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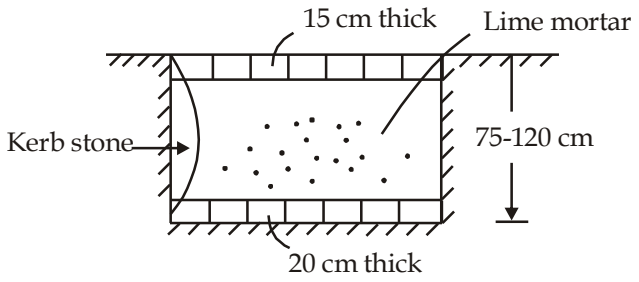
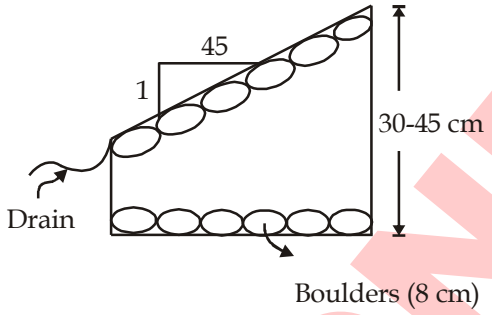
CHAPTER - 1
(INTRODUCTION OF HIGHWAY)

1. Roman Road:-



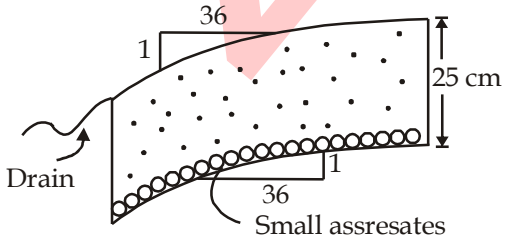
→ No cross slope/Camber
→ Boulder's at top and bottom
→ No side drain
→ High thickness of Pavement

2. Trasasuet and Telford:-



→ Cross slope 1V: 45H
→ Boulder's at top and bottom
→ Side drain provided
→ High thickness

3. Macadam construction:-



→ Cross slope 1V: 36H
(start from the subgrade)
→ Macadam said that superior quality material should be provided at top surface and inferior quality material can be provided at bottom layer.
→ Side drain provided

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→ In 1927 a committe was established with "Jay kar" known as Jay Kar committe.

Recommendation:-

→ Road development should be deal as a National issue.

→ Extra tax should be leaved on petrol and diesel for

→ A techanical body should be formed to be work as a advisory body for road development.
Result → Indian Road Congress (IRC-1934)

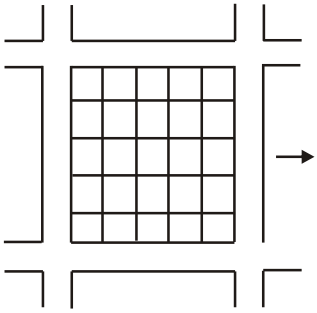
→ A research institute should be developed to take care of research developments in road.
Result → Central Road Research Institute (CRRI-1950)

Road Plans:-

	Ist	IInd	IIIrd
Year	(1943-1961)	(1961-1981)	(1981-2001)
Venue	Nagpur	Bombay	Lucknow
Target Density	16 km/100 km^2	32 km/100 km^2	82 km/100 km^2
Total Length	5.29 lakh km	10.57 lakh km	27.02 lakh km
Road categories	NH, SH, MDR, ODR, VR		Primary → Express way, NH Secondary → SH, MDR Tertiary → ODR, VR
Other category		• 1600 km express way • Connect areas with population more than 2000 by MDR	• Connect areas with population more than 15000 by MDR and areas with population 1000-1500 by ODR • 2000 km express way

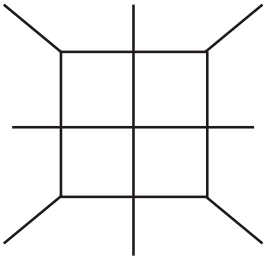
Road Patterns:-

1. Rectangular & Block Pattern:-



→ Chandigarh

2. Star and Block Pattern:-



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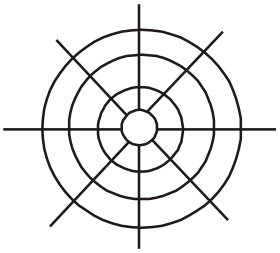
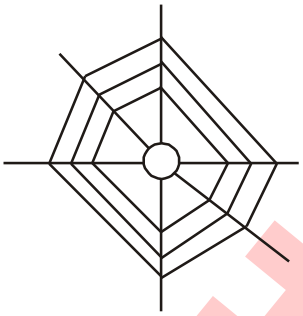
3. Star and Circular:-



→ Cannought Place
New Delhi

Note:- Motor vehicle Act-1939
Highway Research Board-1973
National Highway Act-1956

4. Star and Grid Pattern:-



→ Nagpur Road Plan

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CHAPTER - 2
(GEOMETRIC DESIGN OF HIGHWAY)

1. Terrain/Topography:-

Terrain	Cross slope/Country slope
Plain	0-10%
Rolling	10-25%
Mountaneous	25-60%
Steep	> 60%

Hilly Terrain

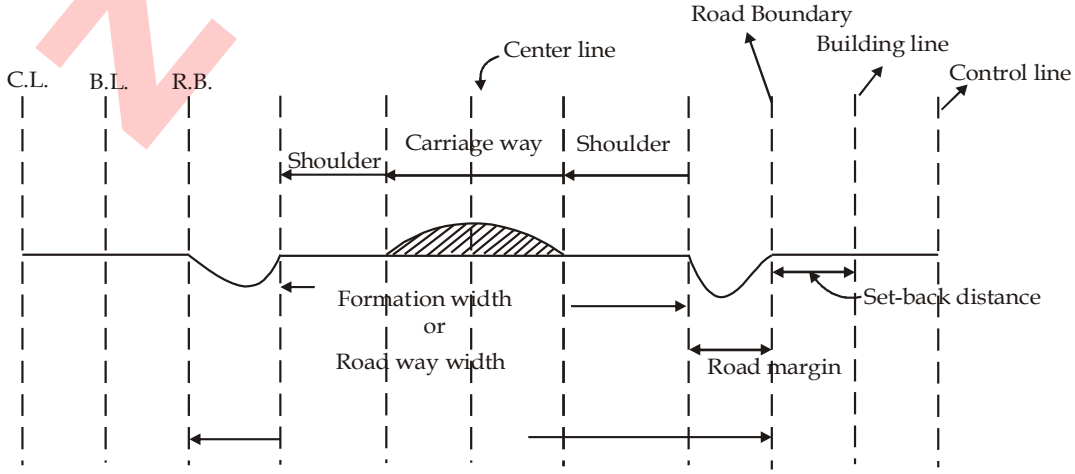
2. Design Speed:-

Terrain	For Design speed/ Maximum speed	NH/SH (km/hr) min.
Plain	100	80
Rolling	80	65
Mountaneous	50	40
Steep	40	30

Depend upon:-

→ Terrain
→ Class of Road
→ For Express ways Ruling speed can be increased (120 km/hr).
→ **Minimum speed:-** If at any section of road we cannot provide ruling speed. (Ex:- Sharp curves)

(a) Highway - Cross section Element:-



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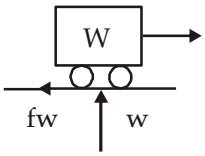
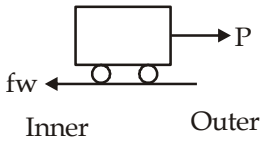
(b) Shoulder:- Required in Emergency stoping of vehicle:
→ Minimum width 2.5 m
→ Desirable it 4.64 m
(c) Formation width:- Carriage way + Shoulder + Shoulder + Median/Divider
(d) Road margin:- Required for future widening of road.
Consist:- Footpath + Cycle Track + Drain
(e) Land width:- Land required for road along its alignment.
(f) Set back difference:- We have to buy this land also.
For Plain Terrain/For NH & SH:-
B.L to B.L → 80 m
C.L to C.L → 150 m
Land width → 30 m - 60 m (Range)
45 m (Average)
Pavement Surface characteristics:-

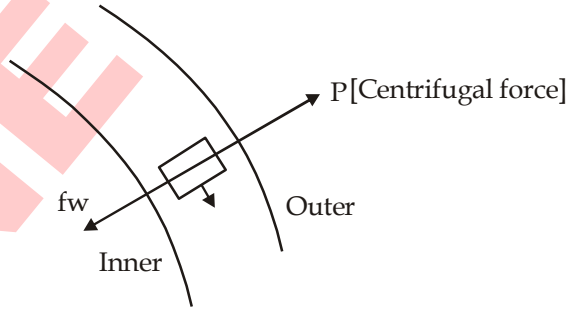
1. Friction:-

Longitudinal Friction:-



→ As per IRC - [$f_{Long} = 0.35$ to 0.4]
→ Speed (v)↑ → f(↓) → [speed ≥ 80 km/hr, For f = 0.35]





∵ ($f = F_{Lateral}$)
→ As per IRC - [$f_{Lateral} = 0.15$]

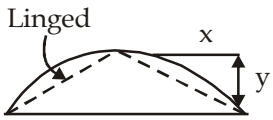
2. Pavement Un-Evenness:-

→ It is the cumulative measure of vertical undulations of the pavement surface per unit length (horizontal length) of road.
< 150 cm/km → Good
< 250 cm/km → Satisfactory (upto 100 km/hr)
> 320 cm/km → Unsatisfactory (Even for 50 km/hr)
→ Unevenness (↑) → Comfort (↓), fuel consumption (↑) wear and tear (↑), speed (↓)
→ It is measured by:- Bump integrator, Roughometer

3. Camber/Cross slope:-

→ Camber is provided to drain the rainwater from the road surface.
→ It is provided in transverse direction.
→ Camber boards are used to provide camber.

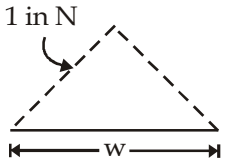
(a) Parabola:-



$$\left[y = \frac{2x^2}{Nw}\right], \left[y_{max} = \frac{w}{2N}\right]$$

→ Used for fast moving vehicles (For overtaking operation on two-lane highway) because at crown slope decreases.

(b) Straight line Camber:-

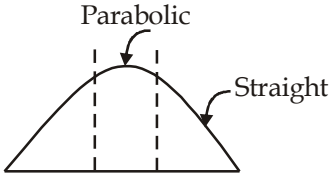


$$\left[y_{max} = \frac{w}{2N}\right]$$

→ Used in Rigid & thick Bitumin pavements.

→ On two lane highway it's not satisfactory for overtaking purpose. (Uncomfortable)

(c) Combined Camber:-



→ Commonly used in High Speed Roads.

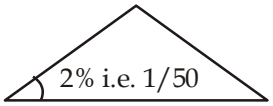
→ Both for slow and fast moving vehicles.

Camber depends upon:-

→ Type of surface of road

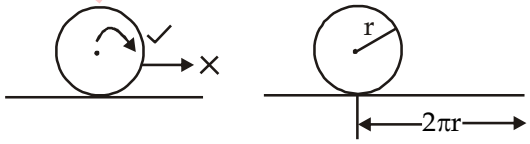
→ Rainfall

Road Type	Light Rainfall	Heavy Rainfall
Concrete road/ Thick bitumen road	1.7% (1/60)	2% (1/50)
Thin bitumen road	2% (1/50)	2.5% (1/40)
WBM Gravel Road	2.5% (1/40)	3%(1/33)
Earth Road	3% (1/33)	4% (1/25)

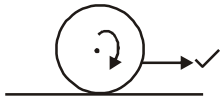


than slope of Pavement and minimum should be 3% for unpaved shoulder.
Roughness of shoulder is generally kept higher than roughness of carriage way.

Slip:- Rotational Movement > Longitudinal movement.



Skid:-



Longitudinal > Rotational Movement.

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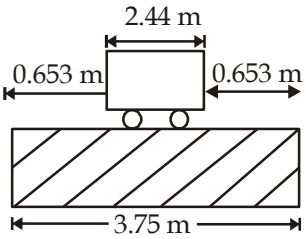
→ Slip occurs when movement on sand or suddenly accelerate the vehicle.
→ Skid occurs when brakes are applied.

Single lane - 3.75 m
Two lane, No kerb - 7.0 m
Two lane, kerb - 7.5 m
Intermediate lane - 5.5 m
Multilane - 3.5 m/lane

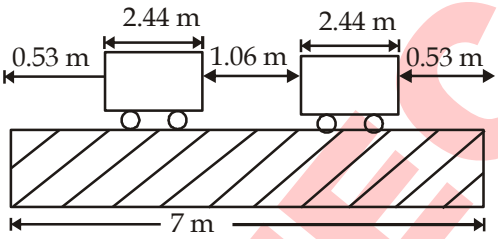
→ Predicated traffic volume and design traffic volume for each lane.

→ As per IRC Maximum width of vehicle =2.44 m

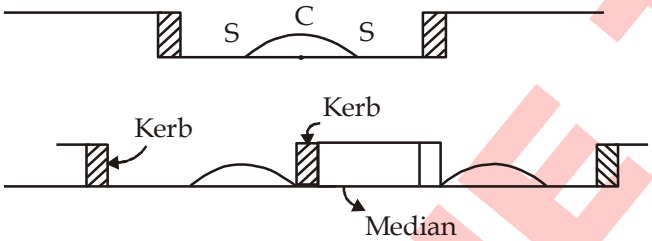
Single lane:-



Two lane:-

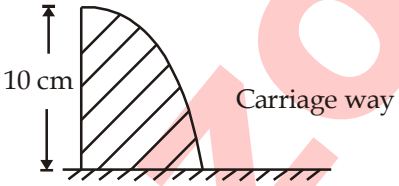


Kerb:-



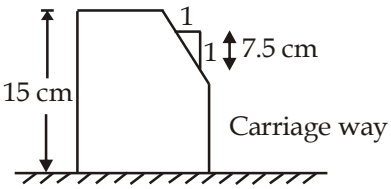
→ Kerb is the boundary between footpath, median and Pavement.
→ It also serve the purpose of drain.

(i) Low Mountaneous (Ist)



Ist

(ii) Semi-Barrier (IInd)



IInd

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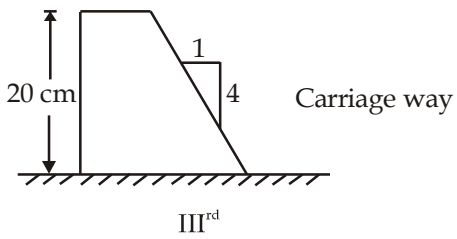
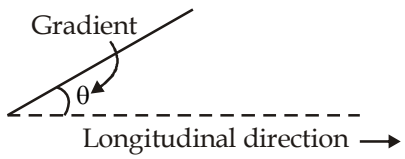
(iii) Barrier (IIIrd)



Low Mountaneous	Semi Barrier	Barrier
•Used in median.	•Vehicle can climb very difficultly.	•Vehicle can't climb.
•Vehicle can climb easily.	•Used in footpath where padestrain volume is low.	•Used where volume on footpath is high.

Gradient:-



→ It is the slope along the length of the road.
→ Gradient depend upon the type of terrain.
There are three types of Gradient:-

1. **Ruling Gradient:-**
→ It is the maximum design gradient which designer can provide under general conditions.
→ With this gradient ruling speed can be achieved.

2. **Limiting Gradient:-**
→ More than ruling gradient.
→ It is provided when colt factor is there.
→ With this gradient minimum speed can be achieved.

3. **Exceptional Gradient:-**
→ More than limiting gradient.
→ Provided at unavoidable conditions.
→ Speed of vehicle becomes very less.
→ This gradient should not be provided for a strech/horizontal length of more than 100 m.

Minimum Gradient:-
→ Less than ruling gradient.
→ Provided to drain away the water.
→ For concrete drain = 1/500
→ For inferior surface = 1/200

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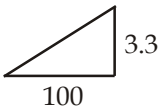
Terrain	Ruling	Limiting	Exceptional
Plain and Rolling	1/30 (3.3%)	1/20 (5%)	1/15 (6.7%)
Mountaneous	1/20 (5%)	1/16.7 (6%)	1/14.3 (7%)
Steep	1/16.7 (6%)	1/14.3 (7%)	1/12.5 (8%)



$\tan\theta = \frac{3.3}{100}$

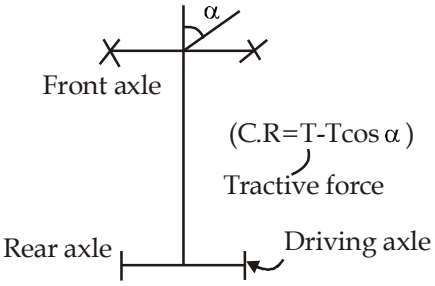
Imperical formula:-

Gradient = 2 × Camber

G = 2C

When driving axle is front

then C.R = 0



Grade Compensation:-

→ Reduction in gradient on horizontal curve is known as grade compensation.

→ Grade compensation is required because of curve resistance on horizontal curve.

$$\text{G.C.} = \text{minimum of} \begin{cases} \frac{30+R}{R} \\ \frac{75}{R} \end{cases}$$

Radius of curve

→ If gradient is less than equal 4% then no need of grade compensation.

Compensated Gradient:-

→ Gradient to be provided on horizontal curve.

C.G = Gradient of straight - Grade compensation highway.

Sight Distance:-

It is the distance upto which clear visibility is present at every section of highway.

Type of sight distance:-

1. Stopping Sight Distance (SSD) → Non-passing sight distance.
2. Overtaking Sight Distance (OSD)
3. Intermediate Sight Distance (ISD) → (ISD = 2SSD)

1. **Stopping Sight Distance (SSD):-**

It is the minimum sight distance available on road upto which a vehicle will stop which moving at a particular speed.

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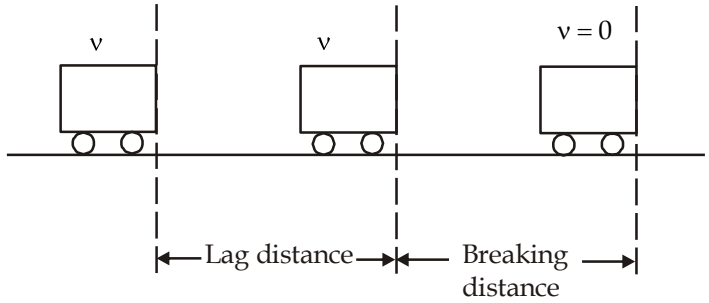


[SSD = Lag distance + Breaking distance]

Lag distance - $= v.t_R$

$= 0.278\ v\,t_R$ $[v = 0.278V]$

where t_R = Reaction time (≈ 2.5 sec)

v = Design speed

→ Lag distance is the distance travelled by vehicle in reaction time.

→ Reaction time is generally explained by PIEV Theory:-

(i) **Perception:-**

→ Time required to send signals from eye to brain.

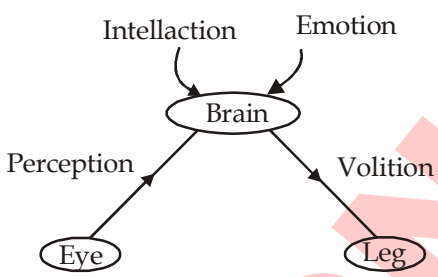
(ii) Intellaction:-

→ Time required to consider different thoughts.

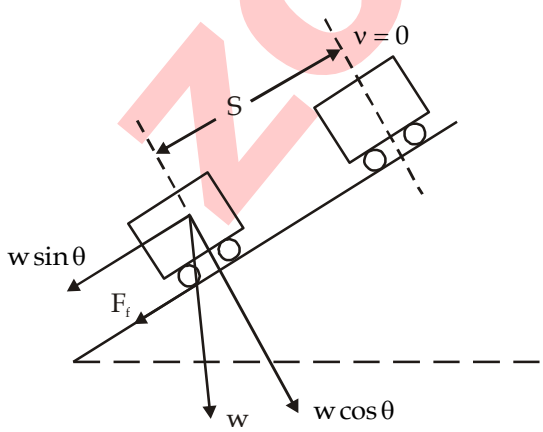
→ Time required to take final decision.

4. **Volition:-**

→ Time required to send signal from brain to leg.



Breaking Distance:-



$F_f = f_{long.} \times W\cos\theta$

By Work-Energy Theorem:-

$$\frac{1}{2} m v^2 - 0 = (F_f + w\sin\theta) \times S$$

$$\frac{1}{2} m v^2 = [f\, mg\cos\theta + mg\sin\theta]\, S$$

$$\frac{1}{2} v^2 = \{g\cos\theta\,[f + \tan\theta]\}S \qquad \begin{cases} \because \tan\theta \simeq G \\ \because \theta \text{ is less, hence } \cos\theta \simeq 1 \end{cases}$$

$$\frac{1}{2} v^2 = g[f + G]S$$

$$S = \frac{v^2}{2g(f+G)} = \frac{v^2}{2g(f \pm G)} \leftarrow \text{Breaking Distance}$$

where $+ \rightarrow$ Up the grade
$- \rightarrow$ Down the grade

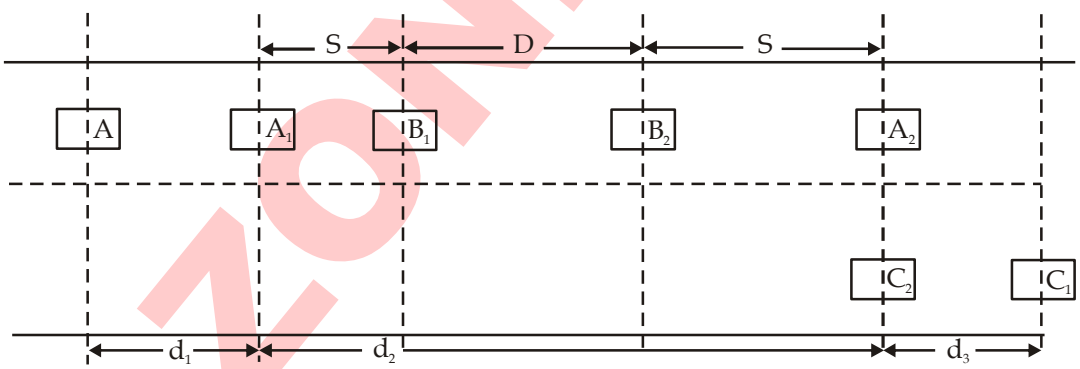
Stopping sight distance:-

$$\left[\text{SSD (In meter)} = 0.278\, v t_R + \frac{v^2}{254(f \pm G)}\right]$$

- Speed of vehicle
- Break efficiency
- Reaction time
- Gradient
- Friction

2. Overtaking Sight Distance (ISD):-

(i) One lane/One way traffic $\rightarrow$ (ISD = SSD)
(ii) One lane/Two way traffic $\rightarrow$ (ISD = 2 × SSD)
(iii) Two lane/Two way $\rightarrow$ (ISD = 2 × SSD)



$\rightarrow$ $d_1 = v_B t_R = 0.278\, v_B t_R$

where ($t_R = 2$ sec) $\quad [d_2 = 2S + v_B T]$

$\rightarrow$ $S = ut + \frac{1}{2} at^2 \quad [d_3 = 0.278VT] \quad V = \text{Design speed}$

$$d_2 = v_B T + \frac{1}{2} at^2 \qquad ....(i)$$

$$d_2 = 2S + D \qquad ....(ii)$$

$$D = v_B T$$

A → Overtaking vehicle
B → Overtaken vehicle
C → Vehicle coming from opposite side
T → Overtaking Time

→ In this time A move from A_1 to A_2 and B move from B_1 to B_2 and C move from C_1 to C_2.

→ $OSD = d_1 + d_2 + d_3$
One way → $d_1 + d_2$
Two way → $d_1 + d_2 + d_3$
Equation (1) = Equation (2)

$$v_B T + \frac{1}{2} a T^2 = 2S + v_B T$$

Space head way-

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

Emperical formula for S-

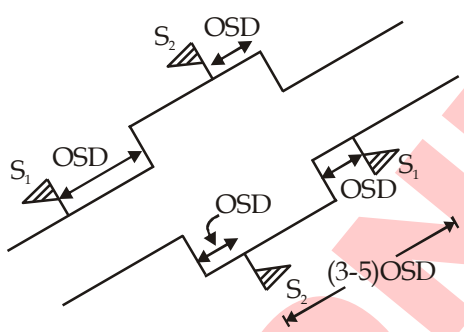
$[S = 0.2 v_B + l]$
l = length of vehicle
(6m if not given)

Note:-

→ If speed of overtaken vehicle is not given, then
$[V_B = (V\text{-}16)\text{km/hr}]$ provided and (ISD = 2 × SSD) may be provided.

→ IRC suggested that it's not necessary to provide OSD on four or more lane divided highways.

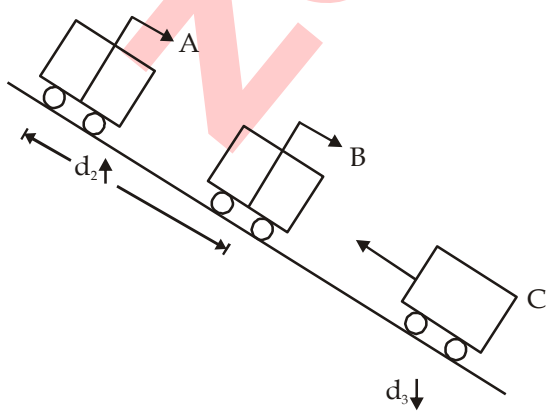
Overtaking Zone:-



Min → 3 × OSD
Desirable → 5 × OSD

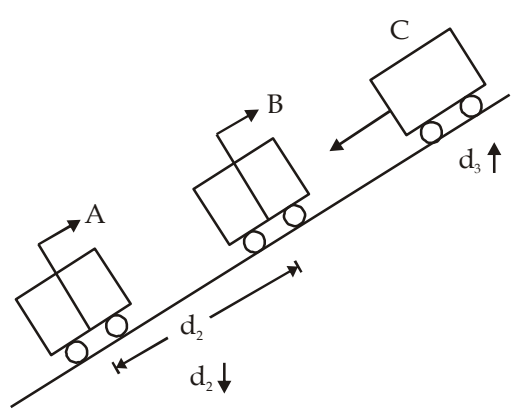
S_1 = Overtaking zone ahead, S_2 = Overtaking zone ended

Down Grade



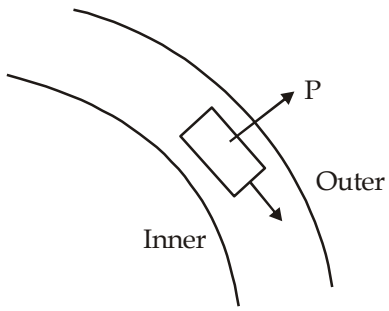
If C is considered:- OSD- No change

Up Grade

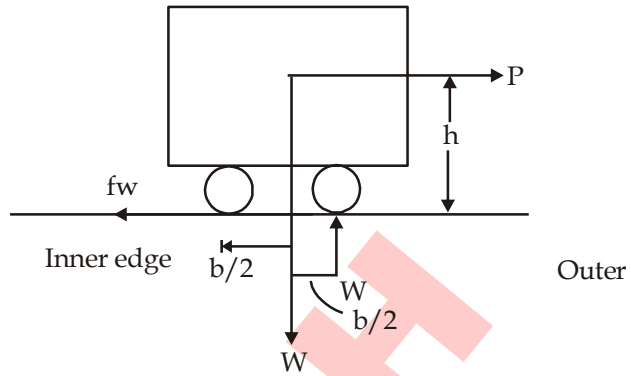


If C is considered:- OSD- No change

If C is not considered:- OSD↑



If C is not considered:- OSD↓



For safety against lateral skiding:- $fw \geq P \Rightarrow [f \geq P/w]$ $P/w = \text{Centrifugal Ratio/Impact factor}$

For safety against overturning:-

$$P.h \leq W \times b/2 \Rightarrow \left[\frac{P}{W} \leq \frac{b}{2h}\right]$$

$$\Rightarrow \left[\frac{P}{W} \not> \frac{b}{2h} \not> f\right] \quad \text{where } P \rightarrow \text{Centrifugal Force } \left(\frac{mv^2}{R}\right)$$

→ Horizontal cuves are provided to change the direction of alignment.

→ At the verge of overturning contact between inner tyre and road is lost. Hence normal reaction passes through outer wheel and overturning will be about outer wheel. This will increase the chance of road deteriation on outer side of curve.

→ Hence, to provide safety against overturning either increase 'b' or decrease 'h'.

$$\frac{P}{W} \not> \frac{b(\uparrow)}{2h(\downarrow)}$$

→ To increase safety in lateral skiding and over turning superelevation is provided.

<u>Case I:</u>- If $\frac{P}{W} \not> \frac{b}{2h}$ (Safe against overturning and lateral skiding)
$\not> f$

<u>Case II:</u>- If $\frac{P}{W} > \frac{b}{2h}$ (Not safe in over turning)
$\not> f$

<u>Case III:</u>- If $\frac{P}{W} \not> \frac{b}{2h}$ (Not safe in lateral skiding)
$> f$

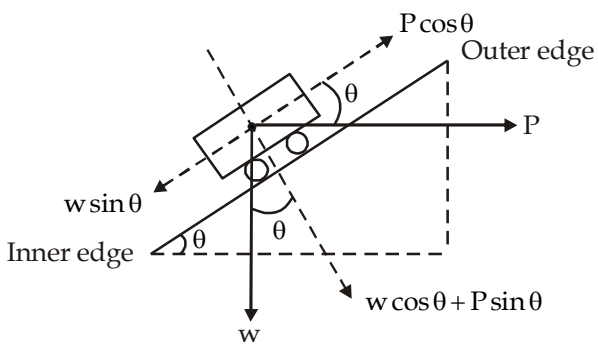
(a) If $\frac{b}{2h} > f$ (Not safe in lateral skiding first)

(b) If $f > \frac{b}{2h}$ (Not safe in over turning first)

(c) If $f = \frac{b}{2h}$ (Over turning dominate lateral skiding)

ZONE TECH

Super elevation/Cant/Angle of Banking:-



→ Raising of outer edge with respect to inner edge on horizontal curve is known as super elevation.
→ It is provided to counter act the effect of centrifugal force.

$F_f = f(w\cos\theta + P\sin\theta)$

$\because (\tan\theta = e)$

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

$$\frac{mv^2}{R}\cos\theta = mg\sin\theta + f\left(mg\cos\theta + \frac{mv^2}{R}\sin\theta\right)$$

$$\frac{v^2}{R} = g\tan\theta + f\left(g + \frac{v^2}{R}\tan\theta\right) = g\tan\theta + fg + \frac{fv^2}{R}\tan\theta$$

$$\frac{v^2}{R} = (1 - f\tan\theta) = g\tan\theta + fg$$

$(\because \tan\theta = e = \text{angle of super elevation})$

$$\frac{v^2}{R}(1 - ef) = g(e + f)$$

$(e_{max} = 0.1,\ f_{max} = 0.15,\ \text{so } 1 - ef \approx 1)$

$$\frac{v^2}{R} = g(e + f) \Rightarrow \qquad e + f = \frac{v^2}{9R} = \frac{(0.278v)^2}{9R}$$

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

e_{max} Value:-

Terrain	e_{max}
Plain and Rolling	7%
Mountaneous and steep	10%
Built up area	4%

Ruling minimum Radius:-

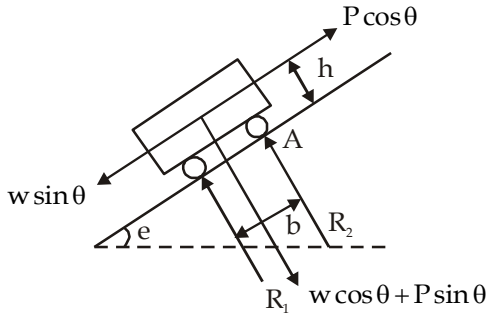
$$R_{Ruling\ min} = \frac{v_{max}^2}{127(e_{max} + f_{max})}$$

Absolute minimum Radius:-

$$R_{absolute\ min} = \frac{v_{min}^2}{127(e_{max} + f_{max})}$$

→ Ruling minimum Radius is the minimum radius required to balance ruling speed.
→ Absolute minimum radius is the minimum radius required to balance minimum speed.

Equilibrium Super Elevation:-



$$P\cos\theta = w\sin\theta \quad ....(i)$$

$$R_1 + R_2 = w\cos\theta + P\sin\theta \quad ....(ii)$$

Taking moment about A

$$(P\cos\theta - w\sin\theta)h + R_1.b - (w\cos\theta + P\sin\theta).b/2 = 0 \quad ....(iii)$$

$$(w\sin\theta - w\sin\theta)h + R_1.b - (w\cos\theta + P\sin\theta)b/2 = 0$$

$$2R_1 = (w\cos\theta + P\sin\theta) \quad ....(iv)$$

Equating Equation (ii) and (iv)

$$R_1 + R_2 = 2R_1$$

$$R_1 + R_2 = 2R_1 \Rightarrow (R_1 = R_2)$$

$$e_{eq.} = \frac{v^2}{127R}$$

→ Hence at equilibrium super elevation or balanced super elevation pressure on inner and outer tyre will be same.

1. As per IRC design is done for mixed traffic flow
So 75% of maximum speed is balanced by super elevation (and rest higher speed will be balance by lateral friction)

$$e_{design} = \frac{(0.75v)^2}{127R} = \frac{v^2}{225R}$$

If $e_{min} \le e_{design} \le e_{max}$ (ok)
If $e_{design} < e_{min}$ (Provide $e = e_{min}$)
If $e_{design} > e_{max}$ (Provide $e = e_{max}$)

2. If $e_{design} > e_{max}$, we have to check for lateral friction-

$$(e_{max} + f = \frac{v^2}{127R})$$

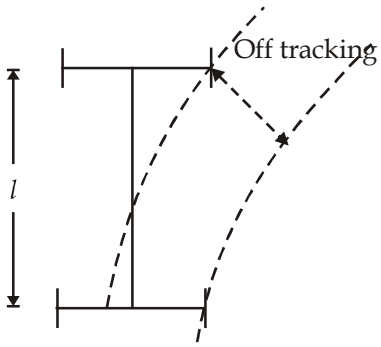
If $f \le f_{max}$ (ok)
If $f > f_{max}$ (Then either reduce the speed or increase the radius)

3. $V_{lim} = \sqrt{(e_{max} + f_{max})127R}$ and $R_{min} = \frac{v^2}{(e_{max} + f_{max})127}$

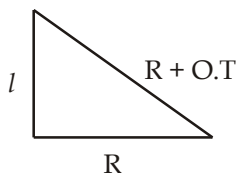
→ Equilibrium super elevation gives higher comfort but if vehicle moves with the speed less than design speed, then it skid or fall inward.

→ Therefore equilibrium super elevation is not possible in practise.

OFF-Tracking:-



→ It is the difference between radius of curve followed by front axle and radius of curve followed by rare axle when vehicle is moving on a curve.



$$(R + O.T)^2 = R^2 + l^2$$
$$R^2 + 0.T^2 + 2R(O.T) = R^2 + l^2$$

If we neglect $(O.T)^2$

$$O.T = \frac{nl^2}{2R}$$

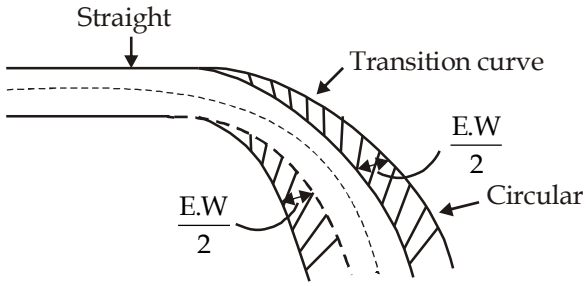
where l = length of wheel base
R = Radius of curve

→ Because of off-tracking on circular curves, the width of road has to be increased, this extra width is called as extra widening.

E.W = Mechanical E.W + Psychological E.W

$$E.W = \frac{nl^2}{2R} + \frac{v}{9.5\sqrt{R}}$$

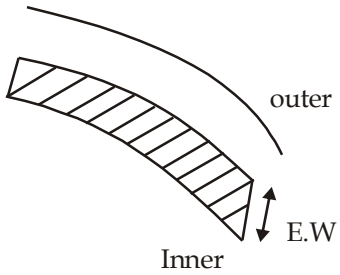
where n = number of cane
R = Radius of curve(meter)
V = Design speed on curve (km/hr)



ZONE TECH

Note:-

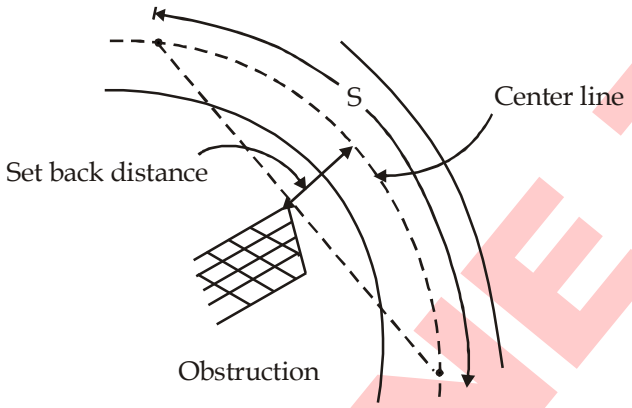
→ On hills or sharp curve (R ≤ 50 m) extra widening is provided fully inside.



→ In general conditions (R > 50 m) extra widening is provided equally on both inner and outer side.

→ As per IRC, if radius is greater than 300 m, no need to provide extra widening.

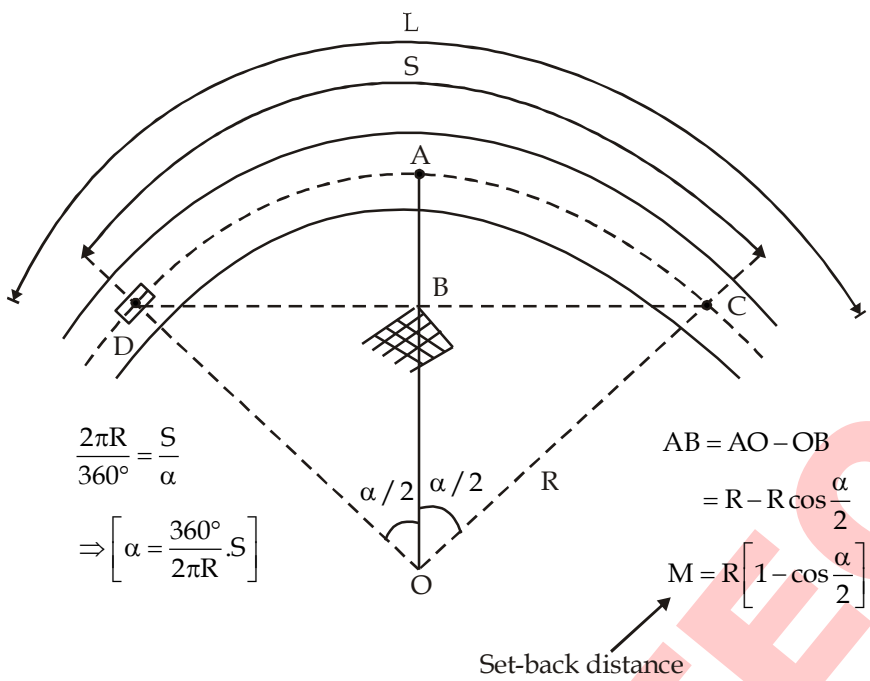
S = Sight distance
(OSD, ISD, SSD)



→ It is the transverse distance measured from the center line of road towards the inner side obstructions, so that clear visibility is present on the circular curve upto sight distance.

<u>Case I:-</u> One lane Road (L > S):-

ZONE TECH



$$\frac{2\pi R}{360^\circ} = \frac{S}{\alpha}$$

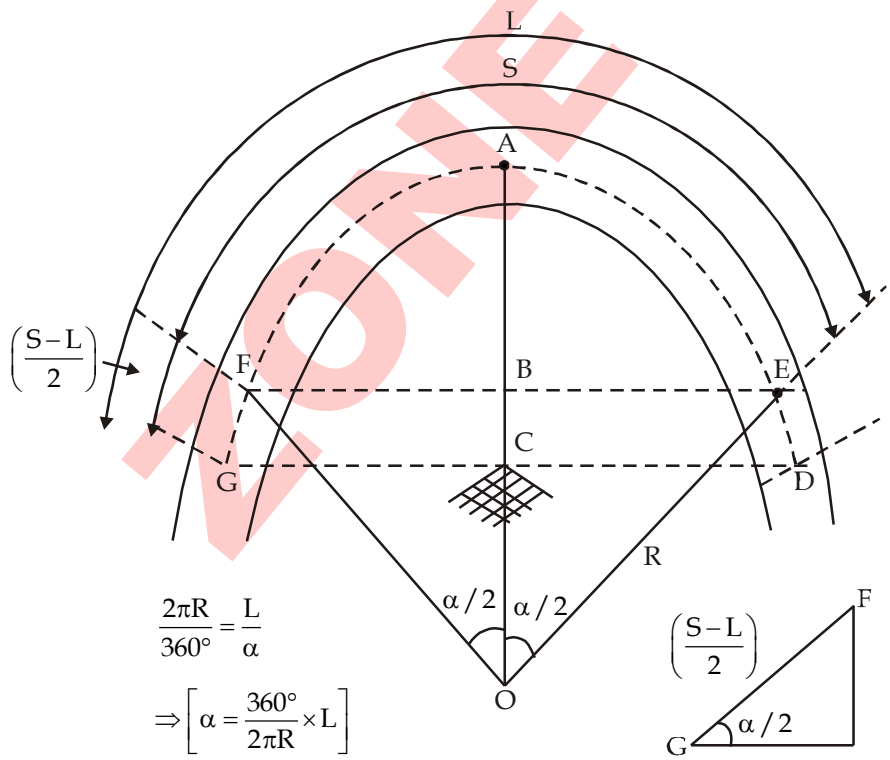
$$\Rightarrow \left[\alpha = \frac{360^\circ}{2\pi R}.S\right]$$

$$AB = AO - OB$$

$$= R - R\cos\frac{\alpha}{2}$$

$$M = R\left[1 - \cos\frac{\alpha}{2}\right]$$

<u>Case II:-</u> One lane Road (L < S):-



$$\left(\frac{S-L}{2}\right)$$

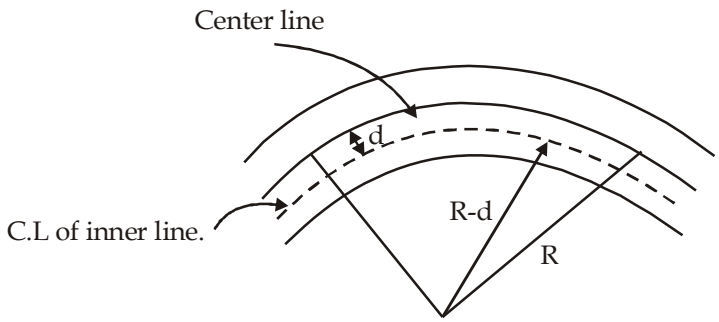
$$\frac{2\pi R}{360^\circ} = \frac{L}{\alpha}$$

$$\Rightarrow \left[\alpha = \frac{360^\circ}{2\pi R} \times L\right]$$

ZONE TECH

$$M = AC = (AO - BO) + BC = \left[R - R\cos\left(\frac{\alpha}{2}\right)\right] + \left(\frac{S-L}{2}\right)\sin\left(\frac{\alpha}{2}\right)$$

Case III:- Multi-lane Road (L > S):-



$$\left[\alpha = \frac{360°}{2\pi(R-d)} \times S\right]$$

$$\left[m' = (R-d) - (R-d)\cos\frac{\alpha}{2}\right]$$

m' is from center line of inner line

$$\left[m_{actual} = (m' + d)\right]$$

$$4d = W + E.W$$

$$\left[d = \frac{W + E.W}{2n}\right]$$

lane, then it will be definately available on outer lane. That's why we calculate set-back distance by considering required sight distance on center line of inner lane.

Case IV:- Multi lane Road (L < S):-

$$\left[\alpha = \frac{360°}{2\pi(R-d)} \times L\right]$$

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

This m' is from the center line of inner line.

$[M_{actual} = m' + d] \rightarrow$ m from center line of Road.

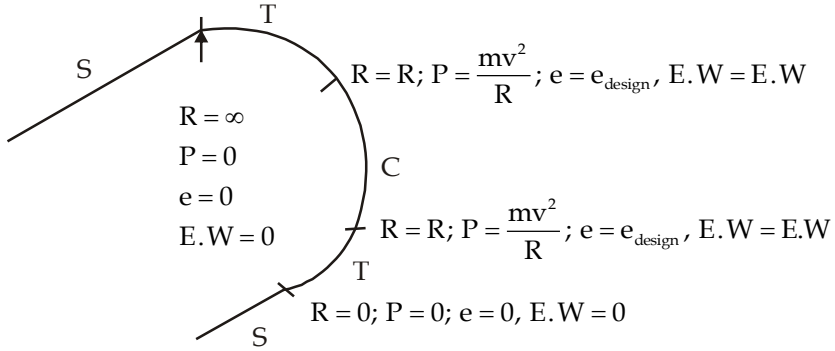
Transition Curve:-

It is introduced between straight line and circular curve.

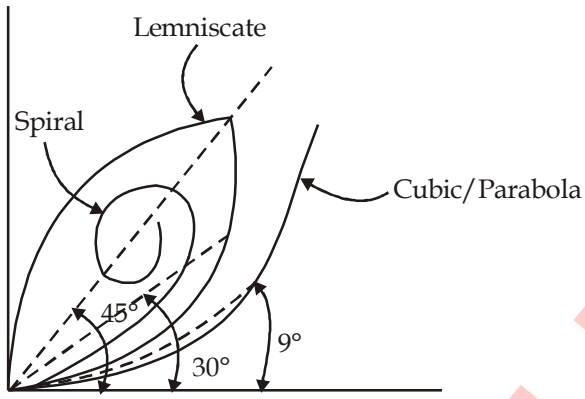
Purpose:-

→ To introduce gradually increased centrifugal force.

→ To introduce super elevation and extra widening gradually.



Types of transition curve:-



Same shape:-

→ For the spiral, clothoid the rate of change of radius is uniform throughout the length.

→ For Bernauli lemniscale the rate of change of radius is uniform upto 30° deflection angle and non-uniform beyond 30°.

→ For Cubic Parabola the rate of change of radius is uniform upto 9° deflection angle and beyond 9° rate is uniform but with high degree.

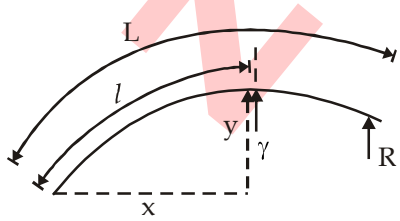
Note:-

→ As per IRC spiral or clothoid is the ideal shape of the transition curve.

→ In highways spiral or clothoid is used.

→ In railways cubic parabola is used.

1. **Clothoid:-**



$$l\gamma = \text{constant}$$

$$l\gamma = LR$$

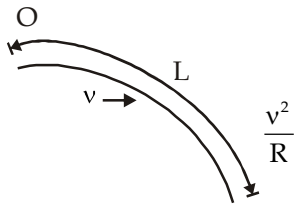
2. **Cubic spiral:-**

$$y = \frac{l^3}{6RL}$$

3. **Cubic Parabola:-**

$$y = \frac{x^3}{6RL}$$

Length of Transition curve:-



1. Rate of change of centrifugal acceleration:-

$$F = m \times a = \frac{mv^2}{\gamma}, \; a = \frac{v^2}{\gamma}$$

$C =$ Rate of change of centrifugal acceleration

$$C = \frac{\frac{v^2}{R} - 0}{t} = \frac{v^2}{Rt} = \frac{v^2}{R \times 1} \times v \Rightarrow \left[L = \frac{v^3}{CR}\right]$$

Emperical formula:- $\left[C = \overline{75 + V}\right]$ $V =$ kmph

2. On the basis of rate of application of super elevation:-

$\frac{1}{N} =$ Rate of application of super elevation

$\frac{1}{N} = \frac{1}{150}$ (Plain and Rolling area)

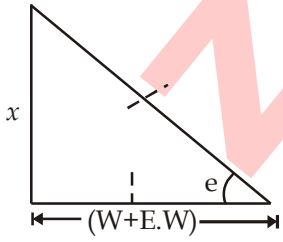
$\frac{1}{N} = \frac{1}{60}$ (Mountaneous and steep area)

$\frac{1}{N} = \frac{1}{100}$ (Built-up area)

$[L = N \times x]$

where $x =$ Raise of outer edge w.r. or to general ground level.

(a) Pavement rotated about inner edge:-



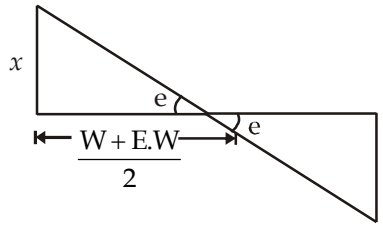
$x = (W + EW)e$

→ No drainage problem

→ Cut ≠ Fill

→ Center line/Vertical alignment changed

(b) When rotated about center line:-



$$x = \left(\frac{W + E.W}{2}\right)e$$

→ Drainage problem

→ Cut = Fill

→ Alignment not changed

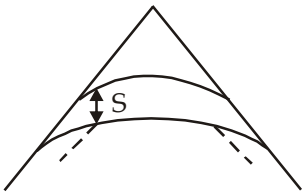
3. Emperical formula:- (Minimum length)

(i) $L = \frac{2.7v^2}{R}$ (Plain and Rolling)

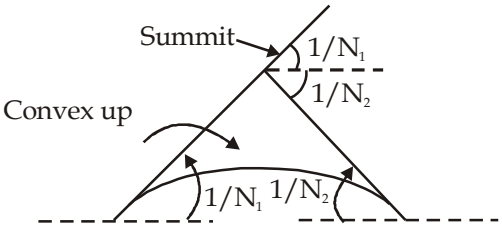
(ii) $L = \frac{v^2}{R}$ (Mountaneous and steep)

(iii) where $v \rightarrow$ kmph
$R \rightarrow$ meter

Vertical Curve:-



Vertical curves are of two types:-



1. **Summit curve:-**

→ Summit curves are convex upward.

→ At Summit curve centrifugal force will act against weight of vehicle, hence comfort is there. So there is no need to provide transition curve.

→ Parabolic curve is generally used as summit curve. It allows a comfortable transition from one end to other end.

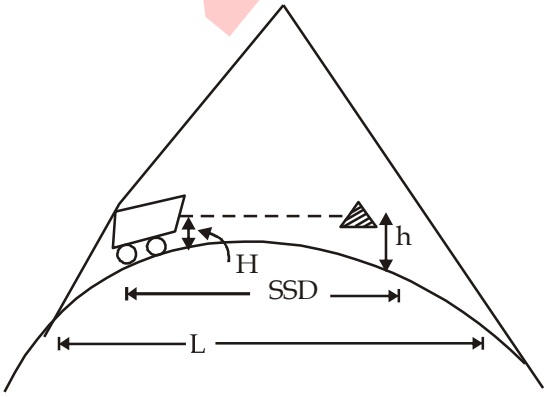
→ Equation used for summit curve:- $y = ax^2$

L = Length of Summit curve $\left[y = \frac{Nx^2}{2L}\right]$

Length of Summit curve:-

→ Since comfort is there on summit curve, hence we will calculate the length of summit curve on the basis of sight distance.

1. <u>When L > S:-</u>



As per IRC → Height of driver eye (H) = 1.2 m
Height of object = 0.15 m

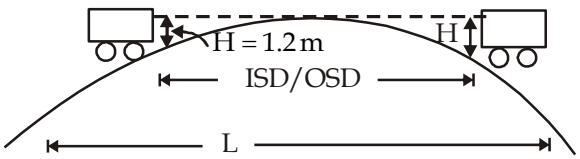
$$L = \frac{NS^2}{\left(\sqrt{2}H + \sqrt{2}h\right)^2} = \frac{NS^2}{4.4}$$

(S = SSD)

$$\left[L = \frac{NS}{\left(\sqrt{2}H + \sqrt{2}H\right)^2} = \frac{NS}{9.6}\right]$$

S = ISD/OSD

2. When L < S:-



(i) When L < SSD:-

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

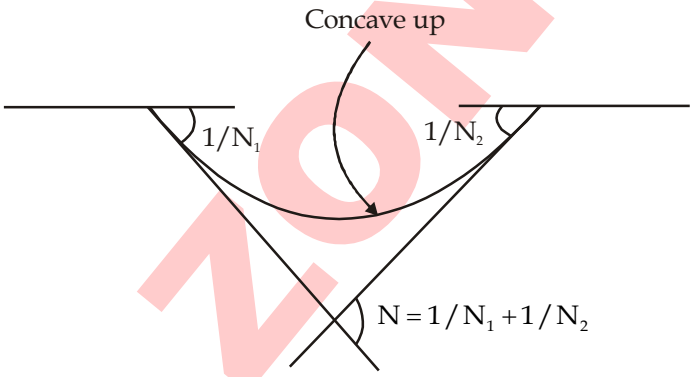
$$L = 2S - \frac{4.4}{N}$$

(ii) When L < ISD/OSD:-

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

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

2. **Valley Curve:-**



→ Valley curve is made fully transition by providing two similar transition curves of equal length.
→ Cubic Parabola is the ideal shape for valley curve but in field practise we generally provide square parabola.

→ Cubic Parabola:- $y = \frac{2Nx^3}{3L^2}$

→ Square Parabola:- $y = \frac{Nx^2}{2L}$

→ Valley is designed on two basis:-

Comfort criteria:- Allowable rate of change of centrifugal acceleration is limited to 0.6 m/sec^3

Safety criteria:- Driver should have adequate head light sight distance (equal to SSD) at any part of curve.

→ This criteria become critical when vehicle is at the lowest point of valley curve.

Length of valley curve:-

1. On the Basis of rate of application of centrifugal acceleration or Based on comfort criteria:-

$$\because \quad C = \frac{\frac{v^2}{R} - 0}{t} = \frac{v^2}{Rt} = \frac{v^2}{R \times L} \times v = \frac{v^3}{RL} \qquad (\because L = RN)$$

$$C = \frac{Nv^3}{L.L} \Rightarrow = L^2 = \frac{Nv^3}{C} \Rightarrow \left[L = \sqrt{\frac{Nv^3}{C}} \right]$$

$L =$ Length of one transition curve.

Total length of valley curve:-

$$\left[L = 2\sqrt{\frac{Nv^3}{C}} \right] \qquad \text{where } (C = 0.6 \text{ ms}^{-3}) \text{ (If not given)}$$

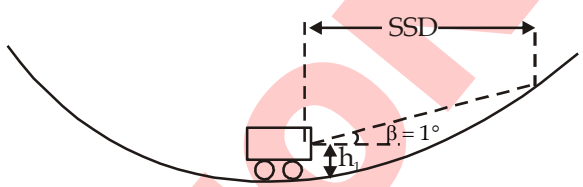
2. On the Basis of Head Light sight distance/visibility in night:-

Minimum head light sight distance = SSD

$h_1 =$ Height of head light

$h_1 = 0.75$ m

$\beta =$ Beam angle $= 1°$



(a) When L > S:-

$$L = \frac{NS^2}{2(h_1 + S\tan\beta)}$$

(b) When L < S:-

$$L = 2S - \frac{2(h_1 + S\tan\beta)}{N}$$

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CHAPTER - 3 (TRAFFIC ENGINEERING)

Traffic Characteristics:-

(i) Road user characteristic
(ii) Vehicular characteristic
(iii) Breaking characteristic

Traffic studies:-

(i) Volume study
(ii) Speed study
(iii) Origin and destination study
(iv) Traffic flow characteristic
→ Diverging
→ Merging
→ Crossing
→ Weaving
(v) Traffic capacity study
(vi) Parking study
(vii) Accident study

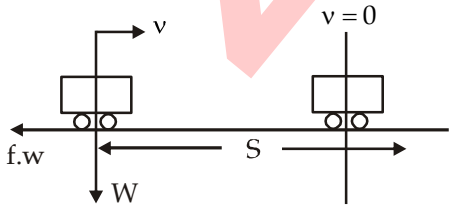
Traffic control devices:-

(i) Traffic signal
(ii) Design of traffic signal
(iii) Intersections
(iv) Road marking
(v) Signs

Change in K.E = Work done

$$\frac{1}{2}mv^2 - 0 = f \times mg \times S$$

$$\left[S = \frac{v^2}{2gf}\right] \qquad .....(i)$$



(i) $v = u - at$ (a = Retardation)

$0 = v - at$

$$\Rightarrow \left[a = \frac{v}{t}\right] ....$$

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(ii) $S = ut - \frac{1}{2}at^2$

$S = vt - \frac{1}{2}\left(\frac{v}{t}\right)t^2$

$\left[S = \frac{vt}{2}\right]$ ....

(iii) $v^2 = u^2 - 2as$

$0 = v^2 - 2as$

$\left[S = \frac{v^2}{2a}\right]$ .....(ii)

Equation (i) = Equation (ii)

$$\frac{v^2}{2gf} = \frac{v^2}{2a}$$

$$a = gf$$

Note:-

If sometimes the maximum skid resistance is already known, then we can find break efficiency:-

$$\eta = \frac{f_{obtained}}{f_{max}} \times 100$$

Traffic Volume Study

Traffic Volume (q):-

→ It is the number of vehicles (PCU) crossing a section of road in unit time.
q → vehicle/hr or PCU/hr

→ In PCU, the weight of vehicle is not considered.

Representation of Traffic Volume Data:-

1. **Annual Average Daily Traffic (AADT):-**

→ It is the average 24 hours traffic volume at a given location over a full year.

$$AADT = \frac{\text{Total traffic in a year}}{365} \text{ PCU/day}$$

2. **Average Daily Traffic (ADT):-**

→ It is the average 24 hours traffic at a given location for some period of time less than a year but for a minimum of 7 days.

3. **Trend Chart:-**

→ Trend chart shows volume trend over period of years.

→ Useful for planning, future expansion, design and regulation.

4. **Variation Chart:-**

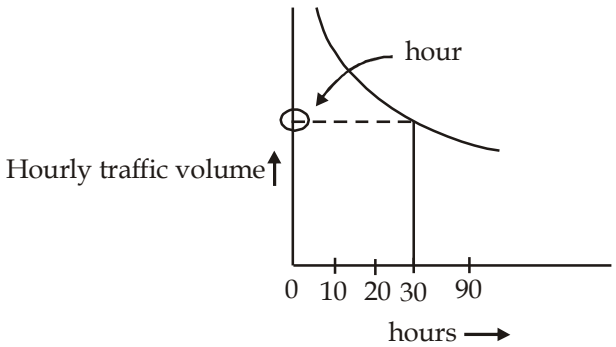
→ It shows hourly, daily and seasonal variation.

→ Useful for regulation during peak traffic periods.

5. **30th Highest Hourly Volume:-**

→ The 30th Highest Hourly volume is the hourly volume that will exceed only 29 hours time in a year and all other hourly volume.

$$30^{th} \text{ Highest hourly } (0.33\% \text{ time}) = \frac{29 \text{ hrs time}}{365 \times 24}$$



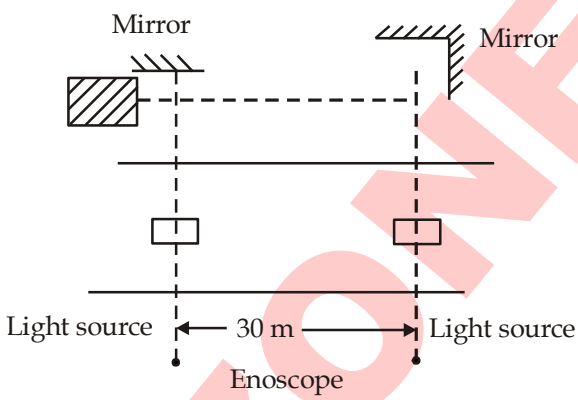
→ As per Indian conditions 30th highest hourly is 8 - 10% AADT.
Ex:- If AADT is 2000 PCU/day than 30th highest hourly volume will be 160 - 200 PCU/hour.
Expansion Factors:-

1. Hourly Expansion Factor $= \dfrac{\text{Total volume of 24 hrs period}}{\text{volume of particular hour}}$

2. Daily Expansion Factor $= \dfrac{\text{Total volume for a weak}}{\text{Average volume for a day}}$

3. Monthly Expansion Factor $= \dfrac{\text{AADT}}{\text{ADT for particular month or weak}}$

(1) **Spot Speed:-**



→ It is the instaneous speed of vehicle at a specified location or instant.
→ It is measured by Enoscope, Pressure contact tube, loop detactor, doppler radar.
→ Used in designing for horizontal signal design and vertical curve.

(2) **Average Speed:-**

→ It is the average of spot speeds of all vehicles passing a given point on the road.
→ There are two types of average speed or mean speed:-

(i) **Time Mean Speed (V_t):-**

→ It is the arithmetic mean of the speeds of vehicles passing a point on a highway during an interval of time.

$$\left[V_t = \frac{\sum_{i=1}^{n} V_i}{n} \right]$$

where $n =$ Number of vehicle

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V_i = Speed of ith vehicle

(ii) Space Mean Speed (V_s):-

→ It is the average speed of a vehicle over a certain road length at any time.

$$\left[V_s = \frac{D}{t_{average}}\right]$$

where $$t_{average} = \frac{t_1 + t_2 + ...t_n}{\eta} = \frac{\frac{D}{v_1} + \frac{D}{v_2} + ... + \frac{D}{v_n}}{\eta}$$

$$\left[V_s = \frac{\eta}{{}^{\eta}\Sigma 1/v_1}\right]$$

Space Mean Speed $\leq$ Time Mean Speed $\Rightarrow [V_s \leq V_t]$

Relation between V_s and V_t:-

$$\left[V_t = V_s + \frac{\sigma^2}{V_s}\right]$$

σ^2 = variance

σ = standard deviation

$$\sigma = \sqrt{\frac{\left(V_i - V_{average}\right)^2}{\eta}}$$

3. **Running Speed:-** $\frac{\text{Length of travel}}{\text{Total time in which vehicle was moving}}$

4. **Journey Speed/Travel/Overall Speed:-** $\frac{\text{Length of travel}}{\text{Total Journey time}}$

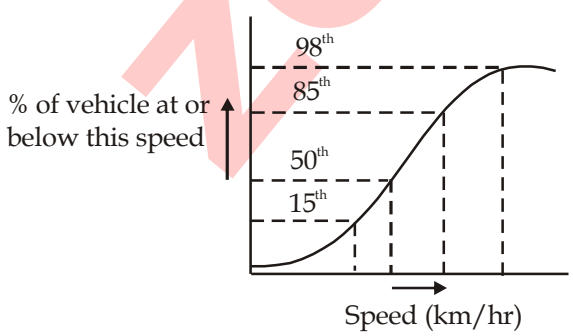
→ Total Journey time includes stopped delays while running time exclude stopped delays.

→ Space Mean Speed (V_s) is used for Flow Density Relationships (Flow - Density)

→ Running Speed is used in road condition studies.

→ Journey Speed is used in delay studies.

3. **Cumulative Speed of vehicle:-**



→ 85th % speed is considered as safe speed.

→ 98th% speed is used in Geometric design.

→ 15th% speed is taken as lower speed limit.

→ 50th% speed is considered as average speed.

(II) Speed and Delay Study

Since, spot speed cannot give the delay time, hence we perform speed and delay study.

Methods:-

→ Floating Car MTD
→ Interview technique
→ Photographic technique
→ This method is suitable for two lane highways.
→ This test method is done to estimate the average travel time through the section.
→ In floating car method a test car is driven for a particular length of road.
→ Four observers are required in this case.

Calculation of flow, average travel time and journey time in north-south method/direction:-

If x = Number of vehicles counted in north-south direction when the test vehicle was moving in south-north direction.

If y = Number of vehicles overtaking the test vehicle in north-south direction - Number of vehicles overtaken by test vehicle in north-south direction.

If t_w = Travel time of test vehicle in north-south direction.

t_a = Travel time of test vehicle in south-north direction.

Traffic Volume in north-south direction:- $q = \frac{x+y}{t_w + t_a}$

Average travel time in north-south direction:- $\bar{t} = t_w - \frac{y(t_a + t_w)}{x+y}$

Mean Journey Speed:-$V_{mean} = \frac{l}{\bar{t}}$

Running Time = $\bar{t}$ - stop delay

Running Speed = $\frac{l}{\text{Running time}}$

(III) Origin and Destination Studies (O & D)

→ Origin and Destination studies of vehicles determines there numbers, origin and destination in the concerned zone of study.
→ Origin and Destination study is helpful in planning new highways and improving existing highways.
→ "Desire Lines" are drawn to represent Origin and Destination data.
→ Desire lines are straight lines connecting the Origin and Destination point.
→ The width of desire line $\propto$ Number of vehicle in both direction.

Traffic Density (k):-

→ It is the number of vehicles occupying a unit length of road at a given instaned.

Unit → Vehicle/km/lane

Traffic Volume = Traffic Density × Speed ⇒ $q = k.v$

Traffic Capacity:-

→ It is expressed as number of vehicle in a lane or a road that can pass a given point in unit time for certain level of service (A to F).

Traffic Capacity is categorized as:-

(1) Basic Capacity
(2) Possible Capacity
(3) Practical Capacity

(1) **Basic Capacity:-**

→ It is the maximum number of vehicles that can pass a given point on a lane or road during unit time under the most ideal roadway and traffic condition.

→ Basic Capacity is the theoretical capacity.

(2) **Possible Capacity:-**

→ It is the volume on a road or lane under different and traffic conditions.

→ It vary from 0 to Basic Capacity.

(3) **Practical Capacity:-**

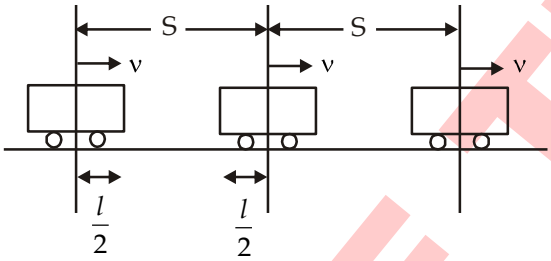
→ In Prevelling road conditions volume present on the road is called Practical Capacity.

→ For designing purpose Practical Capacity is used.

→ It is also called as Design Capacity.

Calculation of Theoritical Maximum Capacity:-

(i) When vehicles are moving with constant speed and constant space headway:-

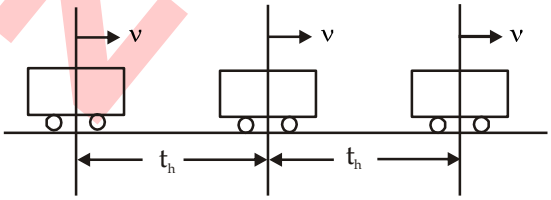


$$\text{Density} = \frac{1000\,\text{m}}{5\,\text{m}}$$

$$\left[\text{Capacity} = \frac{1000 \times V}{S}\right]$$

S = Space headway ($S = 0.2V + l$)

(ii) When vehicles are moving with constant time head way (t_h) and speed:-



$$\text{Capacity (C)} = \frac{3600}{t_h}\ \text{Vehicle/hr}$$

Note:-

Based on observations it is seen that with increase in speed space headway increases and time head way decreases first and then increases.

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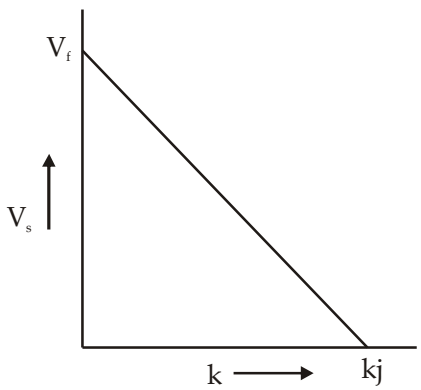
Relation between Speed, Density and Volume:-



$$y = mx + C \Rightarrow V_s = mk + C$$

When $V_s = 0;\quad k = kj$

$V_s = V_f;\quad k = 0$

$0 = mkj + C$ ...(1)

$V_f = mx + C \Rightarrow (C = V_f)$

$$mkj = -V_f \Rightarrow m = \left(\frac{-V_f}{kj}\right)$$

$$\left[V_s = -\left(\frac{V_f}{kj}\right)k + V_f\right]$$

$q = k \times V_s$

For maximum value of q

$$q = k \times \left[V_f - \frac{V_f}{kj}k\right]$$

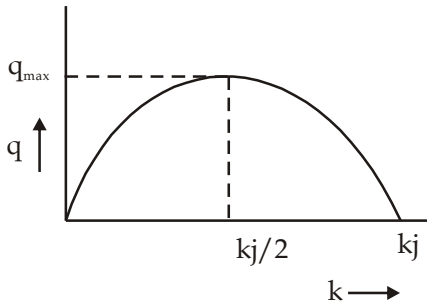
$$\Rightarrow \left(k = \frac{kj}{2}\right) \text{and} \left(V_s = \frac{V_f}{2}\right)$$

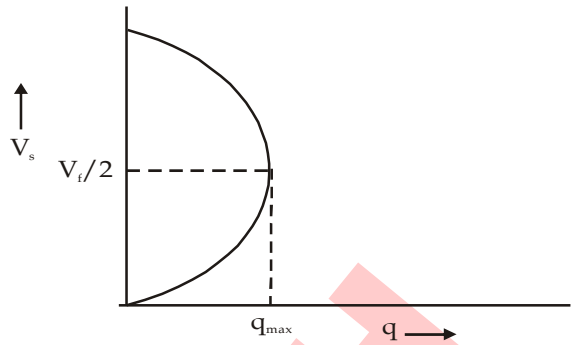
$$\left[q = KV_f - \left(\frac{V_f}{kj}\right)k^2\right] \quad .....(A)$$

$$q = k \times V_s = \left(\frac{V_f - V_s}{V_f}\right) kj \times V_s$$

$$\left[q = kj.V_s - \frac{kjV_s^2}{V_f}\right] \quad .....(B)$$

$$\left[q_{max} = \frac{kjV_f}{4}\right]$$





Passenger Car Unit (PCU):-

→ Since on the roadway there is mixed traffic flow, hence all types of vehicle classes are converted into a standard vehicle unit known as PCU.

Factors affecting PCU:-

→ Speed of vehicle

→ Length and width of vehicle

→ Transverse and longitudinal gap allowed between vehicles.

→ Presence of intersection, traffic control devices, excess control, etc.

Passenger car, tempo, Auto-rickshaw, Agricultural tractor	1.0
Bus, Truck, Agricultured tractor, trailor	3.0
Motor cycle, scooter, Pedal cycle	0.5
Cycle rickshaw	1.5
Horse drawn vehicle	4.0
Small bullock cart and hend cart	6.0
Large bullock test	8.0

Types of Parking Facilities:-

→ Off Streat → On streat

→ In On-streat Parking vehicles are parked on kerb.

→ Parallel parking cover's minimum width of road and minimum number of vehicles can be parked. Perpendicular parking (90° angle) covers maximum width of road and maximum number of vehicles can be parked.

→ Hence out of various angle 45° angle is considered the best.

→ Minimum width required for parking → 3 m (Parallel Parking)

→ Parking studies are carried out using video recordings.

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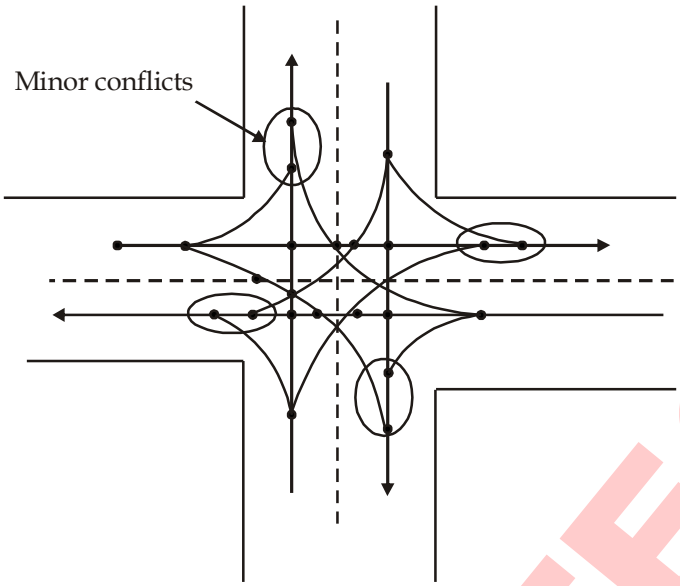
Intersection:-

→ Intersection is the area where two or more roads joint or cross.



Major Conflicts → Crossing

Minor Conflicts → Merging, Diverging

Different Cases	Number of conflicts
Two lane, Two way traffic on both roads	24
Two lane roads, One way traffic on one road and two way traffic on another road.	11
Two lane roads, one way traffic on both roads	6

→ To reduce number of conflicts we resoout to intersection control.

(1) **Passive Control:-**

→ When volume of traffic is less no explicit is required.

→ Road users are required to follow traffic rules.

→ Road Signs and Road Marking are used in this control.

Ex:- Giveway control requires the driver in the mirror to slow down and allow the vehicle on major road to proceed.

(2) **Semi-Control / Pertial Control:-**

→ Drivers are gently guided to avoid conflict.

→ Channelization and traffic rotary coines in this control.

(3) **Active Control:-**

→ Road users are forced to follow the path.

→ Traffic Signals and Grade Separation intersection comes in this category.

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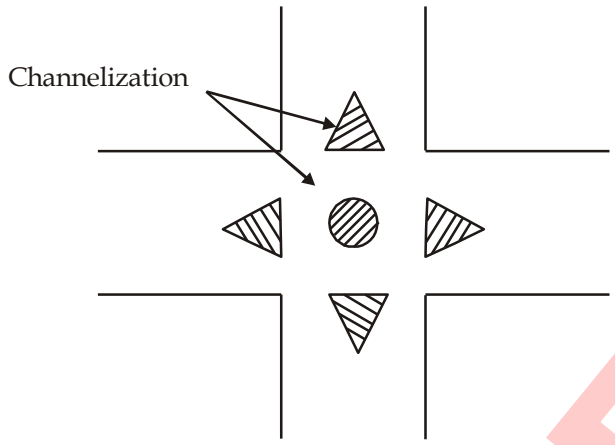
Types of Intersection:-

(1) **At Grade Intersection:-**

→ When all roads meet at the same level.

→ Merging, diverging, crossing and weaving traffic manoevours are called intersections at grade.

→ These intersections are further classified as Channelized, Unchannelized and Rotary.



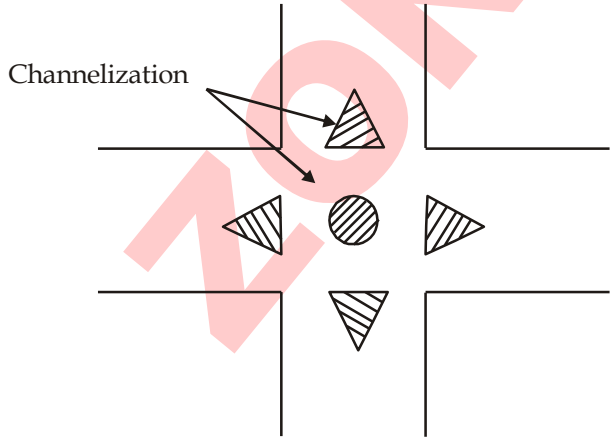
→ Traffic islands are raised areas constructed within the roadways physical channels through which the regular traffic may be guided.

Classification:-

(1) **Divisional Island:-**

→ Used to separate opposing flow of vehicle.

(2) **Channelizing Island:-**



→ They are used to guide the traffic in Proper channel through the intersection.

(3) **Pedestrial Loading Island:-**

→ These are provided at regular bus stops and similar places for the protection of passenger.

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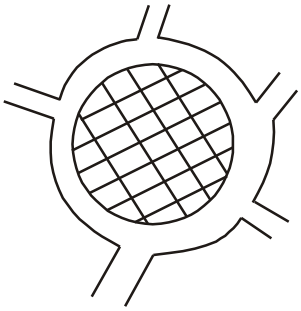
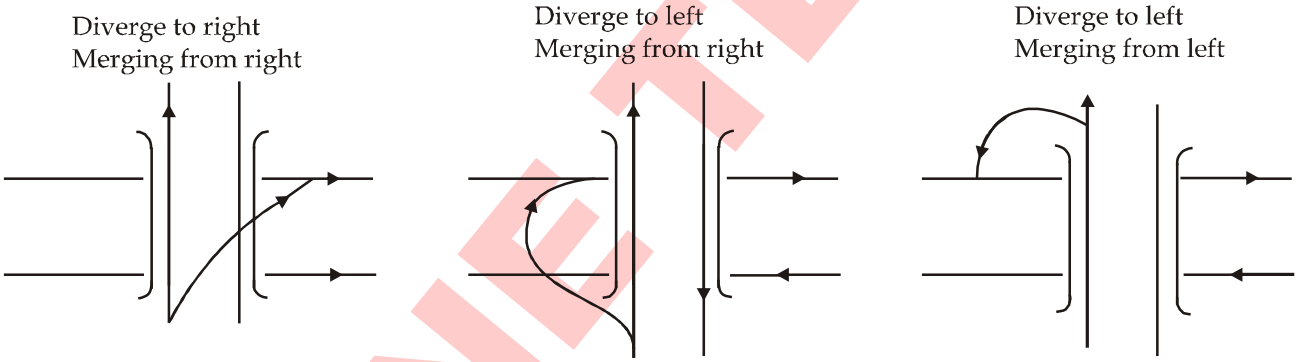
(4) **Rotary Island:-**

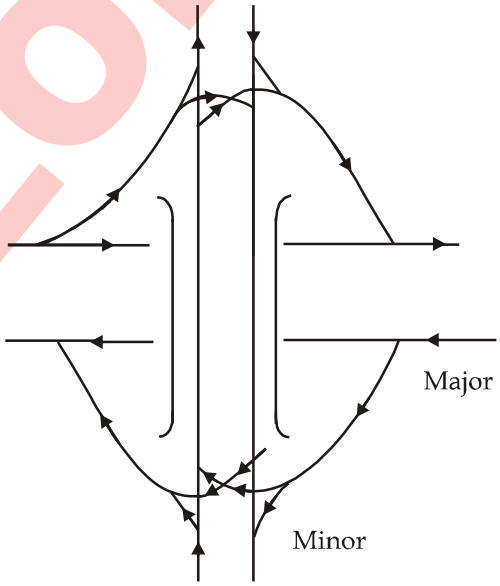


→ It's a large central island crossing is converted into weaving by providing sufficient weaving length.

Grade Separated Intersection:-
Grade Separation is the crossing of two highways at different grades or levels.
Ex:- Underpass, Overpass, interchange.

(1) **Interchange:-**
→ It has varies turning roadways or ramps.





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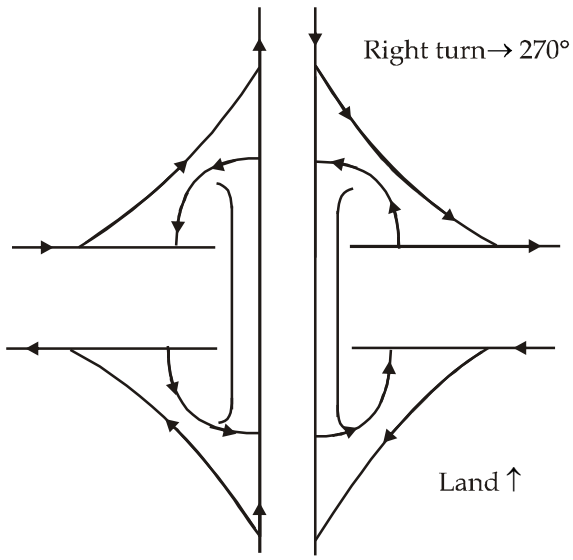
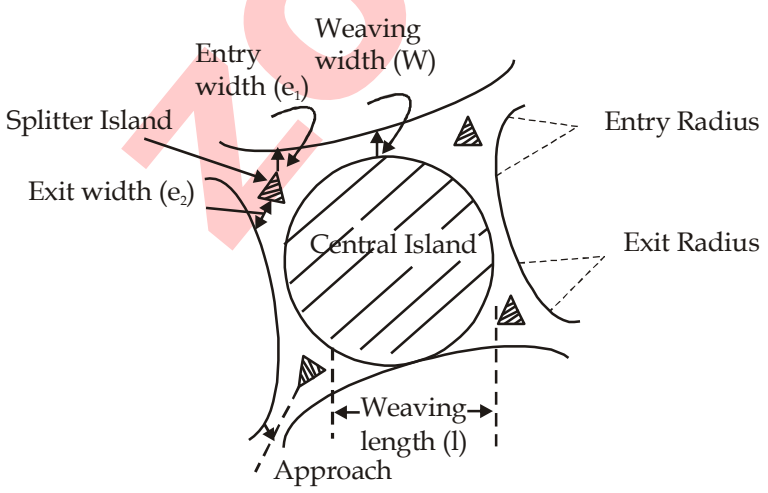
→ Require minimum amount of land and economic.
→ It is a four lag interchange.
→ Used where major and minor road crosses.
→ It provide partial separation of traffic.

Full Clove Leaf:-



→ Four lag interchange.
→ Used when two highways of high volume and speed intersect.
→ Provide complete seperation of traffic.
→ Require large area as compare to diamond.

3. **Rotary Intersection:-**



.....move around a central island.

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→ In rotary intersection vehicles are forced to form weaving operation.
→ Traffic rotary is suitable when volume from all legs more than 500 vehicle/hour and less than 3000 vehicle/hour.
→ A rotary is very beneficial when right turn traffic is more than 30%.
→ Rotary intersection is desirable when intersection roads are between 4 to 7.

Design Criteria:-

Speed:- 40 kmph → Rural
30 kmph → Urban

Radius:- Rentry = 15 to 25 m → Urban
= 25 to 35 m → Rural

$\left[R = \frac{v^2}{127f}\right]$ (Super elevation is not provided. Camber is provided. Hence e neglected)

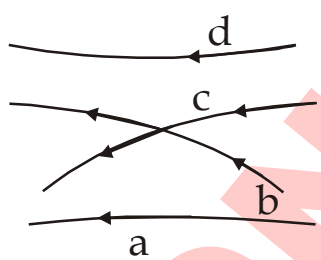
Friction:- f = 0.43 → Rural and f = 0.47 → Urban

Weaving width (W):- $W = \left(\frac{e_1 + e_2}{2}\right) + 3.5\text{ m}$

Length of weaving section (L):- [L = 4 × W]

Minimum weaving length:- 45 m → Rural
30 m → Urban

Weaving Ratio (P):- $\left[P = \frac{b+c}{a+b+c+d}\right]$



It is the ratio of traffic which are weaving at a section to the total traffic passing through that section.

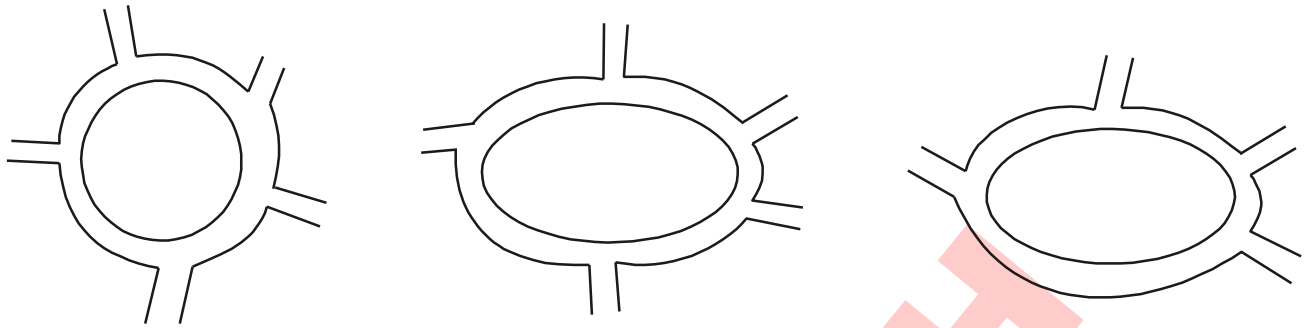
$$Q_P = \overline{\left(1 + W/L\right)}\ \text{PCU/hr}$$

where e = average entry width = $\frac{e_1 + e_2}{2}$

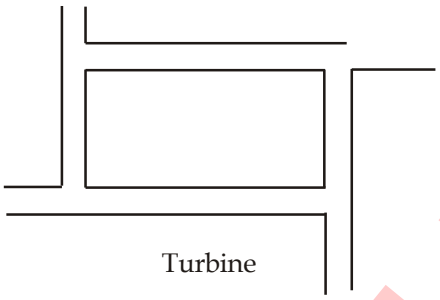
Width of approaching road	e_1 and e_2
7 m (2 lane)	6.5 m
10.5 m (3 lane)	7 m
14 m (4 lane)	8 m

Note:- Minimum radius of Central Island = 1.33 × Rentry

Types of Rotary:-



Q will be minimum = when P maximum



Phase:-

A single phase consist green interval plus amber interval.

Cycle length:-

It is the time in second between the starting of green for one aproach till the next time green starts.

$$[C = G_A + A_A + R_A]$$

Green Time/Green Interval (G):-

It is provided on the basis of traffic volume.

Amber Time/Amber Interval (A):-

It is designed on two basis:-

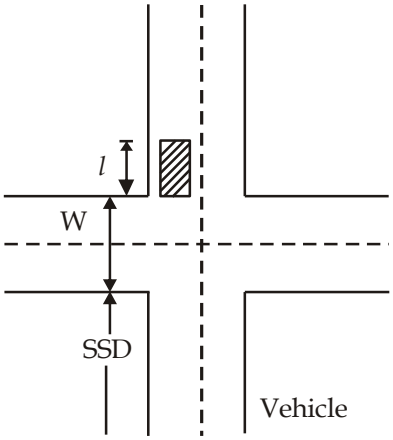
1. If vehicle approaching at the intersection is beyond its SSD:-
   In this case we wants to stop the vehicle.

   $(A = t_R + V/a)$ $t_R \rightarrow$ Reaction time, V = speed of vehicle

   $a \rightarrow$ Retardation

2. If vehicle approaching at intersection is within SSD:-

$$A_t = \frac{SSD + W + l}{V}$$



.....

(1) Trial cycle Method
(2) Approximate Method
(3) Webster Method
(4) IRC Method

(1) **Trial Cycle Method:-**

If η_A = Vehicle accomodate at road A in 15 min./lane

η_B = Vehicle accomodate at road B in 15 min./lane

Assume cycle time = t sec

$$x_A = \frac{\eta_A}{15 \times 60} \times T \text{ vehicle and } x_B = \frac{\eta_B}{15 \times 60} \times T \text{ vehicle}$$

If time head way = t_h sec, then Green Time require:-

$G_A = x_A.t_h$ and $G_B = x_B.t_h$

Total Cycle Time = $G_A + A_A + G_B + A_B$

→ If assumed cycle time equal to calculated cycle time then its ok otherwise assume new cycle time.

(2) **Approximate Method:-**

η_A = Number of vehicles accomodate on road A in 1 hour/lane.

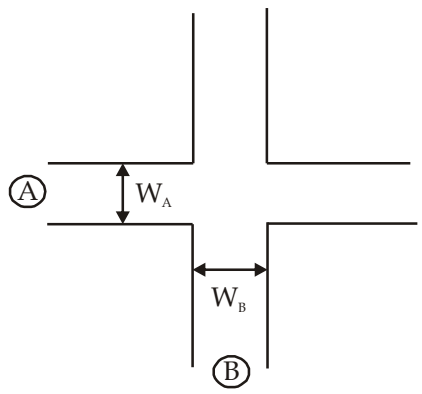
η_B = Number of vehicles accomodate on road B in 1 hour/lane.

Pedestrain Crossing Requirement:-

→ It can be taken care of by two ways:-

1. When Phase is red then pedestrain movement can be allowed.
2. By Providing an exclusive pedestrain phase (But this will increase the cycle time).

ZONE TECH



Green time for Pedestrain on
Road A
Initial Time = 7 sec
Speed = 1.2 (ms^{-1})

$$= 7\,\text{sec} + \frac{W_A(m)}{1.2(ms^{-1})}$$

Green time for pedestrain on
Road B

$$R_A = (G_P)_A \text{ and } R_B = (G_P)_B$$

$W_B(m)$ = Clearance Interval

$$= 7\,\text{sec} + \frac{W_B(m)}{1.2(ms^{-1})}$$

If Amber time on roads A and B is A_A and A_B, then
Green time on A → $G_A = R_B - A_A$
$G_B = R_A - A_B$

→ Maximum of G_A and G_B is adopted and another is calculated by following relation:-
.....
Now maximum of G_B and G_B' will be the green time on road B.
[Total Cycle Time = $G_A + A_A + G_B' + A_B$]

3. **Webster Method:-**

η_A = Vehicle accomodate on road A in Vehicle/hr/lane.

η_B = Vehicle accomodate on road B in Vehicle/hr/lane.

S_A = Saturated volume of vehicle on road A Vehicle/hr/lane.
S_B = Saturated volume of vehicle on road B Vehicle/hr/lane.

$$Y_A = \frac{\eta_A}{S_A} \text{ and } Y_B = \frac{\eta_B}{S_B}$$

[Y(Utility Factor) = $Y_A + Y_B \not> 1$]

If utility factor is greater than 1, we should increase the number of lanes.

$$\text{Optimum Cycle Time } (C_O) = \frac{1.5L + 5}{1 - Y}$$

L → Loss of Time in one cycle (L = 2n + R)
↓ Amber Time

N → Number of Phase

Road width	Saturation Flow (Vehicle/hr)
3 m	1850
3.5 m	1890
4 m	1950
4.5 m	2250
5 m	2550
5.5 m	2990
> 5.5 m	525 Per meter width of Road

→ Saturated Volume $= \frac{3600}{t_h}$ Vehicle/hr/lane

$t_h \rightarrow$ Time head way

OR

Saturated Flow $= \frac{1000 \times V}{S}$ Vehicle/hr/lane

$S \rightarrow$ Space Head way

4. **IRC Method:-**

Step 1:- Design the signal timing by using approximate MTD. Say calculated time T sec.

Step 2:- Use this calculated cycle time in trial cycle MTD.

If η_A = Vehicle accomodate on road A vehicle/hr/lane.

η_B = Vehicle accomodate on road B vehicle/hr/lane.

→ $x_A = \frac{\eta_A}{60 \times 60} \times T$ and $x_B = \frac{\eta_B}{60 \times 60} \times T$ vehicles

→ G_A = 6 second + $(x_A - 1) \times 2$

↓ Time head way

→ It is assumed that first vehicle we take 6 second and other vehicle we take seconds.

G_B = 6 second + $(x_B - 1) \times 2$

Step 3:- Check for signal timing by webstar MTD.

$C_O = \frac{1.5L + 5}{1 - Y}$, $L = 4n + A_A + A_B$

↓

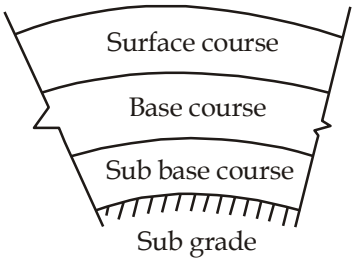
Startup Loss

→ This cycle time should be sufficient for both vehicles as well as pedestrial.

CHAPTER - 4 (PAVENENT DESIGN)

Flexible Pavement:-

→ Flexible Pavement are constructed using stone aggregate with or without some binder.

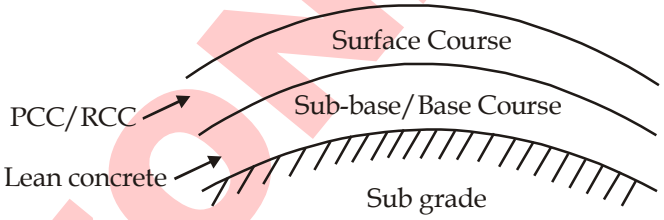


Properties of Flexible Pavement:-

(1) Load is transfer through grain to grain contact.
(2) There is no flexible/flexural strength in this pavement.
(3) The pavement deform in the shape of lower subgrade.

Rigid Pavement:-

→ Rigid Pavement is designed by Elastic thin Plate Theory.
→ Load is transfered through Slab action.
→ There is flexural strength in rigid pavement.
→ The pavement does not deform in the shape of lower soil subgrade.



Note:-

(1) Fatigue cracking and pumping is an important criteria for rigid pavement.
(2) Thermal cracking are important failure criteria for flexible pavement. (Due to repetation of load)

Rutting →

Thermal Cracking →

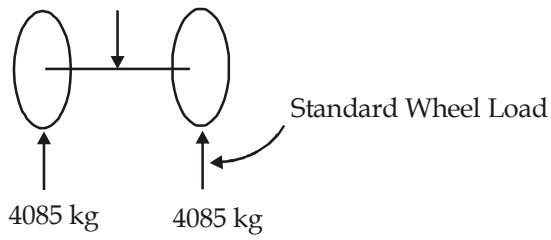
Fatigue Cracking →

Pumping →

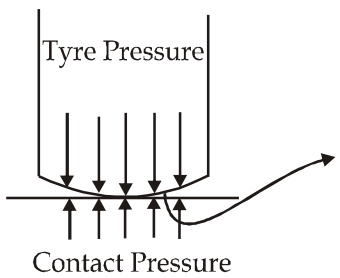
....

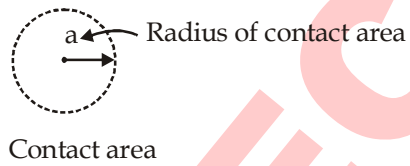
As per IRC - Standard Axle Load → 8170 kg

ZONE TECH



Tyre Pressure and Contact Pressure:-

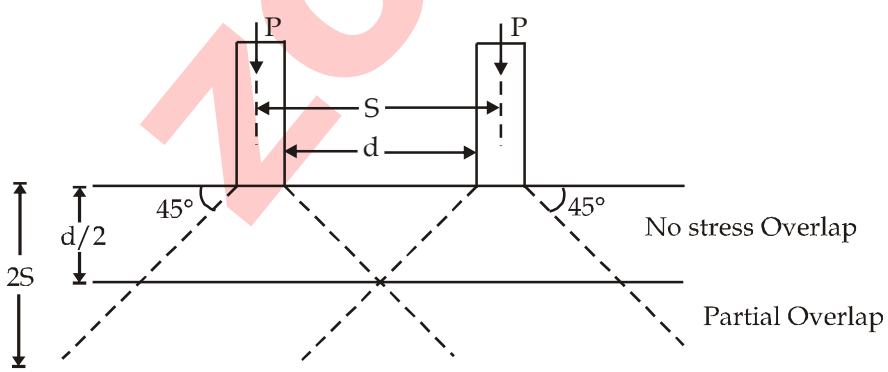




Rigidity Factor:- $R.F = \dfrac{\text{Contact Pressure}}{\text{Tyre Pressure}}$

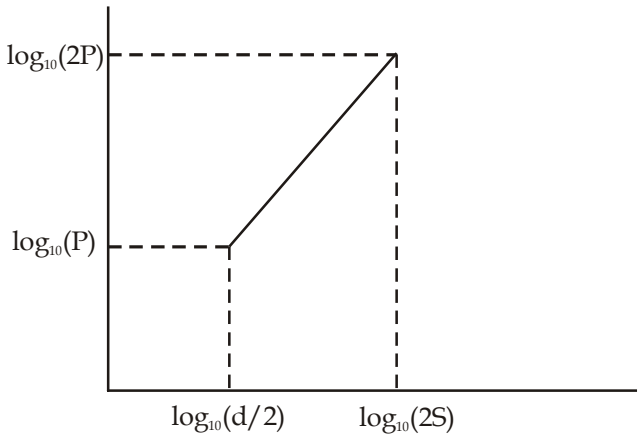
Tyre Pressure	Contact Pressure	Rigidity Factor
7 kg/cm^2	C.P=T.P	1
< 7 kg/cm^2	C.P > T.P	> 1
> 7 kg/cm^2	C.P < T.P	< 1

Equivalent Single wheel Load of dual wheel:-



S = ...between tyres
d = Clear distance between tyres

ZONE TECH



.....

(1) **Group Index Method:-**

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

Type of subgrade soil	G.I. Value
Good	0 - 1
Fair	2 - 4
Poor	5 - 9
Very Poor	10 - 20

$a = p - 35 \not> 40$

$b = p - 15 \not> 40$

$c = Wl - 40 \not> 20$

$d = I_p - 10 \not> 20$

$P \rightarrow$ % finer than 75

$Wl \rightarrow$ Liquid Limit

$I_P \rightarrow$ Plasticity Index

Limitations:-

→ It gives the total thickness of pavement irrespective of material used in pavement.

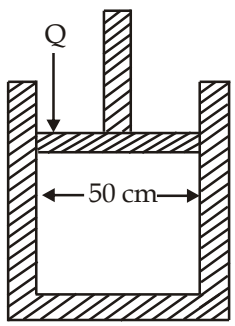
→ It did not consider the load applied on pavement

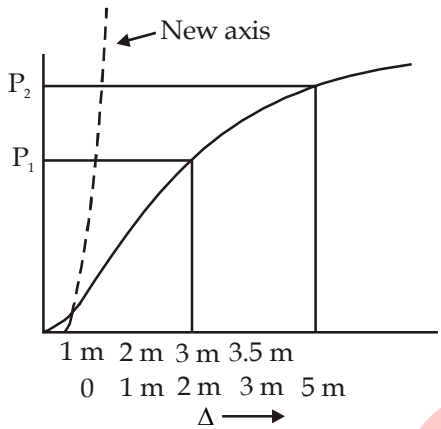
→

G.I Value	0	5	10	15	20
Thickness (cm)	30	45	53	62	70

ZONE TECH

(2) **CBR (California Bearing Ratio) Test:-**





$$CBR_{2.5} = \frac{P_1}{1370(kg)} \times 100 = \frac{P_1(kg/cm^2)}{70(kg/cm^2)}$$

$$CBR_5 = \frac{P_2}{2055(kg)} \times 100 = \frac{P_2}{105(kg/cm^2)}$$

$$(CBR_{2.5} > CBR_5)$$

→ $CBR_{2.5}$ should be greater than $CBR_{5.0}$ if not then repeat the test further if $CBR_{5.0} > CBR_{2.5}$, then adopt CBR_5 as CBR value.

$$T(cm) = \sqrt{\frac{1.75P}{CBR\%} - \frac{P}{\rho\pi}}$$

P = Wheel Load (kg)

ρ = Tyre Pressure (kg/cm²) $\Rightarrow \left[\rho = \frac{P}{\pi a^2}\right]$ where a = Radius of contact area

CBR% = CBR value

→ If there is initial concavity in load v/s settlement graph, then it should be remove by drawing the tangent from highest point of concave curve and vertical axis should be shifted to the point where the trangent meet on horizontal axis.

→ If mould surface is not levelled, this may be the reason of initial concavity.

→ This method is generally adopted when CBR value is less than 12%.

F_1(Vehicle damage factor (V.D.F)):- It converts non standard axle into standard axles.

$$F_1 = \left[\frac{\text{Axle Load}}{\text{Standard Axle Load}}\right]^4$$

F_2 (Lateral/lane distribution factor):- It is a factor which accounts utilization of a lane in road.

	(L.D.F)
One lane	1
Two lane	0.75
Four lane	0.4

(4) **California Resistance Value Test:-**

$$T(cm) = \frac{K(T.I)(90-R)}{(C)^{1/5}}$$

Number of Axle	EWL(Equivalent Wheel Load) (kg)
2	330
3	1070
4	2460
5	4620

$K = \text{constant} = 0.166$
$T.I = \text{Traffic index}$
$= 1.35\ (EWL)^{0.11}$
$R = \text{Stabliometer Reading}$
$C = \text{Cohesionmeter Reading}$

$$\frac{T_1}{T_2} = \left(\frac{C_2}{C_1}\right)^{1/5}$$

.....

$$T(cm) = \sqrt{\left(\frac{3P \times Y}{2\pi E_s \Delta}\right)^2 - a^2}$$

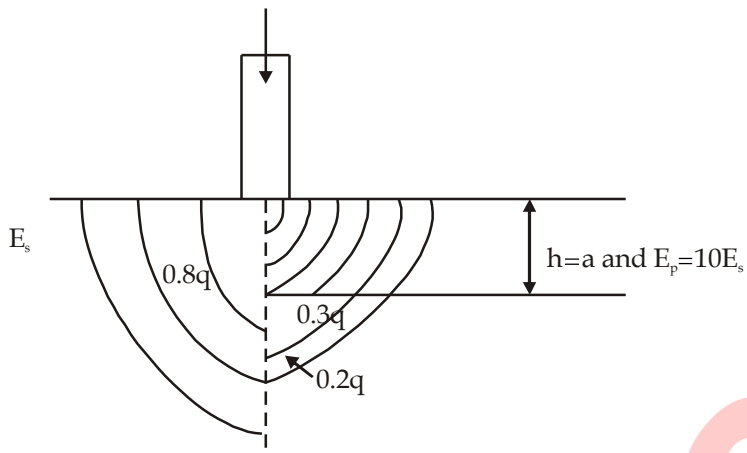
where $P = \text{Wheel Load (kg)}$, $Y = \text{Rainfall coefficient}$
$X = \text{Traffic coefficient}$, $E_s = \text{M.O.E of soil subgrade}$
$\Delta = \text{Permissible deflection} = 0.25\ \text{cm}$
$a = \text{Radius of contact area}$

Note:-
If Pavement is to be constructed of different material then soil subgrade following formula is used-

$$T(cm) = \left[\sqrt{\left(\frac{3P \times Y}{2\pi E_s \Delta}\right)^2 - a^2}\right] \times \left(\frac{E_s}{E_p}\right)^{1/3}$$

$E_p = \text{M.O.E of Pavement material}$
.....

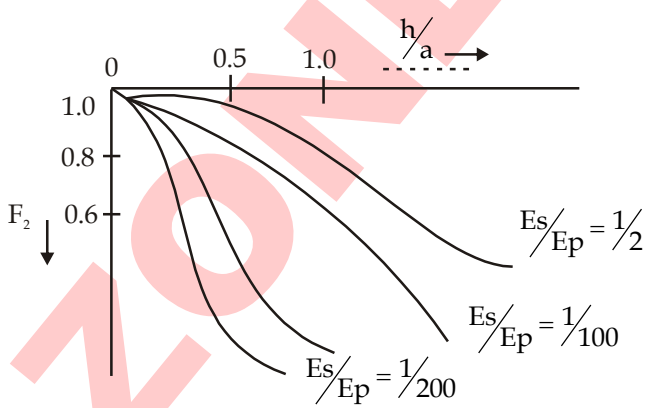
ZONE TECH



→ Burmister performed and experiment in which he took pavement thickness equal to radius of contact area and M.O.E of pavement equals to 10 times of M.O.E of subgrade then he observed that maximum stresses (40% - 70%) maximum stresses has been consumed within this pavement thickness, this action of pavement is called "reinforcing action of pavement." Hence he concluded that superior quality material should be used at top.

$$[E_{surface\ course} > E_{base\ course} > E_{sub\text{-}base} > E_{subgrade}]$$

→ He described a deflection factor (F_2) which depends upon h/a and E_s/E_p.



$h = 0$ then $F_2 = 1.0$.

Design deflection for Rigid Plate:-

Δ = Deflection

ρ = Contact/Tyre Pressure

a = Radius of contact area

E_s = M.O.E of subgrade

F_2 = Deflection factor

If Load is applied by steel plate

$$\left[D = \frac{1.18p_a}{E_s} \times F_2\right]$$

Tyre/Wheel

$$\left[\Delta = \frac{1.5p_a}{E_s} \times F_2\right] \rightarrow \text{Flexible plate}$$

Note:-

→ If load is applied by tyre or wheel, then flexible plate formula is used.

→ If load is applied by steel plate then rigid plate formula is used.

Note:-

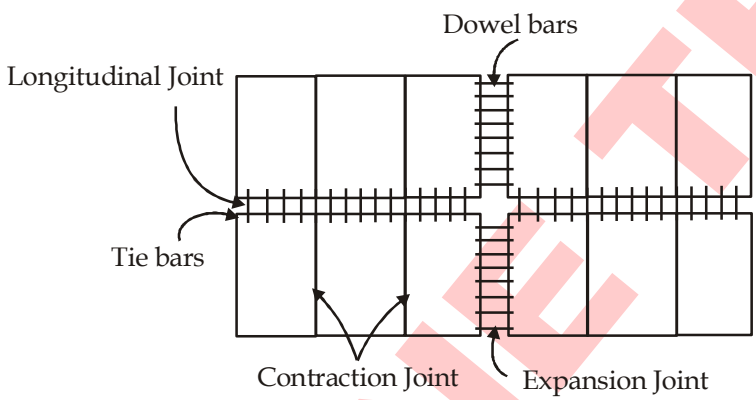
(1) Burmister Method → Theoritical Method

(2) Triaxial Test Method → Semi-theoritical/Semi-imprical

(3) GI Method/CBR/California Resisting → Emperical Method

.....

→ Based on Elastic thin Plate Theory.



(1) **Contraction Joint:-**

→ They occurs due to warping and shrinkage.

→ These provides h/4 to h/2 (where h = Depth).

→ These are the joints which are used to "Counter-act the tensile stresses" developed in panel due to warping and shrinkage.

→ Maximum spacing of contraction joint-

PCC → 4.5 m

RCC → 14 m

(2) Longitudinal Joint

→ These joints are also known as construction joint.

→ They are used to separate two panels in longitudinal direction.

→ They are provided when width of panel exceed 4.5 m.

(3) **Expansion Joint:-** (Provide full depth)

→ These are the joints which are provided to counter-act the expansion of pavement.

→ Generally spacing between two expansion joints is not more than 140 m.

→ Maximum width of expansion joint = 2.5 cm

.....

→ It is defined as the pressure per unit deflection for a plate.

$$K = \frac{p(kg/cm^2)}{\Delta(cm)}$$

$\Delta(cm) = 0.125$ cm

→ Standard size of plate = 75 cm diameter

→ If K for a certain diameter plate is given then K for another diameter plate can be calculated as

$$(K_1 a_1 = K_2 a_2)$$

Radius of Relative Stiffness:-

→ Generally some amount of stiffness in rigid pavement developed due to soil subgrade and some amount of from concrete slab hence a relative term radius of relative stiffness is defined.

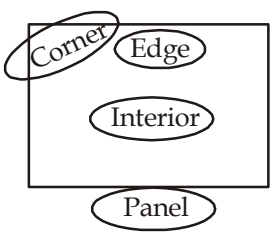
$$l = \left[\frac{Eh^3}{12K(1-\mu)^2}\right]^{1/4}$$

E = M.O.E of Pavement (kg/cm²)
h = Thickness of Pavement (cm)
K = Modulus of soil subgrade reaction (kg/cm²)
μ = Poisson's Ratio of slab

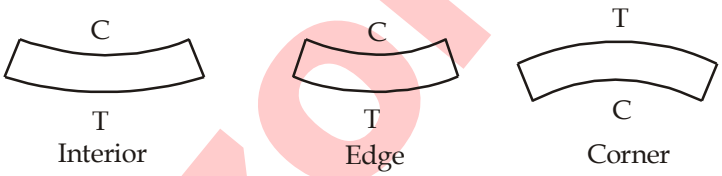
Equivalent Radius of Resisting section:-

(i) If $a \geq 1.724h$, $b = a$

(ii) If $a < 1.72h$, $b = \sqrt{1.6a^2 + h^2} - 0.675h$



Load Effect →



Westerguard Theory for Load Stresses:-

$$S_i = \frac{0.316P}{h^2}\left[4\log_{10}\left(\frac{l}{b}\right) + 1069\right]$$

$$S_e = \frac{0.572P}{h^2}\left[4\log_{10}\left(\frac{l}{b}\right) + 0.359\right]$$

$$S_c = \frac{3P}{h^2}\left[1 - \left(\frac{a\sqrt{2}}{l}\right)^{0.6}\right]$$

where
P = Wheel Load (kg)
l = Radius of relative stiffness (cm)
a = Radius of contact area

b = equivalent radius of resisting section

Note:-

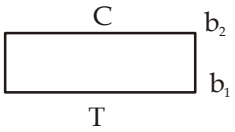
Due to load stress at edge is more than stress at corner and stress at corner is more than stress at interior part.

$$S_e > S_c > S_i$$

Warping Stress/Daily Stress:-

→ Due to temperature gradient along the depth.

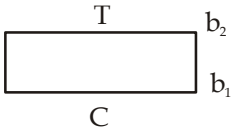
During day time:-



$(b_2 > b_1)$*

Warping down

During Night time:-



$(b_2 < b_1)$*

Warping up

$$St_i = \frac{E\alpha T}{2}\left[\frac{C_x + \mu C_y}{1-\mu^2}\right] \text{ or } \left[\frac{E\alpha T}{2} + \left(\frac{C_y + \mu C_x}{1-\mu^2}\right)\right] \text{.....}$$

$$St_e = \frac{C_x . E\alpha T}{2} \text{ or } \frac{C_y . E\alpha T}{2} \text{.....}$$

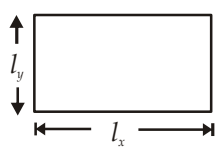
$$St_c = \frac{E\alpha T}{3(1-\mu)}\sqrt{a/l} \text{.....}$$

where E = M.O.E of concrete (3×10^5 kg/cm²)

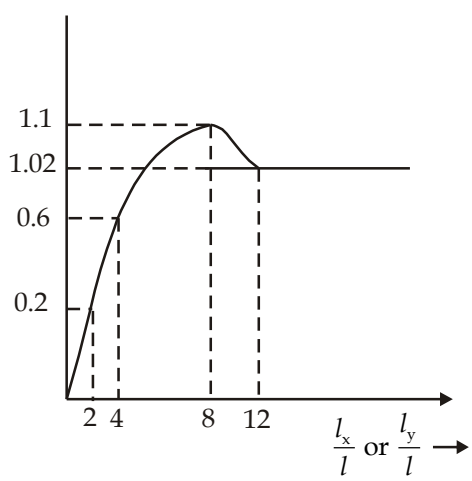
α = Linear coefficient of thermal expansion (10×10^{-6}/°C)

T = Temperature difference between top and bottom surface

$$C_x \propto \frac{l_x}{l} \text{ and } C_y \propto \frac{l_y}{l}$$

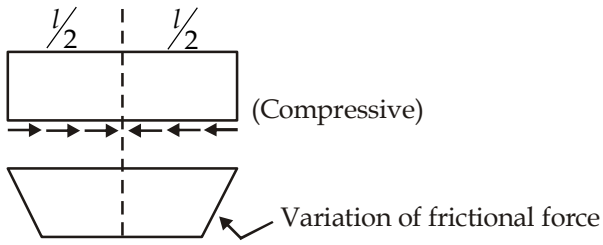


2	0.2
4	0.6
8	1.1
12	1.02

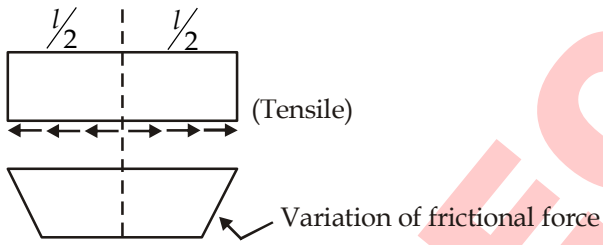


ZONE TECH

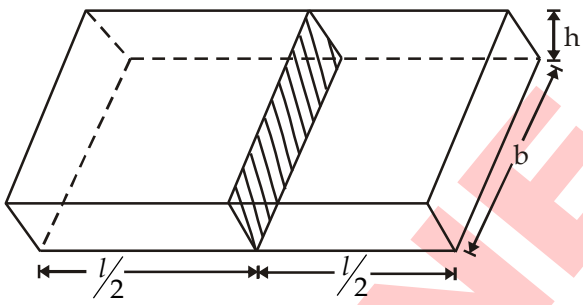
During summer:-Temperature↑than design temperature.



During winter:- Temperature↓than design temperature.



Frictional Stress During Summer:-



Weight of Slab $= \frac{l}{2} \times b \times h \times \gamma$

Friction Force $= f \times \frac{l}{2} \times b \times h \times \gamma$

If maximum permissible stress $= S$, then

$$f \times \frac{l}{2} \times b \times h \times \gamma = S \times b \times h$$

$$f \times \frac{l}{2} \times \gamma = S$$

$S =$ Frictional stress

$\gamma =$ Unit weight

(1) Due to loading $\rightarrow S_e > S_c > S_i$

(2) Due to warping $\rightarrow S_e/S_i > S_c$ If ask $(S_e > S_i)$

(3) Due to Friction $\rightarrow (S_c \simeq 0)$ (at corner)

and

Maximum at interior and edge ($S =$ maximum)

Mean $(S_i = S_e)_{\text{maximum}}$

(1) **For interior (Critical Combination):-**

$S_p + S_b + S_f$ (Bottom)

Load, Day Time, Winter

(2) **For edge (Critical Combination):-**

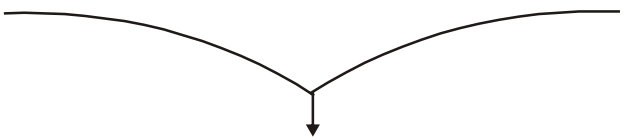
$S_p + S_b + S_f$ (Bottom)

Load, Day Time, Winter

(3) **For Corner (Critical combination):-**

$S_p + S_b + S_f$ ← - - - - Neglected for corner (Top)

Load, Night, Winter



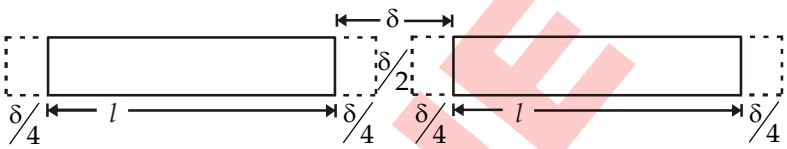
For Edge we get maximum stress after combination (if asked)

→ $\mu = 0.15$

$f = 1.5$

If not given for concrete

.....



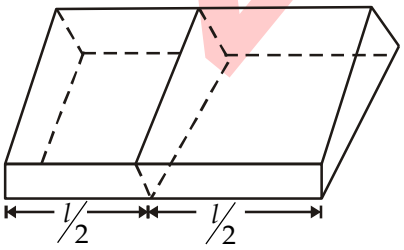
$$l.\alpha.\Delta T = \delta/2$$

$$\Rightarrow l = \frac{\delta}{2\alpha\Delta T}$$

→ As per IRC at maximum expansion in slab these should be $\delta/2$ gap remains at expansion joint.

Design of Contraction Joint:-

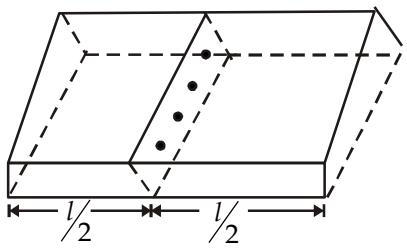
(i) **Slab without Reinforcement:-**



$\gamma \rightarrow$ Density of concrete

$$\left(l = \frac{2S}{F\gamma}\right) \text{.....}$$

(ii) **Slab with Reinforcement:-**



$$f \times \frac{l}{2} \times b \times h \times \gamma = n \times A_{sb} \times \sigma_t$$

$$\left(l = \frac{2nA_{sb}\sigma_t}{Fbh\gamma}\right) \ldots\ldots\ldots\ldots$$

where A_{sb} = Area of bar

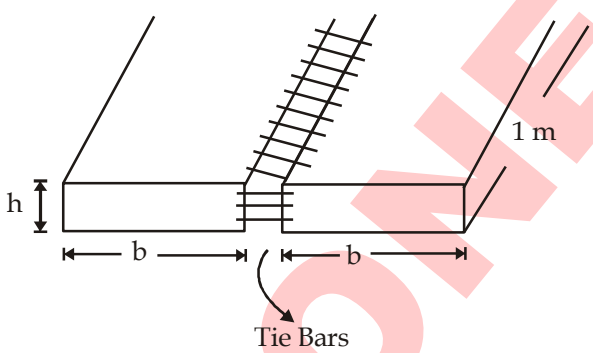
n = Number of bars

σ_t = Tensile stress in one bar

b = Width of slab

→ In this case all tensile force due to friction will be resisted by reinforcement.

Design of Longitudinal Joint:-



$(b \times h \times l \times \gamma \times f = A_{st} \times \sigma_{st})$

l = Design for unit meter length

.....

→ Development length $(l_d) = \dfrac{\phi\sigma_{st}}{4\tau_{bd}}$

Note:-

(1) Tie bars are provided in longitudinal joints. They are not designed to carry any load.

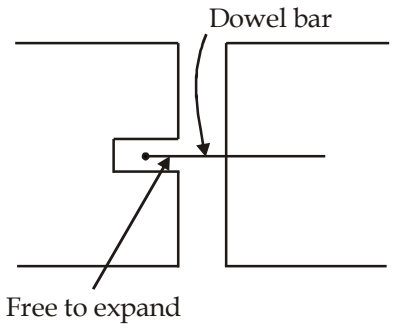
(2) Tie bars designed for tension.

(3) In transverse joints dowel bars are provided.

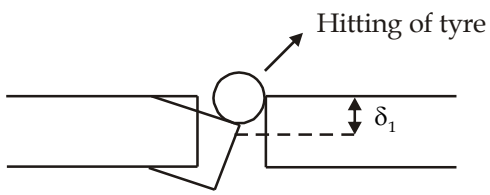
Dowel Bars:-

→ Dowel bars are provided for smooth movement of traffic on expansion joint and avoid hitting action of

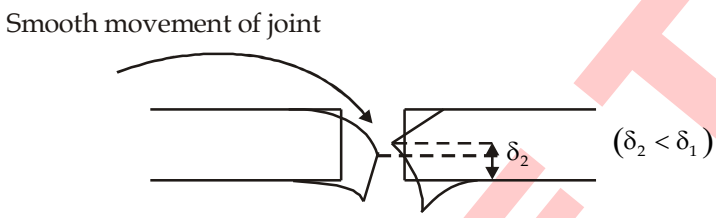
tyre with the pavement at expansion joint.



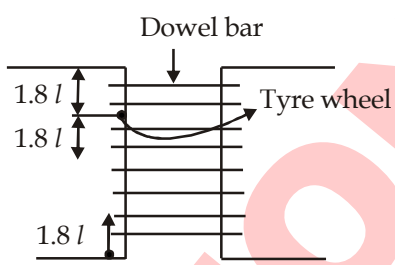
(a) Without dowel bar



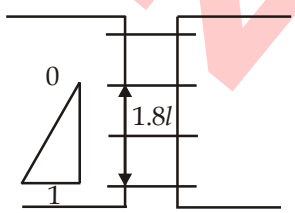
(b) With dowel bar



→ Dowel bars are designed to carry load.



→ Capacity factor for a dowel bar is assumed to be 1, just below the wheel load and it is assumed to be zero at a distance of 1.8l from the wheel.



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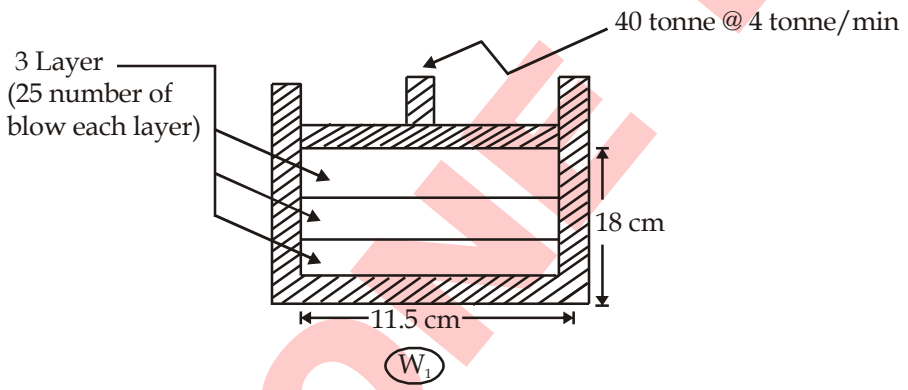
CHAPTER - 5 (HIGHWAY MATERIAL)

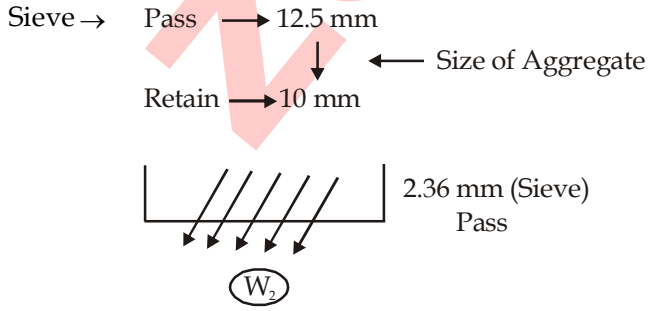
Highway Material
- → Aggregate
- → Bitumen
- → Subgrade soil

(1) **Properties of Aggregate:-**

(a) Strength (Crashing Test)
(b) Hardness (Abrasion Test)
(c) Toughness (Impact Test)
(d) Acid Rain/Weathering/Resistance/Durability (Soundness test)
(e) Shape Test (Flaky is ignored)
(f) Adhesion with Bitumen.

(a) **Strength Test (Crushing Test):-**





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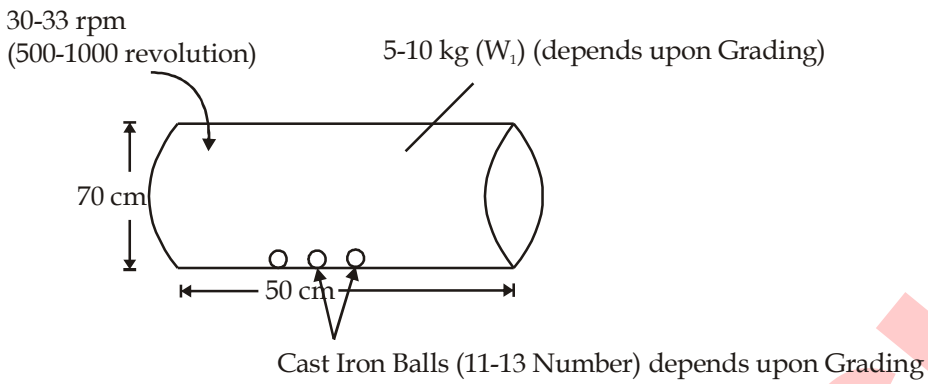
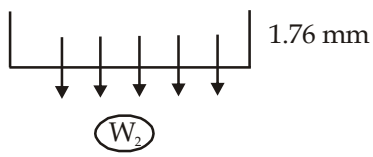
(b) Hardness (Abrasion Test)



Diameter = 4.8 cm (wt. - 340 - 445 gm)



- For surface course $\not>$ 30%
- For base/sub base $\not>$ 50%

$$\left[LAAV = \frac{W_2}{W_1} \times 100\right]$$

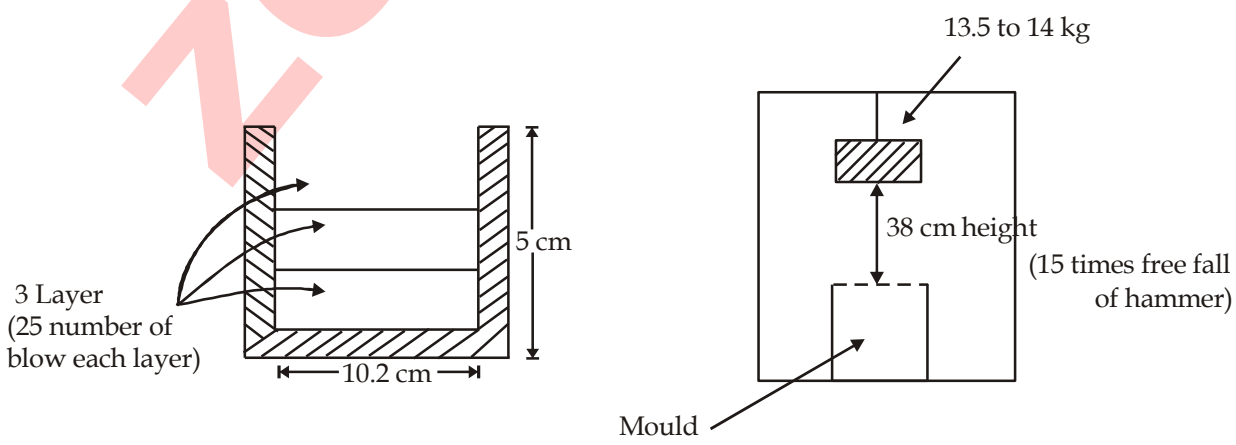
LAAV ↑ ; Hardness ↓

Other Tests:-

(i) Dorry Abrasion Test

(ii) Deval Attrition Test

(c) **Toughness Test (Impact Test)**



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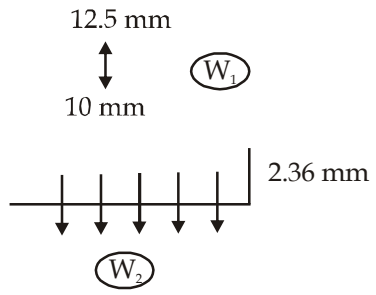


Base course → Bituminous macadam $\not>$ 35%
Base course → WBM $\not>$ 40%

(d) **Durability (Weathering Resistance)(Soundness Test):-**

→ Take W_1 kg of sample.
→ Absorb this into either Na_2SO_4 or $MgSO_4$ solution for 16-18 hours.
→ After that take them out and dry in oven at 105 - 110°C temperature.
→ Repeat this process 5 times (5 cycle).
→ After that calculate the loss in weight.

$$\text{Loss in weight} = W_1 - W_2$$

$$\% \text{ Loss in weight} = \frac{W_1 - W_2}{W_1} \times 100$$

→ For Na_2SO_4 $\not>$ 12%
→ $MgSO_4$ $\not>$ 18%

(e) **Shape Test:-**

Flakiness Index:-

→ When least dimension of aggregate is less than 0.6 times the mean size, the particle is called flaki particle. (0.6 d average)

Elongation Index:-

→ When largest dimension of aggregate is more than 1.8 times mean size, the particle is called elongated particle. (> 1.8 d average)

Note:-

1. Flakiness test is done first and then on remains aggregates elongation test is done.
2. Both tests are applicable for aggregates > 6.3 mm.

→ Flakiness Index and Elongation index value generally should not exceed 15%, however no recognized limits has been given .....

(f) **Angularity Number:-**

Angularity Number = (67% - % Solid Volume)

It represent the volume of solid of most rounded gravels in a well compacted state, which has 33% voids.

→ Higher the angularity number more is the angular aggregate.
→ The range of angularity number for aggregates used in construction is 0-11.

(g) **Water Absorption:-**

W_1 = Dry weight of aggregate
W_2 = Weight of aggregate after imerging in water for 24 hours then

$$\text{Water absorption} = \frac{W_2 - W_1}{W_1} \times 100$$

→ Water absorption $\not>$ 0.6% (By dry weight)

→ Specific Gravity generally ranges between 2.6-2.9.

.....

→ Static Emersion test is done to find the stripping value of aggregate.

→ Stripping value $\not>$ 5.0%

Bitumen

→ From Assam → "A"
From other source → "B"

→ Bitumen is formed by fractional distillation of petrolium.

Different forms of Bitumen:-

(1) **Cut-Back Bitumen:-**

→ Some solvents are added in bitumen to reduce its viscosity and obtained bitumen is called cut-back bitumen.

(a) Rapid Curing Cut back (RC) → Solvent "Petrol".
(b) Medium Curing Cut back (MC) → Solvent "Kerosene or diesel".
(c) Slow Curing Cut back (SC) → Benzene or high boiling point substance.

→ RC is used for Patch work and Surface dressing.

→ MC is used for Pre mix with less quantity of fine aggregate.

→ SC is used for pre mixed with more quantity of fine aggregate.

→ Viscosity is designated by suffix number 0, 1, 2, 3, 4 and 5 number indicate definate viscosity in respective of the type of cut back.

Ex:-

→ RC-2, MC-2, SC-2 will have some initial viscosity at specified temperature.

→ As the number increases 0 to 5, viscosity increases.

→ Bitumen Emersion is a liquid product in which a bitumen is suspended in a finally divided condition in a aquous medium.

→ In Emersion normally bitumen content is 60% and remaining is water (40%).
Emersion = Bitumen + Water + Emulsifier

(a) Rapid Setting (RS) → Surface drening, Patch work.
(b) Medium Setting (MS) → Premix job, Repair work.
(c) Slow Setting (SS) → Rainy season.

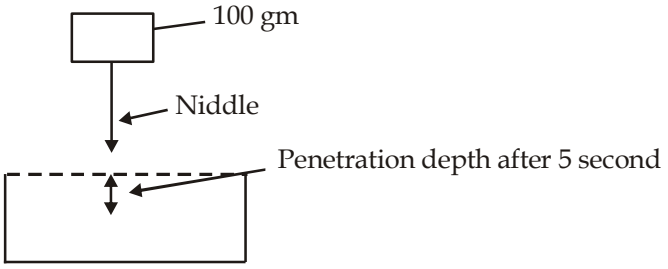
Note:-

→ Bitumen Emersions are used in hill road construction where heating of bitumen and aggregate is difficult.

→ Emersions are used in soil stabilization in desert.

Test on Bitumen:-

(1) **Penetration Test:-**



Temperature → 25°C

→ Penetration test tells about hardness and softness of bitumen.

→ Bitumen grade is defined in terms of Penetration value.

Ex:-

→ Grade $^{80}/_{100}$ → means Penetration value is 8 - 10 mm.

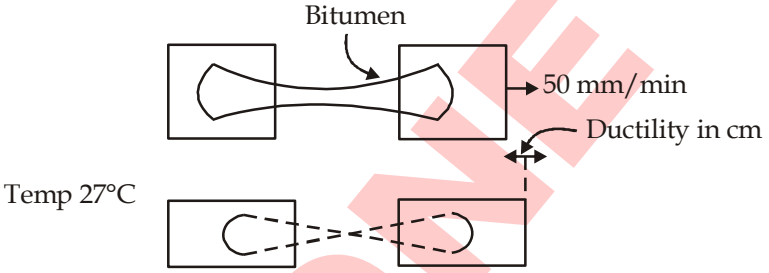
→ In hot climate generally $^{30}/_{40}$ grade bitumen is used.

Note:-

→ Penetration test is used only for bitumen not for cut-back and emersion.

→ Penetration Value (↑), Softness↑

.....



Note:-

→ Ductility varies from → 5 -100 cm.

→ A minimum value is 75 cm for Grade → S-45 and above.

→ A minimum value is 50 cm for Grade → S-35.

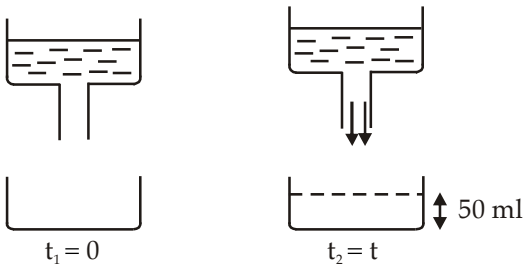
→ For Assam bitumen or Wax bitumen minimum value → 15 cm

(3) **Viscosity:-**

→ It is the property of fluid which resist the flow.

→ It is measured by orifice viscometer at temperature 35, 40, 45, 55°C.

→ The diameter of orifice varies from 3 mm - 10 mm and fluid volume varies from 50 ml - 200 ml.



$t_2 - t_1 = t$ (Se) → Represent viscosity

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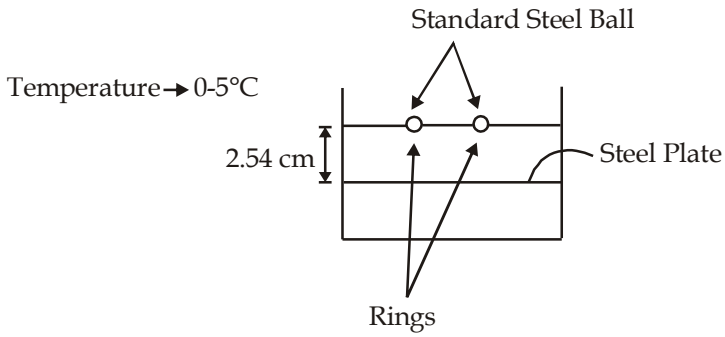
t↑ ; viscosity↑

t↓ ; viscosity↓

....



→ The temperature at which standard steel ball placed on the bitumen which is kept in a standard ring passes through the bitumen layer and touch the bottom plate kept at a distance of 2.54 cm is the softening point.

→ Softening point indicates the temperature at which bitumen passes from solid to liquid consistency.

→ For satisfactory performance bitumen should have a softening point 5-10°C above the maximum atmospheric temperature.

(5) **Flash and Fire Point Test:-**

→ "Pensky Martin Closed Cup" Test.

→ Minimum Flash Point → 175°C

→ Minimum Fire Point → 500°C

(6) **Specific Gravity:-**

→ Measured by Pycnometer at 27°C.

→ For bitumen specific gravity varies from 0.72 to 1.02.

(7) **Solubility Test:-**

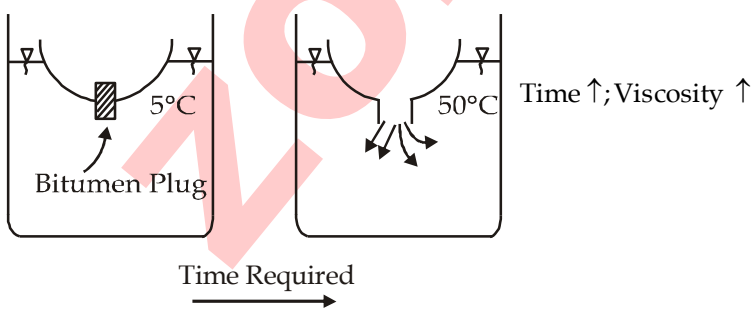
→ Pure bitumen is completely soluble in CS_2 (Carbon di-sulphide) and CCl_4 (Carbon Tetra-chloride)

→ Minimum Solubility in CS_2 → 99%.

(9) **Water Content Test:-**

→ Maximum water content in bitumen should not be $\not>$ 0.2% (By weight).

(10) **Float Test:-**



→ Float Test is used for those bitumen for which neither penetration nor viscometer test can be used.

→ It is used for highly viscous bitumen.

(11) **Spot Test:-**

→ Used for detecting overheated or cracked bitumen.

→ A 29 m bitumen + 10 ml Napthal solution is preferred.

→ A drop of this solution is placed on filter paper, if stain is uniform in colour it is uncracked bitumen. If spot from dark brown or black colour in center with light colour surrounding it is considered as overheated bitumen.

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.....

→ It is formed by Destructive distillation of coal or wood.
→ Specific gravity → 1.1 - 1.25
→ Soluble in Toluene.
→ Bitumen is more resistant to water then tar.
→ Tar has more free carbon than bitumen.
→ Tar has more temperature susitible than bitumen.

RT1:- Low viscosity, surface painting under cold weather.
RT2:- Surface Painting under Indian climatic condition.
RT3:- Surface Painting, Pre mixing
RT4:- Pre-mixing for macadam
RT5:- Grouting Purpose

Planning Survey:-

(1) Economic Studies (Population Forecast)
(2) Financial Studies (Source of Income, taxes, etc.)
(3) Traffic Studies (Volume, O and D studies, etc.)
(4) Engineering Survey:-
(a) Map Study
(b) Reconnaiscence
(c) Preliminary (Final alignment is decided)
(d) Final allocation and detailed survey.

Index Map:-

→ It shows general topography of area.

Key Map:-

→ It shows proposed existing roads and important places to be connected.

(1) Subgrade and Earthen Shoulder → Relative Compaction $\not<$ 97%.

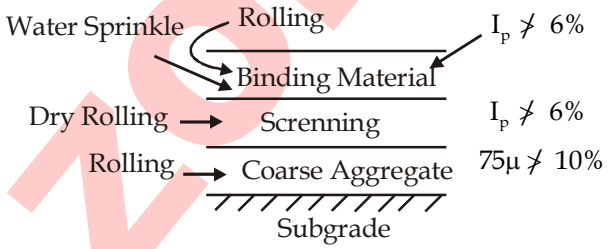
(2) Embankment → Relative Compaction $\not<$ 95%

Construction of Base, Sub-base or Shoulder (Non-Bituminous):-

→ The material passing 425 micron sieve shall have liquid limit and plasticity index not more than 25 and 6% respectively.

Water Bound Macadam (Sub-base/Base):-

→ Three types of grading of CA are defined Grade Number 1, 2 and 3.



..... be 100 mm while for grading 2 and 3 shall be 75 mm.

→ Rolling is done with three wheeled power rollers of 80-100kg or tandam or vibratory roller of 80-100 kg static weight.
→ Rolling is always started from edges and proceed towards center.

Wet-Mix Macadam:-

→ No plastic materials are used.
→ Prepare a mix of (Crushed aggregate + Granular material + Water) to a dense mass.
→ The Compacted single layer thickness $\not<$ 75 mm.

Rolling → Mix of (Crushed Aggregate + Granular Material + Water)

Subgrade

Smooth Wheel Roller (80 - 100 KN) → When thickness of single compacted layer $\not>$ 100 mm.

Vibratory Roller (80 - 100 KN) → When thickness of single compacted layer $\not>$ 200 mm.

Bituminous Base or Binder Course:- Aggregate used should be "Hydrophobic".

↓

That have great attraction to asphalt.

1. **Bituminous Macadam:-**

→ Bitumen of Penetration grade $^{30}/_{40}$ to $^{80}/_{100}$

(Crushed aggregate premixed with bituminous binder.)

Rolling → Spreading of mix } Bituminous Macadam

Sub-base/base

(80-100 KN Rollers)

Subgrade

→ Mix compacted thickness 100 mm.
→ Bitumen content = 3-3.5% of total mix (By weight)
→ "Seal Coat" shall be used.
....
→ Thickness of course shall be 75 mm.
→ Bitumen of Penetration Grade → $^{30}/_{40}$ to $^{80}/_{100}$

Rolling → Application of key aggregate

Binder Material

Spreading of course aggregate } Bituminous Penetration Macadam

Base/Sub-base

Subgrade

→ "Seal Coat" shall be used in bituminous penetration macadam.

3. **Built-up Spray Grout:-**

→ Commonly used for strengthening of existing bituminous pavement.
→ "Seal Coat" should be used.

4. **Dense Bituminous Macadam:-**

→ $^{60}/_{70}$ Penetration grade bitumen is used, if not available then $^{80}/_{100}$ may be used.
→ Bitumen content $\not<$ 4% of total mix (By weight)
→ Thickness of compacted single layer → 50-100 mm.
→ A hot mixture of (Bitumen + C.A + F.A + Filler) is prepared.
→ Rolling shall be done at 100°C temperature fall below this value.

Rolling → Hot Mix } DBM

Base/Sub-base

Subgrade

→ Speed of roller → 5 km/hr

→ Dense Bituminous macadam (DBM) shall be provided with weaving course as easily as possible.
....

1. **Single and Two-Coat Surface dressing using Bitumen:-**

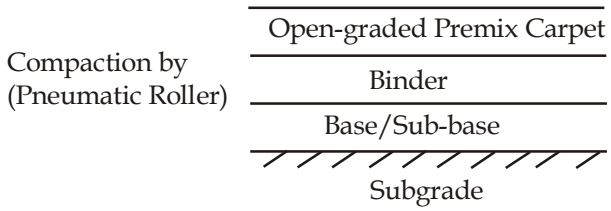
→ Work as weaving course.
→ Nominal Size of stone chipping = 13.2 mm
→ Bitumen should be straight Run Bitumen of suitable grade.
→ Stone chipping value $\not<$ 55.

2. **Two Coat Surface dressing using Cationic Bitumen Emersion:-**

→ Work as weaving course.
→ Binder should be cationic type bitumen emersion of rapid setting.

3. **Open Graded Premix Carpet using Bitumen:-**

→ Work as weaving course.
→ Premix of (Bitumen binder + Small size aggregate) is compacted in 20 mm thick layer.



→ "Seal Coat" should be used.

4. **Semi-Dense Bituminous Concrete:-**

→ Work as Binder/Weaving course.
→ Binder content $\not<$ 4%
→ A 25 -100 mm thickness is compacted.

5. **Bitumen Concrete:-**

→ Work as Binder/Weaving course.
→ Binder content $\not<$ 4.5%
→ Material a construction is same as in DBM except grading of aggregates.

5. **Bitumen Mastic/Mastic Asphalt:-**

→ Work as weaving course.
→ Binder content = 14-17%
→ Binder should be straight run bitumen ($^{30}/_{40}$ Penetration grade)
→ Hot Premix of (C.A + F.A + Binder)

6. **Sheet Asphalt:-**

→ Work as weaving course.
→ Premix of (Well graded sand + Bitumen)
→ Used laid over cement concrete pavement to provide good riding surface.

Premix:-

(1) Sheet Asphalt/Rolled asphalt.
(2) Mastic asphalt
(3) Bitumen concrete
(4) Carpet
(5) DBM

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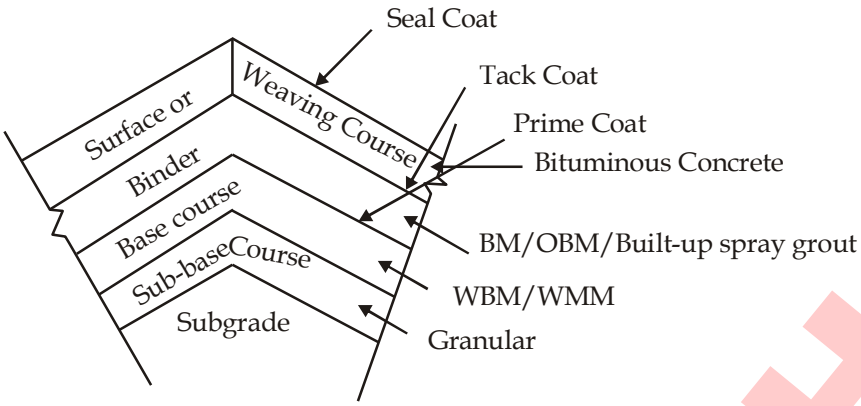


Prime Coat:-

→ It is the first application of "low viscosity" liquid.
→ Used to plug the voids.
→ Mc or Sc cutbacks of suitable grades are used based on the porosity of surface.

.....

→ A single coat of "low viscous" bituminous material applied over an existing road surface to construct another bitumen layer over it.
→ Emersion or cutback shall be used.

Seal Coat:-

→ Seal Coat is a top coat over certain bituminous pavements which are not impervious, such as open graded bitumen construction like Premix Carpet.

Main Function of Seal Coat are:-

→ To seal the surface against the ingress of water.
→ To develop skid resistance texture.

Liquid Seal Coat:-

→ Bitumen is sprayed over it 6.7 mm size aggregate is sprayed and then rolled.

Premix Seal Coat:-

→ Bitumen and coarse sand (Passing 2.36 mm and retained 180 u) are mixed and the applied on surfaced then rolled.

.....

→ Bridge is a structure providing passage over an obstacle without closing the way beneath.

Passage:- Pedestrain, Road, Railway, Canal etc.

Obstacle:- Rivers, Roads, Railways, Valley etc.

Types of Bridge:-

(A) Basis of Function:-

(1) Aqueduct- Water converging bridges for transportation of boats and ships.
(2) Viaduet - To carry a road or railway over water body a valley or another road.
(3) Padestrain
(4) Highway
(5) Railway

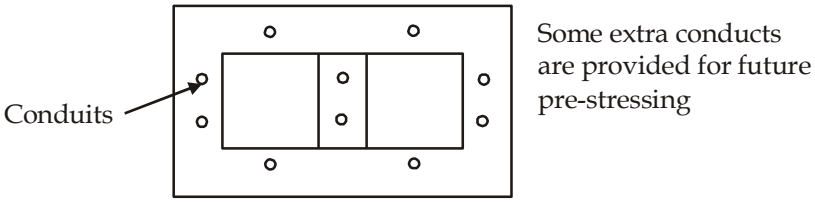
(B) Basis of length of bridge:-

(1) Culvert:- Bridge length is less than 6m. (Span $\leq$ 6m)
(2) Minor Bridge → Span $\leq$ 6m
(3) Major Bridge → Span > 6m

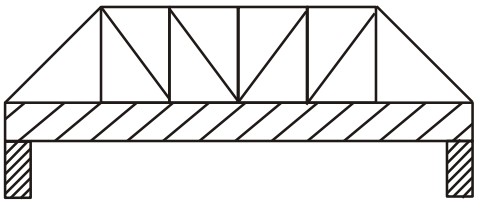
(C) Basis of Types of Super structure:-

(1) Slab Bridge:- A thick slab is used instead of girders.
→ This reduce the depth of bridge, hence increase the vertical clearance.
(2) Beam Bridge:- Girders are provided and a slab rest over girders.
→ Load is carried by flexure.

(a) Plate Girder Bridge → Simply supported span = 50 m maximum.
(b) Box Girder Bridge → Continuous span of 250 m.
→ Best in resisting torsion.

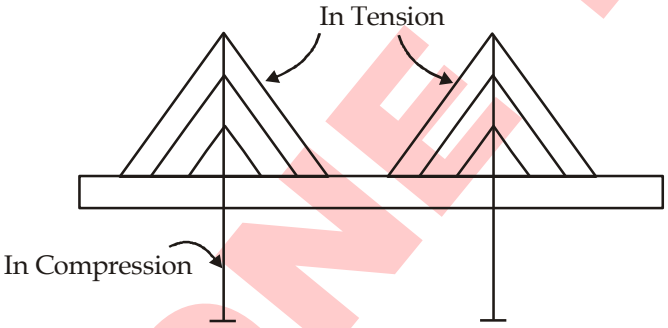


→ It behave like a beam but it carries vertical load by bending.

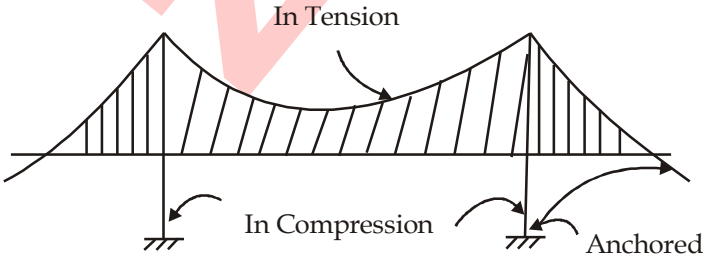


(4) **Arch Bridge** → (span → 200 - 500 m)

→ Loads carried primarily in compression.
(5) **Cable Stayed Bridge:-**



→ Span → 150 m - 700 m
→ The vertical load on deck carried by straight inclined cables are in tension.
(6) **Suspension Bridge:-**
→ It carried vertical loads from deck through curved cables in tension.



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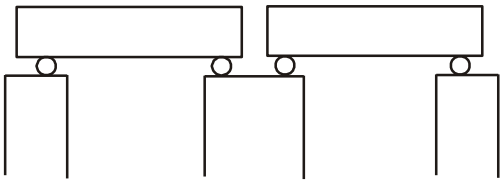
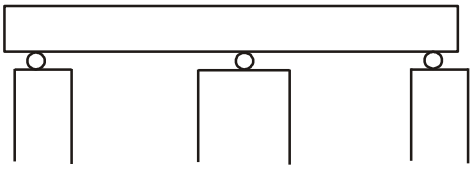
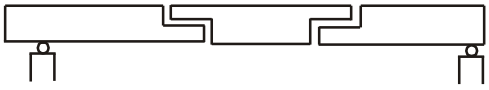


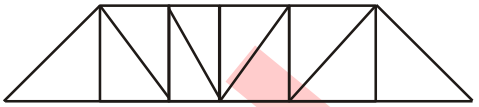
Simple



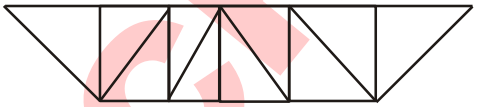
Continous



Cantilever



Through type



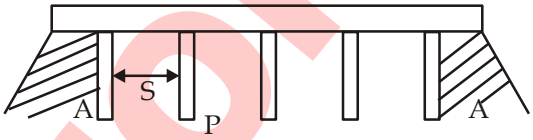
Deck Type

.....

(1) Cost can be minimised by providing Road Cum Railway bridge.
(2) For large navigational clearance → Arch, Cantilever, Suspension.
(3) For un-interupted traffic as on a NH need to reduce number of piers as cantilever bridge suspension bridge are best.
(4) Due to environmental condition such as corosive in sea, cable stayed or suspension bridges are used.
(5) For weak subsoil → Simply supported span bridge.
(6) If both ends are rocky firm → Arch bridge is best.

Ideal Site for Bridge:-

(1) A straight reach of river.
(2) Steady river flow without previous whires.
(3) A narrow channel with firm banks.
(4) Absence of sharp curves in the approach.
(5) Suitable high banks above high flood level on each side.
(6) Absence of expensive river training work.



For Economical Bridge →

(S = P)

S = Cost of one span

P = Cost of one Pier

.....

→ The actual standard loads are expressed in railway bridge rules as equivalent uniformly distributed loads (EUDL).

→ The EUDL depends upon span length.

For Bending moment:-

$$\text{EUDL in KN} = 317.97 + 70.83l + 0.21888l^2 \geq 449.2 \text{ KN}$$

For Shear Force:-

$$\text{EUDL in KN} = 435.58 + 75.15l + 0.0002l^2 \geq 449.2 \text{ KN}$$

Highway Bridge:-

(1) **IRC Class 70R Loading:- (Tracked or Wheeled)**

→ Adopted for all roads on which permanent bridges and culverts are constructed.

→ Bridge designed for 70R loading should be checked for class A loading also.

(2) **IRC Class AA Loading:-**

→ This loading is adopted within certain muncipal limits in certain exciting industrial are in specified areas along certain specified highways.

→ Bridges designed for class AA loading should be checked for class A loading also.

(3) **IRC Class A Loading:-**

→ Adopted on all roads on which permanent bridges and culverts are constructed.

(4) **IRC Class B Loading:-**

→ Adopted for Timber bridges and for all temporary bridges.

.....Two-lane - 7.5 m.

Impact:-

Provision for impact or dynamic action shall be made by increasing the live load by an impact factor.

> For class A or B Loading - Span between 3 and 45 m

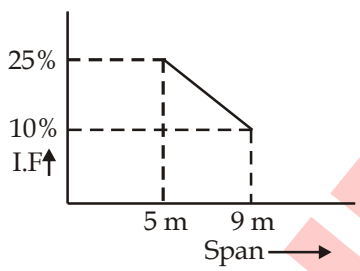
For concrete Bridges → $\frac{4.5}{6+L}$

For Steel Bridge → $\frac{9}{13.5+L}$

> For Class AA and 70R Loading:-

(1) **For span less than 9m:-**

Tracked vehicle → 25% for span upto 5 m.
10% for span upto 9 m.



Wheeled vehicle → 25%

(2) **For span of 9m or above-**

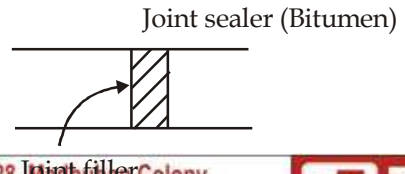
RCC Bridge
- → Tracked Vehicle → 10% for span upto 40 m
- → Wheeled Vehicle → 25% for span upto 12 m

Steel Bridge
- → Tracked Vehicle → 10% for all span
- → Wheeled Vehicle → 25% for span upto 23 m

For Footway Loading → No impact factor is applied.

Racking Force → 6 KN/m

Curvature Force → $\frac{mv^2}{R}$



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