0.278\times320)^2}{9.81\times335}$

$\boxed{f = 0.686}$

Superelevation as per IRC :-

(1) Max superelevation →

	e_{max}
urban Area	4%
Plain and Rolling terrain	7%
mountaneaus and steep terrain	10%

(2) Min superelevation

e_{min} = camber of road

$e_{min} \le e_{provided} \le e_{max}$

- **Design of superelevation** is a complex Problem under mix traffic cond^d bcoz different vehicle moving different speed and Hence required superelevation is also different. In this case IRC suggest to design the superelevation for 75% of design speed considering coeff. of friction '0'

Step (1) Design superelevation for

Step (1) Design superelevation for 75% of design speed considering $f=0$

$e+f = \frac{(0.75V)^2}{127R} = \frac{V^2}{225.7R}$

2018 ** $\boxed{e = \left(\frac{V^2}{225R}\right)}$ $\ngtr e_{max}$ (design speed)

if $e \le e_{max}$ ⇒ then Provide (e)

But if $e > e_{max}$ ⇒ then Provide $e = e_{max}$ and check (f)

Step (2). Check f with 100% of design speed

$f = \left(\frac{V^2}{127R} - e_{max}\right) \ngtr 0.15$

if $f \le 0.15$ Provide $e = e_{max}$ is safe

if $f > 0.15$ ⇒ then speed Restriction Read

Step (3) If $f > 0.15$ (then speed of restriction Read)

max allowable speed

$V_{max} = \sqrt{127R(e_{max}+0.15)}$

imp [mix traffic design $= \frac{V^2}{225R}$]

Q-(49) $R = 240$m, $V = 90$ km/h

$e = \frac{V^2}{225R} = \frac{(90)^2}{225(240)} = 0.15 \ngtr 0.07$

Provide $e = 0.07$ and check (f)

$f = \left(\frac{V^2}{127R} - e_{max}\right) = \left(\frac{90^2}{127\times240} - 0.07\right) = 0.195 \ngtr 0.15$

speed restriction read

$V_{max} = \sqrt{127R(e_{max}+0.15)}$

$= \sqrt{127\times240(0.07+0.15)}$ $= 81.89$ ≈ 80 km/h

Types of Radius :-

1] RMR (Ruling min Radius) $= \frac{V^2_{Ruling}}{127(e_{max}+0.15)}$

2] AMR

Absolute mini Radius

$$AMR = \frac{V_{min}^2}{127(e_{max} + 0.15)}$$

(2004)

Pb- 50 $\quad \frac{V^2}{225 \times camber} = \frac{(80)^2}{225 \times (0.03)}$

$\boxed{= 948.14 m}$

3] R_{BNSN} (Radius Beyond which no superelevation needed)

e_{min} = camber of Road

(It is radius corr. to which camber of road is converted into superelevation. It is design on the basis of 75% design speed considering coeffi. of friction 0)

$$\boxed{R_{BNSN} = \frac{V^2}{225 \times camber}}$$

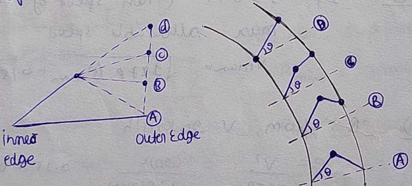
Attainment of superelevation.

Stage 1] Elimination of crown of camber [C → SE]

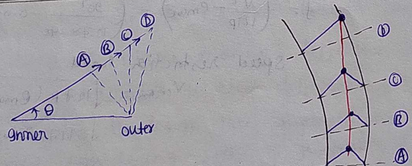
Stage-2] Rotation of Pavement [SE → Required superelevation]

1 Elimination of crown of camber →

[A] Elevation of outer edge about crown of camber:

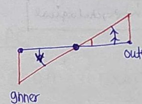


[B] Diagonal crown method:



Stage-2 [Rotation of Pavement]

Rotation about centre



Rotation about inner edge

→ centre lines remain same

→ Earthwork is balance

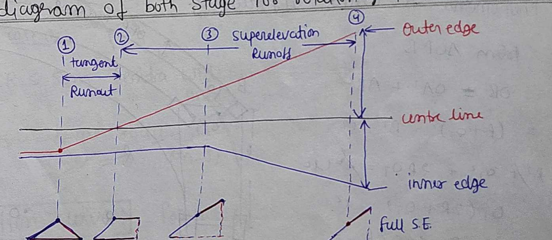
→ It may interfare drainage system

→ centre line elevated

→ Filling Reqd.

→ will nt interfare drainage system

combine diagram of both stage for rotation of paument about centre



1 Tangent Run out It is length of road needed to change outside lane cross-slope from normal cross slope to zero or vice-versa

2 Superelevation Runoff It is length of road needed to change outside lane cross slope from '0' to full superelevation or vice-versa