1 GEOMETRIC DESIGN

It deals with the visible elements of the Road.
various Geometric design components depends on

1) Types of Roads

A) Rural Roads

i) Expressway → speed upto 120 KMPH
ii) National Highway → joins various states
iii) State Highways → joins various Districts
iv) Major District Roads → joins Areas of population or production with Main highway
(v) Other District Roads → joins Rural Areas with Markets
vi) village Roads → joins various villages

NOTE IRC 73 deals with the Geometric Design of Rural highways

B) URBAN Roads

i) expressway → 120 KMPH (Devided Arterial)
ii) Arterial Roads → 80 KMPH
iii) Sub-Arterial Roads → 60 KMPH
iv) collector streets → 50 KMPH
v) local streets → 30 KMPH

2) Type of vehicle

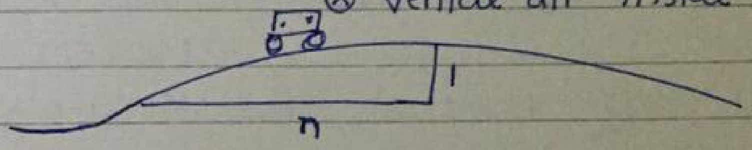
The vehicle for which the Road elements are designed are called design vehicle
Length, Height, Width of Designed vehicle are used as design parameter for the Roads
IRC:003

Width of vehicle → 2.5 m
Height of vehicle → 3.8 to 4.75 m → Height of Double Decker BUS.

3) Topography

It is classified on the basis of general country slop accross the Road alignment

It is expressed as 1 in n or x %
x % = x in 100



cross country slop	class
0 – 10 %	plain
10 – 25 %	Rolling
25 – 60 %	Mountaneous
> 60 %	steep

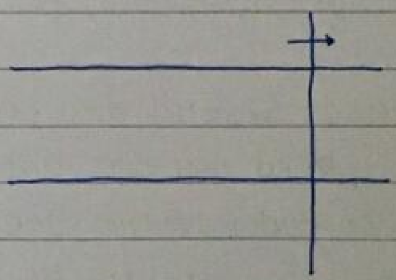
If cross slop of the country is large then large expenditure has to be made in Altering the Alignment for design speed to provide a larger Radius of curve to counter act against centrifugal force which causes skidding or overturning problems.

Hence when cross country slop is large the velocity should be restricted

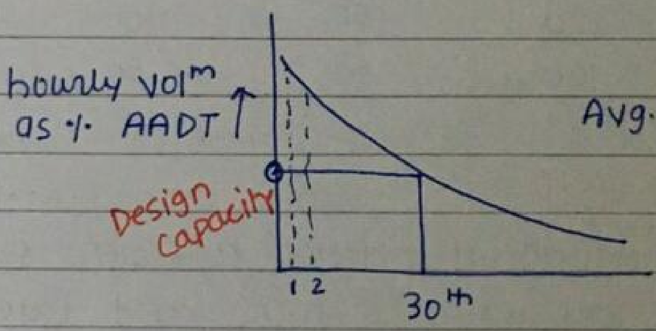
4) Traffic capacity:- It is the ability of Road to accomodate Max. Traffic volume. → at a perticular LOS.

Traffic volume is no. of vehicles crossing a point or section on the road in unit time.

capacity and volume are both expressed in veh / Hr.



Normally design capacity is taken as 30th highest hourly volume



AADT
⇓
Avg. Annual Daily traffic
⇓
$\frac{\text{Yearly Traffic}}{365}$

Generally 30th highest hourly volm for Indian conditions comes around 8-10% AADT

for ex. if AADT = 2000 veh/day the design capacity or 30th highes hourly volume will be around 160 - 200 veh / Hr

Depending upon traffic capacity width of Road is decided.

5) Design speed :- It is theortically decided as 98th percentile speed, That is the speed at or below which 98% of vehicles are Moving.

However from economical point of view IRC has Limited the design speed based on Topography

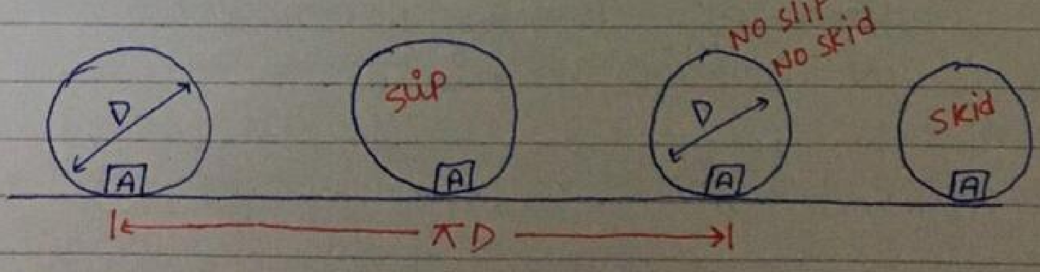
- Normally Ruling speed should be the Guiding criteria However Min. design speed can be adopted in localised sections where cost considerations does not permit Ruling speed.

	Plain Ruling	Plain Minimum	Rolling Ruling	Rolling Minimum
Express way	120	100	100	80 KM/H
NH/SH	100	80	80	65

6) surface charecteristics :-

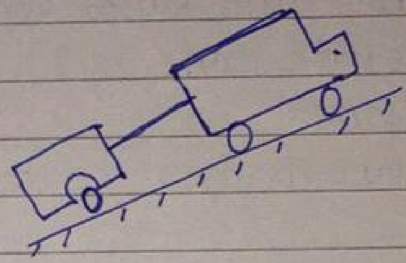
A) Friction :- Longitudnal friction cofficient as recommended by IRC → 0.35 - 0.4 and lateral or Transverse friction cofficient as recommended by IRC is 0.15

lack of friction causes slipping or skidding.



if one revolution of wheel leads to longitudnal Movement
less than πD → slipping
more than πD → skidding

B) Unevenness index :- This index is a cummulative Measure of vertical undulations per unit length of the road. It is Measured using Bump Integrator



Classification of Roads Based on unevenness index

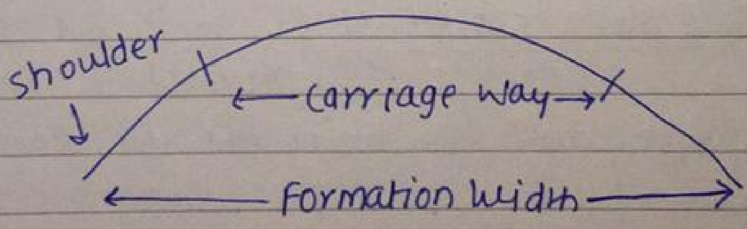
1) UI < 1500 mm/km → Good surface
2) UI upto 2500 mm/km (100 kmph speed) → Satisfactory surface
3) UI > 3200 mm/km (55 kmph speed) → unsatisfactory surface

Various Geometric Design components of Highway

1) cross-sectional Element
2) sight Distance
3) Horizontal alignment details
4) vertical alignment details
5) Intersection detail

① cross-sectional Elements:-

a) carraige Way :- It is the part of pavement designed to carry vehicles.



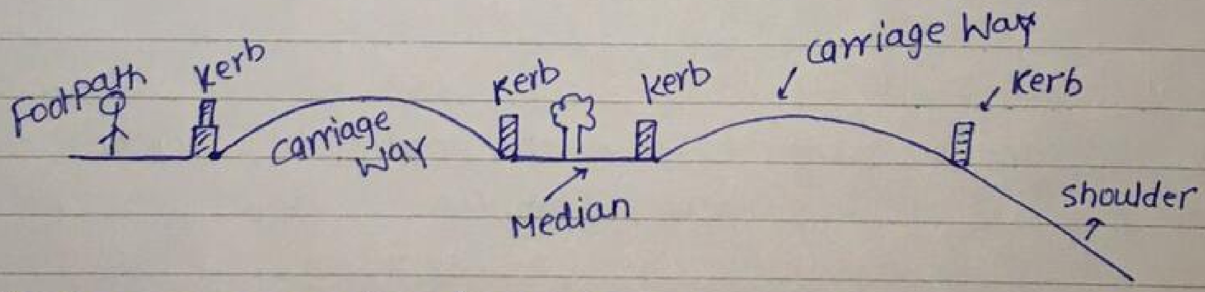
Type of Road	Carriage Way Width
single lane	3.75 m
Two lane with No kerb	7 m
Two lanes with Raised kerb	7.5 m
Intermediate Lane	5.5 m
Multi lane	3.5 m / Lane
Multi lane bridge	3.5 m / Lane + 0.5 m per carriage way

b) **shoulder :-** shoulders are provide to accomodate stopped vehicles and to provide lateral confinement to the pavement layers

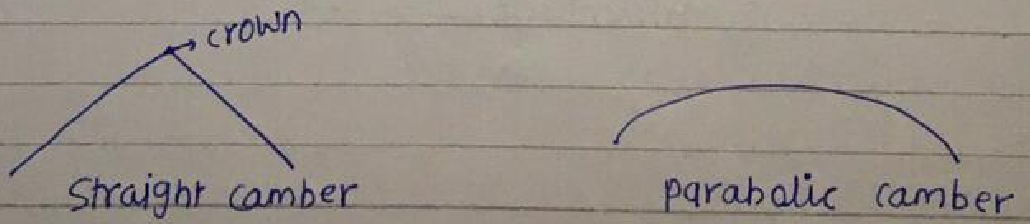
Desirable width of shoulder is 4.6 m with a Min. of 2.5 m For 2 lane Rural highway

NOTE → formation width for single lane / two lane NH section is 12 m as per IRC

c) **kerb :-** It indicates the boundary b/w pavement and shoulder or Median or footpath



d) **camber or cross-slope / cross fall :-** It is the slop provided to the road surface in transverse dir^n to drain off the Rain-water



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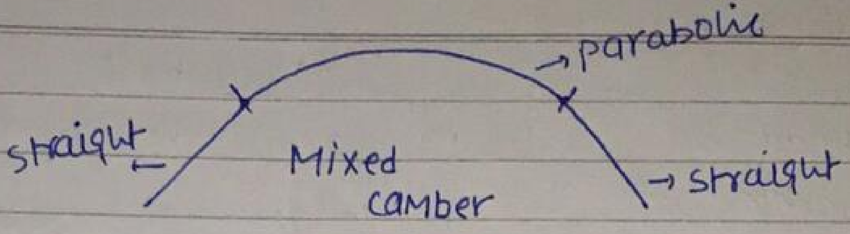
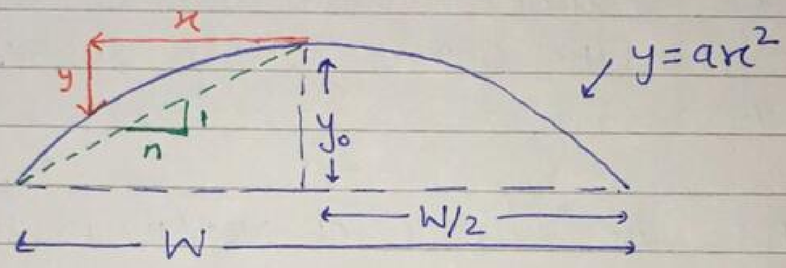


For slow moving traffic straight camber can be adopted but for High speed traffic where crown has to be crossed frequently during overtaking, parabolic camber is preferred.

Eq^n of parabolic camber



From similar Δ $\quad \frac{1}{n} = \frac{y_0}{W/2} \qquad y_0 = \frac{W}{2n}$ —(i)

at $x = W/2$, $y = y_0$

$$y_0 = a\left(\frac{W}{2}\right)^2 \quad \text{—(ii)}$$

From ① & ②

$$a\left(\frac{W}{2}\right)^2 = \frac{W}{2n}$$

$$a = \frac{2}{nW}$$

Hence Eq^n of parabola is $\boxed{y = \frac{2}{nW}x^2}$

In field camber is checked by camber boards / Templates

NOTE Bitumineous pavement → Parabolic camber
Rigid pavement → straight camber

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IRC Reccomandations for camber :-

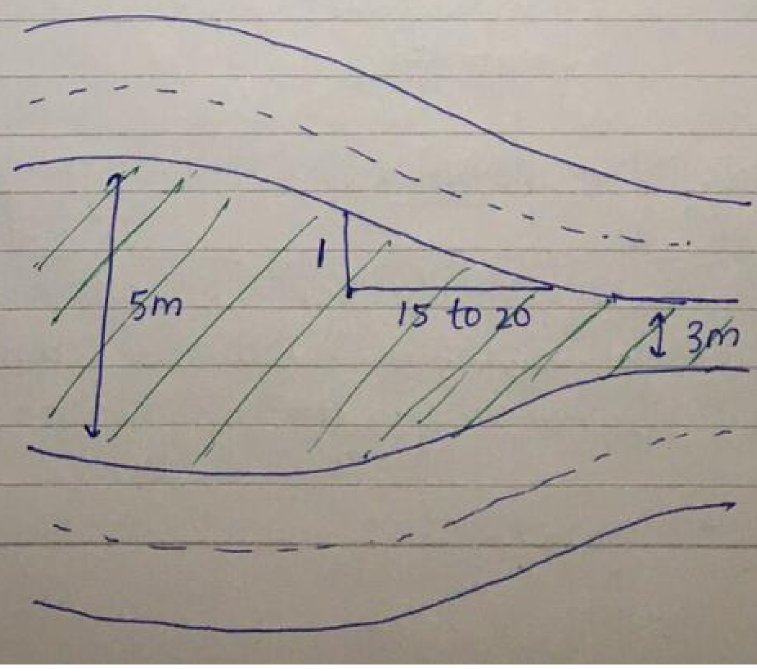
Type of Road	Rainfall Low (<100 cm)	Rainfall Heavy (>100 cm)
Cement concrete or High type Bituminous pavement	1.7 % ~~2%~~	2 %
WBM / Gravel	2.5 %	3 %
Thin Bituminous pavement	2 %	2.5 %
Earthen	3 %	4 %

NOTE slope of shoulder should at least be 0.5 % steeper than the slop of camber subjected to a Min. of 3 %

e) **Median :-** The purpose of Median is to prevent head on collission of vehicles. It is also known as traffic seprator

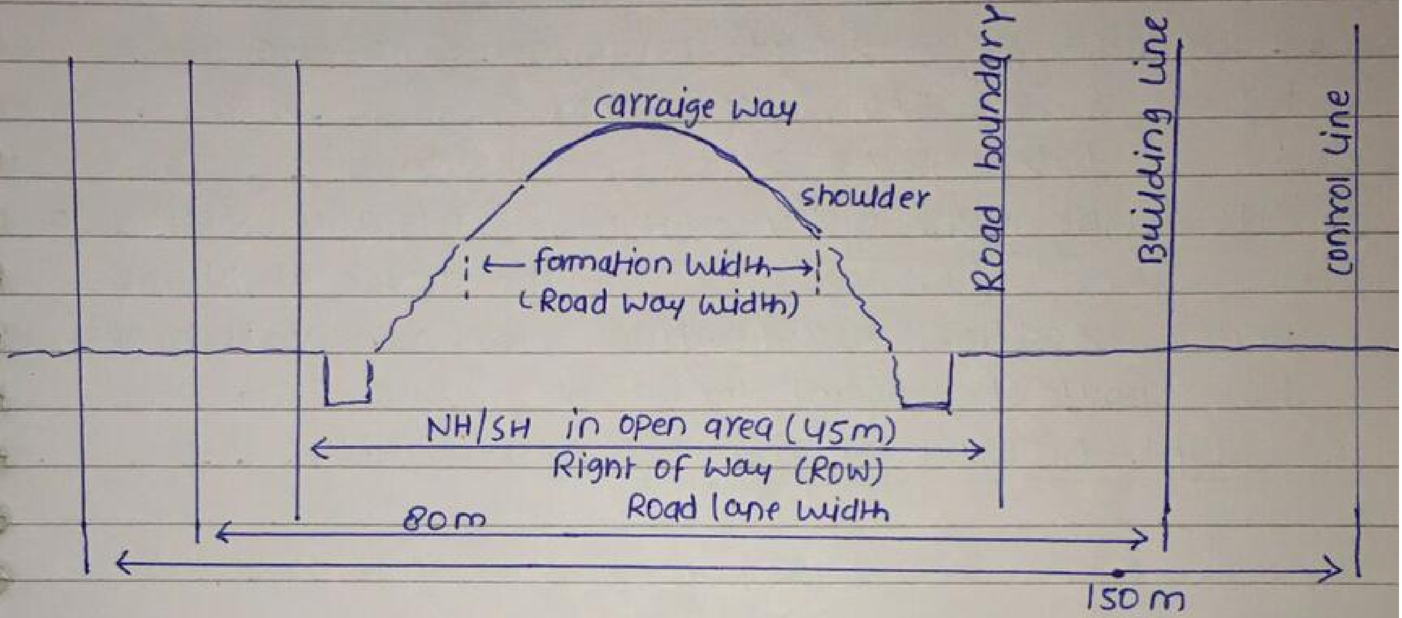
Min. desirable width for Rural highways is 5 m and if lane width is restricted then the value Maybe reduced to 3 m

Width of Median for bridges should be b/w 1.2 – 1.5 m



Transition in Median should be 1 in 20 to 1 in 15

f) Road Margins :-



Building line → Represents the Road width upto which No Building Activity is permitted

control line → Represents distance upto which Nature of Building is controlled

2) sight Distance :- 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 sight distances are :-

1) stopping sight Distance, SSD:- It is also known as absolute Min. sight distance or non-passing sight distance.

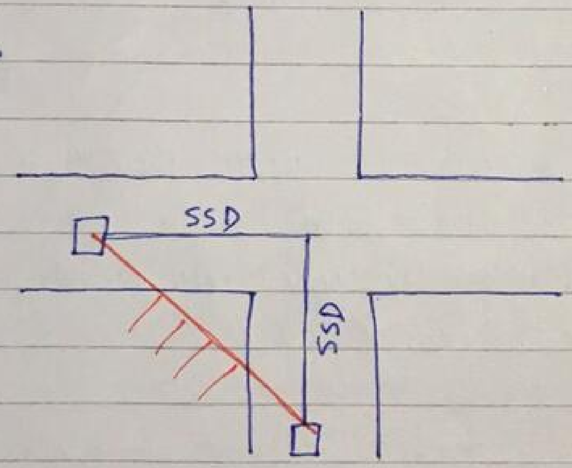
2) Overtaking sight Distance (OSD) :- It is also known as passing sight Distance

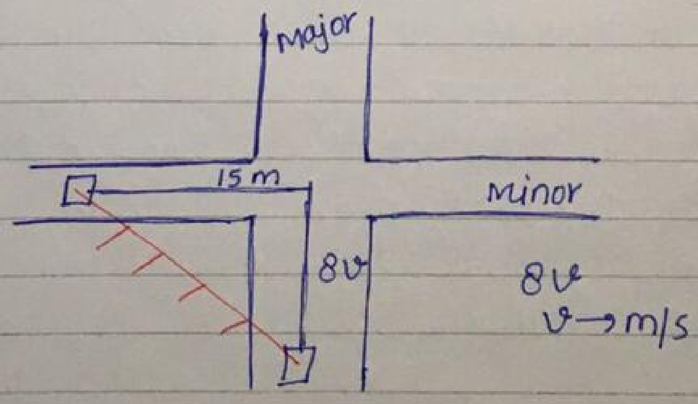
3) Intermediate sight Distance (ISD) :- When overtaking sight Distance can not be provided, we provide ISD so as to give some degree of overtaking opportunity

ISD = 2 x SSD

4) Headlight sight Distance (HSD) :- Distance visible to the driver at Night under headlight illumination, the Min. value of HSD should be equal to SSD

5) Sight Distance at Intersections :-





At priority intersections (Where a Major Road crosses a Minor Road) the sight Tringle is Formed by providing a Min. visibility of of 15m along the Minor Road and 8 sec travel distance along the Major Road (v in m/s)

Stopping sight Distance :- SSD.

It is the Min. sight distance (visibility) that should be available from all spots on highway so that vehicles travelling at design speed could be safely stopped within that distance.

SSD depends on :-

1) Reaction time of Driver :- IRC recommends 2.5 sec. as the reaⁿ time for SSD calculation
2) speed of vehicle
3) Brake efficiency :- IRC assumes brake efficiency as 50% It has already been included in longitudnal friction cofficient recommended by IRC
4) Friction cofficient of Road (longitudna) :- As per IRC 0.35→0.4

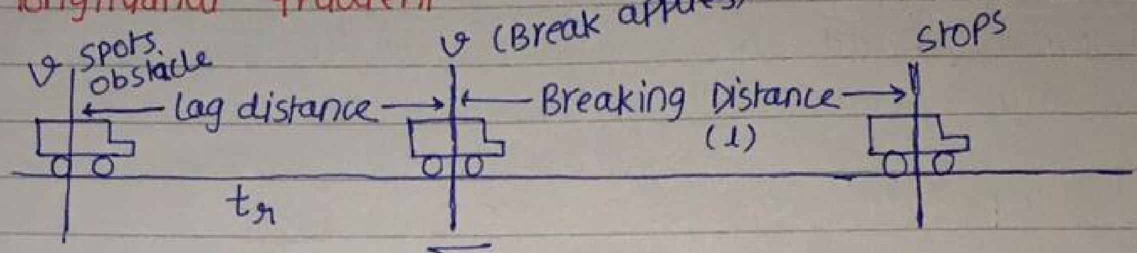
speed (kmpH)	μ
≤ 30	0.4
60	0.36
≥ 80	0.35

5) longitudnal Gradient of Road :- Up Gradient will lead to a lower value of SSD and DownGradient will lead to a higher value of SSD

$\vartheta \rightarrow m/s$
$V \rightarrow KmpH$

Calculation of SSD :-

i) When the vehicle is moving on level Road that is No longitudnal Gradient



$f = \mu mg$

$a = -\mu g$

Lag distance $= \vartheta t_r$

Breaking distance (l)

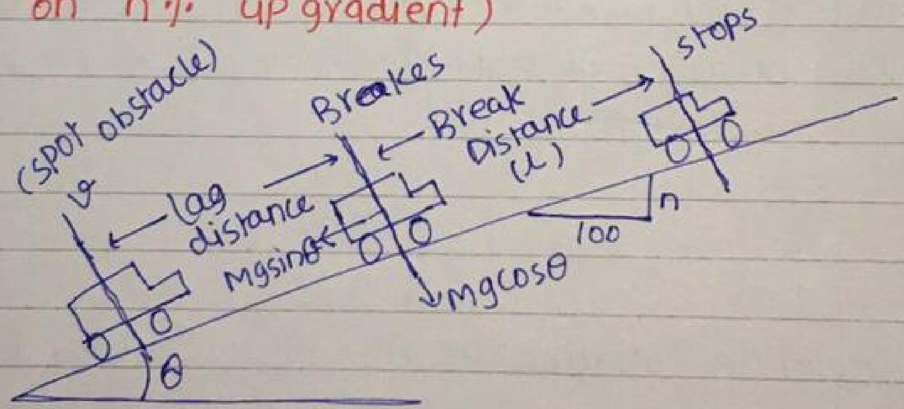
$$\vartheta^2 = u^2 + 2as$$

$$0 = \vartheta^2 - 2\mu g l$$

$$l = \frac{\vartheta^2}{2\mu g}$$

$$SSD = \vartheta t_r + \frac{\vartheta^2}{2\mu g}$$

ii) When the vehicle is moving on a longitudnal Gradient (say on n% up gradient)



$f = \mu mg\cos\theta + mg\sin\theta$

$a = -(\mu g\cos\theta + g\sin\theta)$

lag distance $= \vartheta t_r$

Braking distance (l)

$$v^2 = u^2 + 2as$$

$$0 = v^2 - 2(\mu g\cos\theta + g\sin\theta)\,l$$

$$l = \frac{v^2}{2g(\mu\cos\theta + \sin\theta)}$$

$$l = \frac{v^2}{2g\cos\theta(\mu + \tan\theta)}$$

for small θ

$$l = \frac{v^2}{2g(\mu + 0.01n)}$$

SSD = lag distance + Braking distance

$$SSD = v t_r + \frac{v^2}{2g(\mu \pm 0.01n)}$$

$+ \rightarrow$ up gradient

$- \rightarrow$ down gradient

$v \rightarrow$ Design speed in m/s

$t_r \rightarrow$ reaction time (2.5 Sec)

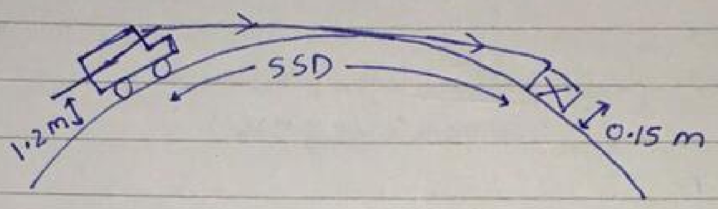
$\mu \rightarrow$ longitudnal friction Cofficient (0.35 – 0.4)

$n\% \rightarrow$ longitudnal Gradient

IRC Recommendations :- i) On a single lane Road with Two Way traffic the Min SSD should be equal to twice of SSD (for same speed)

ii) For undevided highway with two way traffic condition the effect of Gradient is not considered in SSD calculations However on devided Highways effect of Gradient should be considered.

SSD on vertical surves should be the length along centre line of curv from which a driver with an eye level of 1.2 m can spot top of an obstacle 0.15 m above ground



If SSD can not be provided in a perticular strech of Road, proper sign boards with speed restrictions must be provided.

Que. calculate safe SSD for a design speed of 50 KMPH on i) two-way traffic on a two-lane Road.
ii) two-way traffic on a single lane Road.

$V = 50$ KMPH , $v_0 = 13.88$ m/s

i) $SSD = vt_r + \frac{v^2}{2g\mu}$

$= 13.88 \times 2.5 + \frac{13.88^2}{2 \times 0.36 \times 9.8}$

$= 62.025$ m

ii) $SSD = 2 \times 62.025$

$= 124.05$ m.

Que. Driver of a vehicle travelling at 60 KMPH on an upgradient requires 9m less to stop after applying the brakes. as compare to a driver travelling down the slop at same speed.
What is the Gradient of Road.

$V = 60\,KMPH,\ v = 16.67\ m/s$

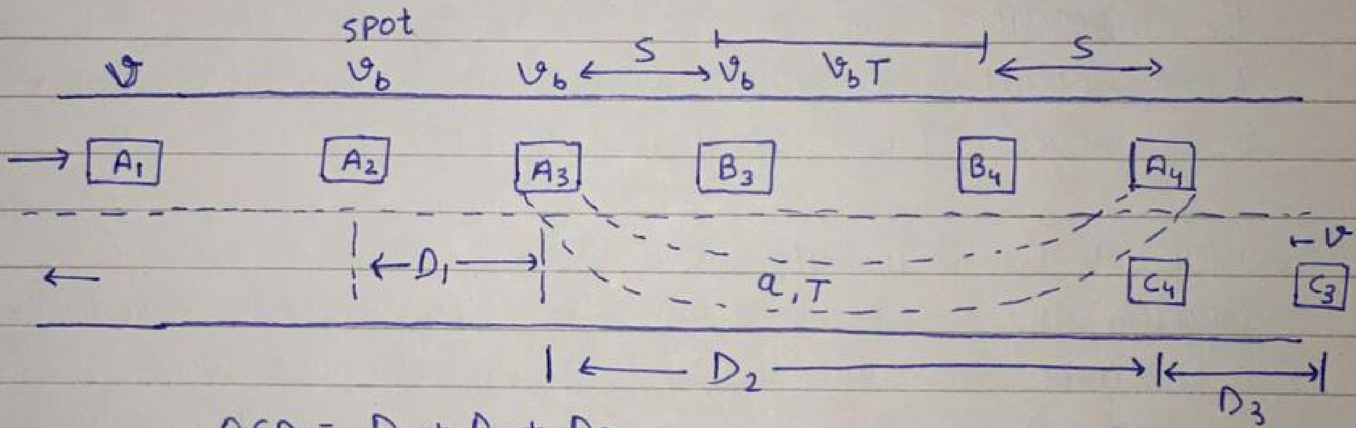
$$\frac{v^2}{2g(\mu - 0.01n)} - \frac{v^2}{2g(\mu + 0.01n)} = 9$$

$$\frac{16.67^2}{2\times 9.8(0.36-0.01n)} - \frac{16.67^2}{2\times 9.8(0.36-0.01n)} = 9$$

$n = 4.066\ \%$

OVERTAKING SIGHT DISTANCE :-

It is provided for safe overtaking operations.



$OSD = D_1 + D_2 + D_3$

$D_1 = v_b t_r$

$D_2 = 2S + v_bT = v_bT + \frac{1}{2}aT^2$

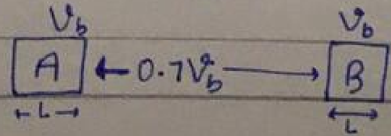
$T = \sqrt{\frac{4S}{a}}$

$D_3 = vT$

if the speed of slow-moving vehicle is not given it can be taken as $v_b = v - 4.5\ (m/s)$

$V_b = V - 16\ (km/H)$

spacing b/w vehicles $S = 0.7v_b + L$



$(v_b \to m/s)$

$L \to 6m$ assume (if Not given)

$S = 0.2V + L$ (V – KMPH)

IRC Recommendations for acceleration :-

V_b (KM/H)	a (m/s^2)
80	0.72
100	0.53

A → represents overtaking vehicle
B → overtaken vehicle
C → vehicle coming from opposite Dir^n
v → Design speed (m/s)
v_b → speed of overtaken vehicle (m/s)
t_r → Reaction time in sec. (2 sec as per IRC)
T → Actual time taken in overtaking Maneuver (in sec)
S → Distance from c/c b/w vehicles A & B

Vehicle A with initial speed v is moving after reducing it's speed to v_b and looking for an opportunity to overtake a slow moving vehicle B. At some instance (A_2), A spots an opportunity But persiving the opportunity some time is lost in reaction (2 sec) and in this time vehicle A moves by a distance D_1, But the moment A starts accelerating it may find that the opportunity to overtake is no longer available Hence it may remain moving behind vehicle B maintaining a distance S at a lower speed v_b. if However the vehicle A finds that the opportunity is still available it will accelerate moving into the adjacent lane and again come back to it's initial lane maintaining the same distance S as before

The distance moved by A in actual overtaking maneuver is D_2 in Time T, in this time the ~~vehicle~~ Distance moved by vehicle coming from opposite lane is D_3

NOTE if the spacing b/w vehicle A & B is not same say (S_1 and S_2)

$$D_2 = (S_1+S_2) + V_bT = V_bT + \frac{1}{2}aT^2$$

$$T = \sqrt{\frac{2(S_1+S_2)}{a}}$$

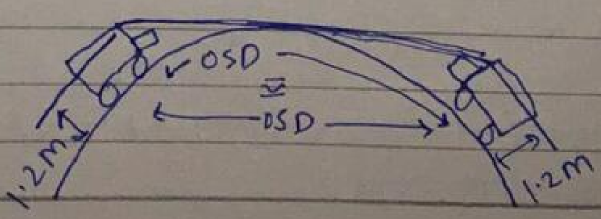
IRC Recommendations :-

(i) on devided highways and for roads with one way traffic regulations OSD is taken as $D_1 + D_2$

(ii) on devided highways with 4 or more lanes IRC suggests that there is no need to provide OSD But SSD should Always be provided

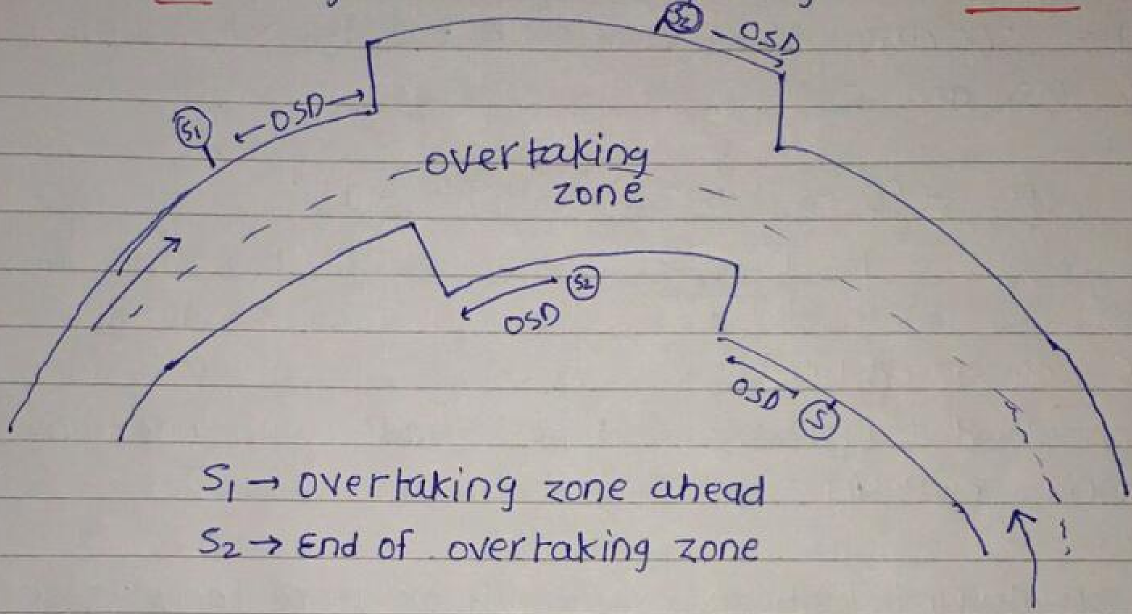
NOTE Effect of Gradient is not considered in OSD calculations (However Gradient tends to increase the OSD slightly)

(iii) on vertical curve OSD should be along the center line of the curve ~~from~~ of Road from which a driver with it's eye level at 1.2 m ~~can b~~ about road surface and can see the top of object 1.2 m



iv) if OSD can't be provided throughout the length of the Road we provide overtaking zones at certain intervals.

Desirable length of overtaking zone is 5 x OSD and Min. length of overtaking length is 3 x OSD



$S_1 \rightarrow$ overtaking zone ahead

$S_2 \rightarrow$ End of overtaking zone

Que. On a two way traffic Rode the speed of an overtaking veh. and overtaken veh. are 65, 40 KMPH respectively if the avg. acceleration is 0.92 m/s²

Determine the OSD ?

$V = 65$ KMPH , $v = 18.05$ m/s

$V_b = 40$ kmph , $v_b = 11.11$ m/s

$D_1 = v_b t_r = 11.11 \times 2 = 22.22$ m

$S = 0.7\left(\frac{5}{18} \times 40\right) + L = 13.77$

$T = \sqrt{\frac{4S}{a}} = \sqrt{\frac{4 \times 13.77}{0.92}} = 7.74$

$D_2 = 2S + v_b T = 2 \times 13.77 + 11.11 \times 7.74$

$D_2 = 113.56$ m

$D_3 = VT = 18.05 \times 7.74 = 139.75$

$OSD = D_1 + D_2 + D_3 = 275.53$ m.

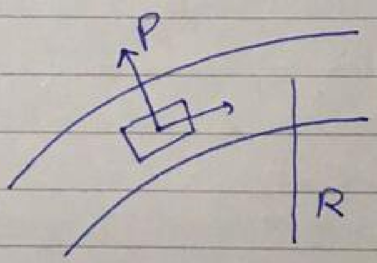
HORIZONTAL ALIGNMENT DESIGN :-

Design elements of Horizontal Alignment are :-

1) Radius of circular curve
2) Superelevation
3) Extra widening at Horizontal curve
4) Design of Transition curve
5) set back distance

- Design speed is the single most important factor in the design of Horizontal Alignment

presence of Horizontal curve imparts centrifugal Force (P)



$$P = \frac{mv^2}{R}$$

$$\frac{P}{mg} = \frac{v^2}{gR}$$ centrifugal Ratio or impact Ratio

$v \rightarrow$ Design speed , $R \rightarrow$ Radius of curve

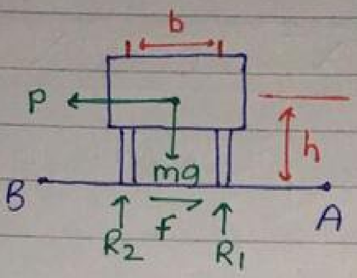
on Horizontal Road surface the centrifugal force generated is counter acted by transverse Friction

centrifugal force has two effects

1) Transverse skidding
2) overturning about the outer wheel

Condition for No overturning / Skidding.

Case (i) When the Road surface is Flat i.e No cross slop



$N = R_1 + R_2 = mg$

A) For No overturning

In the limiting case when vehicle is just about to overturn about the outer wheels ($R_1 = 0$), Balancing moment about the outer wheel we have

$$Ph = mg(b/2)$$

Hence for no overturning we should have

$$Ph \leq mg\left(\frac{b}{2}\right)$$

$$\frac{P}{mg} \leq \frac{b}{2h}$$

$$\boxed{\frac{v^2}{gR} \leq \frac{b}{2h}}$$

B) For No skidding

In the limiting case when the veh. is just about to skid ($f = \mu mg$). Balancing forces we've

$$P \leq \mu mg$$

Hence for No skidding we should have

$$P \leq \mu mg$$

$$\frac{P}{mg} \leq \mu$$

$$\boxed{\frac{v^2}{gR} \leq \mu}$$

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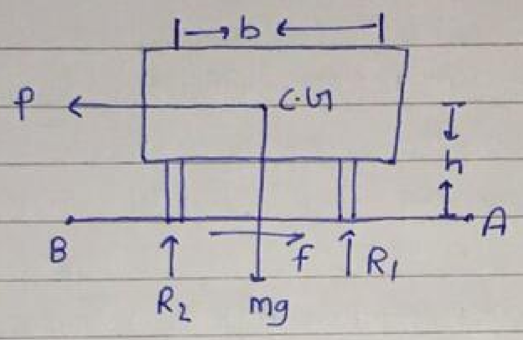
if $\mu \leq \frac{b}{2h}$, skidding occurs before overturning

if $\mu > \frac{b}{2h}$, overturning before skidding.



Balancing moment about center of gravity

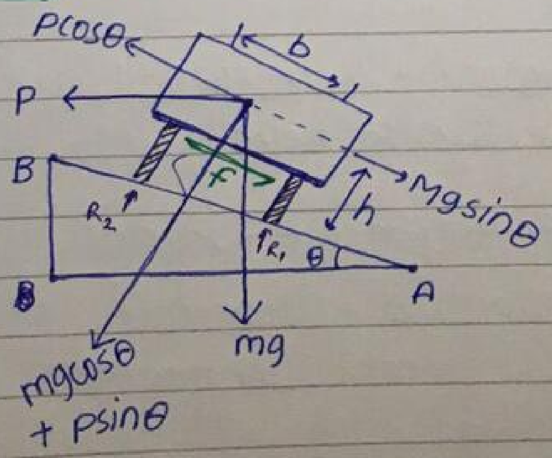
$$R_2\left(\frac{b}{2}\right) = R_1\left(\frac{b}{2}\right) + fh$$

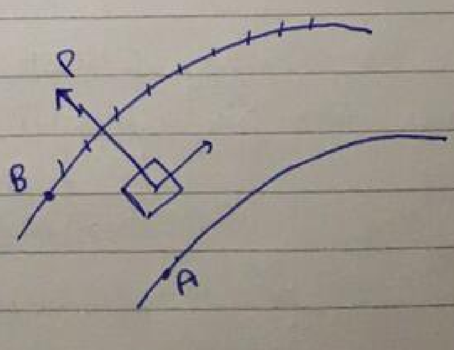
$$\boxed{R_2 = R_1 + \frac{f}{b/2h}}$$

{ f_{max} for above fig. = μmg

When a veh. negotiate a horizontal curve then the pressure on outer wheel > inner wheel, so long friction is mobilised inwards

Case-(ii) When the vehicle is moving on a banked road





$$N = R_1 + R_2 = mg\cos\theta + P\sin\theta$$

A) For No-overturning.

In the limiting case when veh. is just about to overturn about the outer wheel $(R_1 = 0)$, Balancing Moment about the outer wheels we've

$$P\cos\theta \times h = (mg\cos\theta + P\sin\theta) \times \frac{b}{2} + mg\sin\theta \times h$$

Hence for no overturning we should have

$$P\cos\theta \times h \le (mg\cos\theta + P\sin\theta) \times \frac{b}{2} + mg\sin\theta \times h$$

$$P\cos\theta \times h - P\sin\theta \times \frac{b}{2} \le mg\cos\theta \frac{b}{2} + mg\sin\theta \times h$$

$$P\cos\theta h \left(1 - \frac{b}{2h}\tan\theta\right) \le mg\cos\theta h \left(\frac{b}{2h} + \tan\theta\right)$$

$$\boxed{\frac{v^2}{2g} = \frac{P}{mg} \le \frac{b/2h + \tan\theta}{1 - b/2h \tan\theta}}$$

B) For No skidding

In the limiting case when vehicle is just about to skid $(f = \mu(N) = \mu(mg\cos\theta + P\sin\theta))$, Balancing Forces we've

$$P\cos\theta = mg\sin\theta + \mu(mg\cos\theta + P\sin\theta)$$

Hence for No skidding we should have

$$P\cos\theta \le mg\sin\theta + \mu(Mg\cos\theta + P\sin\theta)$$

$$P\cos\theta - \mu P\sin\theta \le mg\sin\theta + \mu mg\cos\theta$$

$$P\cos\theta(1 - \mu\tan\theta) \le mg\cos\theta(\mu + \tan\theta)$$

$$\frac{P}{mg} \le \frac{\mu + \tan\theta}{1 - \mu\tan\theta}$$

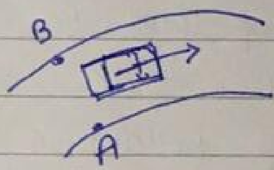
$$\boxed{\frac{v^2}{gR} \le \frac{\mu + \tan\theta}{1 - \mu\tan\theta}}$$

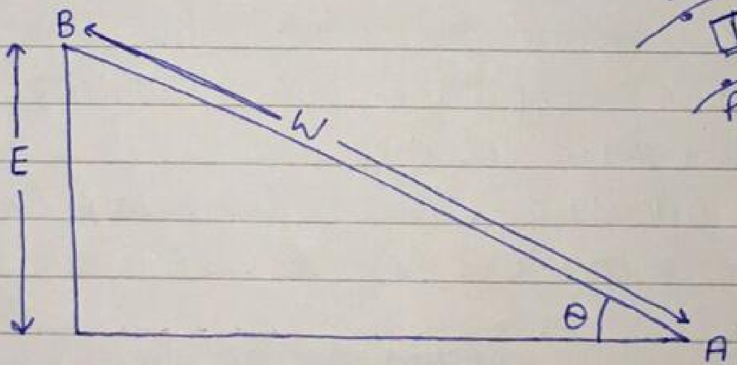
$v \rightarrow$ Design speed (m/s)
R $\rightarrow$ Radius of curve (of center line)
b $\rightarrow$ c/c distance b/w inner & outer wheels
h $\rightarrow$ height of C.G above Road surface
$\mu \rightarrow$ friction cofficient in transverse dir^n (0.15)

* Generally skidding takes place before overturning.

SUPERElevation :-

superelevation or bank or cant is the transverse slop provided at horizontal curves to counter act of centrifugal force by raising the outer edge of Road with respect to inner edge.





superelevation (e) = $\tan\theta = \sin\theta = \frac{E}{W}$ ($E \leftarrow$ rise, $W \leftarrow$ width)

for exactly balancing forces in case of NO skidding we've

$$\frac{v^2}{gR} = \frac{\mu + \tan\theta}{1 - \mu\tan\theta} = \frac{\mu + e}{1 - \mu e}.$$

$\{\because \mu \times e << 1$ ($\mu \rightarrow 0.15$, $e \rightarrow 0.07$)

$$\boxed{\frac{v^2}{gR} = \mu + e}$$

if friction is not Moblised i.e $\mu = 0$ we've

$$\frac{v^2}{gR} = e$$

such a super-elevation is called equilibirium superelevation

At equilibirium superelevation since friction is not moblished the pressure on inner and outer wheel is same.

NOTE An adequaly super elevated Road means that equilibirium superelevation has been provided

Guidelines for providing superelevation (For Mixed Traffic)

Equilibirium super elevation provided for design vehicle may lead to toppeling of slow-moving vehicles on the inner side. Hence to counter this IRC has recommended the following approach for providing superelevation under Mixed traffic condition.

Steps. ① calculate equilibirium Superelevation corresponding to 75% of design speed

$$e = \frac{(0.75v)^2}{gR} = \frac{V^2}{225R} \qquad V \to kmpH$$

if the calculated $e \leq 0.07$ it is acceptable and if calculated e comes greater than 0.07 then move to Next step.

② provide a superelevation of 0.07 and check for friction cofficient.

$$\frac{v^2}{gR} = \mu + e \quad \left\{ \frac{V^2}{127R} = \mu + e \qquad V \to kmpH \right.$$

$$\Rightarrow \left(\mu = \frac{v^2}{gR} - 0.07 \right)$$

if the calculated $\mu < 0.15$ then acceptable
o/w move to next step

③ calculate the Max. permissable velocity on that Road

$$V_{max} = \sqrt{(\mu + e)_{max} \cdot gR}$$

($\mu \to 0.15$, $e \to 0.07$)

if the Design velocity is less than V_{max} → acceptable
if not then restrict the design velocity to V_{max}.

① $\frac{v^2}{gR} = \mu + e$ need / required

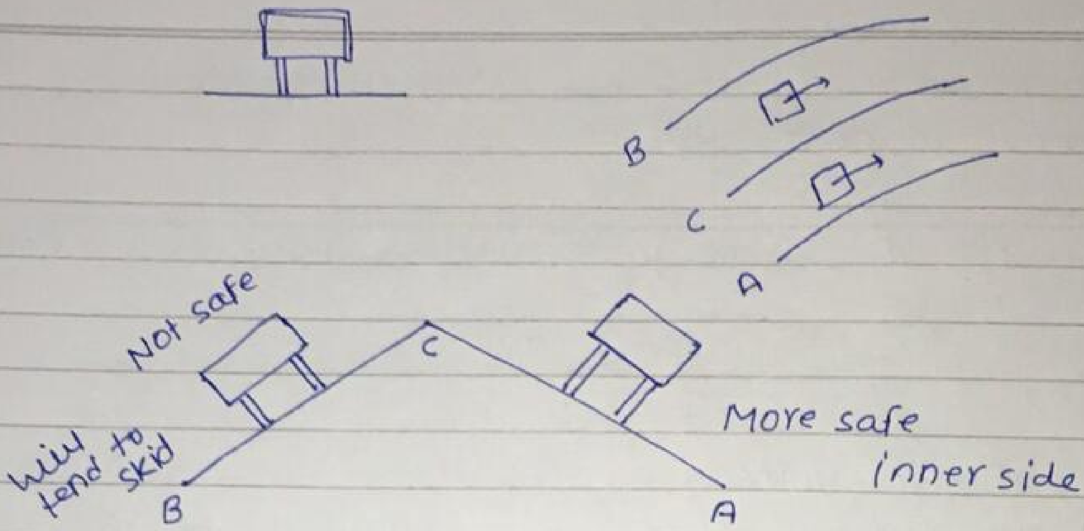
② $\frac{v^2}{gR} = e_{eq.}$ Equivelent superelevation
or adequetly superelevated
or $R_1 = R$

③ $\frac{(0.75v)^2}{gR} = e$ IRC / Design / Mixed traffic

IRC recommendation For ~~Mixed traffic~~ Max. superelevation :-

Type	e_{max}
1) Urban Roads	4 %
2) Plain / Rolling	7 %
3) Hilly terrain bounded by SNOW	7 %
4) Hilly terrain not bounded by SNOW	10 %

NOTE e_{min} is provided for drainage of water, Hence camber is taken as the value of Min. super elevation



<u>check</u>: $\frac{v^2}{2g} \leq \mu - c$ $\quad$ $c \rightarrow$ slop of camber

When camber is taken as superelevation we must check for the stability of the vehicle on the outer half of the pavement for skidding since the outer half now has a Negative superelevation.

Min. Radius of curve beyond which no superelevation is provided as per IRC is

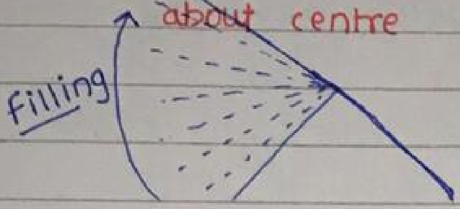
$$R_{min} = \frac{(0.75v)^2}{gc}$$

Attainment of superelevation (straight camber)

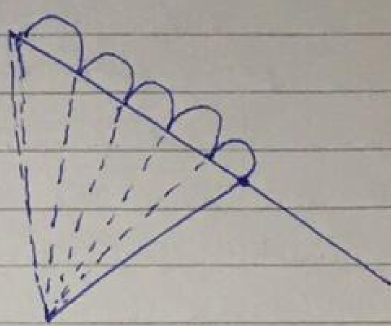
superelevation is attained in following 2 steps
1) elemination of crown
2) Rotation of pavement to archive full superelevation

i) Elimination of crown:-

(i) Rotation of outer pavement about centre



(ii) shifting of crown



Advantage of (i)

- Negative superelevation is never too high in the outer pavement

Dis. (i) Drainage problem at some stage of Road

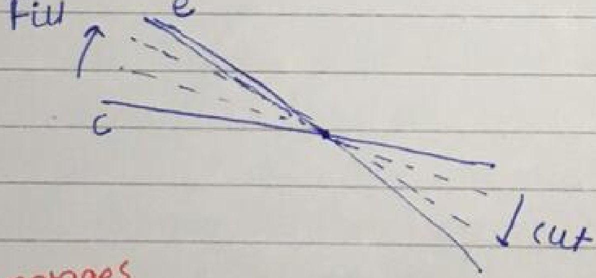
Advantage of (ii)

No Drainage problem anywhere

Dis (ii) super elevation too high in the outer pavement

ii) Rotation of pavement to archive full super elevation

(i) Rotation about centre

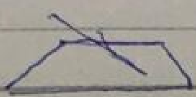


Advantages

- Balance Earthwork is required
- centre line profile of the Road does not changes

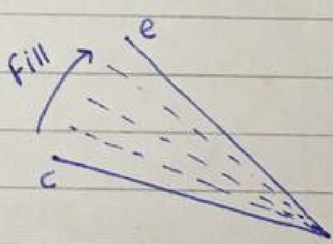
Dis-advantage

- There may be drainage problem on the inner side of the Road



✓ preferred.

(ii) Rotation about inner edge



Advantage

- No Drainage problem on the inner side

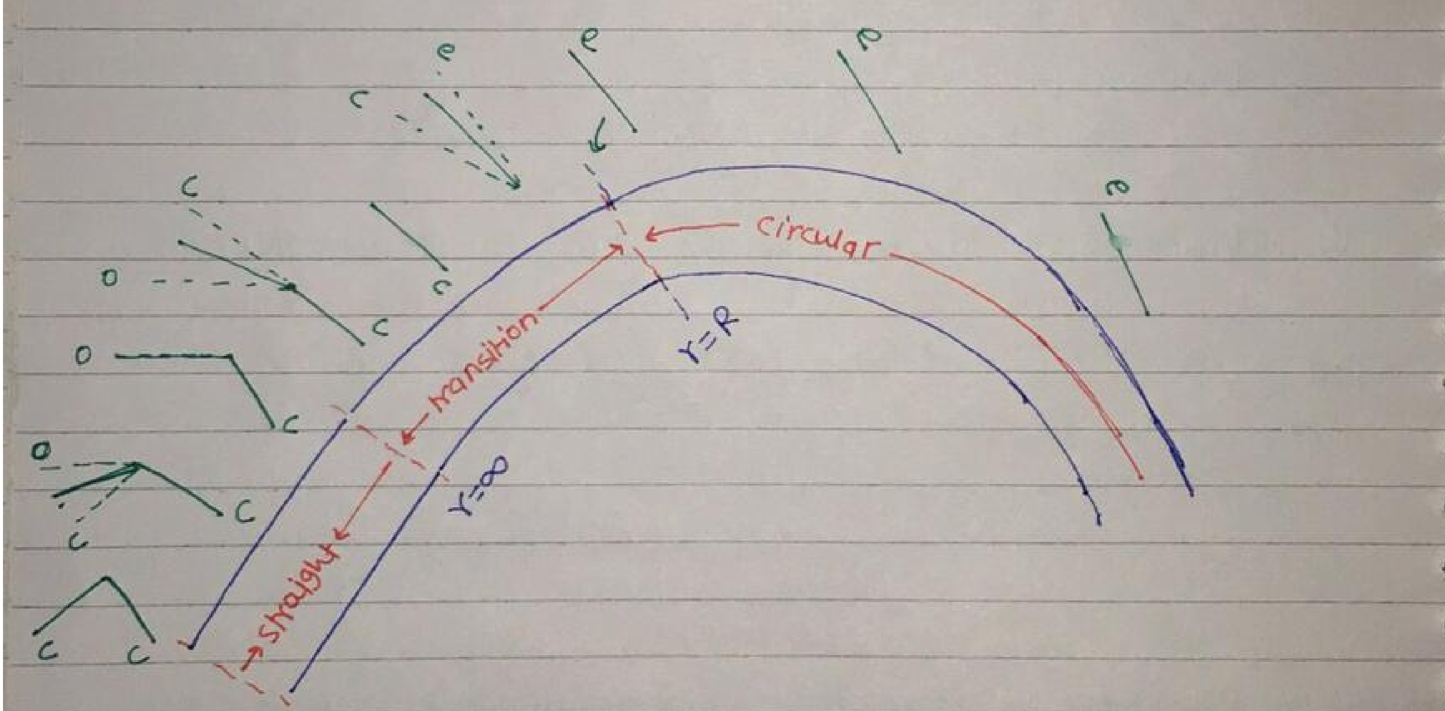
Dis Advantage

- Excess filling earthwork is required
- center line profile of the Road changes.

CROSS-SECTION Along Transition curve :-

We don't start circular curve immediatly after the straight portion of the Road because it will lead to jerk due to sudden introduction of centrifugal force Hence a transition curve is provided b/w the straight and circular portion such that the centrifugal force is Gradually introduced from $0 \longrightarrow \frac{mv^2}{R}$

Start of transition curve → 0; end of the transition curve or start of the circular curve → $\frac{mv^2}{R}$



At the begining of transition curve one leg of the cambered section is made Horizontal and by the end of Transition curve full super elevation is achived

NOTE if Transition curve is not provided then $\frac{2}{3}$rd of the superelevation is provided on the straight portion of the Road and the remaining $\frac{1}{3}$rd is provided on the circular portion.

Ruling Minimum Radius and Absolute Min. Radius of Curve:-

$$\frac{v^2}{gR} = \mu + e \quad \Rightarrow \quad R = \frac{v^2}{(\mu+e)g}$$

$$R_{Min.} = \frac{v^2}{(\mu+e)_{Max.}\, g}$$

$$R_{Ruling\ Min.} = \frac{v^2_{Ruling}}{(\mu+e)_{Max.}\, g}$$

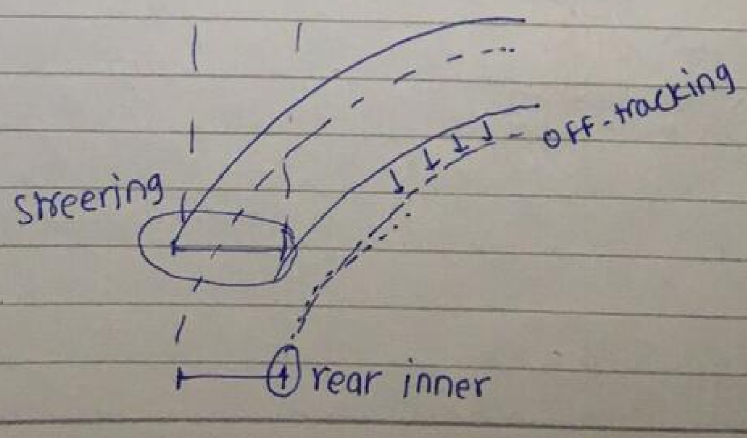
$$R_{absolute\ Min.} = \frac{v^2_{Min.\ design\ speed}}{(\mu+e)_{max.}\, g}$$

EXTRA-WIDENING ON HORIZONTAL CURVES (W_e):-

Extra widening on Horizontal curves is required for two reasons -

(i) if the front wheel (steering wheel) follows the curve, the inner rear wheel will go off track due to Rigidity of wheel base

(ii) Generally the driver has a tendency to drive closer to the outer edge



For Rigidity of Wheel Base we provide Mechanical widening $\left(\frac{l^2}{2R}\right)$ per lane

And for tendency of driver to drive closer to the outer edge we provide physcological widening $\left(\frac{v}{2.64\sqrt{R}}\right)$

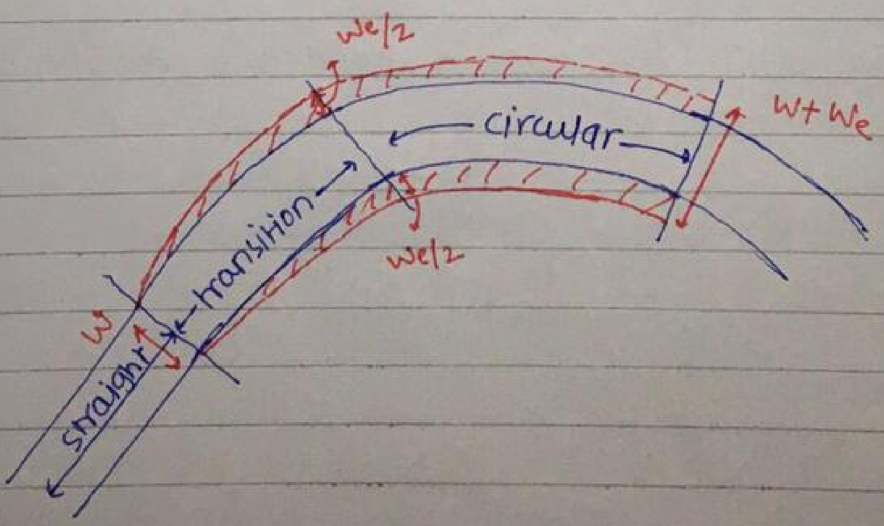
Total extra widening for n lane

$$W_e = \frac{nl^2}{2R} + \frac{v}{2.64\sqrt{R}}$$

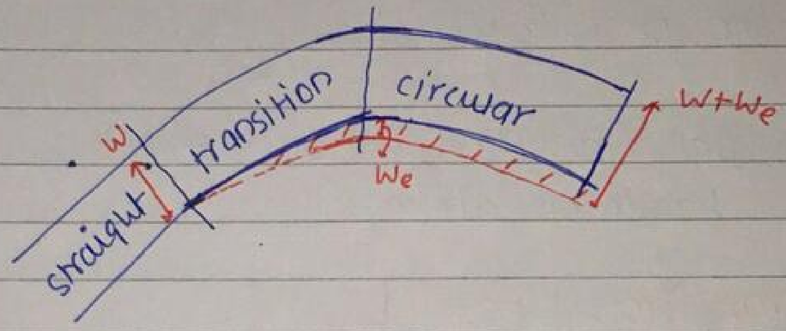
$l \rightarrow$ length of wheel Base
$R \rightarrow$ Radius of curve
$v \rightarrow$ design speed in m/s

- for single lane, only Mechanical widening is provided
- If $R > 300m$, extrawidening is not required

Extra widening is provided along the transition curve Gradually



on sharp curv on hills extrawidening is provided on the inner side



If transition curve is not provided then 2/3rd of the extrawidening is provided on the straight portion of the road and the remaining 1/3rd is provided on the circular portion of the Road

Horizontal Transition curve

objectives of providing horizontal transition curve are

i) Gradual introduction of centrifugal force to facilitate jerk free movement.

ii) Gradual introduction of superelevation and extrawidening

iii) ~~ex~~ To enable the driver to tern the steering Gradually

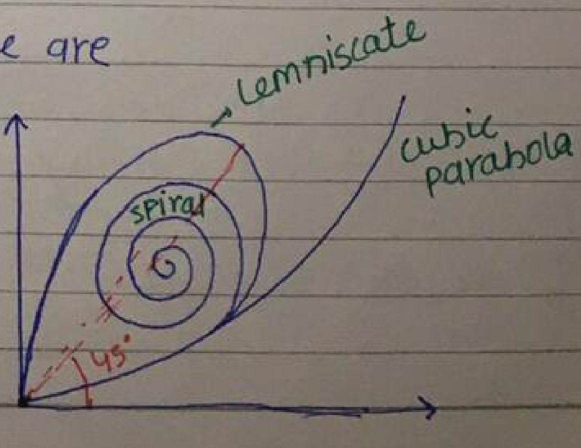
iv) To enhance the appearance of Road.

Different type of transition curve are

i) spiral (clethoid)

ii) Lemniscate

iii) cubic parabola



IRC Recommends spiral as the shape of Horizontal transition curve.

In case of spiral curve we've $l \propto \frac{1}{R}$, $P \propto \frac{1}{R}$

centrifugal force P is also $P \propto \frac{1}{R}$

Hence for spiral transition we've $P \propto l$.
Where $l \rightarrow$ length of curve

LENGTH OF Transition curve (L_s)

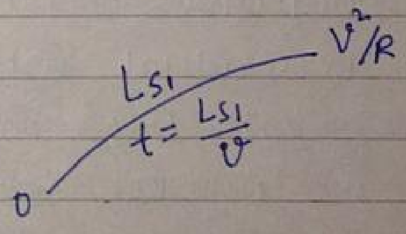
length of Transition curve is taken as Max of length calculated from the following two criterias.

(i) Rate of change of centrifugal acceleration
(ii) Rate of change of introduction of superelevation

(i) Rate of change of centrifugal acceleration :-

Let c be the rate of change of centrifugal acceleration

$$c = \frac{\left(\frac{v^2}{R} - 0\right)}{t} = \frac{\frac{v^2}{R}}{L_{s1}/v}$$



$$c = \frac{v^3}{L_{s1} R}$$

$$\boxed{L_{s1} = \frac{v^3}{cR}}$$

$v \rightarrow m/s$

$c \rightarrow m/s^3$

c is calculated emperically as $\left\{ c = \frac{80}{75 + V_{(KMPH)}} \right\}$

subjected to a Min $0.5\ m/s^3$ to $0.8\ m/s^3$

(ii) Rate of Introduction of superelevation

Rate of change of superelevation that is longitudnal Grade of pavement edge as compared to the through grade along the center line should be such as not to cause dis-comfert to the traveller or to make the Road appear unsightly.

Rate of change should not be steeper than 1 in 150 for plain / Rolling terrain and should not be steeper than 1 in 60 for Mountaineous / steep terrain.

Based on these statements IRC has given emperical EQ^n to calculate Length of transition curve

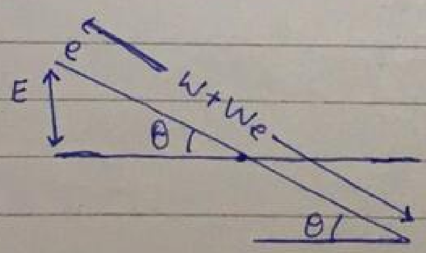
$L_{s_2} = \frac{35 v^2}{R}$	→ plain / Rolling Topography
$L_{s_2} = \frac{12.96 v^2}{R}$	→ Mountaneous / steep

$v \to m/s$

length of transition curve = $L_s = \text{Max.}\{L_{s_1}, L_{s_2}\}$

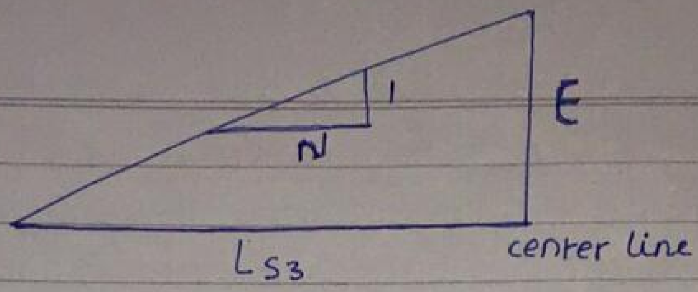
NOTE sometimes length of transition curve is also calculated analytically Based on the 2nd criteria As follow :–

a) When rotation is about center



$$e = \tan\theta = \sin\theta = \frac{E}{\left(\frac{W+W_e}{2}\right)}$$

$$E = \frac{e(W+W_e)}{2} \quad \text{---(i)}$$



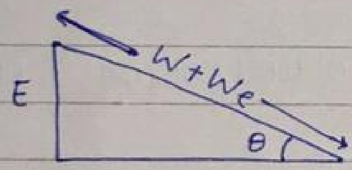
$$\frac{E}{L_{s3}} = \frac{1}{N}$$

$$E = \frac{L_{s3}}{N} \quad \text{----(ii)}$$

from eq^n (i) and (ii)

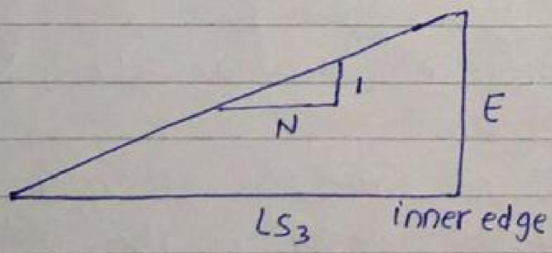
$$\boxed{L_{s3} = \frac{eN(W+W_e)}{2}}$$

b) When rotation is about inner edge



$$e = \frac{E}{W+W_e}$$

$$E = e(W+W_e) \quad \text{---(i)}$$



$$\frac{E}{L_{s3}} = \frac{1}{N}$$

$$E = \frac{L_{s3}}{N} \quad \text{---(ii)}$$

from (i) and (ii)

$$\boxed{L_{s3} = eN(W+W_e)}$$

$e \rightarrow$ superelevation
$W \rightarrow$ width
$W_e \rightarrow$ extra-widening

$N \geq 150$ for Plain/Rolling
$N \geq 60$ for Mountaneous/steep

Scanned with CamScanner

Length of transition curve $L_s = \max\{L_{s1}, L_{s2}, L_{s3}\}$

Que. An expressway has 4 lanes and it is a devided highway. The expressway is passing through a flat terrain as a horizontal curve of Radius = Ruling Min. Radius, design speed = 120 KMPH calculate

a) Ruling Min Radius
b) superelevation
c) extra-widening
d) length of transition curve

Sol^n V = 120 KMPH, $v = 120 \times 5/18 = 33.33$ m/s

a)
$$R_{\text{ruling Min.}} = \frac{v^2_{\text{Ruling}}}{(\mu + e)_{max}\, g} = \frac{33.33^2}{0.22 \times 9.81} = 514.83 \text{ m.}$$

$\mu \to 0.15$, $e \to 0.07$

b) Assuming Mixed traffic condition
$$e = \frac{(0.75v)^2}{gR} = \frac{(0.75 \times 33.33)^2}{9.81 \times 514.83} = 0.124$$

$0.124 > 0.07$ (Hence not acceptable), Adopt $e = 0.07$.

Check μ
$$\mu = \frac{v^2}{gR} - e = \frac{33.33^2}{9.81 \times 514.83} - 0.07 = 0.15$$

$0.15 \leq 0.15$ Hence acceptable

c)
$$W_e = \frac{nl^2}{2R} + \frac{v}{2.64\sqrt{R}} \qquad l = 6 \text{ m.}$$

$$W_e = \frac{4 \times (6)^2}{2 \times 514.83} + \frac{33.33}{2.64\sqrt{514.83}} = 0.696 \text{ m.}$$

As $R > 300$, we don't need to provide Extra-widening.

d) $Ls_1 = \frac{V^3}{CR}$ $\qquad C = \frac{80}{75+120} = 0.41$ X

take $C = 0.5$ (Min.)

$= \frac{(33.33)^3}{0.5 \times 514.83}$

$= 143.88$ m

$Ls_2 = \frac{35V^2}{R} = \frac{35 \times 33.33^2}{514.83} = 75.53$ m

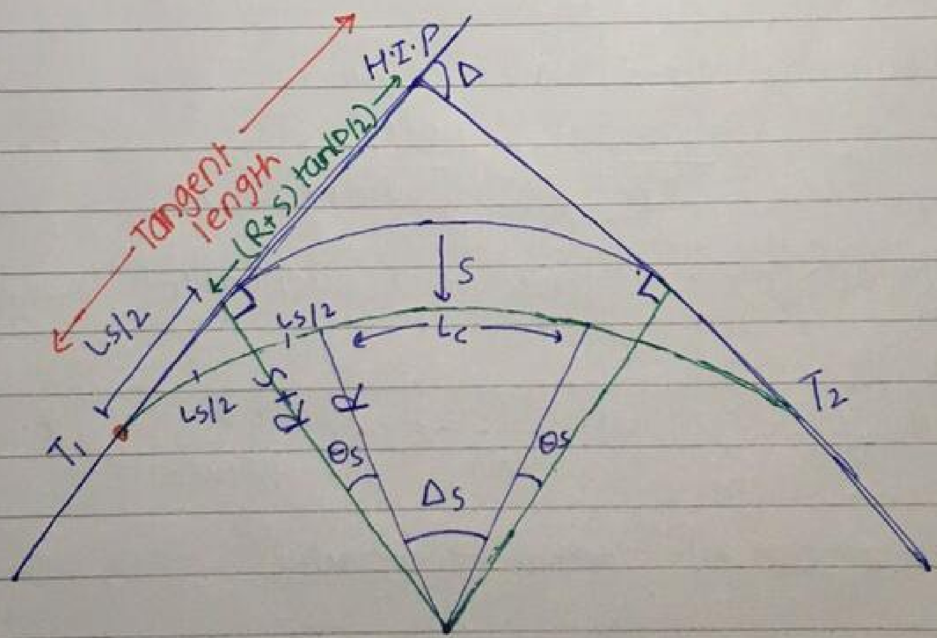
assuming $N=150$

$Ls_3 = \frac{eN(W+We)}{2} = \frac{0.07 \times 150\,(3.5 \times 4)}{2}$

$= 73.5$ m.

SETTING OF TRANSITION CURVE :-

(spiral & cubic parabola)



$180 - \Delta + 90 + 90 + 2\theta_s + \Delta s = 360$

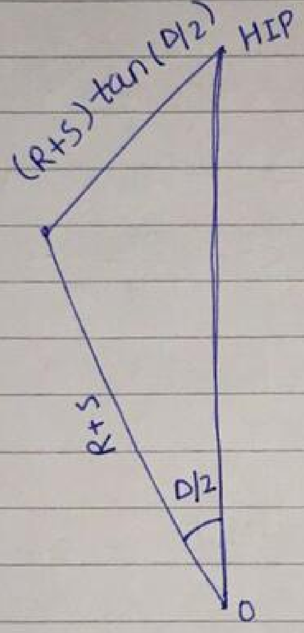
$$\boxed{2\theta_s + \Delta_c = \Delta}$$

$$S = \frac{L_s^2}{24R}$$

$$\theta_s = \frac{L_s}{2R}$$

$$L_c = R\Delta_c$$

Total length of the curve $= 2L_s + L_c$



Tangent length $= \frac{L_s}{2} + (R+S)\tan(D/2)$

- Chainage of first tangent point T_1 = chainage of H.I.P − tangent length
- chainage of 2nd Tangent point T_2 = chainage of T_1 + total length of curve

$\Delta \rightarrow$ deflection angle or deviation angle
$\theta_s \rightarrow$ spiral angle
$\Delta_c \rightarrow$ angle subtended by circular portion at center
$R \rightarrow$ Radius of circular curve
$S \rightarrow$ shift
$L_s \rightarrow$ length of transition curve
$L_c \rightarrow$ length of circular curve

NOTE. All angles are in Radian

Que: A two lane pavement 7m wide on a NH on Hilly terrain (SNOW Bound) has a curve of 60m Design speed = 40 KMPH. Determine length of transition curve, total length of curve and tangent length, $\Delta = 60^\circ$. Also calculate the chainage of tangent points if the intersection point has a chainage of 1000 m.

$$L_{s_1} = \frac{v^3}{CR} \qquad v = 11.11 \text{ m/s}, \quad V = 40 \text{ KMPH}$$

$$C = \frac{80}{75+40} = 0.695$$

$$L_{s_1} = \frac{(11.11)^3}{0.695 \times 60}$$

$$L_{s_1} = 32.895 \text{ m}$$

$$L_{s_2} = \frac{12.96\, v^2}{R} = \frac{12.96 \times (11.11)^2}{60} = 26.66 \text{ m}$$

$$L_s = \max \{L_{s_1}, L_{s_2}\}$$

$$L_s = 32.895 \text{ m} \cong 33 \text{ m}$$

length of curve

$$\theta_s = \frac{L_s}{2R} = \frac{33}{2 \times 60} = 0.275 \text{ Rad.}$$

$$2\theta_s + \Delta_c = \Delta$$

$$2 \times 0.275 + \Delta_c = \pi/3$$

$$\Delta_c = 0.497 \text{ rad.}$$

$$L_c = R\Delta_c = 60 \times 0.497 = 29.831 \text{ m.}$$

$$\text{length of curve} = 2L_s + L_c$$

$$= 2 \times 33 + 29.831$$

$$= 95.831 \text{ m.}$$

Scanned with CamScanner

$$\text{Tangent length} = \frac{L_s}{2} + (R+S)\tan \Delta/2$$

$$S = \frac{L_s^2}{24R} = 0.75\,m$$

$$\text{Tangent length} = \frac{33}{2} + (60+0.75)\tan 30^\circ$$

$$= 51.574\,m$$

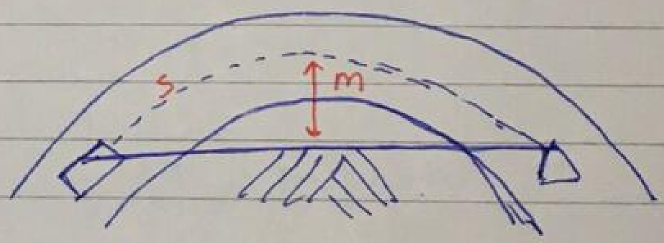
Chainage of 1st tangent point (T_1) = chainage of H.I.P − tangent length

$= 1000 - 51.574$

$= 948.426\,m$

Chainage of 2nd tangent point (T_2) = $948.426 + 95.831 = 1044.26\,m$

SET BACK Distance :-



set back distance on ~~and~~ clearance distance required from the centerline of horizontal curve -

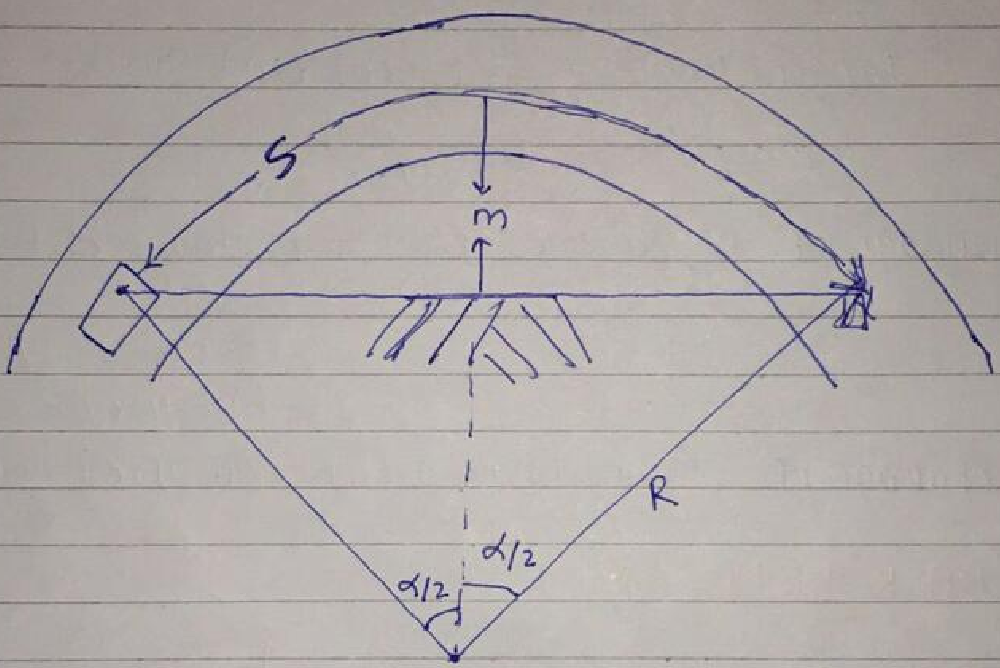
to an obstraction on the inner side of the curve is provided so that adequate sight distance is available on the horizontal curve

- sight Distance can either be SSD, ISD or OSD
- Min. set back distance should be provided corresponding to SSD

NOTE: In our calculations, we'll calculte the setback distance from the center line of the curve.

case-(i)
When length of curve > sight distance S

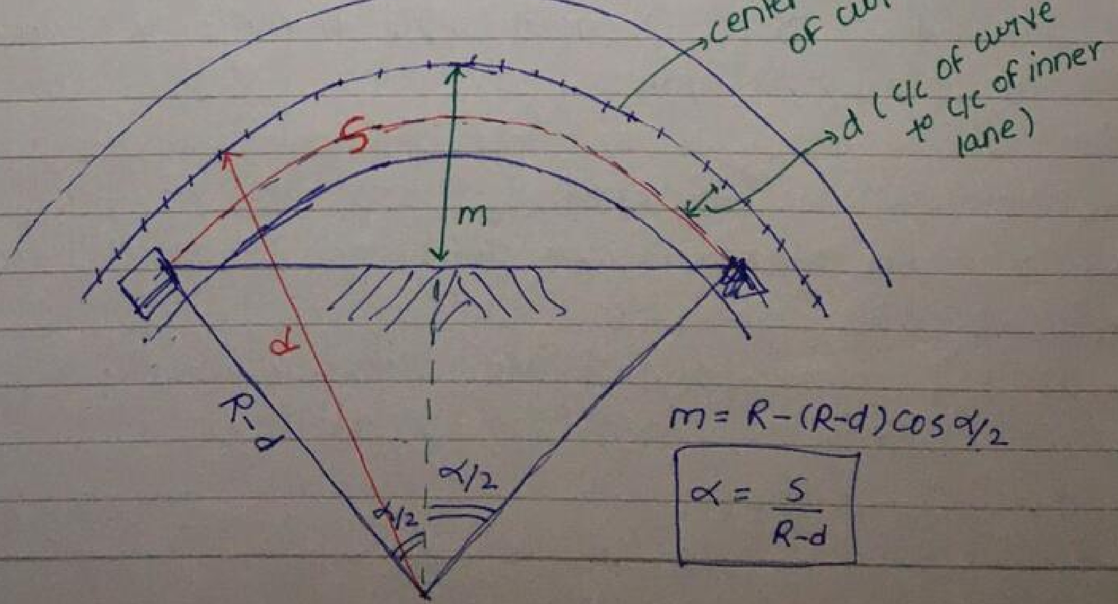
A) for single lane



$$m = R - R\cos(\alpha/2)$$

$$\boxed{\alpha = \frac{S}{R}}$$

B) For Multi lane

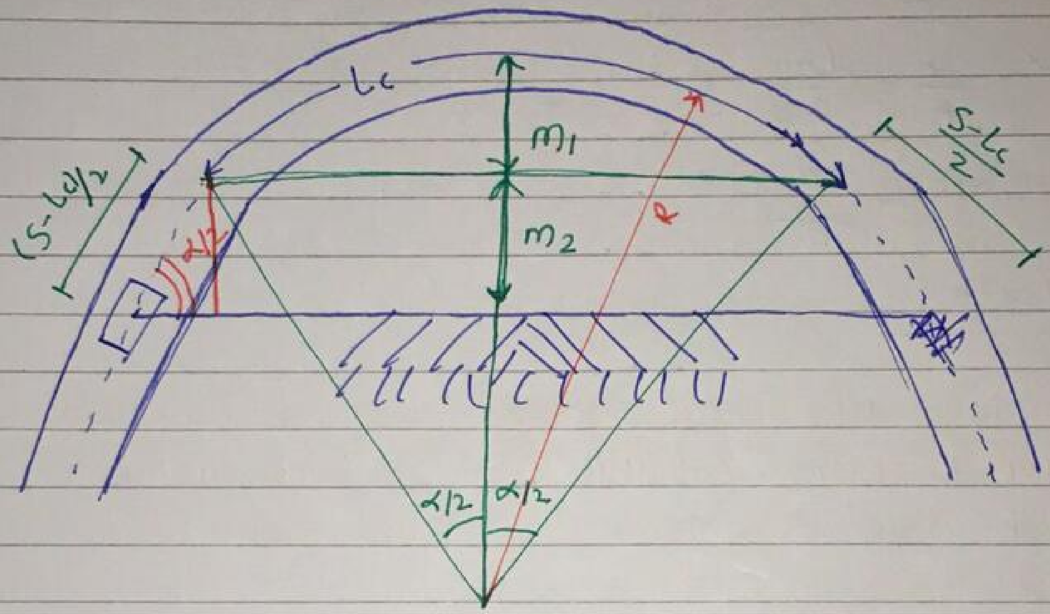


$$m = R - (R-d)\cos\alpha/2$$

$$\boxed{\alpha = \frac{S}{R-d}}$$

case(ii) When length of curve < sight distance S

A) For single lane



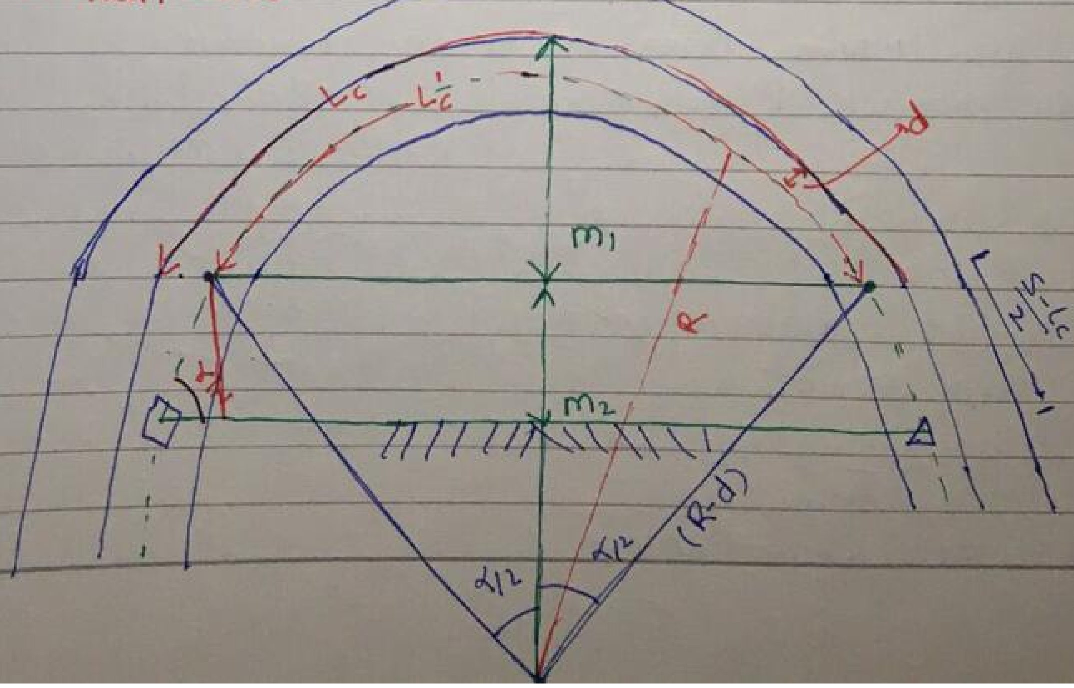
$$m = m_1 + m_2$$

$$m_1 = R - R\cos(\alpha/2)$$

$$m_2 = \frac{S-L_c}{2}\sin(\alpha/2)$$

$$\alpha = \frac{L_c}{R}$$

B) Multi lane



$m = m_1 + m_2$

$m_1 = R - (R-d)\cos\alpha/2$

$m_2 = \frac{S - L_c}{2} \sin(\alpha/2)$

$\alpha = \frac{L_c}{R} = \frac{L_c'}{R-d}$

$L_c' = L_c \frac{(R-d)}{R}$

$L_c' \simeq L_c$

Que. There is a Horizontal highway curve of R = 400 m and length 200 m. Calculate the set back distance required from the center line of the inner lane for providing

a) An SSD of 90 m.

b) An OSD of 300 m.

The distance b/w center line of Road and the center line of inner road is 1.9 m.

a) $\alpha = \frac{S}{R-d} = \frac{90}{400-1.9} = 0.226$ rad

$m = R - (R-d)\cos\alpha/2$

$m = 4.44$ m. from center line of curve

Hence setback from center line of inner lane

$= 4.44 - 1.9 = 2.54$ m.

b) $L_c < S$ (OSD)

$L_c = 200$

$R = 400$, $S = 300$ m (OSD)

$m = m_1 + m_2$

$\alpha = \frac{L_c}{R} = 0.5$

$m_1 = R - (R-d)\cos\alpha/2$

$m_1 = 400 - (400 - 1.9)\cos\left(\frac{0.5}{2}\text{ rad.}\right)$

$m_1 = 14.27$ m.

$m_2 = \frac{S - L_c}{2}\sin(\alpha/2)$

$m_2 = \frac{300 - 200}{2}\sin\left(\frac{0.5}{2}\text{ rad.}\right)$

$m_2 = 12.37$ m

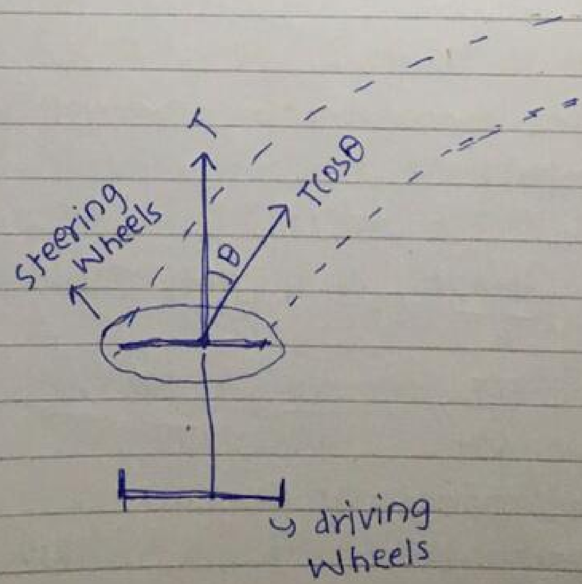
$m = 26.64$ m from c/L of curve

set back distance from c/L of inner lane $= 26.64 - 1.9$

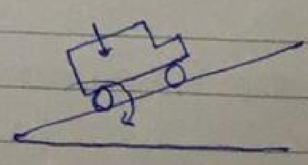
$= 24.74$ m.

CURVE RESIStance and GRade compentation :-

Most of the commercial veh. have rear driving wheels that is thrust is produced by Rear wheels. When such a vehicle is Negotiating a horizontal curve the front wheels (steering wheels) are rotated by the driver hence only a component of Thrust generated is available to Negotiate the curve. This reduction in thrust $(T - T\cos\theta)$ is called Curve Resistance.



curve resistance $= T - T\cos\theta$



NOTE When front wheels are driving wheels (as in passanger cars) there will be no curve resistance

Grade compentation :- When horizontal curve exists together with upgradient the pulling power of veh. decrease. To increase the pulling power the gradient is decreased so as to compentate the loss of tractive effort. This reduction in gradient on horizontal curves is called Grade compentation.

Grade compentation is not required on grades flatter than 4 %.

The Grade compentation is calculated empericaly as

$\frac{30+R}{R}$ % subjected to a Max. of $\frac{75}{R}$ %

Where R → Radius of curve (m)

NOTE. The compentated gradient should not be flatter than 4 %.

Que. if the Ruling Gradient is 1 in 20 What is the Grade compentation and compentated gradient of a curve of Radius 120 m.

Existing Gradient → 1/20 = 5 %

Grade compentation = $\frac{30+R}{R}$ % = $\frac{30+120}{120}$ = 1.25 %

Max. Grade compentation = $\frac{75}{R}$ % = $\frac{75}{120}$ = 0.625 %

Grade compentation provided = 0.625 %

compentated Gradient = 5 − 0.625 = 4.375 %

VERTICAL ALIGNMENT DETAILS :-

vertical Alignment of Road is decided in such a way that 1) Gradient doesn't become excessive
2) There shouldn't be any drainage problem in the sagging portion of the curve
3) As far as possible cutting should be equal to filling.
4) sufficient sight distance is available at every point of the curve.
5) Aesthetic

Types of longitudnal Gradient :-

(i) **Ruling Gradient** :- It is the Max. design gradient upto which a designer attempts to design the vertical profile of the Road. It is taken as the Gradient on which, with it's Max. pulling power, a vehicle is able to maintain a constant speed over a long streach.

(ii) **Limiting Gradient** :- It is adopted when Ruling Gradient leads to enormous increase in cost. it will be steeper than Ruling Gradient but the streach Gradient should be limited (as short as possible) and it should be sandwiched b/w flatter Gradients. (or level grades)

(iii) **Exceptional Gradient** :- It is very steep Gradient but the strech should not exceed 100 m. on both sides of exceptional Gradient there should be milder Gradients for a Minimum length of 100 m.

IRC Recomendations :-

Terrain		Ruling	Limiting	exceptional
Plain/Rolling	→	3.33% (1/30)	5% (1/20)	6.67% (1/15)
Mountaneous/steep	→	5%	6%	7%

for objective. *

* hydraulic Gradient = $\sqrt{L^2+C^2}$
* To avoid erosion slop of camber $\geq$ $\frac{\text{slop of longitudnal gradient}}{2}$

NOTE Minimum longitudnal Gradient However is provided for drainage purpose

for example → open soil drains → 1/200

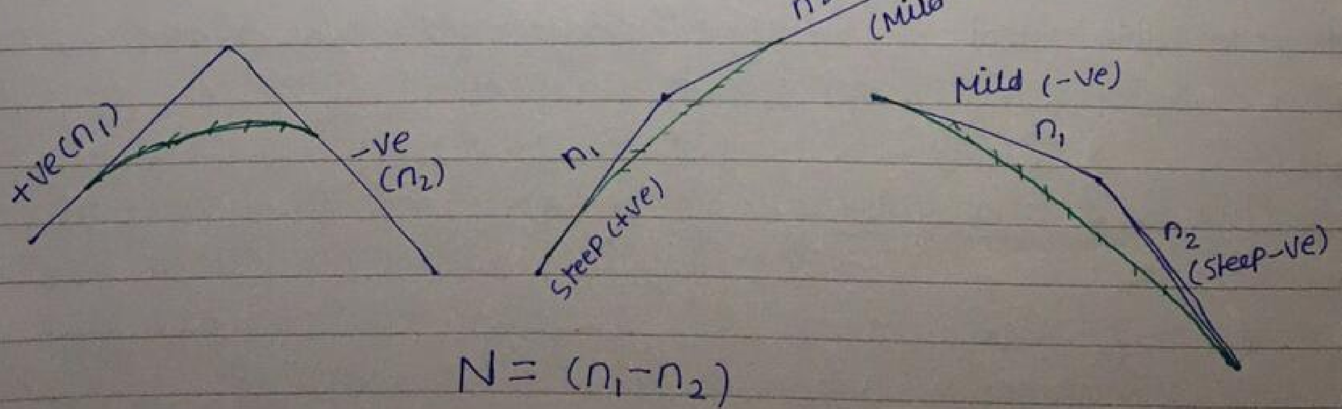
concrete drains → 1/500

Exception → level Grades can be provided on Fill section.

Critical Length of Grade :- It is the length in which a truck can move without it's speed reducing by more than 25 Kmph.

SUMMIT CURVE / CREST CURVE

It is a curve with convexity upward



$N = (n_1 - n_2)$

In case of summit curve centrifugal force does not creates discomfert hence it is not designed for rate of change of centrifugal acceleration and it only designed for sight distance criteria. From sight distance criteria the ideally suited curve would be circular since the circular curve has equal sight distances from all points. However IRC recommends the use of square parabola for the design of summit curve due to following reasons:-

(i) calculation is easier

ii) Rate of change of Grade is constant ⇓

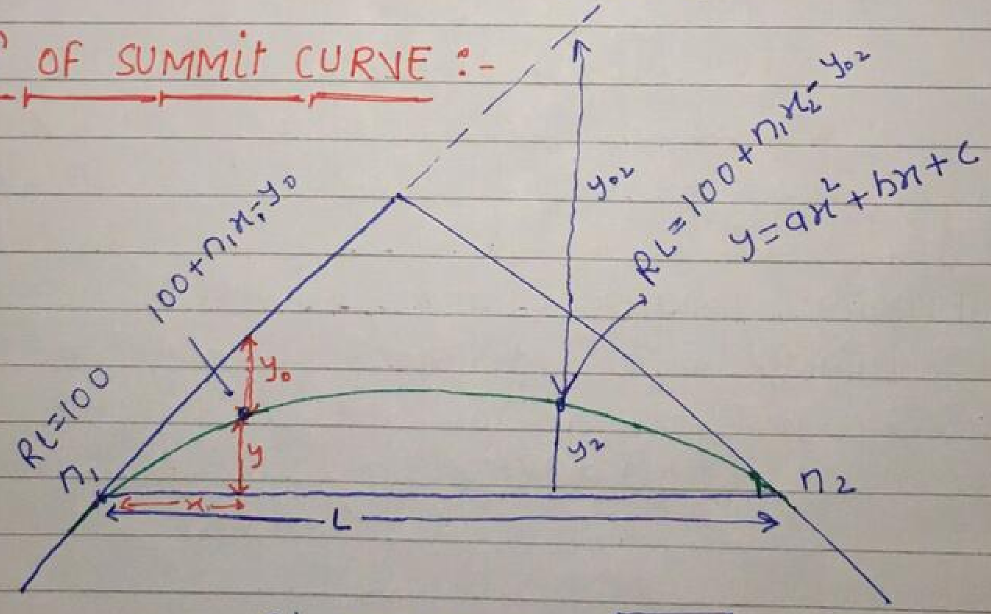
iii) The top portion of parabolic curve is flatter providing Greater sight distance.

$$Y = ax^2 + bx + c$$

$$\frac{dy}{dx} = 2ax + b$$

$$\frac{d}{dx}\left(\frac{dy}{dx}\right) = 2a$$

EQ^n OF SUMMIT CURVE :-



At $x=0, y=0 \Rightarrow \boxed{c=0}$

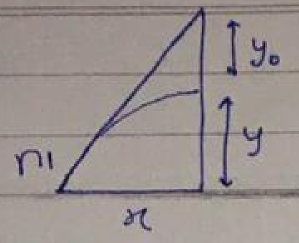
At $x=0, \frac{dy}{dx} = n_1 \Rightarrow \boxed{b=n_1}$

At $x=L, \frac{dy}{dx} = n_2 \Rightarrow a = \frac{-(n_1-n_2)}{2L}$

$$\boxed{a = \frac{-N}{2L}}$$

$$\boxed{Y = \frac{-N}{2L}x^2 + n_1 x}$$

Scanned with CamScanner



$$n_1 = \frac{(y_0 + y)}{x}$$

$$\boxed{y_0 = n_1 x - y}$$

Min. Radius

$$\text{curvature}\left(\frac{1}{R}\right) = \frac{d^2y/dx^2}{\left\{1 + \left(\frac{dy}{dx}\right)^2\right\}^{3/2}}$$

At max. curvature

$$\left(\frac{1}{R_{min}}\right), \quad \frac{dy}{dx} = 0$$

$$\frac{1}{R_{min}} = \frac{d^2y}{dx^2} = 2a$$

$$\frac{1}{R_{min}} = \frac{-N}{L}$$

$$\boxed{|R_{min}| = L/N}$$

Highest point's location on summit curve:-

@ Highest point $\frac{dy}{dx} = 0$

$$2ax + b = 0$$

$$-\frac{N}{L}x + n_1 = 0$$

$$\boxed{x_0 = \frac{n_1 L}{N}} \quad \text{From } 1^{st} \text{ tangent point}$$

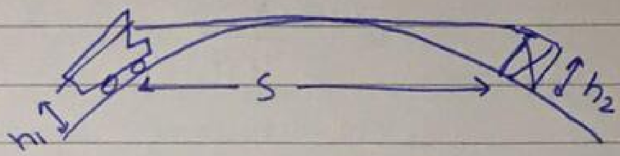
objective

* When the two grades are equal curve will be symmetrical about the verticle bisector and the highest point will lie on this bisector

* in case of unequal grades the highes point will lie on the side of flatter gradient

LENGTH OF CURVE :-

	h_1	h_2
SSD	1.2 m	0.15 m
OSD	1.2 m	1.2 m



case (i) When length of curve L > sight distance S

$$L = \frac{NS^2}{2(\sqrt{h_1}+\sqrt{h_2})^2}$$

case (ii) When length of curve L < sight distance S

$$L = 2S - \frac{2(\sqrt{h_1}+\sqrt{h_2})^2}{N}$$

$$2(\sqrt{h_1}+\sqrt{h_2})^2 = 4.4 \text{ for SSD}$$

$$= 9.6 \text{ For OSD/ISD}$$

NOTE: if the length requirement works out to be -ve it means that there is no sight distance restriction and in that case we simply smooth out the kink by providing a Nominal length.

IRC Recommendation

speed	Max. grade change in % (N) not requiring curve	curve length
80	0.6	50 m
100	0.5	60 m

Que. calculate the length of summit curve for an SSD of 180 m when the upgradient is 1/200 and the downgradient is also 1/200

Assuming $L > S$

$$L = \frac{NS^2}{4.4} = \frac{\left(\frac{1}{200} - \left(-\frac{1}{200}\right)\right)}{4.4} \times 180^2 = 73.63 m$$

$\not> 180$ hence unacceptable

Assume $L < S$

$$L = 2S - \frac{4.4}{N} = 2 \times 180 - \frac{4.4}{\frac{1}{200} - \left(-\frac{1}{200}\right)}$$

$$= -80 m.$$

Hence No restriction of sight so We'll provide length of the curve as 60 m to smooth out the kink

Que. Design a summit curve for a NH for SSD = 180m when $n_1 = 1/50$, $n_2 = -1/30$. set out the curve with a ~~curve~~ chord length of 25 m and also find the reduced level of the highest point on curve when R.L of First tangent point is 100 m.

$$n_1 = 1/50 \qquad n_2 = -1/30$$

$$N = n_1 - n_2 = 4/75$$

assume $L > S$

$$L = \frac{NS^2}{4.4} = \frac{4/75 \times 180^2}{4.4} = 392.73 m > SSD$$

acceptable

location of highest point = $(x_0) = \frac{n_1 L}{N} = \frac{1/50 \times 392.73}{4/75}$

$$= 147.28 m$$

$$RL\Big|_{x=x_0} = 100 + n_1 x\Big|_{x=x_0} - y_0\Big|_{x=x_0}$$

$$RL|_{x=x_0} = 100 + \frac{1}{50} \times 147.28 - \frac{N}{2L} x^2 |_{x=x_0}$$

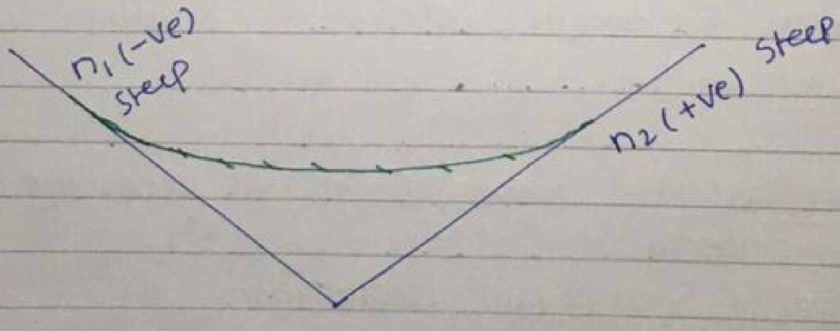
$$= 100 + \frac{147.28}{50} - \frac{4/75 \times 147.28^2}{2 \times 392.73}$$

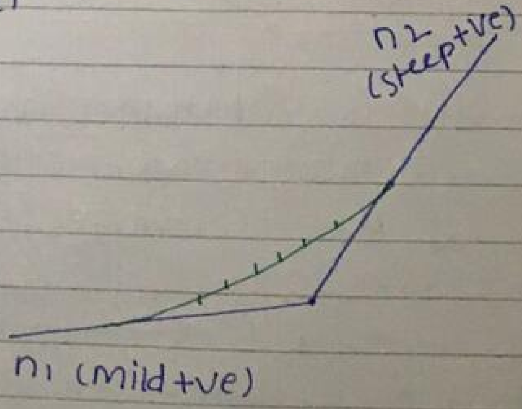
$$= 101.47 \text{ m.}$$

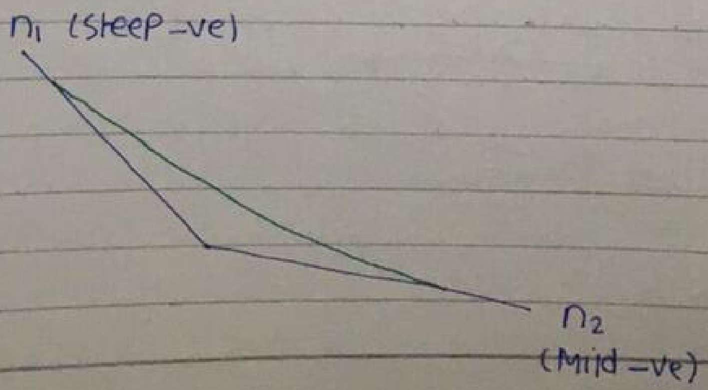
x	$y_0 = \frac{Nx^2}{2L}$	$RL = 100 + n_1 x - Nx^2/2L$
0	0	100
25	0.042	100.458
50	0.164	100.834
⋮	⋮	⋮
392.73	⋮	⋮

VALLEY CURVE or SAG CURVE :-

It is a curve with concavity upward $\quad N = |n_1 - n_2|$







There is no restriction of sight distance on Vally curve during day time. However visibility is reduced under No lighting condition at Night. Visibility at Night is only under Headlight sight distance. Hence Valley curves are designed for Headlight sight distance (Min Value of HSD is taken as SSD)

NOTE There is no problem of overtaking even during Night because of the headlights of the Vehicle coming from opposite lane and the rear lights of the vehicle to be overtaken.

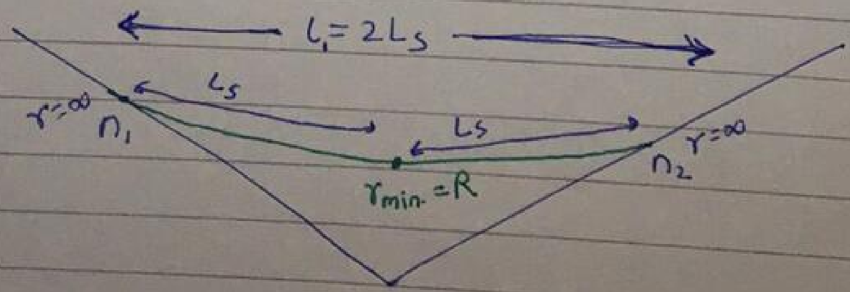
In case of valley curves centrifugal force will be exerted in downward dir^n along with the weight of the vehicle Hence the impact on the vehicle is more. Therefore Rate of change of centrifugal acceleration is also considered in design.

Drainage is also a design criteria for valley curves

LENGTH OF curve :-

It is calculated as the Max. of length from the following two criterias.

i) Rate of change of centrifugal acceleration.



Let c be the rate of change of centrifugal acceleration

$$c = \frac{\frac{v^2}{R} - 0}{t} \Rightarrow c = \frac{v^2/R}{L_s/v} = \frac{v^3}{L_s R}$$

$$c = \frac{v^3}{L_s R} \quad \text{--- (1)}$$

For spiral curves we've $\left\{ R = \frac{L_s}{N} \right.$ --- (2)

from (1) & (2)

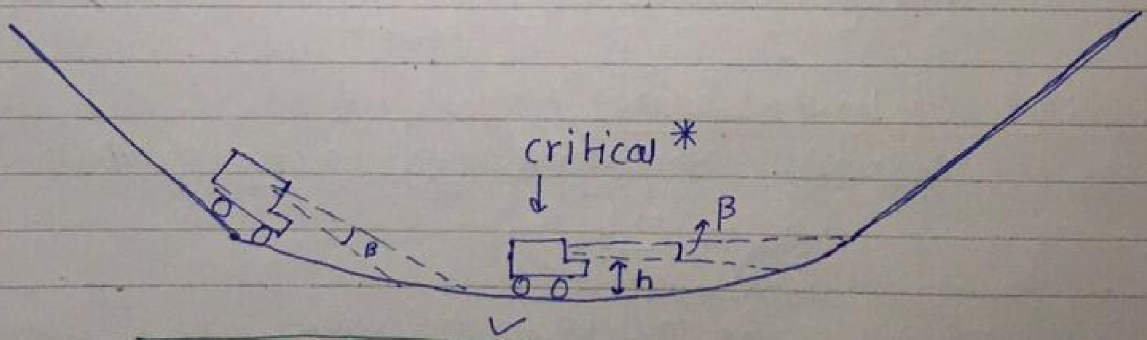
$$c = \frac{v^3 N}{L_s^2} \Rightarrow L_s = \sqrt{\frac{N v^3}{c}}$$

Hence length of curve $\boxed{L_1 = 2\sqrt{\frac{N v^3}{c}}}$ $\quad c = 0.6\, m/s^3$ (IRC)

(ii) sight distance criteria (s = HSD)

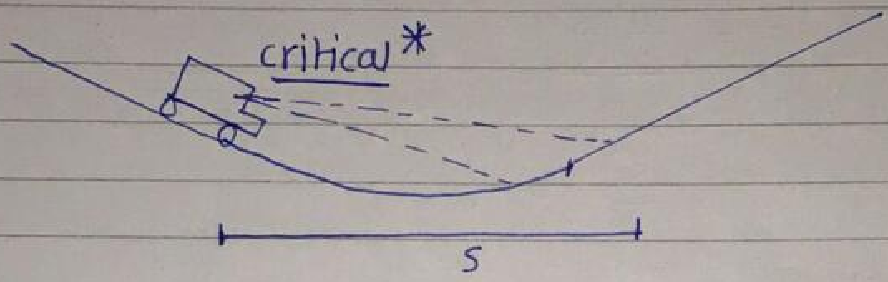
Case(i) When length of curve $L_2 > S$

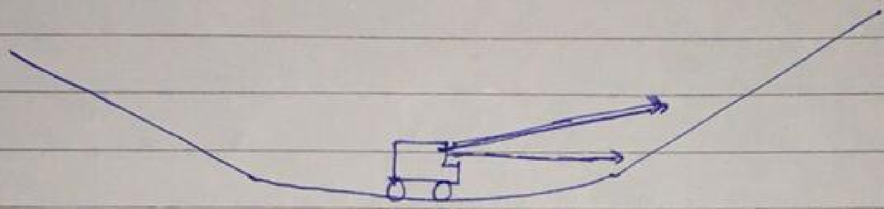
The critical position of veh. is taken at the bottom of the curve!



$$\boxed{L_2 = \frac{N S^2}{2(h + s\tan\beta)}}$$

case-(ii) When length of curve $L_2 < S$





In this case the critical position of veh. is taken at the top of the Road.

$$L_2 = 2S - \frac{2(h + S\tan\beta)}{N}$$

S → sight distance (HSD)
h → height of headlight above Road surface (0.75m IRC)
β → Beam Angle (1° as per IRC)

length of curve L = Max. (L_1, L_2)

Location of lowest point :-

case (i) Assuming the curve to be square parabola

$$x_0 = \frac{n_1 L}{N}$$

where x_0 is the loc^n of lowest point from 1st tangent point
n_1 → initial curve

case (ii) Assuming the curve to be cubic parabola

$$x_0 = L\sqrt{\frac{n}{2N}}$$

x_0 → loc^n of lowest point from tangent point on the flatter gradient
n → flatter gradient

***

* Valley curve is generally designed as 'cubic parabola'
However IRC recommends 'square parabola'

Que: Valley curve of a straight highway is formed by a descending gradient of 1/20 and ascending gradient of 1/30, Design speed = 80 KMPH. Calculate the length of curve? (Make suitable Assumptions)

$V = 80\ \text{kmph}$

$v = \frac{80 \times 5}{18} = 22.22\ \text{m/s}$

$N = \left| -\frac{1}{20} - \frac{1}{30} \right| = \frac{1}{12}$

$S = HSD \cong SSD = v t_r + \frac{v^2}{2g\mu}$

$= 22.22 \times 2.5 + \frac{(22.22)^2}{2 \times 9.81 \times 0.35}$

$= 127.5 \cong 128\ m$

Assume $L > S$

$L_2 = \frac{NS^2}{2(h + S \tan\beta)} = \frac{1/12 \times (128)^2}{2(0.75 + 128 \tan 1^\circ)}$

$L_2 = 228.75\ m.$

$L_1 = 2\sqrt{\frac{Nv^3}{C}} = 2\sqrt{\frac{1/12 \times (22.22)^3}{0.6}}$

$L_1 = 78.08\ m$

Hence $L = \max.(L_1 \& L_2)$

$L = 228.75\ m.$