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-: HAND WRITTEN NOTES:-

OF

CIVIL ENGINEERING

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-: SUBJECT:-

HIGHWAY

ENGINEERING

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Highway Engg — H.K Singh

③

Important Years :-

① Jaykar com'ttee
formed in → Nov. 1927
Submitted Report → 1928

② Central Road fund → 1929

③ Indian Road Congress → 1934

④ Motor vehicle Act → 1939

⑤ First 20 years Road Plan → 1943-63
[Nagpur Road plan]

⑥ CRRI (Central Road research Institute) – 1950

⑦ 2nd 20 years Road plan → 1961-81
[Bombay Road Plan]

⑧ 3rd 20 years Road plan → 1981-2001
[Lucknow road plan]

⑨ National highway Act → 1956

Jaykar Committee recommendation :- (4)

In 1928 Jaykar committee submitted its reports with following recommendations -

① Road development should be considered as a matter of national interest.

② An Extra tax on petrol should be levied for road developement works. → Results was central ~~Road~~ fund 1928

③ A semi official technical body should be formed to Act as an advisory body on various aspects of road (Results - IRC)

④ A research organisation should be instituted to carry out research and development works. Results (CRRI - 1950)

Road plans :-

	1st	2nd	3rd
① Years	1943 - 63	1961-81	1981 - 2001
② Vanue	Nagpur	Bombay	Lucknow
③ Target	16km/100sq km Area	32 km/100 sq km Area	82 km/100 sq km Area
④ Total road length target	5.29 lakh km	10.57 lakh km	27.02 lakh km

(5) Target Expenditure — 448 crore — 5200 caror

(3)

(6) Other points

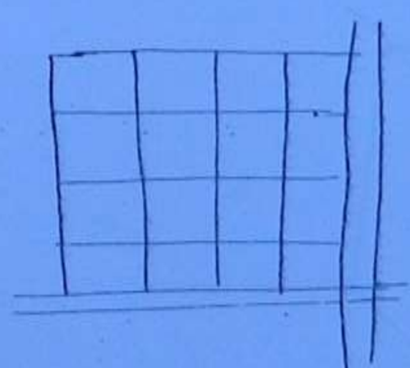
(1) NH
(2) SH
(3) MDR
(4) ODR
(5) VR

Added
(1) 1600 km of Expressway
(2) 5% allowance for future develoment

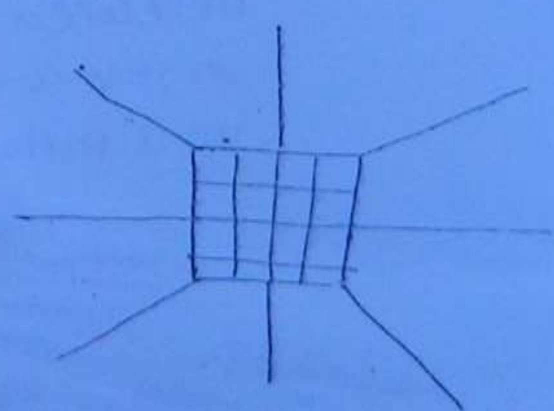
Classification
(1) Primary
(i) Expressway
(ii) NH
(2) Secondary
(i) SH
(ii) MDR
(3) Tertiary
(i) ODR
(ii) VR

* Different Road pattern :-

(1) Rectangular and Block pattern :-



(2) Star and Block pattern :-



) Star and circular :-

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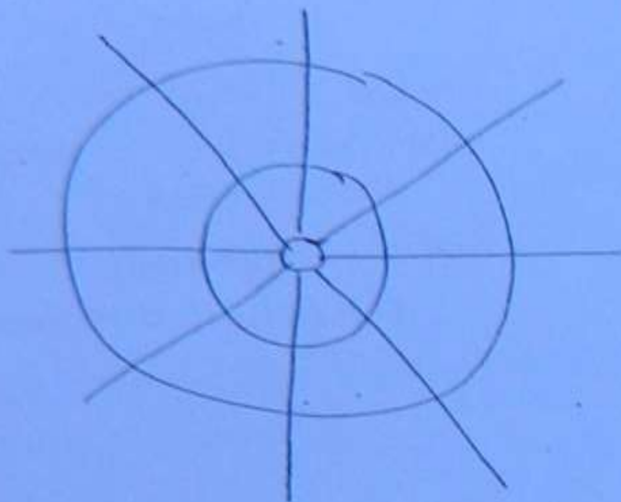
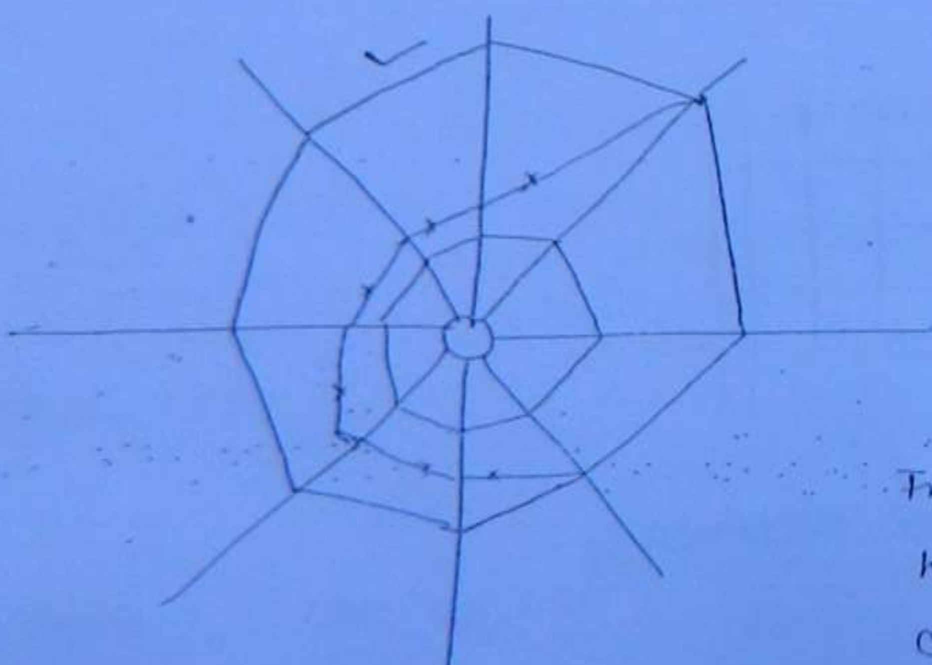


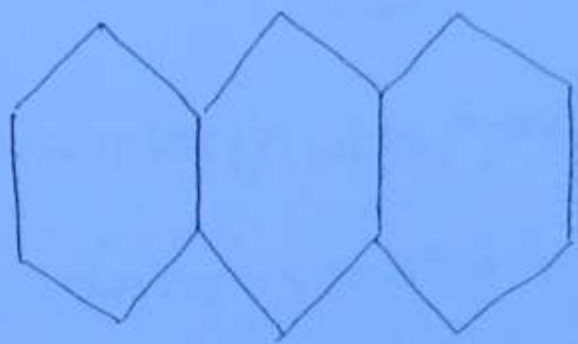
C.P.

I) ~~Star~~ Star and Grid pattern :-



Indian Road have been developed on star and grid pattern

5) Hexagonal :-



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Geometrical design

Terrain classification :-

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Types	Cross slope of terrain
Steep terrain	> 60 %
Mountaineous terrain	25 to 60 %
Rolling terrain	10 to 25 %
Plain terrain	< 10 %

Cross slope is Max^{m} slope of ground available in that area.

Design vehicle :-

Max width = 2.44 m (2.50 m)

Max height :

1) single deck = 3.80 m
2) Double deck = 4.70 m

Max^{m} length :

1) single unit with two axle = 10.7 m

(2) Single unit > 2 axle = 12.2 m

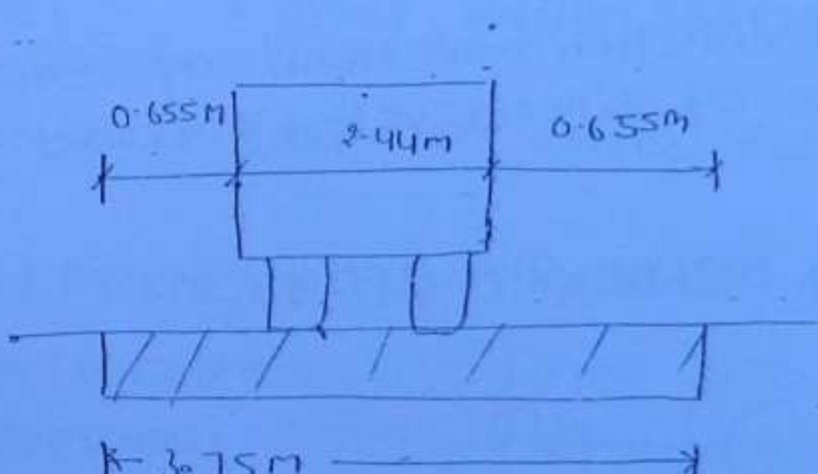
(3) Tractor + Trailor = 18.3M

(9)

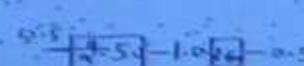
(1) Carraige way width

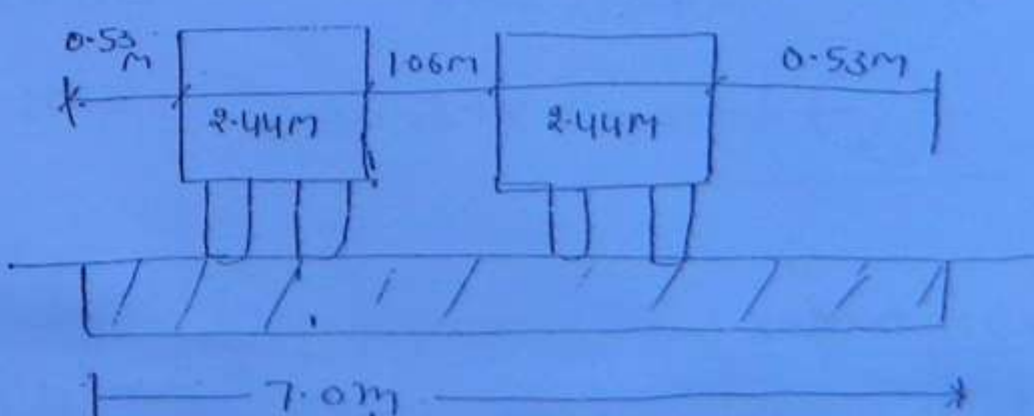
Single lane road = 3.75m

Two lane road = 7.00m



Single lane





Double lane

③ Pavement surface charecteristics:-

① Friction:-

There are two types

ⓐ longitudinal coefficient of friction

$\mu = f = 0.35$

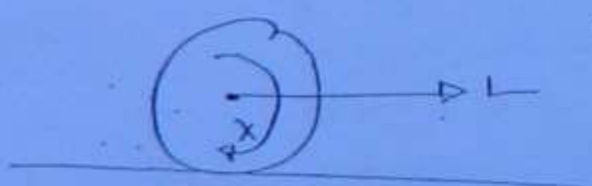
Applicable
[During application of brakes]

ⓑ Lateral coefficient of friction

$\mu = f = 0.15$

In lateral direction movement of vehicles
[Ex- In case of superelevation] or curves

Skid:- when brakes are applied.



Slip:- when accelerating

② Uneven index:-

This is the commutative value of undulation on a road surface measured in cm/km of road.

Type of pavement	uneven index
① Good pavement	< 150 cm/km
② satis factory	250 cm/km
③ unsatis factory [uncomfortable]	> 350 cm/km

③ **camber :-** central portion of road raised w.r.t. edges

Purpose → to drain off water from road surface

Type of pavement	Light Rainfall	Heavy Rainfall
① cemen concrete or high bituminous	1.7 % (1 in 60)	2 % (1 in 50)
② Thin Bituminous	2 % (1 in 50)	2.5 % (1 in 40)
③ WBM/gravel	2.5 % (1 in 40)	3 % (1 in 33.3)
④ Earth road	3 % (1 in 33.3)	4 % (1 in 25)

* **Design speed :-**

NH & SH

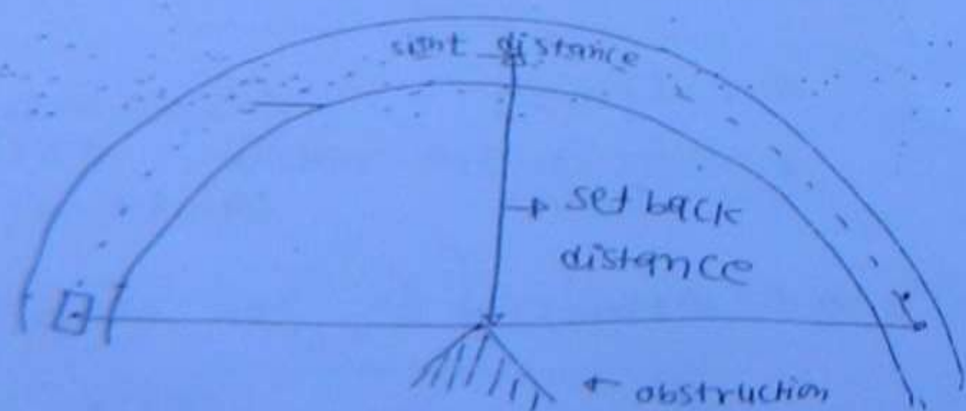
Plain		Rolling		mount		steep	
Ruling (R)	min (m)	R	M	R	M	R	M
100	80	80	65	50	40	40	30

pavement design done for Ruling speed.]

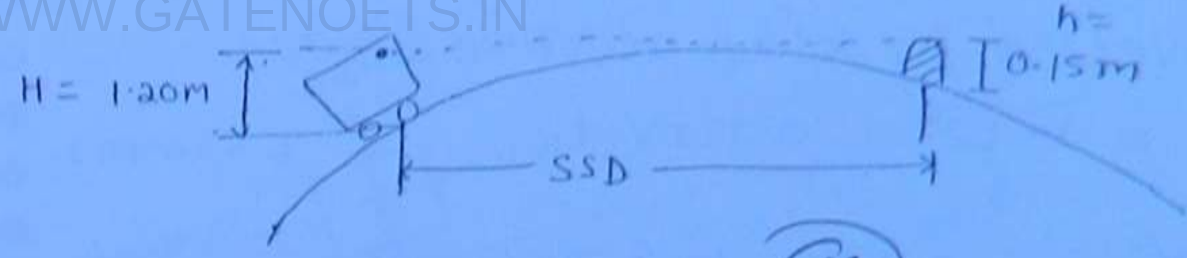
Sight distance :-

As per IRC sight distance requirement

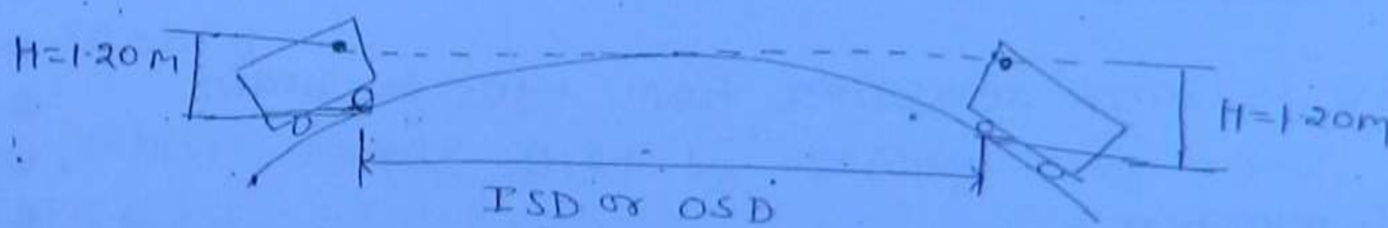
1) on Horizontal curve :-



2) on vertical curve :-



For stopping sight distance

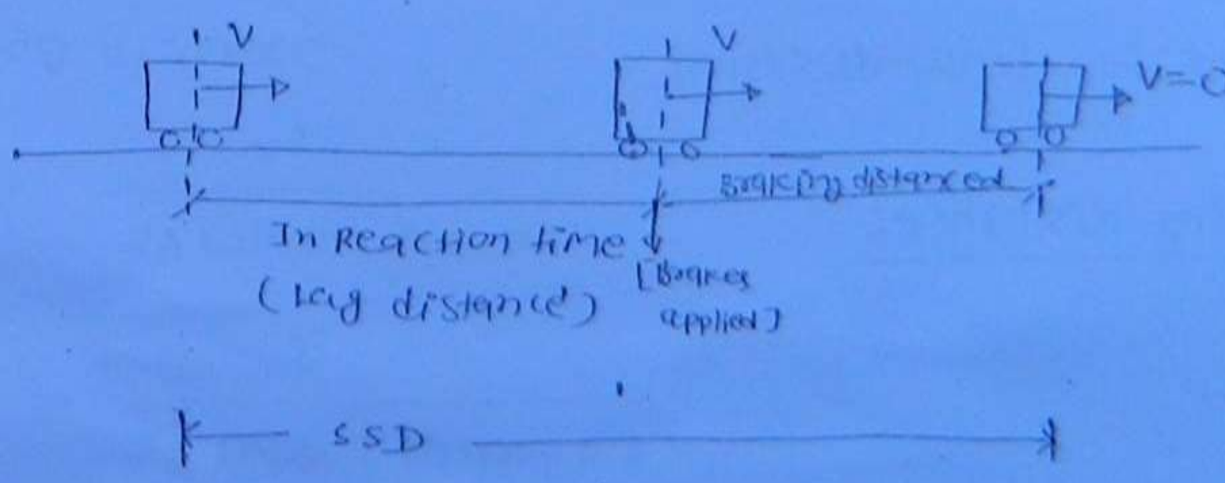


For intermediate or overtaking sight distance

① Stopping sight distance:-

→ Total distance required to a vehicle to stop.

= Lag distance + Braking distance



Lag distance:-

Distance travelled in total reaction time

$= V \cdot t_R = 0.278 V \cdot t_R$ [V = kmph]

Reaction time :- 0.5 sec to 5 sec.

generally :- 2.5 to 3 sec. considered

PIEV Theory :-

P → Perception :-

Time to send sensation from eyes to brain

I - Intellaction :-

Time to rearrange different thoughts, analysing the situation by brain.

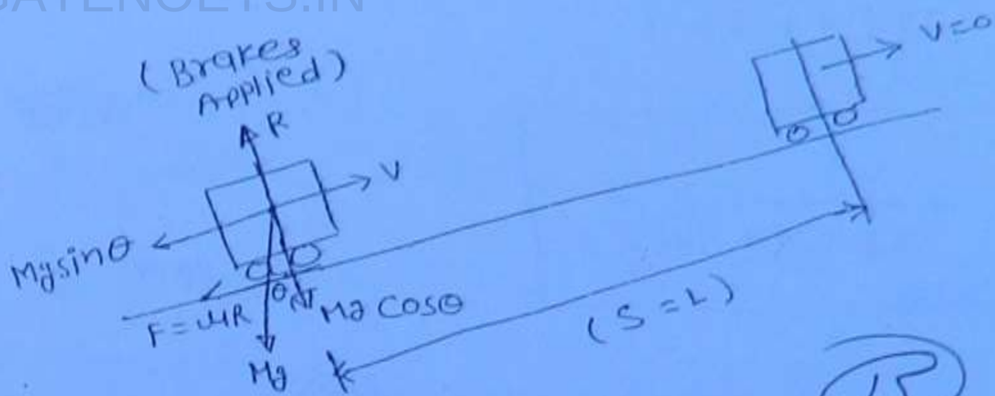
E → Emotion :-

Time elapsed in emotional sensation.

V → Volition :-

Time for final decision.

Braking distance:-



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Assumptions:-

① Brakes are fully applied wheels are fully jammed.

② Vehicle moves just by skiding over road surface.

$$K.E.\ Lost = work\ done$$

$$\frac{1}{2}mv^2 = (\text{Force of Resistance}) \times S$$

$$= (Mg\sin\theta + F)\cdot S$$

$$= (mg\sin\theta + f.mg\cos\theta)\, S$$

S = distance = L

μ = f

R = Mg cos θ

Braking distance

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

$$S = \frac{v^2}{2g\cos\theta\,(\tan\theta + f)}$$

For small θ, θ ≃ 1

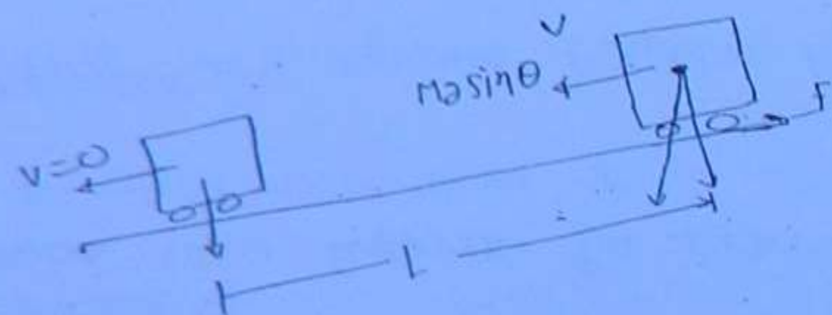
$$S = \frac{V^2}{2g[f + S\%]}$$

[S = L] distance

$$\boxed{L = \frac{V^2}{2g(f \pm S\%)}}$$

S% → slope

when movement is downward (16)



In this case

$$\boxed{L = \frac{V^2}{2g(f - S\%)}}$$ (downward)

Total stopping sight distance

$$\boxed{SSD = 0.278\,V \cdot t_R + \frac{(0.278\,V)^2}{2g(f \pm S\%)}}$$

Cases	Total sight distance
① one way road (one way traffic)	SSD
② one Lane road (Two way traffic)	2SSD
[Also called intermediate sight distance or meeting sight distance]	
③ Two lane road (Two way traffic)	SSD
④ Head light sight distance	SSD

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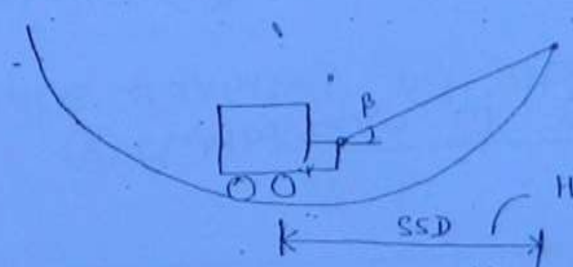
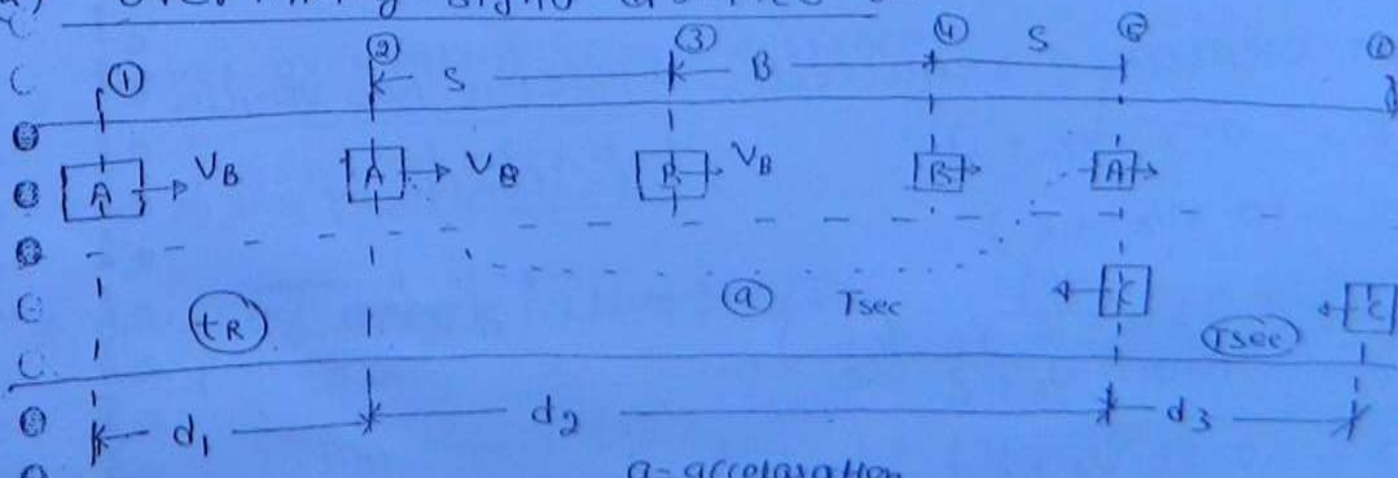


(2) overtaking sight distance :-



speed of (A) (overtaking vehicle) = V_A

speed of overtaken vehicle (B) = V_B

speed of opposite side vehicles (C) = V_C

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) Distance (d_1) :-

Distance travelled by vehicle (A) in reaction time.

[(A) is forced to move with same speed that of speed of vehicle (B)]

$$d_1 = V_B \cdot t_R = 0.278\, V_B \cdot t_R \quad \text{--- (1)}$$

t_R = Reaction time (2.5 to 3.0 sec)

Distance (d_2) :-

Distance travelled by (A) in overtaking (B).

$$d_2 = V_B \cdot T + \frac{1}{2} a T^2$$

$$d_2 = 0.278\, V_B \cdot T + \frac{1}{2} a T^2 \quad \text{--- (2)}$$

Minimum clearance required between two vehicles

$$S = 0.7 \cdot V_B + l$$

l = length of vehicle

$$S = (0.7 V_B + 6)$$

0.7 = t_R - Reaction time

$t_R \cdot V_B$ = Distance

$$S = (0.7 \times 0.278\, V_B + 6)$$

$$S = 0.20\, V_B + 6$$

$$\boxed{S = 0.20\, V_B + 6}$$

where 0.7 sec = reaction time for vehicles moving back to back.

distance $d_2 = 2S + B$

B → distance travelled by vehicle B (V_B)

$$\boxed{d_2 = 2S + V_B \cdot T} \quad \text{—— (3)}$$

Equating (2) and (3)

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

$$\boxed{T = \sqrt{\frac{4S}{a}}} \quad \text{—— (4)}$$

(3) Distance (d_3) :-

Distance travelled by opposite side vehicles (C)

$$= V_C \cdot T$$

$$\boxed{d_3 = 0.278\, V_C \cdot T} \quad \text{—— (5)}$$

Total over taking sight distance

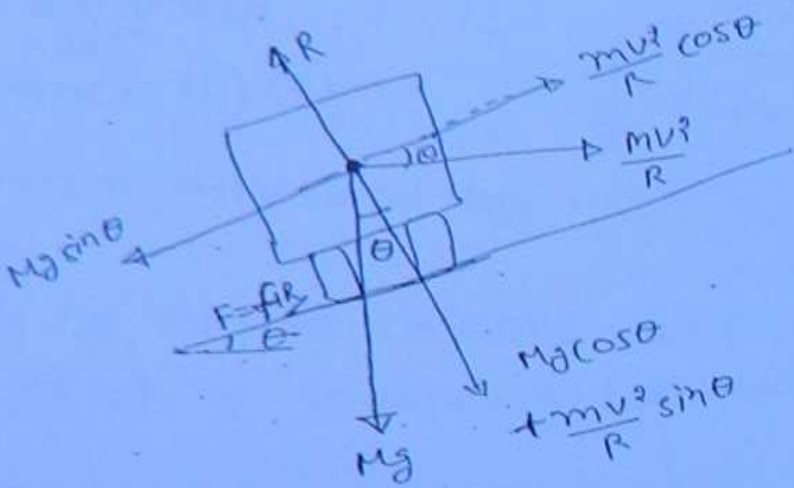
$$\boxed{OSD = d_1 + d_2 + d_3}$$

* Value of acceleration :- (a) (depends on the speed)

speed	25	30	40	50	65	80	100
a	1.41	1.3	1.24	1.11	0.99	0.72	0.53
OSD	–	90	165	235	340	470	640

Superelevation:

Superelevation is provided on curve to counteract the effect of centrifugal force.



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Forces

$mg \rightarrow$ weight

$\frac{mv^2}{R}$ = centrifugal force.

Force of friction

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

Equating all forces along the surface of road

$$Mg\sin\theta + F = \frac{mv^2}{R}\cos\theta$$

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

$$g\tan\theta + fg + f\cdot\frac{v^2}{R}\tan\theta = \frac{v^2}{R}$$

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

put $\tan\theta = e$, superelevation (S.E.)

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

$$\left(\frac{f+e}{1-fe}\right) = \frac{v^2}{gR} = \frac{(0.278V)^2}{9.81R} = \frac{V^2}{127R}$$

$$\boxed{\left(\frac{e+f}{1-fe}\right) = \frac{V^2}{127R}} \quad \text{—— (A)}$$

Max value of e is 10% and f = 0.15 so ef value is small so (1-ef) term is neglected or ≃ 1

so superelevation **

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

Design steps :-

Imp. Max^m superelevation is allowed :-

(A) on plain and rolling terrain = 0.07 (7%)

(B) on Hilly Road = 0.10 (10%)

(C) on urban Road with frequent intersection = 0.04 (4%)

Min. superelevation = camber slope

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Design steps:-

first S.E. is calculated for 75% of design speed (without considering f value)

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

$$e = \frac{V^2}{225R}$$

1) e calculated above is less than max. permissible super elevation hence its o.k.

$e < e_{max}$ → Hence o.k.

provide e value calculated

2) if $e_{cal.} > e_{max}$

limit e value to e_{max}

and check value of f considering full design speed.

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

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

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

if $f < 0.15$ (o.k.) provide e_{max}. 23

④ if f calculated $> f_{max}$ (0.15)

than Limit the speed [Restricted the speed]

$$e_{max} + f_{max} = \frac{V_{max}^2}{127R}$$

$$V_{max}\ (\text{allowed}) = \sqrt{127R\,(e_{max} + f_{max})}$$

⑤ special case :-

If no superelevation is provided max^m speed on a curve

$$V_{max} = \sqrt{127R \cdot f_{max}}$$

Minimum Radius of curve

$$R_{min} = \frac{V_{max}^2}{127\,(e_{max} + f_{max})} \quad \text{[At max. speed]}$$

$$R_{min} = \frac{V^2}{127\,(e + f)} \quad \text{[At Rulling speed]}$$

Extra widening :-

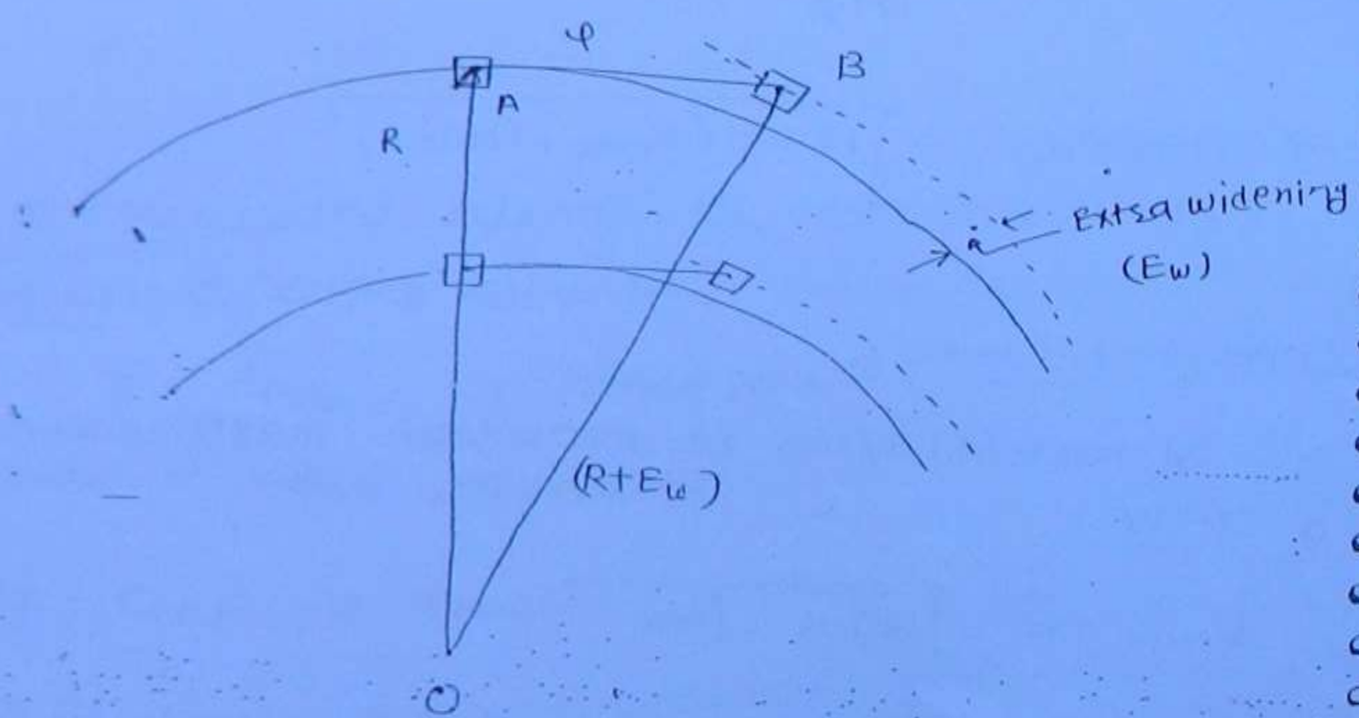
Extra widening is required on curve.

Purpose :-

Mechanical widening (24)

Psychological widening

Mechanical widening :-



In traingle OAB

$$R^2 + l^2 = (R + E_w)^2$$

$$R^2 + l^2 = R^2 + E_w^2 + 2R \cdot E_w$$

$$l^2 = E_w(E_w + 2R)$$

$$\because E_w + 2R \simeq 2R$$

$$E_w = \frac{l^2}{2R}$$

if n = number of lanes

$$\boxed{E_w = \frac{nl^2}{2R}} \quad \text{——— (1)}$$

(2) Psychological widening :-

→ Due to tendency to keep vehicles away from other vehicles.

$$\boxed{E_{pw} = \frac{V}{9.5\sqrt{R}}}$$

same for one lane or more lan.

V = KMph

Total Extra widening

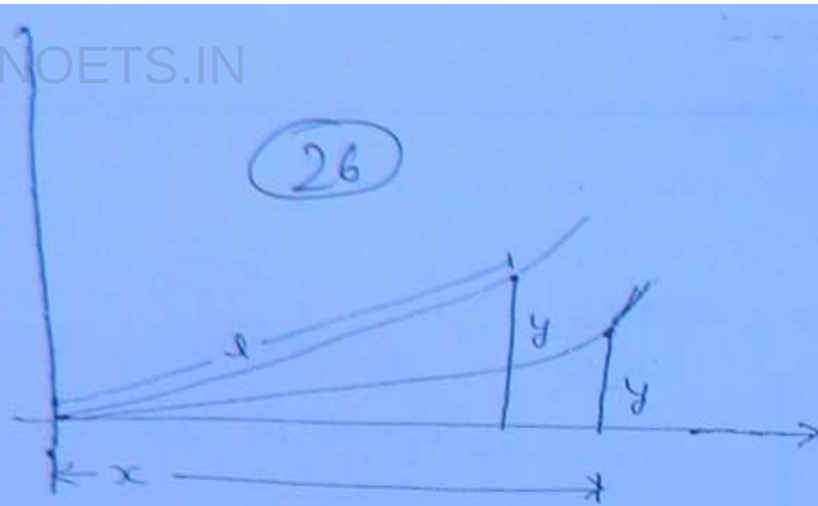
$$\boxed{E_w = \frac{nl^2}{2R} + \frac{V}{9.5\sqrt{R}}}$$

Transistion curve :-

→ For Highway Transition curve → spiral is used

(1) cubic parabola
$$y = \frac{x^3}{6RL}$$

(2) spiral
$$y = \frac{l^3}{6RL}$$



Length of transition curve:-

1) Based on rate of change of radial accelaration

$$\boxed{L = \frac{v^3}{CR}}$$

v = speed in m/sec.

C = Rate of change of Radial Acceleration ($m/sec^2/sec$)

R = Radius in meter

value of C

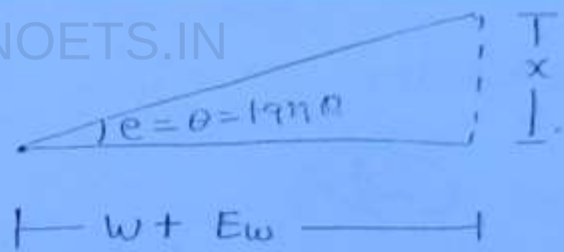
$$\boxed{C = \frac{80}{75 + V}}$$

value lies

$$\boxed{0.50 \leq C \leq 0.80}$$

2) Based on Rate of change of superelevation:-

i) if pavement is roteted about edge



Rise of outer edge

$$x = (w + E_w)\tan\theta$$

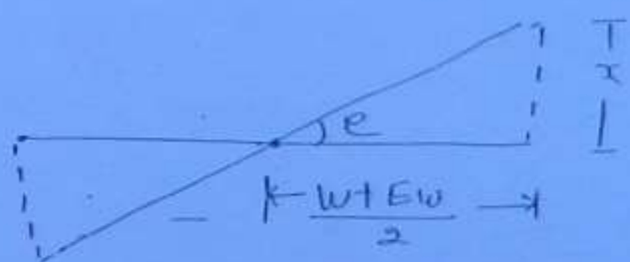
$$x = (w + E_w)\, e$$

W = width of Road

Length of Transistion curve

$$\boxed{L = N \cdot x}$$

ii) if pavement is rotated about centre



Raise of outer edge

$$x = \left(\frac{w + E_w}{2}\right) e$$

T.C = Transistion curve

Length of T.C. $= N \cdot x$

Length of transition curve

1. In plain and Rolling terrain = 150x
2. In built up Area = 100x
3. In hilly Area = 60x

By Empirical formula :-

› on plain and Rolling terrain

$$L = \frac{2.7 V^2}{R}$$ 28

V = Kmph

mountaneous and steep

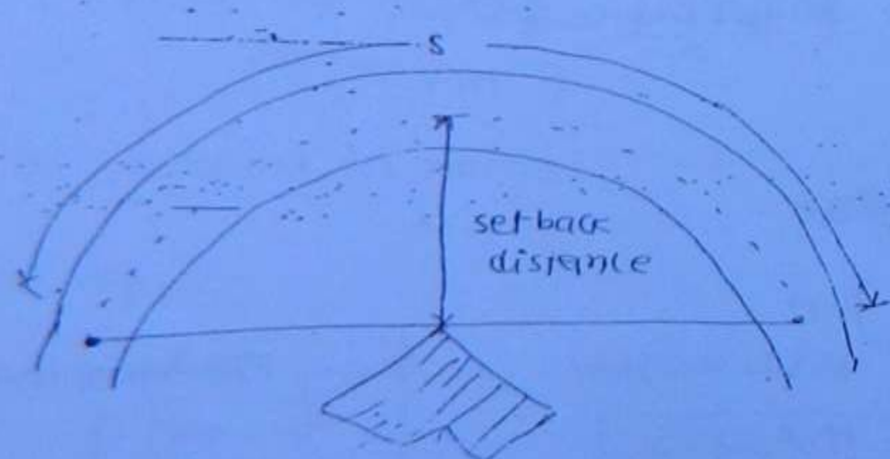
R = in meter.

$$L = \frac{V^2}{R}$$

shift of curve :-

$$\boxed{S = \frac{L^2}{24R}}$$

et Back distance :-



› set back distance is minimum clearance Required from centre of road at any obstruction on inner side of curve, so that full sight distance (SSD, or OSD or ISD) is available throughout the length of curve.

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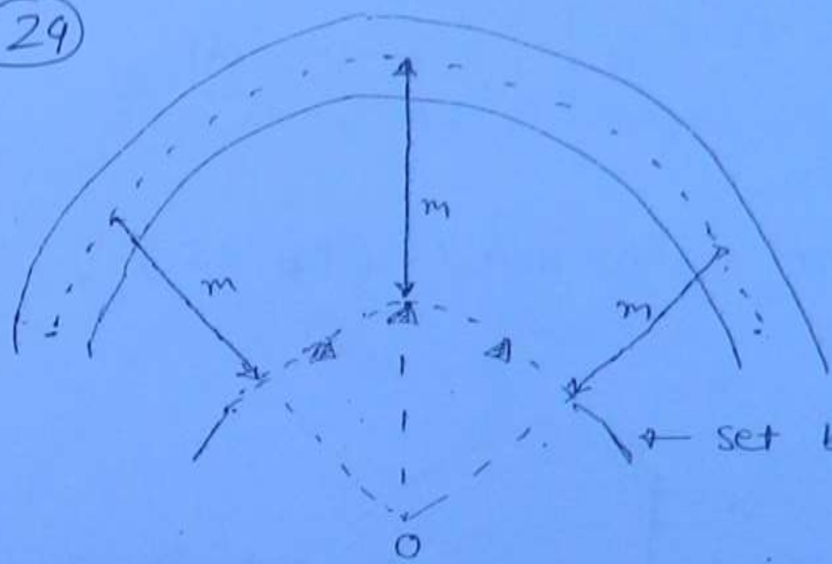
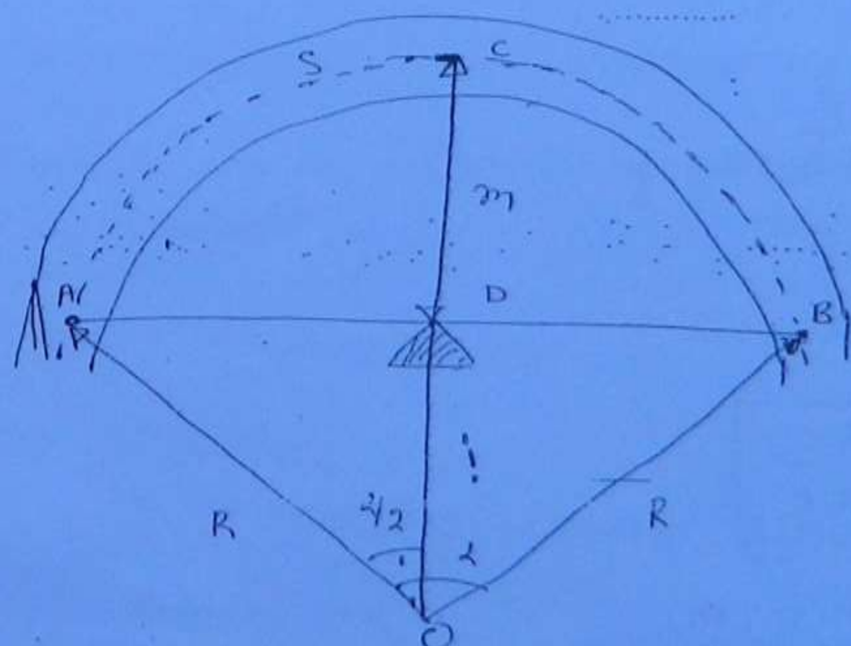


NOTE → Radius of curve and set back distance measured from centre of Road

Case ①

if length of curve (Lc) > sight distance

one lane Road (Lc > S)



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

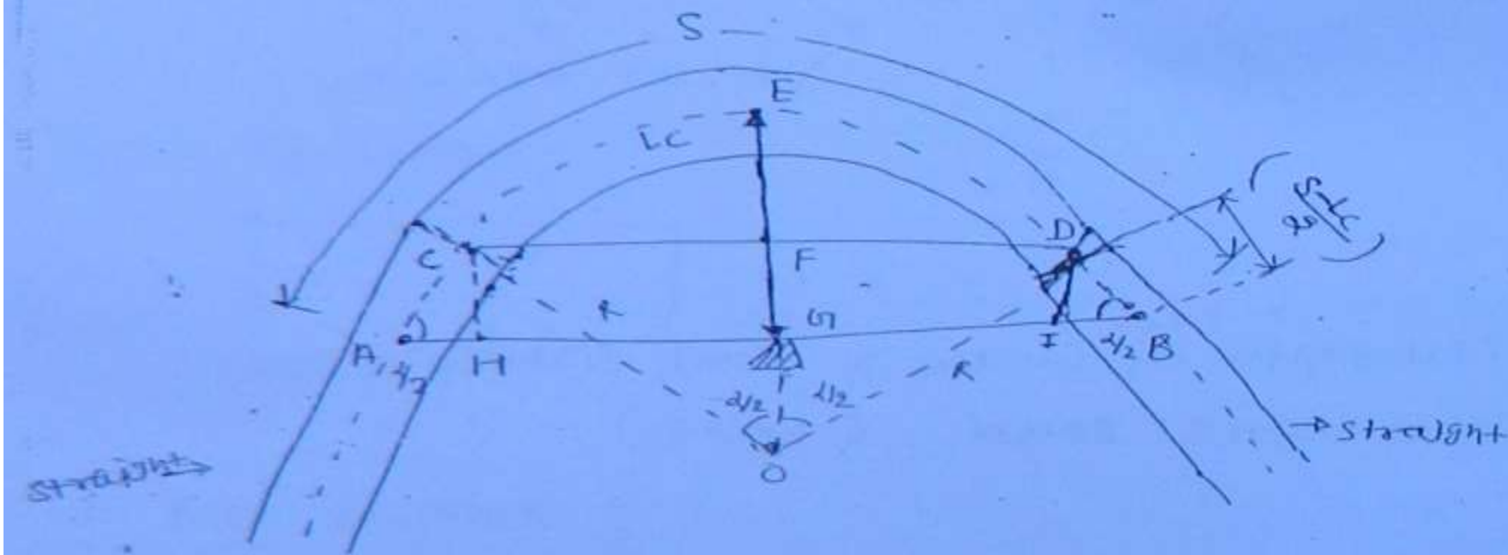
$$\alpha = \frac{360\,S}{2\pi R} \Rightarrow \frac{\alpha}{2} = \frac{180\,S}{2\pi R}$$

set Back distance

$m = CD = OC - OD$ (30)

$$\boxed{m = R - R\cos\frac{\alpha}{2}} \quad \text{—— (A)}$$

Case (2) One Lane Road ($L_c < S$)



$$\frac{L_c}{\alpha} = \frac{2\pi R}{360}$$

$$\alpha = \frac{360 L_c}{2\pi R}$$

$$\boxed{\frac{\alpha}{2} = \frac{180 L_c}{2\pi R}}$$

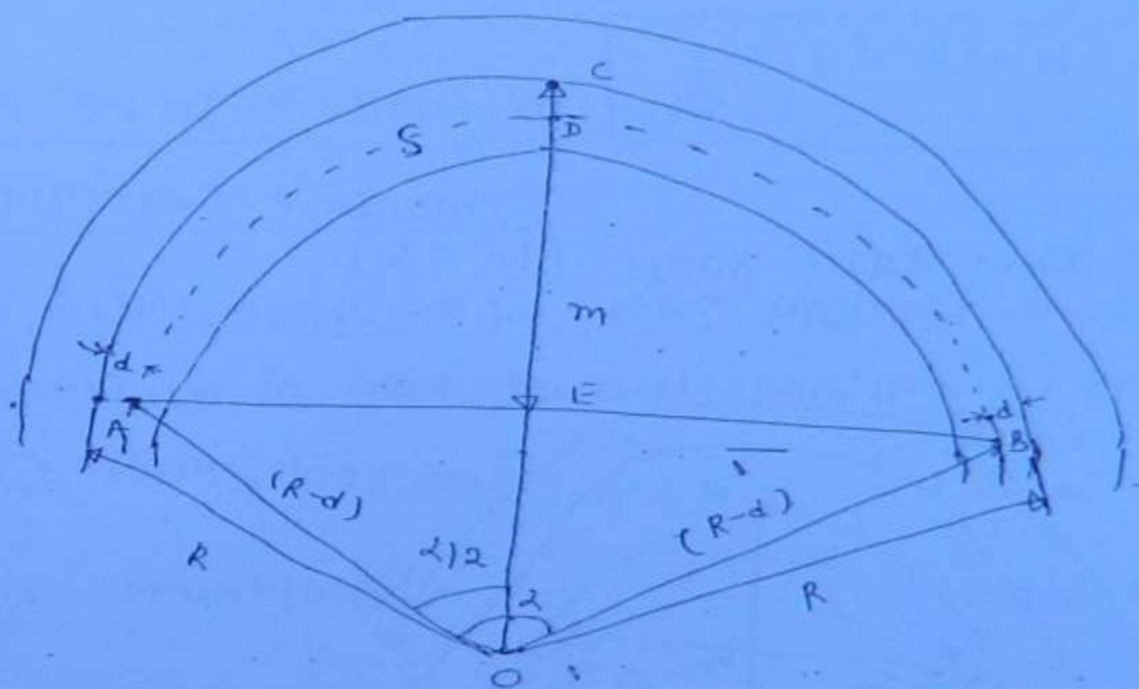
set back distance (m)

$m = EG = EF + FG$

$m = (OE - OF) + DI$

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

case-3 Two lane Road ($L_c > S$)



→ Set back distance from centre of road

→ Radius R from centre of road

→ Radius OA = (R-d)

d = half of one lane

→ sight distance

→ Measured along centre line of inner lane.

$$\frac{S}{\alpha} = \frac{2\pi(R-d)}{360}$$

$$\alpha = \frac{360 S}{2\pi(R-d)}$$

$$\frac{\alpha}{2} = \frac{180 S}{2\pi (R-d)}$$

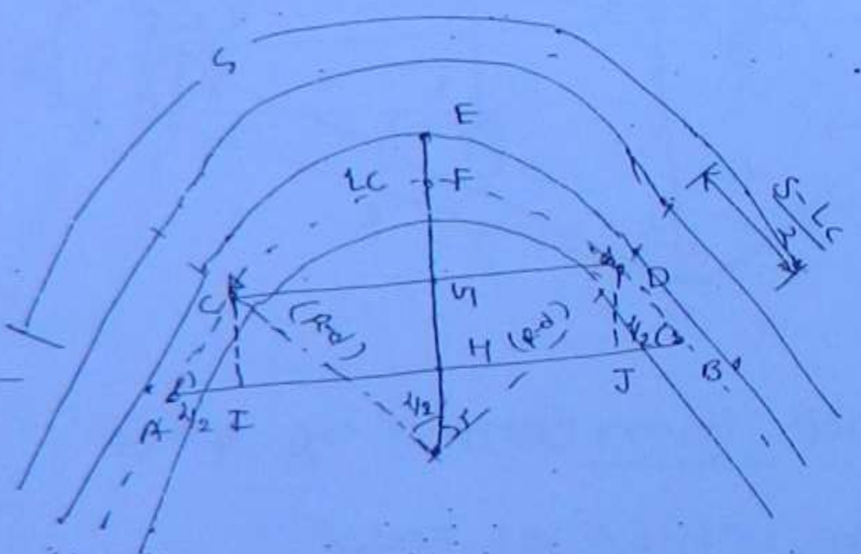
set back distance (32)

$m = CE$

$= OC - OE$

$$\boxed{m = R - (R-d)\cos\frac{\alpha}{2}}$$

ase (4) Two lane Road $(L_c < S)$



$$\frac{L_c}{\alpha} = \frac{2\pi (R-d)}{360}$$

$$\alpha = \frac{360 L_c}{2\pi (R-d)}$$

$$\frac{\alpha}{2} = \frac{180 L_c}{2\pi (R-d)}$$

Setback distance

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$$m = EH$$
$$= EG + GH$$
$$= (OE - OG) + DJ$$

$$\boxed{m = \left[R - (R-d)\cos\frac{\Delta}{2}\right] + \frac{S-L_c}{2}\sin\frac{\Delta}{2}}$$

Design of vertical alignment :-

Different gradients

Ⓐ Ruling gradients :- Max^m gradient that can be provided in most general condition of road, traffic

	(values)
① plain gradient	1 in 30
② mountaneous	1 in 20
③ steep region	1 in 16.7

Ⓑ Limiting gradient :-

Due to cost factor as per topography, gradient can be increased to limiting gradient

	value
① plain and rolling	1 in 20
② mountaneous	1 in 16.7
③ steep gradient	1 in 14.3

Exceptional gradient :- (34)

In very Extra ordinary situation, when there is no option Max^m gradient that can be provided is called Exceptional gradient.

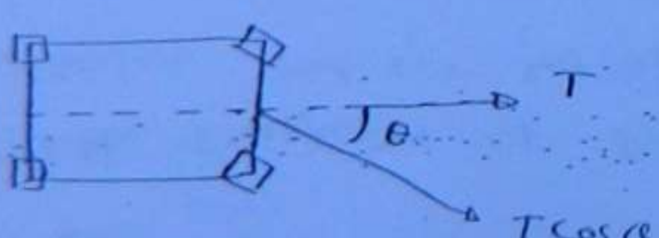
Plain and rolling	1 in 15
Mountanous	1 in 14.3
steep	1 in 12.5

Minimum gradient :-

→ 1 in 500 is required to drain of water in concrete drain

→ 1 in 200 on interior surface

Curve Resistance :-



In a curved track Tractive force available = T cos θ

the direction of movement

Curve resistance = $(T - T\cos\theta)$

Grade compansation :-

Reduction of grade at the location of curve

Grade compansation (35)

$$= \frac{30+R}{R}\ \%\ ,\ \text{subjected to max}^m$$

value of $\left(\frac{75}{R}\ \%\right)$

Ex. For a mountaneous region at the location of a curve, of R = 120m, what max^m Ruling gradient can be provided.

Sol. Ruling gradient [For mountanous] = 1 in 20 = 0.05

Grade compansation

$$= \frac{30+R}{R} = \frac{30+120}{120} = \frac{150}{120}.$$

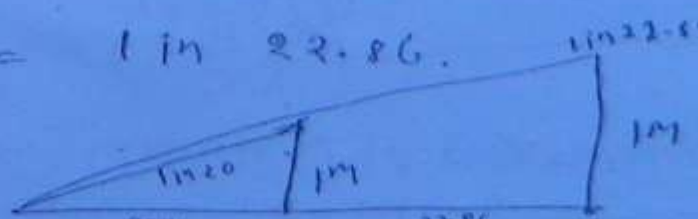
$$\text{Max}^M\ \frac{75}{R} = \frac{75}{120}\ \% = 0.625\%$$

$$= \frac{0.625}{100} = 6.25 \times 10^{-3}$$

Compansated gradient

$$= 0.05 - 6.25\times10^{-3} = 0.04375$$

$$= 1 \text{ in } 22.86.$$



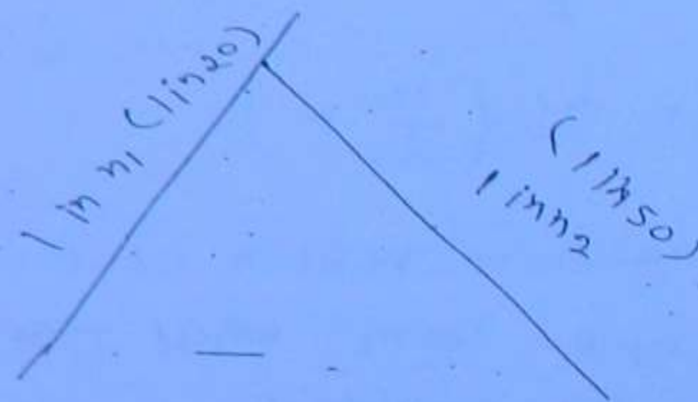
Vertical curve:-

1) summit curve

2) valley curve

(36)

Change in gradient:-(N)



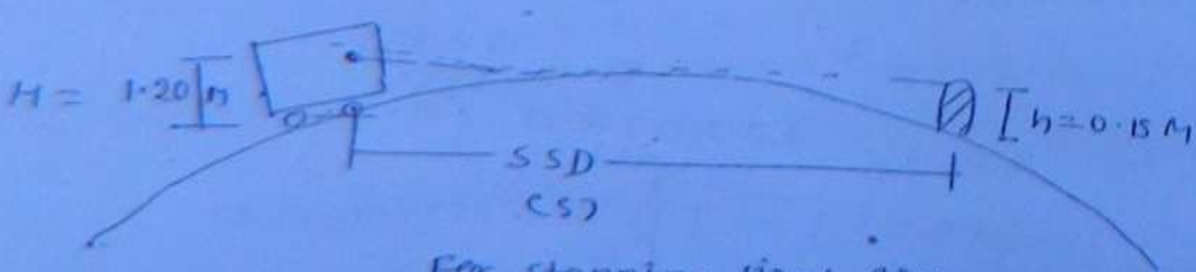
$$\boxed{N = \left| \frac{1}{n_1} - \frac{1}{n_2} \right|}$$ general formula

$$N = \left| \frac{1}{20} - \left(-\frac{1}{15}\right) \right|$$

$$N = \frac{1}{20} + \frac{1}{15} = 0.116667$$

Summit curve:- (simple parabola)

Case 1 when ($L_c > S$)



For stopping sight distance

In this case two transistion curve are provided back to back to form the valley curve.

Length of one transistion curve :-

(Based on Rate of change of Radial Acceleration)

$$L_s = \frac{v^3}{CR}$$

(37)

Radius of T.C. at Junction

$$R = \frac{L_s}{N}$$

$$L_s = \frac{v^3}{C\left(\frac{L_s}{N}\right)} = \frac{N v^3}{C L_s}$$

$$L_s^2 = \frac{N v^3}{C}$$

$$L_s = \sqrt{\frac{N v^3}{C}} = \left(\frac{N v^3}{C}\right)^{1/2}$$

Total length of T.C.

$$\boxed{L = 2 L_s = 2\left(\frac{N v^3}{C}\right)^{1/2}}$$

Length of valley curve

$$L = 2\left(\frac{N v^3}{C}\right)^{1/2}$$

N = Total change in gradient

V = m/se . C = m/sec³

Head light sight distance:-

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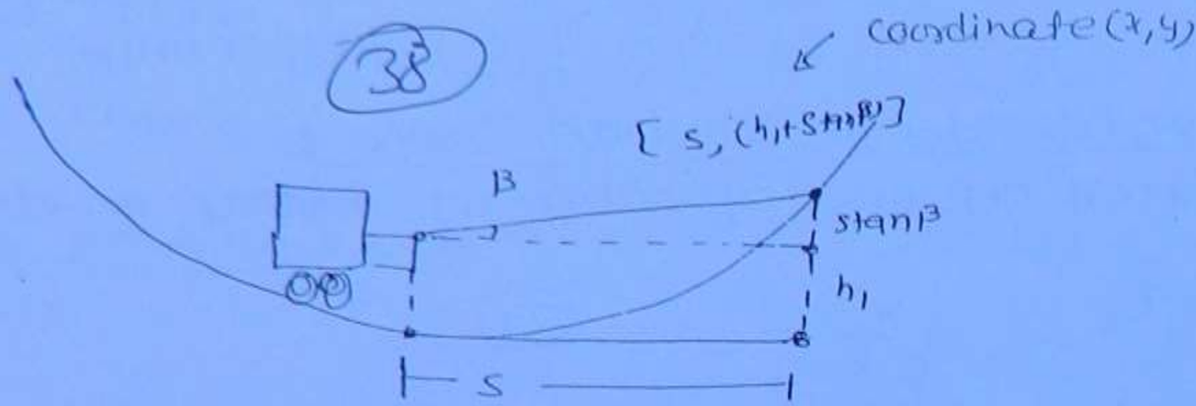


Equation of parabola

$$y = a x^2$$

$$= \left(\frac{N}{2L}\right) x^2$$

$$h_1 + s\tan\beta = \frac{N}{2L}(s)^2$$

Length of valley curve (when $L > s$)

$$\boxed{L = \frac{Ns^2}{2(h_1 + s\tan\beta)}}$$

where

N = Total change in gradient

S = sight distance (SSD/OSD/ISD) in meter

h_1 = height of head light above road surface

$\boxed{h_1 = 0.75}$ if not given

β = Beam angle of head light

$\boxed{\beta = 1^\circ}$ if not given

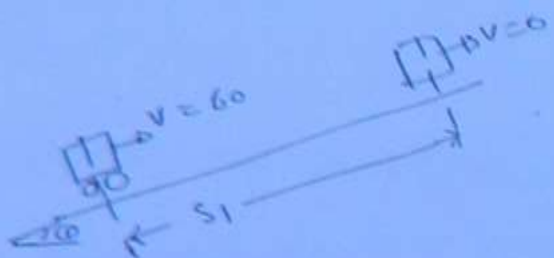
(2) if length $L < S$

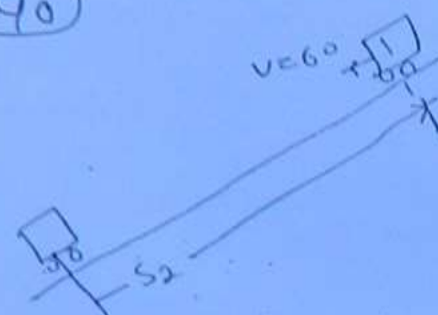
Length of valley curve

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

- The driver of a vehicle travelling 60 Kmph up a gradient required 9m less to stop this vehicle after he applies the brakes, than driver travelling at same speed down the same gradient f = 0.4, what is the % gradient

(40)





(θ = s%)

$$S_1 = S_2 - 9$$

$$S_1 = \frac{V^2}{2g(f + s\%)}$$

$$S_2 = \frac{V^2}{2g(f - s\%)}$$

$$S_2 - S_1 = 9$$

$$\frac{V^2}{2g(f-s)} - \frac{V^2}{2g(f+s)} = 9$$

$$\frac{(0.278 \times 60)^2}{2 \times 9.81(0.4 - s)} - \frac{(0.278 \times 60)^2}{2 \times 9.81(0.4 + s} = 9$$

$$\frac{1}{0.4 - s} - \frac{1}{0.4 + s} = \frac{9}{14.18}$$

- Length of curve required to fulfill IRC condition

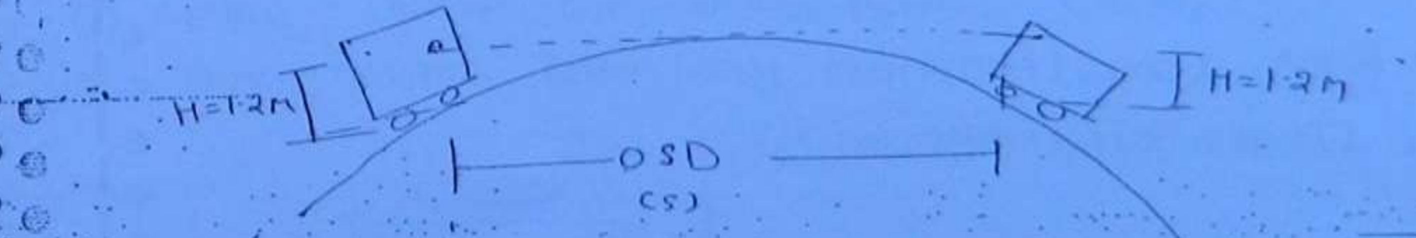
(41)

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

$$L = \frac{NS^2}{(\sqrt{2 \times 1.2} + \sqrt{2 \times 0.15})^2}$$

$$\boxed{L = \frac{NS^2}{4.4}}$$ For SSD

For OSD ~~or BSD~~



Length of curve

$$L = \frac{NS^2}{(\sqrt{2 \times 1.2} + \sqrt{2 \times 1.2})^2} = \frac{NS^2}{9.6}$$

$$\boxed{L = \frac{NS^2}{9.6}}$$

Case-2 if ($L_c \leq S$)

$$\text{Length of curve} = 2S - \frac{(\sqrt{2H} + \sqrt{2h})^2}{N}$$

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

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

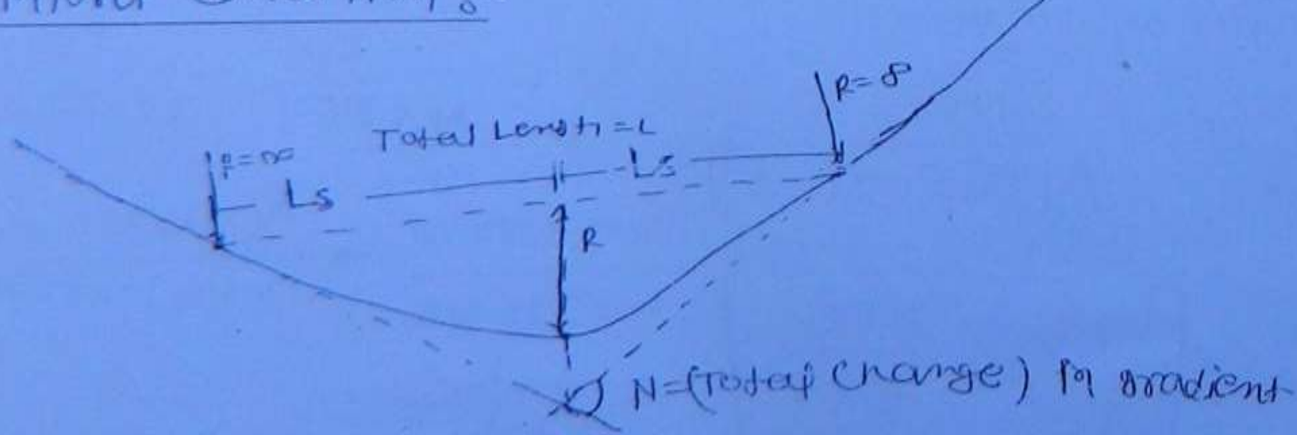
For OSD - $\boxed{L = 2S - \frac{9.6}{N}}$

Valley curve :- (Cubic parabola) is used for Highway valley curve

Two criteria :-

1) Comfort condition
2) Head light sight distance

Comfort condition :-



$$\frac{0.4+s-0.4+s}{(0.4-s)(0.4+s)} = 0.63467$$

43

$$\frac{2s}{0.63467} = 0.4^2 - s^2$$

$$3.15\,s = 0.16 - s^2$$

$$s^2 + 3.15s - 0.16 = 0$$

$$S = 0.049 = 0.05 \quad (1 \text{ in } 20.4) \text{ slope}$$

Q.2
ES 2010

speed of overtaking and overtaken vehicles are 80 (V_A) and 60 (V_B) kmph

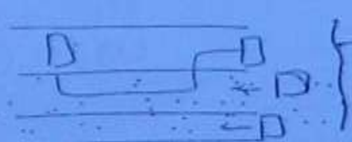
$a = 2.5$ kmph/sec.

calculate safe passing distance.

① single lane one way traffic (d_1+d_2)

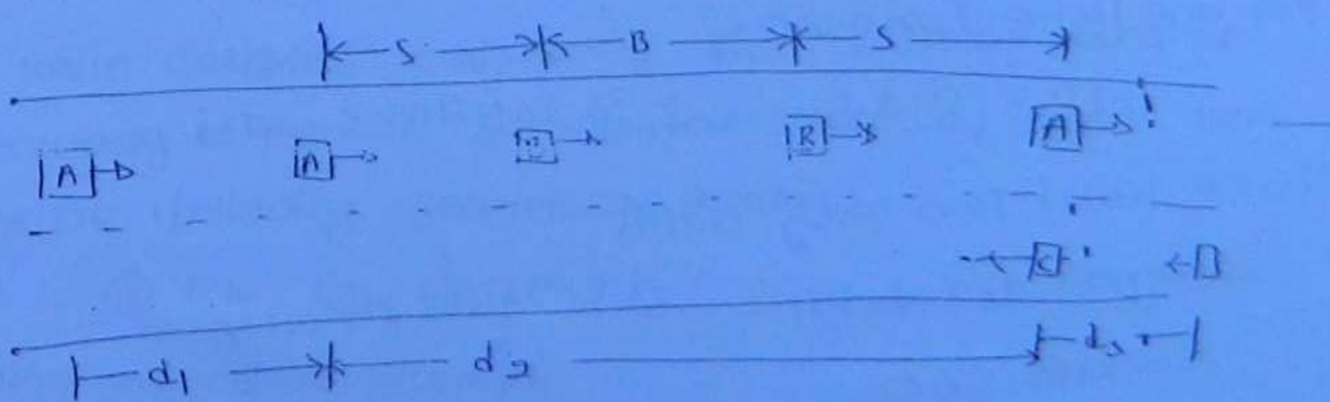
② Three lane both way traffic $(d_1+d_2+d_3)$

Reaction time 2 sec



** when speed of opposite side not given than take $(V_A = V_C)$

Sol^n



Distance $d_1 = 0.278 V_B \cdot t_R$

$= 0.278 \times 60 \times 2 = 33.36m$

Distance d_2 44

Min. distance b/w two vehicles

$s = 0.2V_B + 6$

$s = 0.2 \times 60 + 6 = 18m$

Time (T) $= \sqrt{\frac{4s}{a}} = \sqrt{\frac{4 \times 18}{0.278 \times 2.5}} = 10.18sec.$

↳ change in m

distance

$d_2 = 2s + B = 2 \times 18 + 0.278 \times V_B \cdot T = 205.8m.$

Distance d_3

$= 0.278 V_c \cdot T$

$= 0.278 \times 80 \times 10.18 = 226.40m$

V_c Not give take * $\boxed{V_A = V_c}$

For one lane / one way

$OSD = d_1 + d_2 = 33.36 + 205.8 = 239.16m$

Three lan / Two way traffic

$OSD = d_1 + d_2 + d_3 = 33.36 + 205.8 + 226.4$

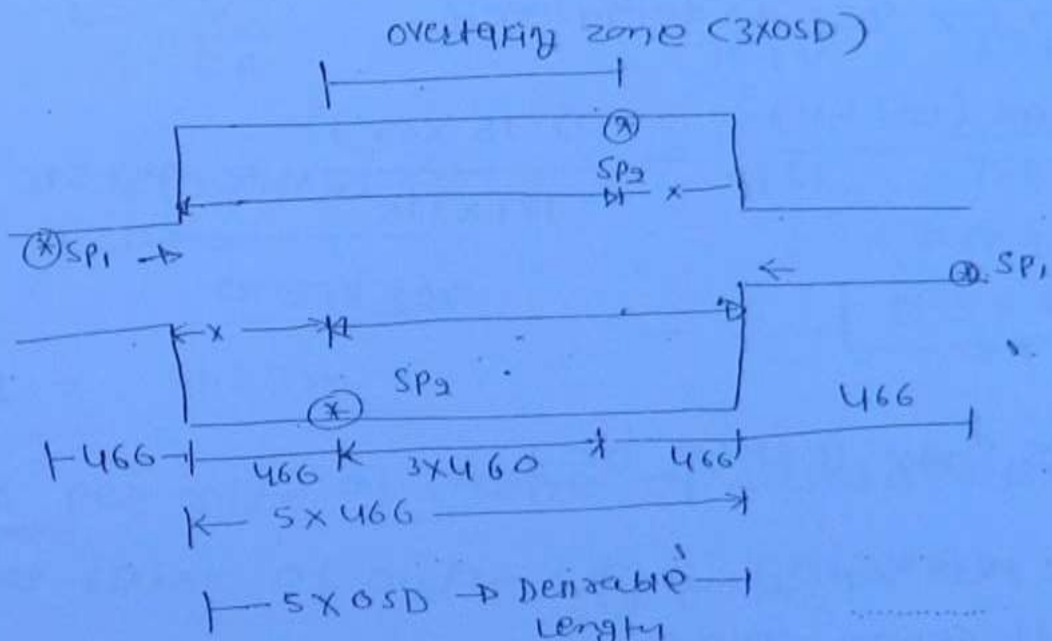
$= 465.56M$

For Total OSD = 466m

* Min length of overtaking zone

= 3 × OSD = 3 × 466 = 1398m

* Desirable length = 5 × OSD = 5 × 466 = 2360



HomeWork

① 1(c) 1995 ② 6(a) 1995

Q. 1992 While designing a highway in a built up area, it was necessary to provide a horizontal curve of Radius 325m. Design the following geometrical features.

① SE ② EW ③ length of T.C. EW = Extra widening

Design speed = 65kmph

length of wheel base = 6.1m

pavement width = 10.5m

$R = 325\,m$

$V = 65\,kmph$

$l = 6.1\,m$

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$W = 10.5\,m$

no. of lane $= \frac{10.5}{3.5} = n = 3$

1) superelevation

a) design for 75% of design speed

$$e = \frac{(0.75V)^2}{127R} = \frac{(0.75 \times 65)^2}{127 \times 325} = 0.0575$$

$= 5.75\%$

$e_{max} = 7\%$

$e < e_{max}$ (Hence ok)

b) check the value of (f)

for full design speed

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

$$f = \frac{65^2}{127 \times 325} - 0.0575 = 0.045 < 0.15 \text{ (o.k)}$$

provide ~~max for~~ Into both values

$\boxed{S.E = 5.75\%}$

2) Extra widening

$$E_w = \frac{nl^2}{2R} + \frac{V}{9.5\sqrt{R}} = \frac{3 \times 6.1^2}{2 \times 325} + \frac{65}{9.5\sqrt{325}}$$

$= 0.55\,m$

Total width of road

$$= W + E_W = 10.5 + 0.55 = 11.05\,m$$

(3) Length of transition curve

(a) As per Rate of change of Radial acceleration

$$L = \frac{V^3}{CR} \qquad C = \frac{80}{75+V} = \frac{80}{75+V}$$

$$= \frac{80}{75+65}$$

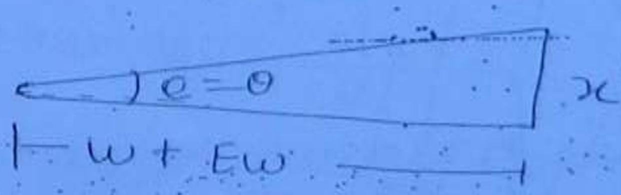
$$L = \frac{(0.278 \times 65)^3}{0.57 \times 325} \qquad = 0.57$$

$$\boxed{0.5 \le C \le 0.8}$$

$$L = 31.85\,m$$

(b) As per rate of change of superelevation

Total raise of outer edge (Assume)



$$x = (W + E_W)\,e = (11.05)\frac{5.75}{100} = 0.6354\,m$$

$$L = 100 \times x = 100 \times 0.6354 = 63.54\,m$$

(c) Empirical formula

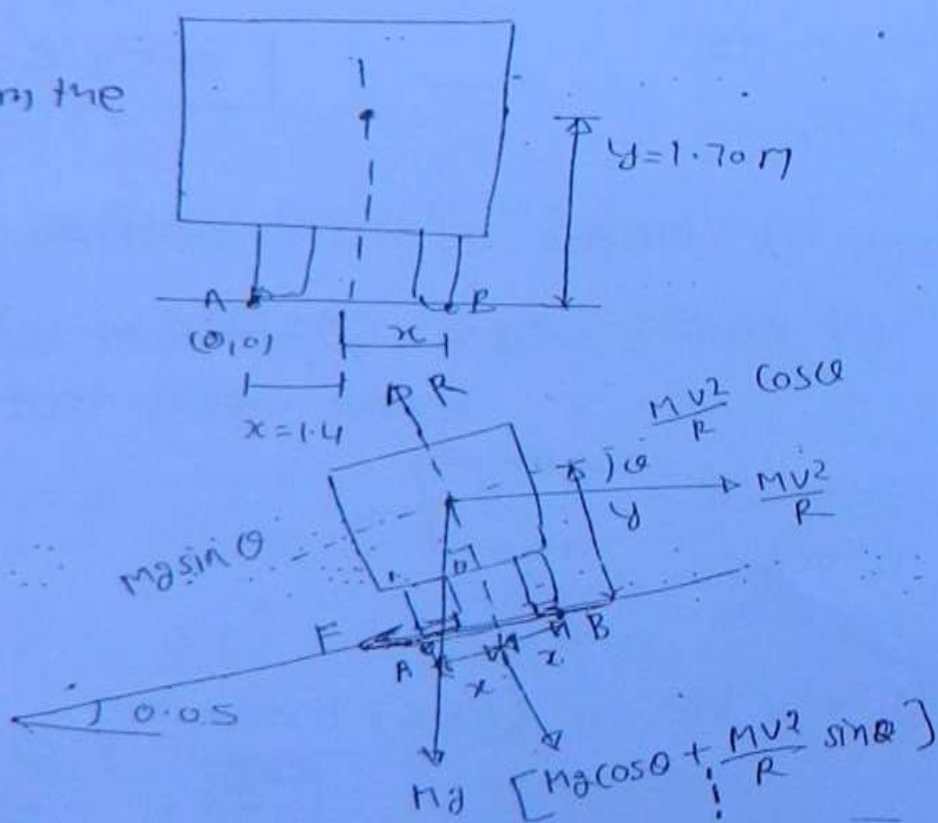
$$L = 2.7\frac{V^2}{R} = \frac{2.7 \times 65^2}{325} = 35.1\,M$$

Length of T.C = 64m

Take Max. value

6. A truck with c.g. at x = 1.4m and y = 1.7m is travelling on a curve road of Radius 200m and S.E = 0.05. Determine max safe speed to avoid both slipping and overturning. coefficient of side friction = 0.15. Sketch explain and derive the expression.

x and y from the wheel



i) For slipping condition:

All the forces along the surface of road should be in Equilibrium

$-mg\sin\theta + F = \frac{mv^2}{R}\cos\theta$

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

$g\tan\theta + \left[fg + f\frac{v^2}{R}\tan\theta\right] = \frac{v^2}{R}$

$$\frac{e+f}{1-ef} = \frac{v^2}{gR}$$

Max speed.

$$\therefore\ V = \sqrt{\frac{gR\,(e+f)}{(1-ef)}} = \sqrt{\frac{9.81\times 200\times[0.05+0.15]}{(1-0.05\times 0.15)}}$$

$V = 19.88\ m/sec. = 71.52\ kmph$

(2) For overturning

vehicle may overturn about point B

Equating moment of all forces about B

$$\frac{mv^2}{R}\cos\theta \times y = \cancel{m}g.\sin\theta\ y + \left(\cancel{m}g\cos\theta + \frac{mv^2}{R}\sin\theta\right)x.$$

$$\frac{v^2}{R}\times y = g\tan\theta\, y + gx + \frac{v^2}{R}\tan\theta\, x$$

$$\frac{v^2}{R}\cdot y = g\cdot e\cdot y + g\cdot x + \frac{v^2}{R}e\cdot x$$

$$\frac{v^2}{R} = \frac{g(x+ey)}{(y-ex)}$$

$$\boxed{\frac{v^2}{gR} = \frac{x+ey}{y-ex}}$$

$$V_{max} = \sqrt{\frac{(x+ey)}{(y-ex)} \times gR}$$

$$V_{max} = \sqrt{\frac{(1.4+0.05\times1.7)}{(1.7-0.05\times1.4)} \times 9.81 \times 200}$$

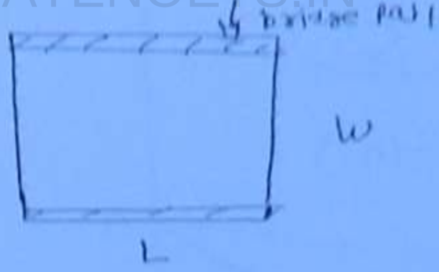
$$V_{max} = 42.27 \text{ m/sec} = 152.05 \text{ KMph}$$

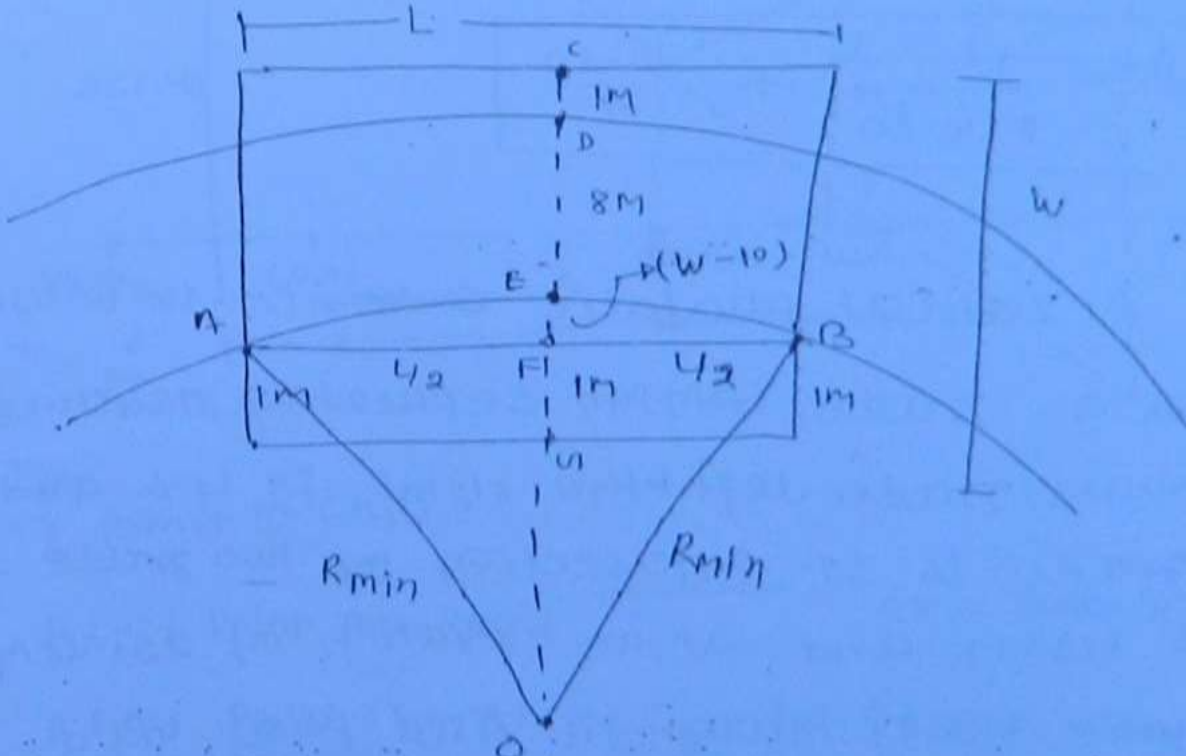
max speed will be allow take minimum

$$\boxed{V_{max} = 71.52 \text{ KMph}}$$

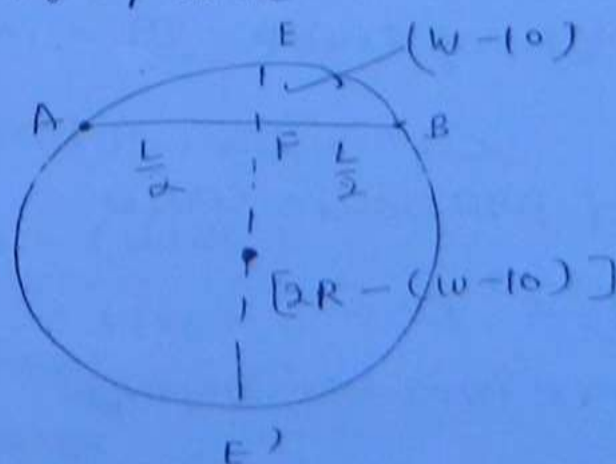
5 Ex. A rectangular bridge span of length L and width w, is used on a Horizontal curve. If the roadway is 8m wide, and minimum clearance of 1m is desired b/w the edge of pavement and bridge rail. Show that minimum radius of curvature

$$R = \frac{L^2}{8(w-10)} + \frac{(w-10)}{2}$$





using property of circle



$AF \times FB = EF \times FE'$

$\frac{L}{2} \times \frac{L}{2} = (w-10)[2R-(w-10)]$ ②

$$\frac{L^2}{4(w-10)} = 2R-(w-10)$$

$$2R = \frac{L^2}{4(w-10)} + (w-10)$$

$$\boxed{R = \frac{L^2}{8(w-10)} + \frac{w-10}{2}}$$

Ques 1995 A vertical parabolic curve is to be used under a grade compan separation structure the minus grade left the right is 4% and plus grade is 3% intersection of two grade is at 435m and at an elevation of 251.48m. The curve passes through a fixed point of a chainage of 460m and RL of 260m.

Find the length of curve.

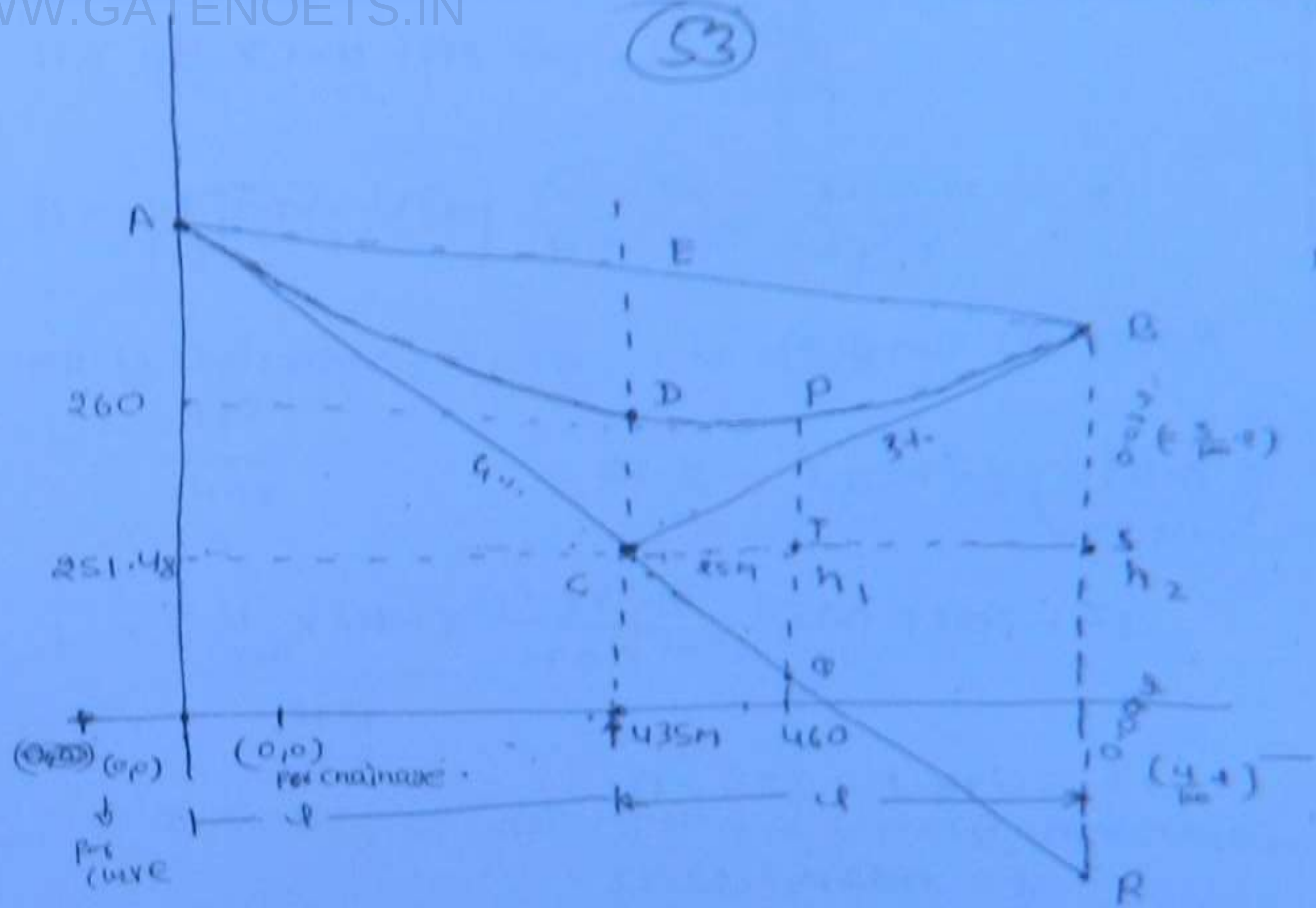
Soln

Equation of parabolic curve

$h = K \cdot x^2$

h is distance from first tangent

(53)



(1) For point Q (h_1)

R.L. of point P = 260 m $\qquad$ CT = 460 − 435 = 25 m

R.L. of point Q = R.L. of C − 4% of CT

$= 251.48 - \frac{4}{100} \times 25 = 250.48$

$h_1 = PQ = 260 - 250.48 = 9.52\,m = Kx^2$

For point P value of x

$x = (l + 25)$

$K \cdot (l+25)^2 = 9.52$ —(1)

(2) For point B

$h_2 = BS + SR = 0.03l + 0.04l = 0.07l = Kx^2$

$h_2 = kx^2 = k(2l)^2 = 0.074$

$\hookrightarrow$ for point B ($x = 2l$)

$$k = \frac{0.074}{4l^2} = \frac{0.07}{4l} \quad \text{--- (2)}$$

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from (1) and (2)

$$\left(\frac{0.07}{4l}\right)(l+25)^2 = 9.52$$

$$l^2 + 50l + 625 = \frac{9.52 \times 4}{0.07} \times l$$

$$l^2 - 494l + 625 = 0$$

$$l = \cancel{492} \; 492.73$$

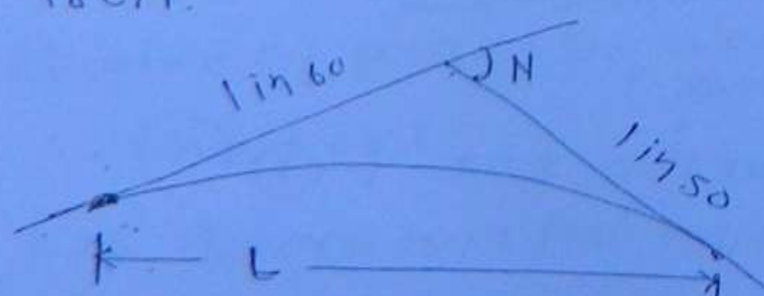
Total length of curve

$L = 2l = 985.46\,m$

IES 2002

An assending gradient of 1 in 60 meets a deconding gradient of 1 in 50. Find out length of summit curves for a stopping sight distance of 180 M.

soln



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

$N = \left| \frac{1}{60} - \left(-\frac{1}{50}\right) \right| = \frac{5+6}{300} = \frac{11}{300}$

* Assuming length of curve $(L_c > S)$

$L = \frac{NS^2}{4.4}$

$L = \frac{\frac{11}{300} \times (180)^2}{4.4} = 270m$

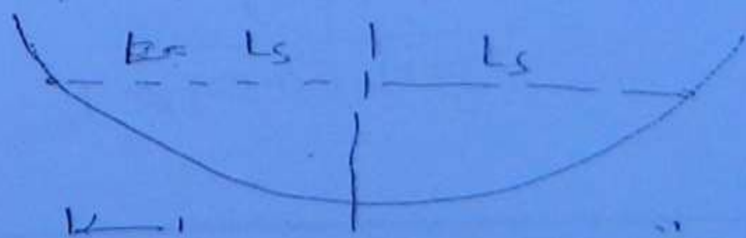
$L > S$, so Assumption is correct, Hence (O.K)

Imp.
ES 2008 Que. A valley curve of a straight Highway is formed by a down gradient 1 in 20 meeting an up gradient 1 in 30. Design the length of valley curve to fulfill both comfort condition and head light sight distance condition.

$C = 0.60\ m/s^2/s$ | $t_r = 2.5s$, $f = 0.35$

Design speed = 80 kmph.

Soln
① Comfort condition



Length of curve

$$L = 2L_s = 2\times\left(\frac{N\cdot v^3}{C}\right)^{1/2}$$

$N_1 = -\frac{1}{20}$, $N_2 = \frac{1}{30}$ SG

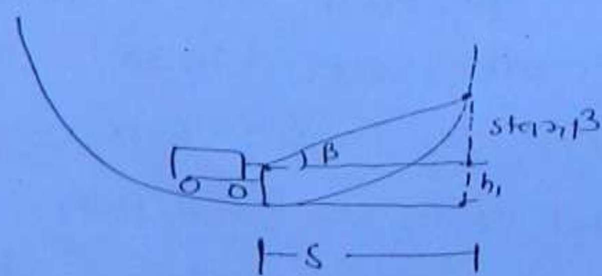
$$N = \left(\frac{1}{N_1} - \frac{1}{N_2}\right) = \left|-\frac{1}{20} - \frac{1}{30}\right| = \frac{50}{600}$$

$$L = 2\times\left[\frac{\frac{50}{600}\times(0.278\times80)^3}{0.60}\right]^{1/2}$$

$L = 782\,m$

(2) Head light side distance

[for S.L = 0 beause Half upard Half dolem gradient]



Assuming $L_c > S$

S = Stoping signt distance

$$S = 0.278\cdot V\cdot t_R + \frac{(0.278V)^2}{2g\,(f\pm S\%)}$$

$\boxed{S\% = 0}$

$$S = 0.278\times80\times2.5 + \frac{(0.278\times80)^2}{2\times9.81\,(0.35\pm0)}$$

SSD (S) = 127.63M , [consider $h = 0.75$, $\beta = 1°$ if not given standard]

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$$L = \frac{NS^2}{2(h_1 + S\tan\beta)} = \frac{\frac{60}{600} \times 127.63^2}{2[0.75 + 127.63\tan 1°]}$$

= 227.93m

say = 228M

228M ≥ S · Hence O.K.

Assumption is correct.

Provide Length of curve = 228 M. [Provide Max. Length in both condition]

Traffic Engg.

opic to discussion (58)

Traffic characteristics

→ Road user characteristic

→ Vehicular characteristic

Imp → Braking characteristic

Traffic studies

→ Traffic volume

→ Traffic density

→ speed study

→ O & D study

→ traffic flow study

→ Traffic capacity

→ Parking study

→ Accident study *Imp

3) Traffic operation and Control

→ Traffic regulations

→ Traffic control devices

→ traffic signs

→ Regulatory sign → police

→ warning sign → यमराज

→ Informatory sign → Just for information

Imp → Traffic signal

→ Traffic Island

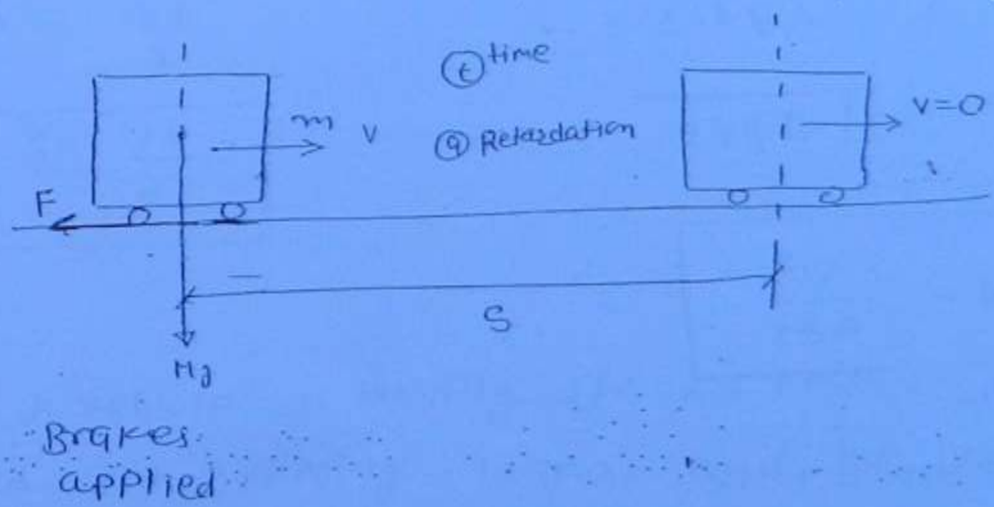
- Imp → Rotary design
  → Design of intersection & grade separation
  → Parking and lighting

(4) Traffic planning

(5) Geometric design

Imp.

Braking Characteristics :-



Assumptions:

(1) After application of brakes, wheels are fully jammed and vehicle is just skidding over road surface.

[Brake efficiency = 100%]

→ Full coefficient of friction (f) is utilised

In case brake efficiency is less than 100%

$$\frac{f_{observed}}{f_{max}} \times 100 = \text{Brake efficiency in \%.}$$

If a vehicle travel s distance after application of brakes.

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K.E lost = work done

$$\frac{1}{2} m v^2 = F \times s$$

$F = f \cdot R$ $\boxed{R = mg}$ Resistance

$F = f \cdot mg$

$$\frac{1}{2} m V^2 = f \cdot mg \cdot s$$

$$V^2 = 2 g f \cdot s$$

$$V = \sqrt{2 g f s}$$

$$\boxed{f_{observed} = \frac{V^2}{2 g s}}$$

if time taken = t sec.

retardation = a

$$-a = \frac{v - u}{t} = \frac{0 - V}{t} \qquad [\, v = u + at \,]$$

$$\boxed{a = \frac{V}{t}}$$

a = Θive = Retardation.

$$V^2 = u^2 + 2gs$$

$$0 = v^2 - 2as$$ initial velocity v, final 0, v=0

$$v^2 = 2as = 2gf \cdot s$$

$$\boxed{a = gf}$$ V.Imp.

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$$\boxed{f = \frac{a}{g}}$$ f = average skid resistance

$$S = ut + \frac{1}{2}at^2$$

$$= vt - \frac{1}{2}\frac{v}{t} \cdot t^2$$

$$= vt - \frac{1}{2}vt$$

$$S = \frac{vt}{2}$$

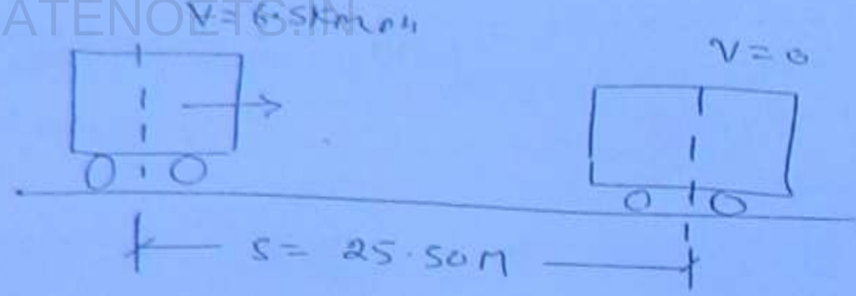
$$\boxed{S = \frac{vt}{2}}$$

2008

Ques. A vehicle a moving at 65 kmph, speed was stopped by applying brakes and the length of skid marks was 25.50 m. If average skid is known to be 0.70. determine the brakes efficiency of left vehicle.

calculate ① . time taken

② retardation.



V = 25.50m

(62)

V = 65 kmph = 0.278 × 65 = 18.07 m/sec

average skid Resistance

$$f = \frac{V^2}{2gS}$$

$$\therefore \quad f = \frac{(18.07)^2}{2 \times 9.81 \times 25.50} = 0.6526$$

Brake efficiency

$$= \frac{0.6526}{0.70} \times 100$$

$$= 93.235\%$$

Time taken = $S = \frac{Vt}{2} \Rightarrow t = \frac{2S}{V}$

$$= \frac{2 \times 25.50}{18.07}$$

$$= 2.82 \text{ sec.}$$

Retardation

$a = gf = 9.81 \times 0.6526 = 6.40$ m/sec^2

$a = \frac{V}{t} = \frac{18.07}{2.82} = 6.40$ m/sec^2

Q.2 If a vehicle takes 4.5sec to stop and skid makes observed are 46m. Calculate

① Initial speed of vehicle

② Average skid Resistance

③ retardation.

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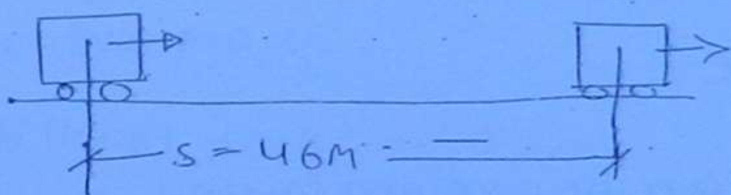
Soln

$t = 4.5\,sec$



① $s = 46\,m$, ② $t = 4.5\,sec$

① Initial speed (V)

$$S = \frac{Vt}{2}$$

$$V = \frac{2S}{t} = \frac{2 \times 46}{4.5} = 20.444\ m/sec$$

$$V = 73.54\ \text{kmph}$$

② $$f = \frac{V^2}{2gS}$$

$$= \frac{(20.444)^2}{2 \times 9.81 \times 46} = 0.463$$

③ Retardation

$$a = gf$$

$$= 9.81 \times 0.463 = 4.54\ m/sec^2$$

raffic study :-

raffic volume :-

(64)

umber of vehicle passing from a road section one unit time.

units = vehicle/hr. or

vehicle/day

) Hourly volume

) Daily volume

raffic volume can be represented as

ADT or AADT [Average annual daily traffic] :-

ll class of vehicles are converted into ne class of vehicles (passanger car). sing a conversion factor (PCU)

different type of vehicle

	PCU
①. passanger car, tempo, smaller tractor, AutoRickshaw	1.0
②) Bus, truck, Agricultural tractor-trailer unit	3.0
③) Motor cycle, scooter, pedal cycle	0.5
④) cycle Rickshaw	1.5
) Horse drawn vehicles	4.0
) small bullock cart and Hand cart	6.0
) Large bullock cart	8.0

(2) Trend Charts :-

showing volume trends over a period of years.

2007	2008	2009	2010	2011	
450	560	790	860	1050	[vehicle pass]

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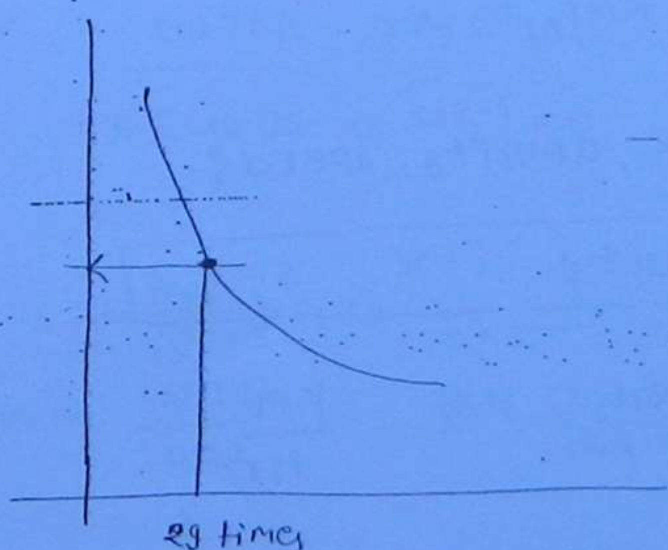
(3) Variation Charts :-

showing variation of volume.

(4) Traffic flow maps:-

— on different routs.

(5) 30^{th} higest hourly volume



The value that has been Exceeded 29 times is called 30^{th} higest hourly volume.

Traffic density:-

Number of vehicle found at a particular instant on a road in 1 km length is called traffic density.

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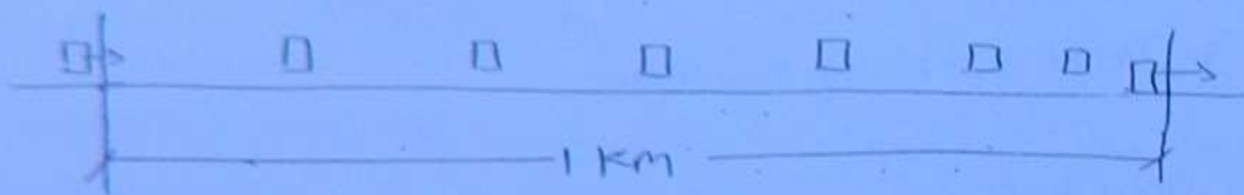


unit = vehicle/km

speed of vehicle = km/hr

Relation b/w volume, density, speed:-

$$\boxed{\text{volume} = \text{density} \times \text{speed}}$$

$$\frac{veh}{hr} = \frac{veh}{km} \times \frac{km}{hr}$$

Ques 15. Speed density relationship for a particular road was found to be

$$v = 42.76 - 0.22k$$

where v = speed in km/hr

and k = density in veh/km

- Find the capacity of road.

Give your comment on the results. Sketch density v/s flow and show important traffic flow parameter.

(67)

Sol^n

$$v = 42.76 - 0.22K$$

capacity of road

(volume that can be accomodated on road)

$$C\,(\text{volume}) = \text{density} \times \text{speed}$$

$$C = K\,(42.76 - 0.22K)$$

$$C = 42.76K - 0.22K^2$$

For $C = 0$

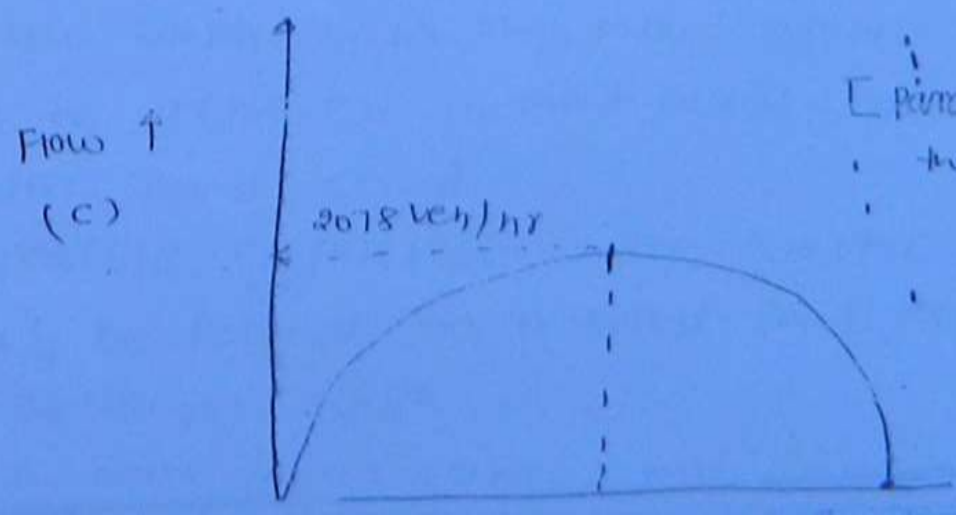
$$42.76K - 0.22K^2 = 0$$

$$K(42.76 - 0.22K) = 0$$

$$K = 0$$

$$(42.76 - 0.22K) = 0$$

$$K = \frac{42.76}{0.22} = 194.33 \text{ vehicle/km.}$$



[Parabolic equation
from parabolic
variation]

For c to be Max^m

$$\frac{dc}{dK} = 0$$

$$42.76 - 2 \times 0.22K = 0$$

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$$K = \frac{42.76}{2 \times 0.22} = 97.18$$

Max^m

$$c = 42.76 \times 97.18 - 0.22 \times 97.18^2$$

$$C = 2078 \text{ veh/hr}$$

Important values

- Volume is zero at zero density
- volume increase if density in increasing and shall be Max^m at K = 97.18 veh/km.
- After this value, volume is reduced and again becomes zero at K = 194.36 veh/km

Max^m flow observed

= 2.78 km/hr

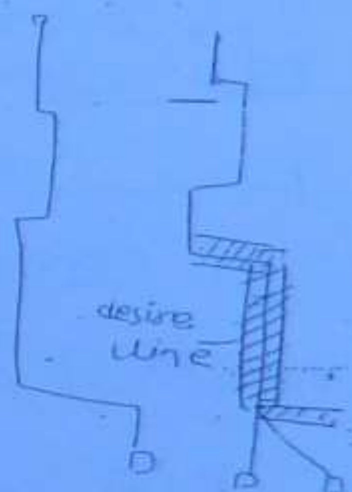
1) origin and destination study :- (O and D study)

① Road side interview
② License plate method
③ Return post card method
④ Tag on car method
⑤ Home interview method
⑥ work spot interview method

(69)

Presentation :-

→ Desire line are prepared
→ Thickness of desire line, show volume on that road



Capacity :- The traffic volume that can be accommodated on a road is called capacity

① Basic capacity :-

Basic capacity is the max. traffic volume that can be achieved in most ideal condition of traffic and road.

② possible capacity :- The traffic volume that may be found on a road in different condition

In worst case = 0

In most ideal condition = basic capacity

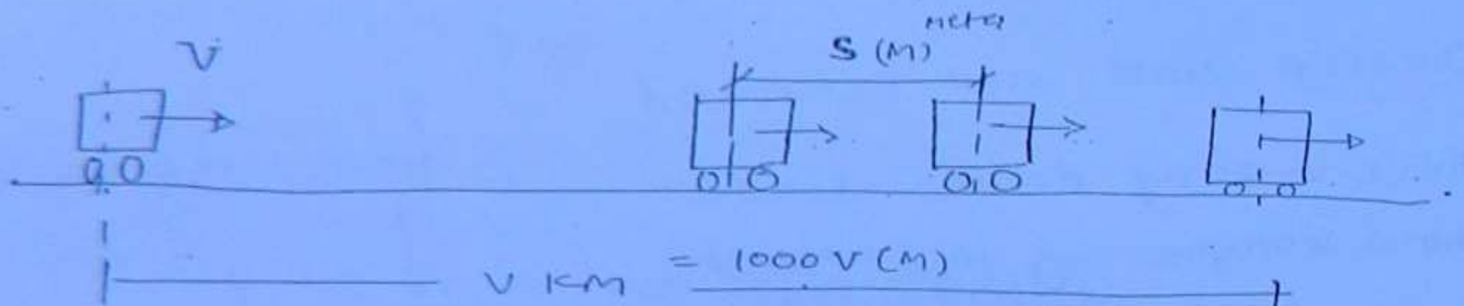
$0 \le$ Possible Capacity $\le$ Basic capacity

practical capacity:-

It is the traffic volume that is on in general condition of road, traffic most of the time.

Theoritical Maximum capacity:-

) As per velocity and distance maintened b/w two vehicle



VKM distance travell in 1 houser.

theoretical Max. capacity

$$C_{max} = \frac{1000\, V}{S} \qquad \left(\frac{veh}{hr}\right)$$

V = speed in KMPH

S = minimum distance b/w two vehicles

$= (0.7V + l)$ $\qquad l$ = avg. length of vehicle

$= (0.7V + 6)$ $\qquad l = 6m$

$= (0.2V + 6)$

0.7 sec = perception reaction time

(2) If time headway b/w two vehicles = t_n sec

$$\boxed{C_{max} = \frac{3600}{t_n} \left(\frac{veh}{hr}\right)}$$

one vehicle pass in t_n sec.

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Que Estimate max^m theoritical capacity of a highway for one way one lane traffic moving at 65 kmph speed consider average length of vehicle = 5.2m and time headway b/w two vehicles = 2.5 sec.

Soln

(1) As per speed $\quad l = 5.2m$

Minimum clearance $s = (0.7v + l) = (0.2v + 5.2)$

$= 0.2 \times 65 + 5.2 = 18.20$

theoritical capacity (max^m)

$$C_{max} = \frac{1000\,V}{s} = \frac{1000 \times 65}{18.20} = 3571 \text{ veh/hr}$$

(2) As per time headway = 2.5 sec

$$C_{max} = \frac{3600}{t_n} = \frac{3600}{2.5} = 1440 \frac{veh}{hr}$$

(5) Accident study :-

Type :-

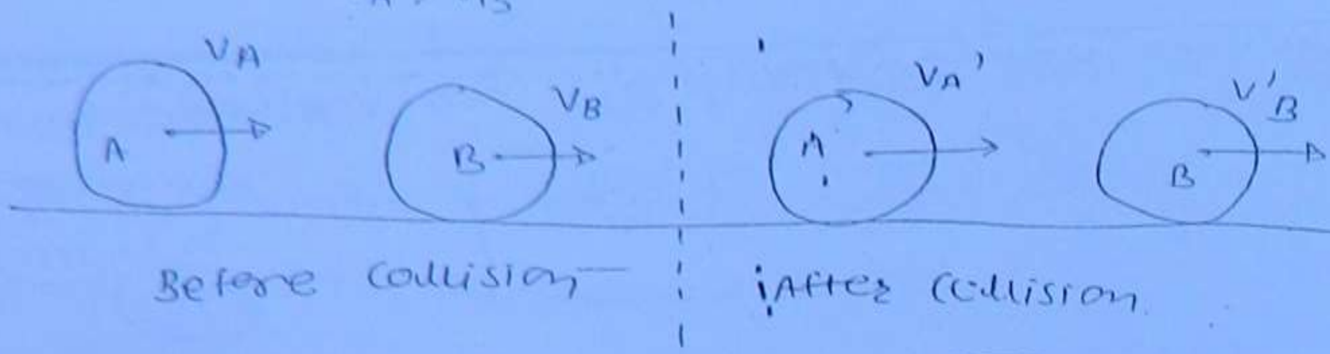
(1) A moving vehicles → hit → A parked vehicle

(2) Two vehicle moving at right angle collide at an intersection

(3) A moving vehicle collide with any object

(4) Head on collison

$V_A > V_B$ $\qquad$ $V_B' > V_A'$



For collision $\qquad V_A > V_B$ $\qquad$ 72

velocity of Approach $= (V_A - V_B)$

After collision

velocity of separation $= (V_B' - V_A')$

Newton law of collision :-

As per this law, velocity of separation bear a constant ratio with velocity of Approach. This Ratio is called "coefficient of restitution denoted by e)

$$e = \frac{\text{velocity of separation}}{\text{velocity of Approach}} = \frac{V_B' - V_A'}{V_A - V_B}$$

[Range b/w 0 to 1]

) perfectly elastic collision

$$e = 1.0$$

$$e = \frac{V_B' - V_A'}{V_A - V_B} = 1.0$$

$$\boxed{(V_B' - V_A') = (V_A - V_B)}$$

(2) perfectly plastic collision

$$e = 0 = \frac{V_B' - V_A'}{V_A - V_B}$$

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$$V_B' - V_A' = 0$$

$$\boxed{V_B' = V_A'}$$

it means both body will move without seperation

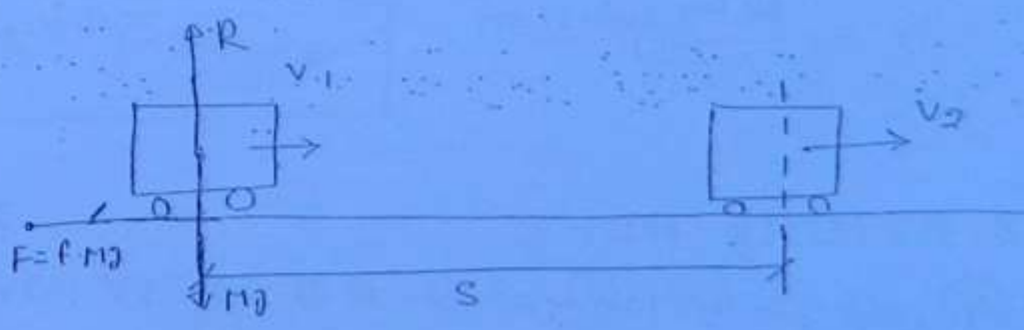
momentum Equation:-

(As per conservation of energy)

Total momentum befor collision

= Total momentum after collision

$$\boxed{m_A \cdot V_A + m_B \cdot V_B = m_A \cdot V_A' + m_B \cdot V_B'}$$



→ movement of vehicle when brakes are applied

Brake efficiency = 100%

K.E lost = work done

$$\frac{1}{2} m v_1^2 - \frac{1}{2} m v_2^2 = F \times S$$

$$= f \cdot mg \cdot S$$

$$\boxed{v_1^2 - v_2^2 = 2gf \cdot S}$$

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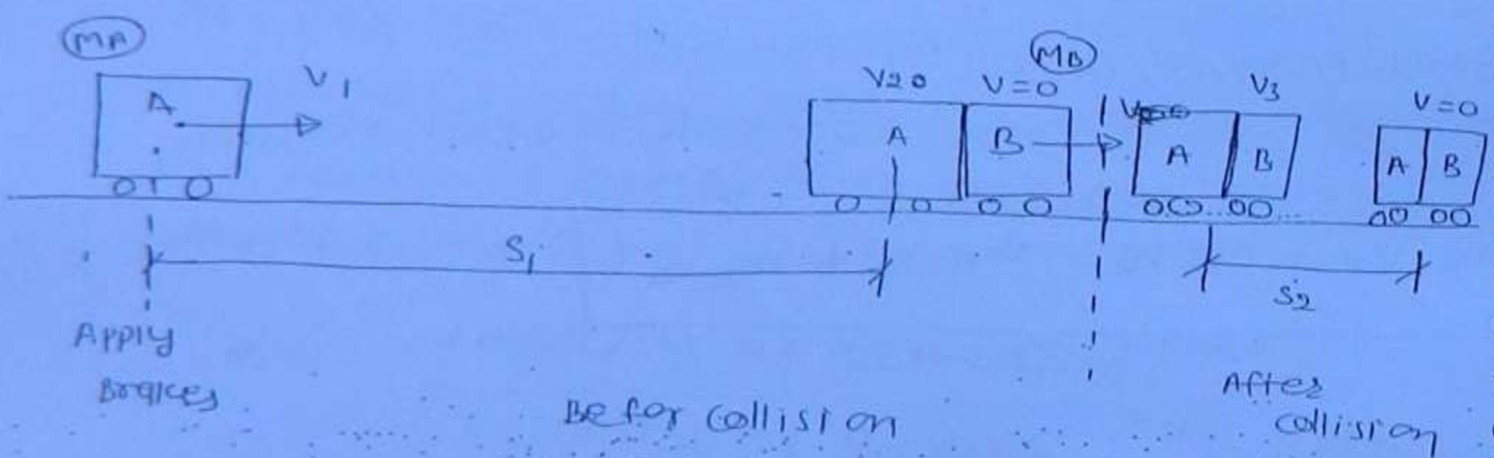
$$v_1^2 = v_2^2 + 2gf \cdot S$$

$$v_1 = \sqrt{v_2^2 + 2gf \cdot S}$$

Case ① Collision of a moving vehicle with a parked vehicles:-



Assumption:-

1) Collision is perfectly plastic

2) Brake efficiency is 100 %

Befor Collision:-

- For vehicle (A)

$$v_1^2 - v_2^2 = 2gf \cdot S_1$$

$$v_1 = \sqrt{v_2^2 + 2gf \cdot s_1} \quad \text{—— (1)}$$

(2) momentum Equation :-

Total momentum just befor Collision = Total momentum just After collision.

$$m_A \cdot v_2 + m_B \cdot 0 = (m_A + m_B) v_3$$

$$\boxed{v_2 = \left(\frac{m_A + m_B}{m_A}\right) v_3} \quad \text{—— (2)}$$

(3) After Collision :-

For vehicle (A) and (B).

$$v_3^2 - 0^2 = 2gf \cdot s_2$$

$$v_3^2 = 2g \cdot f \cdot s_2$$

$$\boxed{v_3 = \sqrt{2g \cdot f \cdot s_2}} \quad \text{—— (3)}$$

steps:-

(1) Given values (1) s_1 (2) s_2 (3) M_A (4) M_B (5) f

(2) calculate v_3 from Eq (3)

(3) calculate v_2 from Eq (2)

(4) calculate v_1 from Equation (1)

Q.16 A vehicle apply brakes and skid through a distance 40 m before colliding another parked vehicle, the weight of which (B) is 60% of former (A) from fundamental principles.
calculate initial speed of moving vehicles if distance which both vehicle skid is 12 m. f = 0.60
show the various stes and assumptions in each step.

Ans

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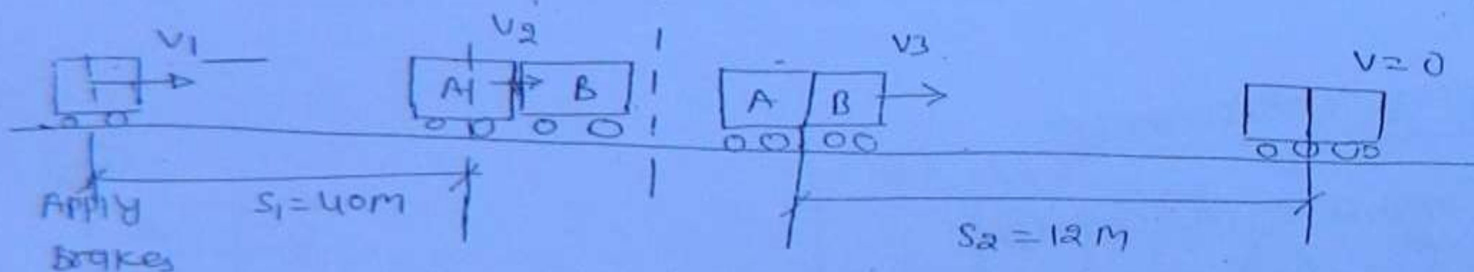


$W_B = 0.60\, W_A$

$\boxed{M_B = 0.60\, M_A}$

After collision:-

For vehicle A + B

$V_3^2 = 2gf \cdot S_2$

$V_3 = \sqrt{2 \times 9.81 \times 0.60 \times 12}$

$V_3 = 11.885$ m/sec

(2) momentum equation

$$m_A \cdot v_2 + m_B \cdot 0 = (m_A + m_B)\, v_3$$

$$v_2 = \frac{m_A + m_B}{m_A} \times v_3$$

$$= \frac{m_A + 0.60 m_A}{m_A} \times 11.80 = 19.017$$

(3) befor collision for (A)

$$v_1^2 - v_2^2 = 2gfS_1$$

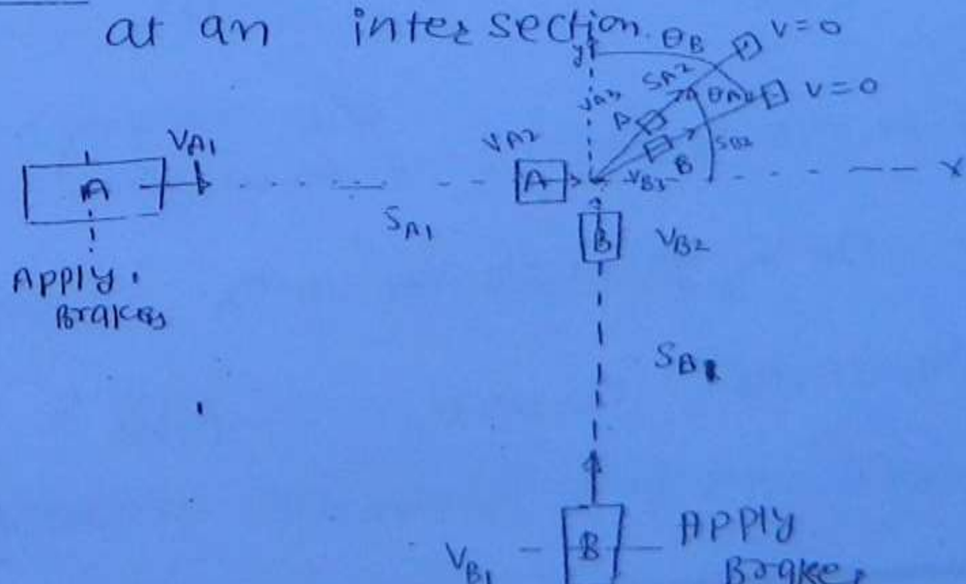
$$v_1 = \sqrt{v_2^2 + 2gfS_1}$$

$$v_1 = \sqrt{(19.017)^2 + 2 \times 9.81 \times 0.60 \times 40}$$

$$v_1 = 28.853 \text{ m/sec}$$

$$v_1 = 103.8 \text{ Kmph}$$

Case (2) Two vehicle moving at right angle collide at an intersection.



Given values

$S_{A1}, S_{A2}, S_{B1}, S_{B2}, f, M_A, M_B$.

Find out

→ $V_{A1}, V_{A2}, V_{A3}, V_{B1}, V_{B2}, V_{B3}$

) After collision case :-

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For (A)

$$V_{A3}^2 - 0^2 = 2g \cdot f \cdot S_{A2}$$

$$\boxed{V_{A3} = \sqrt{2gf \cdot S_{A2}}} \quad \text{——} (1)$$

For B :

$$\boxed{V_{B3} = \sqrt{2gf \cdot S_{B2}}} \quad \text{——} (2)$$

Momentum Equation :-

Total moment in the direction of x ~~~~ [For veh (A)]

$$M_A \cdot V_{A2} + M_B 0 = M_A \cdot V_{A3} \cos\theta_A + M_B \cdot V_{B3} \cdot \sin\theta_B$$

$$V_{A2} = V_{A3} \cdot \cos\theta_A + \left(\frac{m_B}{M_A}\right) V_{B3} \cdot \sin\theta_B \quad \text{——} (3)$$

Total moment in the y direction → for veh (B)

$$m_A \cdot 0 + M_B \cdot V_{B2} = M_A \cdot V_{A3} \cdot \sin\theta_A + M_B \cdot V_{B3} \cdot \cos\theta_B$$

$$V_{B2} = \left(\frac{m_A}{M_B}\right) V_{A3} \cdot \sin\theta_A + V_{B3} \cdot \cos\theta_B \quad \text{——} (4)$$

(5) Before collision

For (A)

$$V_{A_1}^2 - V_{A_2}^2 = 2gf \cdot S_{A_1}$$

$$V_{A_1} = \sqrt{V_{A_2}^2 + 2gf S_{A_1}} \quad \text{——— (5)}$$

For (B)

$$V_{B_1}^2 - V_{B_2}^2 = 2gf \cdot S_{B_1}$$

$$V_{B_1} = \sqrt{V_{B}^2 + 2gf \cdot S_{B_1}} \quad \text{——— (6)}$$

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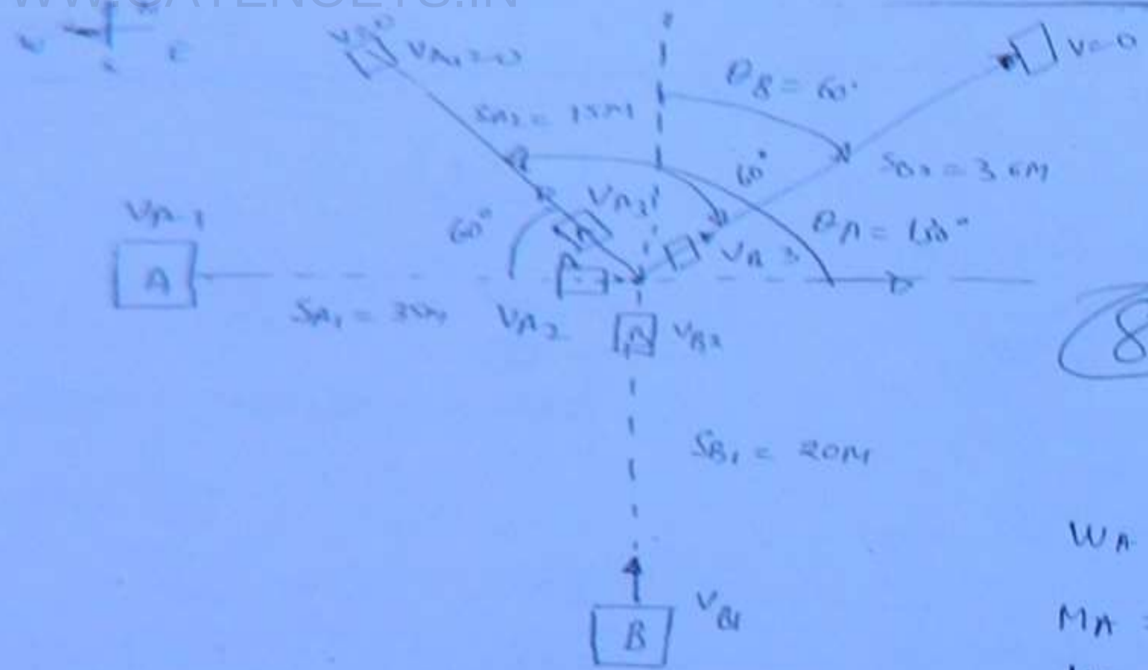
Que. Two vehicle A and B approaching at right angle A from west and B from south, collide with each other

	A	B
(1) skid direction after collision	50° N of W	60° E of W
(2) Initial skid distance before collision	35m	20m
(3) skid distance after collision	15m	36m
(4) weight	0.75 of B	6t

f = 0.55

calculate initial speed of two vehicles.



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$W_A = 0.75 W_B$

$M_A = 0.75 M_B$

$\frac{M_A}{M_B} = 0.75$

$\frac{M_B}{M_A} = \frac{1}{0.75}$

) After collision:

or A:
$$V_{A_3}^2 - 0^2 = 2gf\, S_{A_2}$$

$$V_{A_3} = \sqrt{2\times 9.81\times 0.55\times 15} = 12.722 \text{ M/sec.}$$

for B
$$V_{B_3} = \sqrt{2\times 9.81\times 0.55\times 36} = 19.71 \text{ M/sec.}$$

momentum Equation

$\theta_A = 130°$, $\theta_B = 60°$

In the dirn of (A) → x-dirn

$$M_A \cdot V_{A_2} + M_B \cdot 0 = M_A\, V_{A_3}\cos\theta_A + M_B \cdot V_B \cdot \sin\theta_B$$

$$V_{A_2} = V_{A_3}\cos\theta_A + \frac{M_B}{M_A} V_{B_3} \cdot \sin\theta_B$$

$$V_{A_2} = 12.722\times\cos 130° + \frac{1}{0.75}\times 19.71\times\sin 60°$$

$$V_{A_2} = 14.58 \text{ M/sec.}$$

(2) before collision In the direc (B), y-direction

$$M_A \cdot 0 + M_B \cdot V_{B2} = M_A \cdot V_{A3} \cdot \sin\theta_A + M_B \cdot V_{B3} \cos\theta_B$$

$$V_{B2} = \frac{M_A}{M_B} \cdot V_{A3} \cdot \sin\theta_A + V_{B3} \cdot \cos\theta_B$$

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$$V_{B2} = 0.75 \times 12.722 \times \sin 30^\circ + 19.71 \cos 60^\circ$$

$$V_{B2} = 17.16 \text{ m/sec.}$$

(3) before collision

for (A)

$$V_{A1} = \sqrt{V_{A2}^2 + 2g \cdot f S_{A1}}$$

$$\therefore V_{A1} = \sqrt{(14.58)^2 + 2 \times 9.81 \times 0.55 \times 35} = 24.295 \text{ m/sec}$$

$$= 87.35 \text{ kmph.}$$

For B

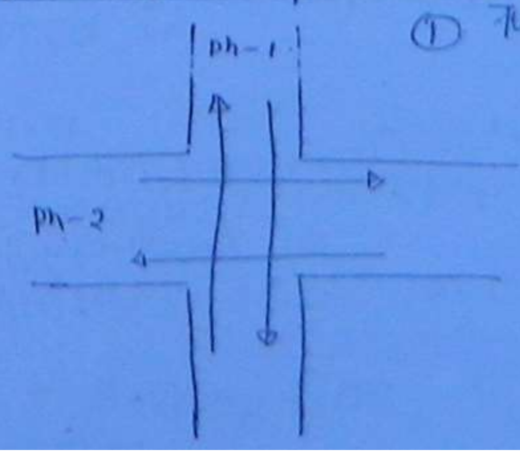
$$V_{B1} = \sqrt{V_{B2}^2 + 2gf \cdot S_{B1}} = \sqrt{(17.16)^2 + 2 \times 9.81 \times 0.55 \times 20}$$

$$V_{B1} = 22.58 \text{ m/sec} =$$

* **Design of signal timing :-**

General principle of signal design :-

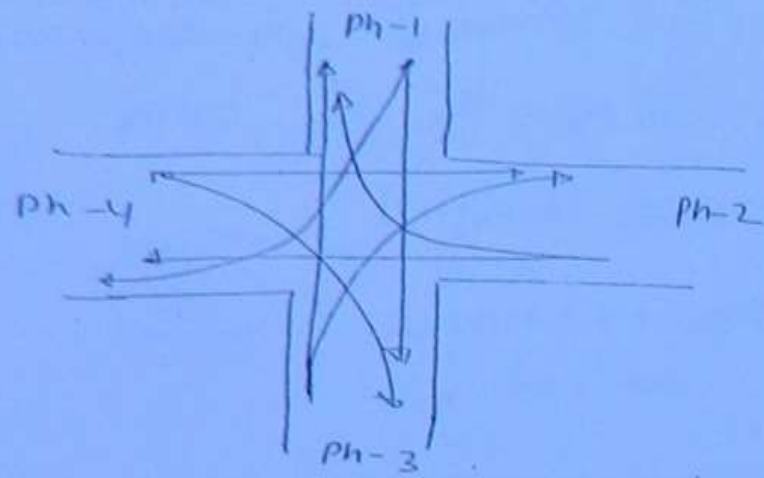
Types:- (1) Two phase system :-



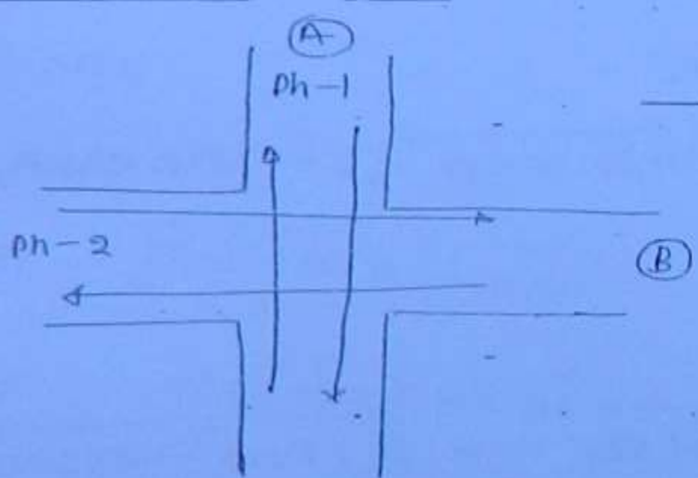
ph - phase

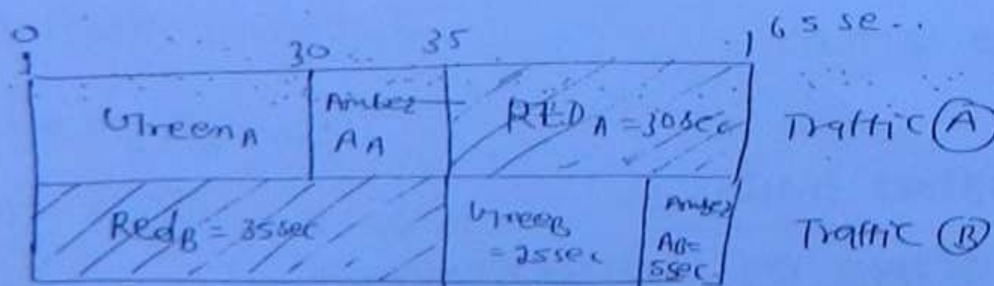
~~Types~~ (2) Four phase system:-

(82)



For Two phase system :-





Properties :-

(1) Red time on one road = (Green + Amber time on Another road)

$R_A = G_B + A_B$

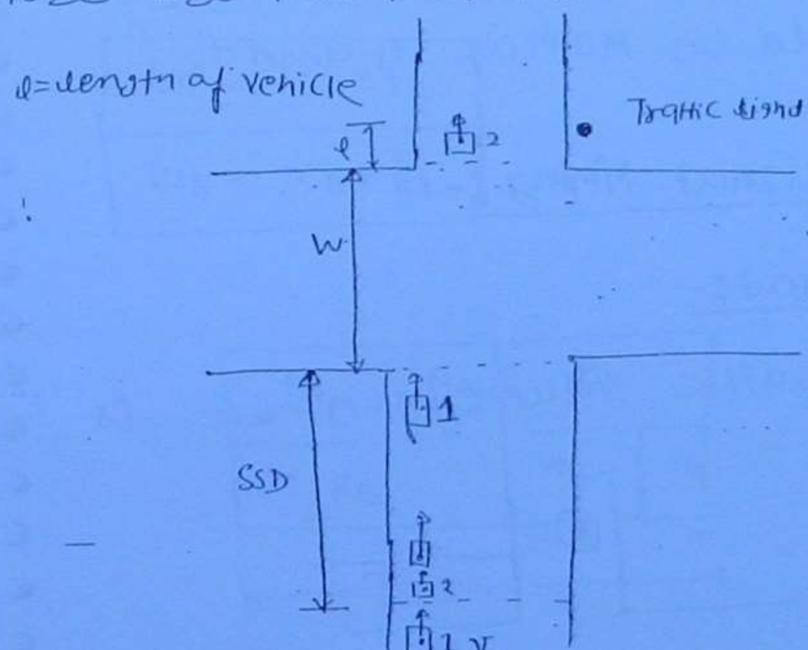
$R_B = G_A + A_A$

2) Green time on two roads is decided as per traffic volume on two roads

$$\frac{G_A}{G_B} = \frac{n_A}{n_B}$$

(3) Amber time :- yellow time provided just After Green time.

There are two purpose



(a) Too allow the vehicle approaching the intersection to stop before intersection.

For vehicle (1)

if design speed is = V (V m/sec)

Retardation = a , $-a = \frac{0-V}{t} \Rightarrow t = \frac{V}{a}$ (Braking time)

(Minm time required to stop the vehicle (Amber time required)

t_R = perception Reaction time

$= t_R + \text{Braking time} = t_R + \frac{V}{a}$

$$\boxed{t_1 = t_R + \frac{V}{a}}$$

 these vehicle that are in danger rea (within SSD line) to go

Max^m time required to cross (say vehicle no-②)

$$\text{time} = \frac{\text{Total distance}}{\text{velocity}} = \frac{(SSD + w + l)}{v}$$

$$t_2 = \left(\frac{SSD + w + l}{v}\right)$$

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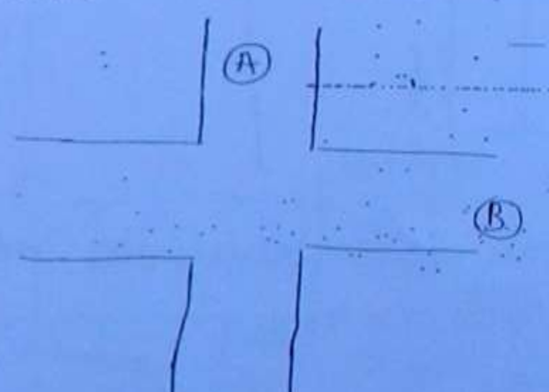
Amber time should be Max^m of t_1 and t_2

Methods for design signal timing :-

1) Trial cycle method :-

* In this case traffic volume/15 minute is used.



- If 15 minute traffic count on two road are n_A and n_B
- Assume a cycle time T sec.
- Number of vehicles approaching the intersection on two road in one cycle time

$$x_A = \frac{n_A}{15 \times 60} \times T$$

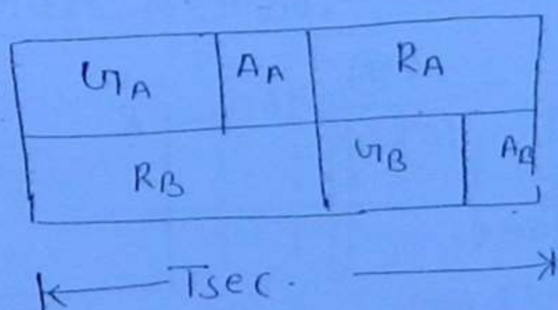
$$x_B = \frac{n_B}{15 \times 60} \times T$$

→ Average time required for one vehicle to cross the intersection = time headway = t_h sec.

→ Green time required on two roads

$$\boxed{G_A = x_A \times t_h}$$

$$\boxed{G_B = x_B \times t_h}$$



→ Total cycle time

$$T_1 = (G_A + A_A) + (G_B + A_B)$$

→ calculated cycle time (T_1) should be equal to assumed cycle time T sec.)

→ If not, Assume another cycle time and repeat the process.

Q. If 15 min traffic count on two roads are 150 and 120 vehicle per lane. If Amber time on two road is 5 sec. Design signal timing by trail cycle method average time headway is 2.5 sec.

Sol.

$n_A = 150\ \text{veh}/15\text{min}/\text{Lane}$

$n_B = 120\ \text{veh}/15\text{min}/\text{Lane}$

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Trail ①

Assume cycle time = 60 sec.

No. of vehicle approaching two road in one cycle time.

$$\therefore x_A = \frac{n_A}{15\times60}\times T = \frac{150}{15\times60}\times60 = 10$$

$$x_B = \frac{n_B}{15\times60}\times60 = \frac{120}{15\times60}\times60 = 8$$

Time headway = t_h = 2.5 sec.

Green time required

$G_A = 10\times2.5 = 25\ \text{sec}.$

$G_B = 8\times2.5 = 20\ \text{sec}.$

Total cycle time

$= (G_A + A_A) + (G_B + A_B)$

$= (25+5) + (20+5) = 55\ \text{sec}.$

Question
Homework = $n_A = 300$
$n_B = 180$

2nd method

$$T = G_A + A_n + G_B + A_B$$

$$= (x_A \times t_h) + A_n + (x_B \times t_h) + A_B$$

(87)

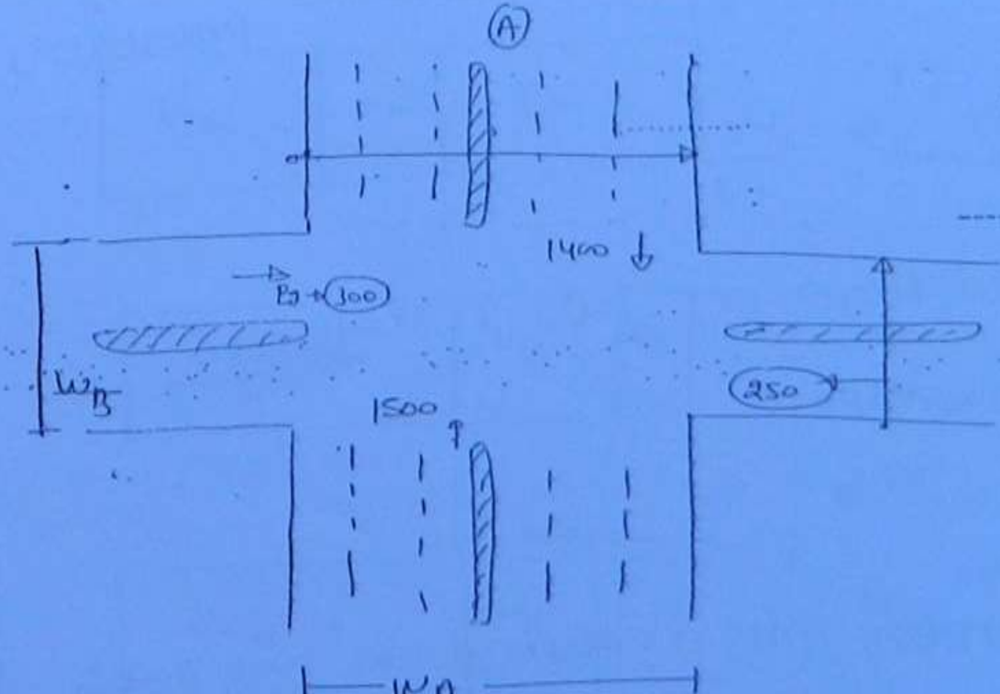
$$= \left(\frac{n_A}{15 \times 60} \times T \times t_h\right) + 5 + \frac{n_B}{900} \times T \times t_h + 5$$

$$= \frac{150}{900} \times T \times 2.5 + 10 + \frac{120}{900} \times 2.5 t_h$$

$$T = 0.416T + 10 + 0.333T$$

$$T = \frac{10}{(1 - 0.416 - 0.333)} = 39.88 \text{ say } 40 \text{ sec.}$$

(2) Approximate method:- v. Imp.



If there are two roads (A) and (B)

width of Road (A) $= W_A$

width of Road (B) $= W_B$

Traffic volume (design volume / per lane)

On Road (A) = $n_A = \frac{1500}{3} = 500$ veh/hr/lane

On Road B = $n_B = \frac{300}{1} = 300$ veh/hr/lane

Design steps :-

Green time (minimum) required for pedestrain signal.

$G_{PA} = (7\,sec.) + \frac{W_A}{1.2}$ → time for pedestrain to cross

↓

:(initial walk period)

[Standard $V = 1.2$ m/se = speed of pedestrain]

$G_{PB} = 7\,sec + \frac{W_B}{1.2}$

minimum Red time on two roads.

$R_A = G_{PA}$

$R_B = G_{PB}$

Minimum green time required on two Roads (for traffic)

$R_A = G_B + A_B \Rightarrow G_B = R_A - A_B$

$R_B = G_A + \cancel{A_A} \Rightarrow G_A = R_B - A_A$

(4) Consider any one green time G_A or G_B as calculated above and another is found using traffic volume on two roads.

$$\frac{G_A}{G_B} = \frac{n_A}{n_B}$$ [Maxm of G_A and G_B is choosen]

if G_B is consider than G_A calculate

$$G_A = \frac{n_A}{n_B} \times G_B$$

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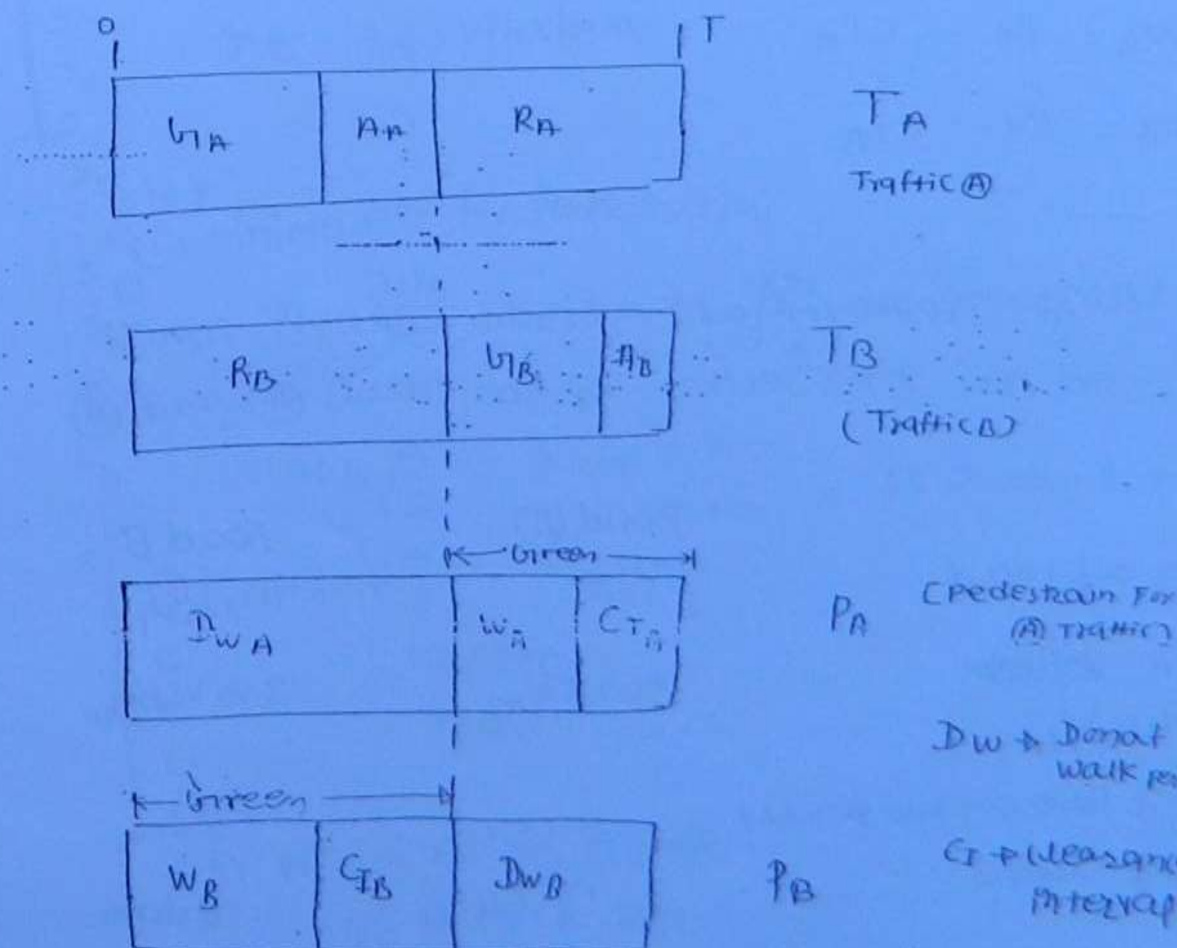
(5) Total cycle time

$$T = (G_A + A_A) + (G_B + A_B)$$



DW → Donot walk period

CI → Clearance interval

W → walk period

$R_A = G_B + A_B$

$R_B = G_A + A_A$

7) Do not walk period [pedestrian signal]

$DW_A = G_A + A_A$

$DW_B = G_B + A_B$

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8) clearance interval

$CI_A = \frac{W_A}{1.2}$

$CI_B = \frac{W_B}{1.2}$

9) walk period on two roads

$W_A = R_A - CI_A$

$W_B = R_B - CI_B$

Ques. Using Approximate method, design signal timing on an intersection of two roads (A) and (B)

	Road (A)	Road B
1) width of road	18M	7.5M
2) Traffic volume (Total)/hr	900 veh/hr	350 veh/hr
3) Amber time on two Roads	5 sec.	5 sec.
4) No. of lane	4 lane	2 lane

Soln

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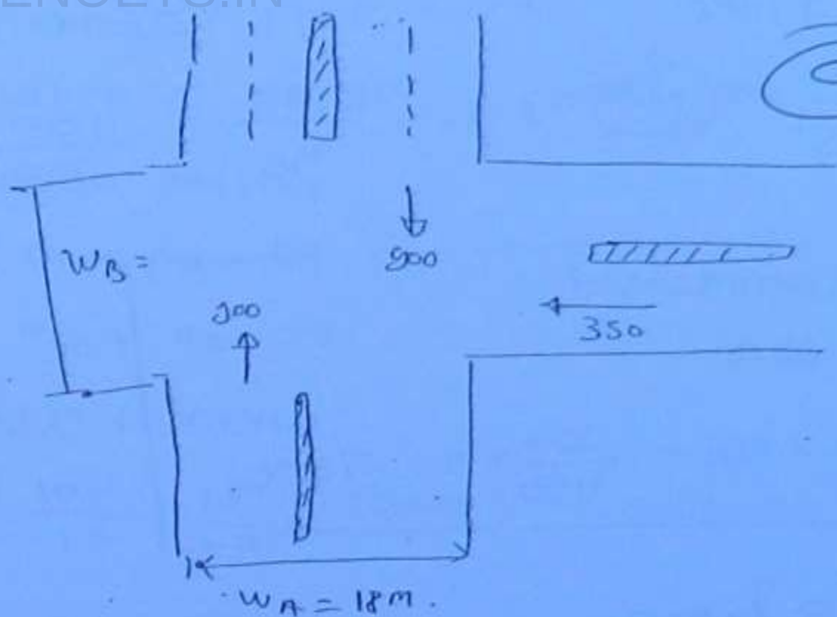


Design vol / lane on two roads

$n_A = 50$ v/hr/lane

$n_B = 350$ v/hr/lane.

Step
(1) minimume for pedestsain

$G_{PA} \frac{W_A}{1.2} \Rightarrow 7.0 + \frac{18M}{1.2} = 22sec.$

$G_{PB} \frac{B}{1.2} = 7.0 + \frac{7.5}{1.2} = 13.25sec = 14sec.$

(2) minimue on traffic

22sec.

14sec.

(3) minimme on traffic

$G\ 14-5 = 20sec.$

$G\ 17\ sec.$

If UTB is max^m

$UT_B = 17 sec$

$$\frac{UT_A}{UT_B} = \frac{n_A}{n_B} \rightarrow UT_A = \frac{UT_B\, n_A}{n_B} = \frac{450}{350} \times 17 = 21.86$$
$= 22 sec$

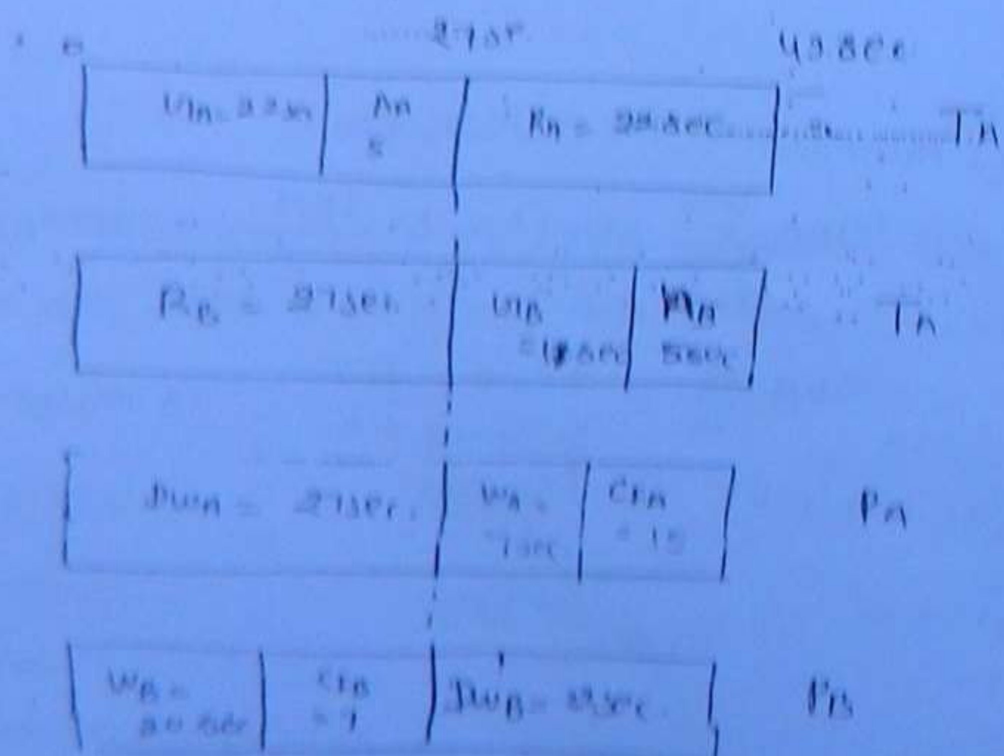
X

if UT_A is considered
$UT_A = 9 sec.$

$$UT_B = \frac{n_B}{n_A} \times UT_A = \frac{350}{450} \times 9 = 7 sec$$

) Total cycle time

$$T = (UT_A + M_A) + (UT_B + M_B)$$
$$= (22+5) + (17+5)$$
$$= 49 sec.$$



(6) $R_A = G_B + A_B = 17+5 = 22$

$R_B = G_A + A_A = 22+5 = 27$ 93

(7) Do not walk period

$DW_A = G_A + A_A = 27$

$DW_B = G_B + A_B = 22$

(8) Clearance interval

$CI_A = \frac{W_A}{1.2} = \frac{18}{1.2} = 15 \text{ sec}$

$CI_B = \frac{W_B}{1.2} = \frac{7.5}{1.2} = 6.25 \simeq 7 \text{ sec.}$

(9) Walk period

$W_A = 22 - 15 = 7 \text{ sec}$

$W_B = 27 - 7 = 20 \text{ sec.}$

(3) Webster's Method :- (signal)

In this method, normal flow values and saturation flow values on different roads are used for design of signal cycle time.

→ If there are two roads

normal flow (design values)

- Road A = q_A
- Road B = q_B

saturation flow values are

Road A = S_A, Road B = S_B

Saturation flow values :-

Road width	3.0	3.5	4.0	4.5	5.(
S (saturation flow)	1850	1890	1950	2250	255(

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Steps :-

① $y_A = \frac{q_A}{S_A}$

② $y_B = \frac{q_B}{S_B}$

$Y = y_A + y_B$

② Total loss time

$L = 2n + R$

n = Numbers of phase

R = All Red time (16 sec)

③ optimum cycle time

$C_0 = \frac{1.5L + 5}{1 - Y}$ sec.

④ Green time required on two Road

$G_A = \frac{y_A}{Y}(C_0 - L)$

$G_B = \frac{y_B}{Y}(C_0 - L)$

Que: Design signal timing for two road (A) and (B). Traffic volume of these two road are.

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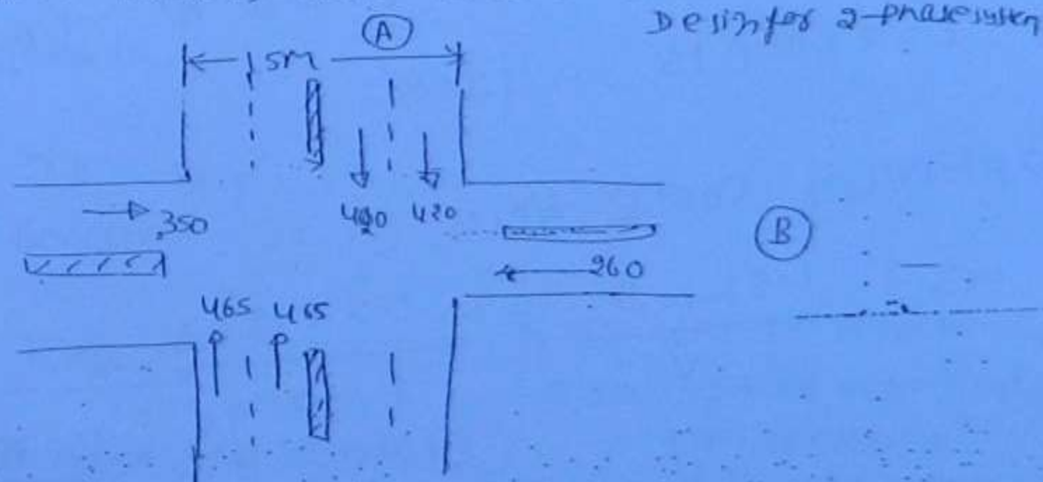
	Road (A)	Road (B)
width of road	15 m	8 m
Nos of Lanes	4 M	2 M
Normal flow in one direction	465 veh/hr/lane	350 veh/hr/lan
In opposite dir^n	420 veh/hr/lane	260 veh/hr/lane

If all red time = 15 sec, use webster method and Design for 2-phase system

Sol^n



(i) Normal flow:-

q_A = 465 veh/hr/lane [Max. for traffic (A)]

q_B = 350 vhe/hr/lane [Max. for traffic (B)]

(2) saturation flow [consider half of total width of road (A) for saturation flow]
two lanes

Road (A), for 7.50 width [from table]

$S_A = 525 \times 7.50 = 3937.5$ veh/hr [for two lane

S_A - per lane $= \frac{3937.5}{2} = 1969$ veh/hr/lane

Road (B) For road width = 4.0 (one lane)

$S_B = 1950$ veh/hr/lane

3) $y_A = \frac{q_A}{S_A} = \frac{465}{1969} = 0.236$

$y_B = \frac{q_B}{S_B} = \frac{350}{1950} = 0.18$

$Y = 0.416$

) Total lost time.

$\therefore L = 2n + R$; $\because$ no. of phase - 2 [R = 15 sec, given] standard]

$L = 2 \times 2 + 15 = 19$ sec.

) Optimum cycle time

$C_0 = \frac{1.5L + 5}{1 - Y} = \frac{1.5 \times 19 + 5}{1 - 0.416} = 57.36$

$= 58.8$ sec.

Green time

$G_A = \frac{y_A}{Y}(C_0 - L) = \frac{0.236}{0.416}[58 - 19]$

$G_A = 22.125 \simeq$ say 23 sec.

$G_B = \frac{y_B}{Y}[C_0 - L] = \frac{0.18}{0.416} \times (58 - 19) = 16.87$ s

tot cycle time = $G_A + A_R + G_B + A_R$ = 22.5 + ... $\simeq 17$ sec.

(4) IRC Method :- Imp

Combination of Approximate and Webster Method

(1) Calculate signal cycle time using Approximate method :-

(97)

Total cycle time (T sec) = $(G_A + A_A) + (G_B + A_B)$

(2) Check for minimum green time required for vehicles accumulated.

→ No. of vehicle accumulated on two road in one cycle time

$$x_A = \frac{n_A}{60 \times 60} \times T$$

$$x_B = \frac{n_B}{60 \times 60} \times T$$

→ Min^m green time :- [6 sec for 1st vehicle and 2 sec for All vehicle after 1st vehicle]

(1) On Road A for x_A vehicle

$$\boxed{G_{A\,min} = 6\ sec + (x_A - 1) \times 2\ sec} \quad < G_A$$

(2) On Road B for x_B vehicle

$$\boxed{G_{B\,min} = 6\ sec + (x_B - 1) \times 2\ sec} \quad < G_B$$

$G_{B\,min} = (2x_B + 4)$ sec

$G_{A\,min} < G_A$ Hence O.K.

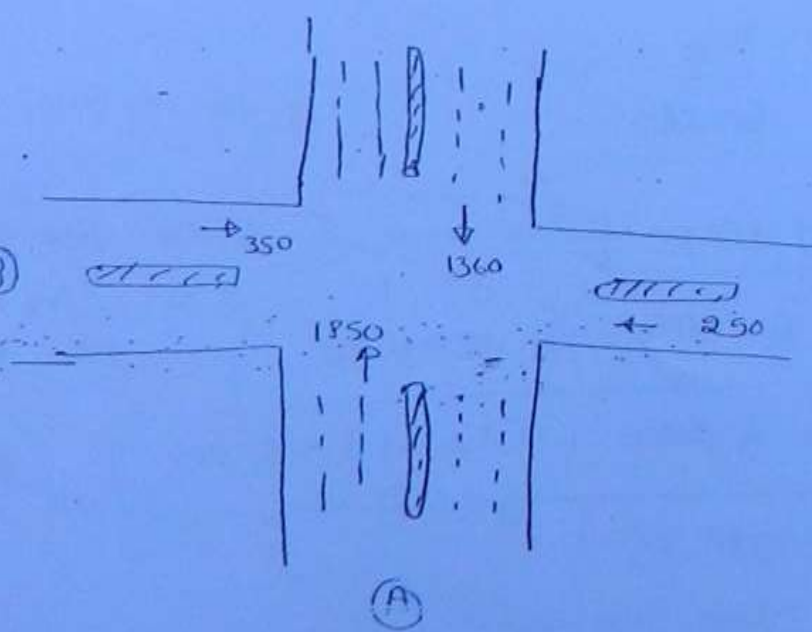
$G_{B\,min}$ < ...

3) Check:- using Websters method

Q. A Right angle intersection has two roads (A) and (B) Design a two phase signal system using IRC method and using following data.

	Road A	Road B
width of road	24 m	7.5 m
Nos of Lane	6	2
traffic volume in one dirn	1850 veh/hr	350 veh/hr
other direction	1360 veh/hr	290 veh/hr
Amber time	5 sec.	5 sec.

Soln



⇒ Design volume on two roads

$$n_A = \frac{1850}{3} = 616.67 \simeq 617 \text{ veh/hr/lane}$$

$$n_B = \frac{350}{1} = 350 \text{ veh/hr/lane}$$

(F) use Approximate method :-

(1) Min^m green time required for pedestrain signal

$$G_{PA} = 7\,sec + \frac{W_A}{1.2} = 7 + \frac{24}{1.2} = 27\,sec.$$

$$G_{PB} = 7\,sec + \frac{W_B}{1.2} = 7 + \frac{7.5}{1.2} = 13.25 \simeq 14\,sec$$

(2) Green time for traffic signal

$R_A = G_{PA} = 27\,sec$

$R_B = G_{PB} = 14\,sec$

Green time

$G_A = R_B - A_A = 14 - 5 = 9\,sec.$

$G_B = R_A - A_B = 27 - 5 = 22\,sec.$

(3) consider

$G_B = 22\,sec$ (Max value in G_A and G_B)

$$\frac{G_A}{G_B} = \frac{n_A}{n_B}$$

$$G_A = \frac{617}{350} \times 22 = 38.78 = 39\,sec.$$

(4) Total cycle time

$T = (G_A + A_A) + (G_B + A_B)$

$T = (39+5) + (22+5).$

$T = 44 + 27 = 71\,sec.$

(2) Number of vehicle Accumulated on two Roads in one cycle time

$x_A = \frac{617}{60 \times 60} \times 71 = 12.17 \simeq 13$ sec. Nos.

Green time required

$G_{AMM} = 6 + (13-1) \times 2 = 30$ sec. < 35 sec.

Hence o.k.

imilarly on Road B

$x_B = \frac{350}{60 \times 60} \times 71 =$ say 7 Nos.

Green time required

$G_{BMM} = 6 + [7-1] \times 2 = 18$ sec < 22 sec.

Hence o.k.

∴

Webster's method :-

[q_A and q_B also design volume on two roads]

$q_A = 617$ veh/hr/lane

$q_B = 350$ veh/hr/lane

Saturation flow value

[Saturation flow value calculate for half width of roads]

$S_A =$ for (12m width)

$= 525 \times 12 = 6300$ veh/hr/ for 3 lane

$= \frac{6300}{3} = 2100$ veh/hr/lane

$S_B =$ [for 3.75m wide road]

$= \frac{1890 + 1950}{2} = 1920$ veh/hr/lane

$$y_A = \frac{q_A}{S_A} = \frac{617}{2100} = 0.294$$

$$y_B = \frac{q_B}{S_B} = \frac{350}{1920} = 0.182$$

$$y = y_A + y_B = 0.294 + 0.182 = 0.476$$

Total loss time

$$L = 2n + R$$

$$= 2 \times 2 + 16 = 20 \text{ sec.}$$

optimum cycle time

$$C_o = \frac{1.5L + 5}{1 - y} = \frac{1.5 \times 20 + 5}{1 - 0.476} = 67 \text{ sec.}$$

$\therefore$

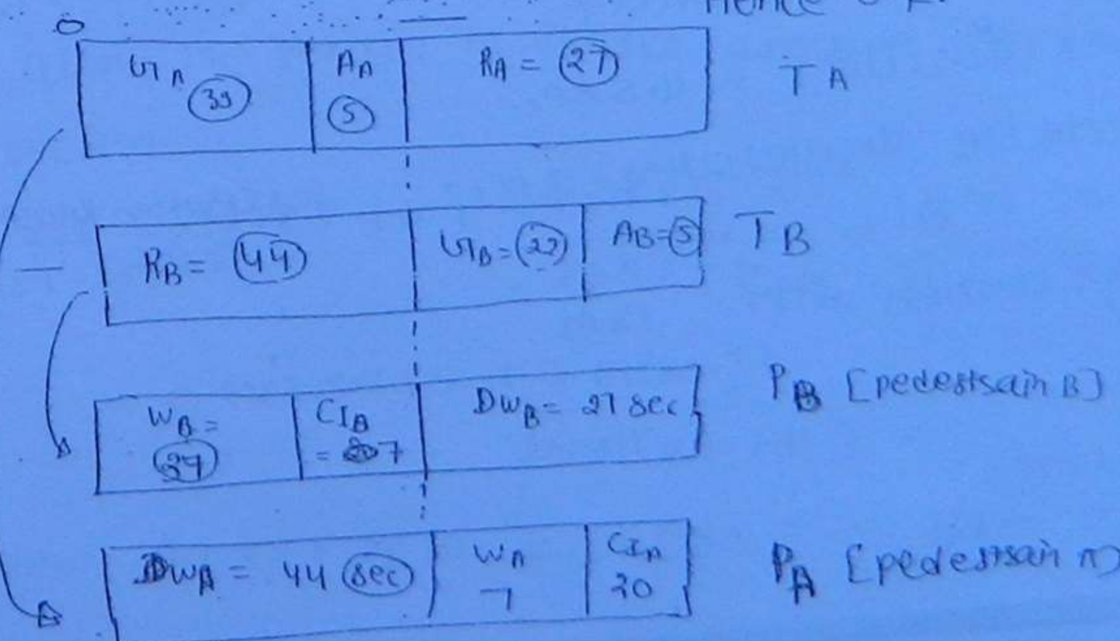
$$G_A = \frac{y_A}{y}(C_o - L) = \frac{0.294}{0.476}(67 - 20) = 29 \text{ sec.} < G_A\ (39)$$

hence o.k

$$G_B = \frac{y_B}{y}(C_o - L) = \frac{0.182}{0.476}(67 - 20)$$

$$= 18 \text{ sec} < 22 \text{ sec}, (G_B)$$

Hence o.k.



Red time = $G_B + A_B = 22+5 = 27$ sec.

$R_B = G_A + A_A = 39+5 = 44$

Donat walk period

$DW_A = G_A + A_A = 44$ sec.

$DW_B = G_B + A_B = 27$ sec.

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Clearance interval

$CI_A = \frac{24}{1.2} = 20$ sec

$CI_B = \frac{7.5}{1.2} = 6.25 \simeq 7$ sec.

walk period

$W_A = R_A - CI_A = 27 - 20 = 7$ sec

$W_B = 44 - 7 = 37$ sec.

15 A driver travelling at speed limit of 50kmph is cited for crossing an intersection the claimed it, duration of amber display was improper and consequently a dilemma zone Existed at that location using following data, determine wether driver claim was correct.

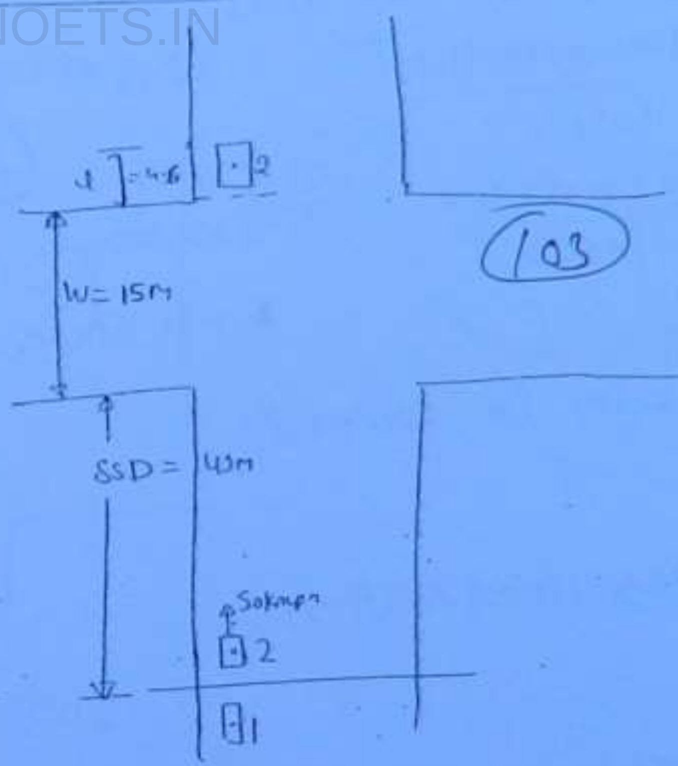
Amber duration = 4.5 sec.

Comfortable deceleration = 3 m/s2

Car length = 4.6m

Intersection width = 15 m

Perception Reaction time(t_R) = 1.5 sec.



Amber display time is required for two purpose

① To stop the vehicle approaching intersection [i/o vehicle ①]

Time required to stop

$$= t_R + \frac{V}{a}$$

$$= 1.5 + \frac{0.278 \times 50}{3} = 6.13\ sec. > 4.50\ sec$$

Amber time provided

② To allow the vehicle in danger area to cross the intersection

$$SSD = 0.278\,V \cdot t_R + \frac{(0.278\,V)^2}{2g\,(f \pm S)}$$

$\boxed{S = 0}$ Consider

$$= 0.278 \times 50 \times 1.5 + \frac{(0.278 \times 50)^2}{2 \times 9.81\,[0.35 + 0]}$$

$$SSD = 20.85 + 28.14 = 48.99 \text{ say } 49\,m.$$

Total time required to cross

$$= \frac{SSD + W + l}{0.278\,V}$$

$$= \frac{49 + 15 + 4.6}{(0.278)50} = 4.935 \text{ sec.}$$

> 4.50 sec.

Yes, driver claim is correct.

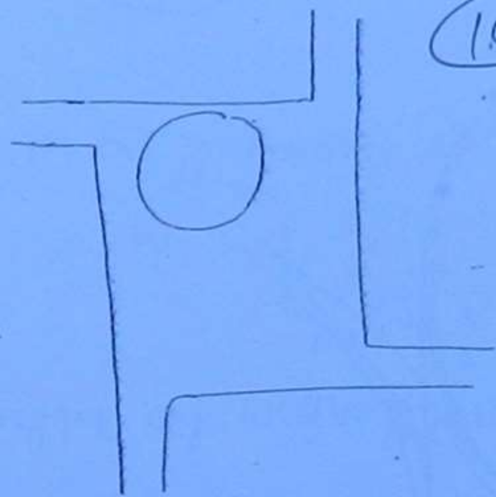
Imp
Design of Rotary intersection :-

Types:-

) Circular Rotary.

Elliptical Rotary

3) Turbine Rotary :-



(4) Tangential Rotary

(2) Design speed :-

Rural Area = 40Kmph
Urban area = 30Kmph

(3) Radius of Rotary [Minimum Radius of traffic Island]

No superelevation is provided [Camber slope is provided to drain of water]

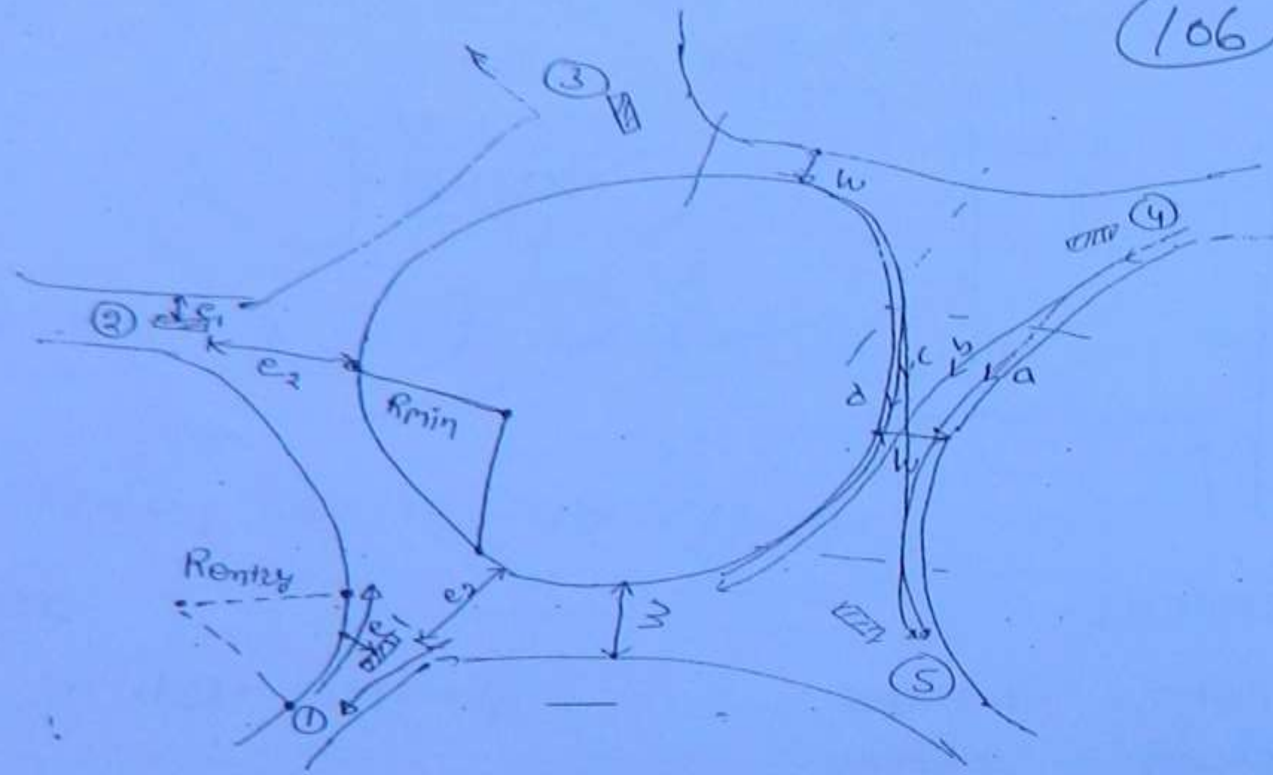
$$\boxed{e = 0}$$

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

$$\boxed{R_{min} = \frac{V^2}{127 f}} \quad \text{———— (A)}$$

here value of $f = 0.43$ → Rural area [40Kmph]

$f = 0.47$ → Urban Area [30Kmph]



(4) As per IRC

Radius of entry [Rentry]

Rural area = 20 to 35m (40kmph)

Urban area = 15 to 25m (30kmph)

- Minimum radius of central island

$R_{min} = 1.33 \times R_{entry}$

5) width of carriageway

(1) At entry e_1

minimum = 5.0m

As per Approach road width	e_1
7.0 m	6.5m
10.5 m	7.0m
14.0 m	8.0 m

② Ad. non weaving section (e_2)

$= e_1$ [if no value suggested or given]

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③ width of weaving section

$$W = \left[\frac{e_1 + e_2}{2} + 3.5 \right]$$

④ Length of weaving section

$L = 4 \cdot W$ = 4 times of width of weaving section

value not given than recommended value

40 kmph → 45 to 90 m

30 kmph → 30 to 60 m

⑤ Capacity of rotary :-

$$Q_p = \frac{280W \left(1 + \frac{e}{w}\right)\left(1 - \frac{p}{3}\right)}{\left(1 + \frac{W}{L}\right)}$$

where

W = width of weaving section

$= \left(\frac{e_1 + e_2}{2} + 3.5 \right)$

$e = \frac{e_1 + e_2}{2}$

L = length of weaving section

p = weaving ratio

$= \frac{b + c}{a + b + c + d} = \frac{\text{Total weaving traffic}}{\text{total traffic}}$

[Weaving section 4 type of movement of traffic can occur which is a, b, c and d.]

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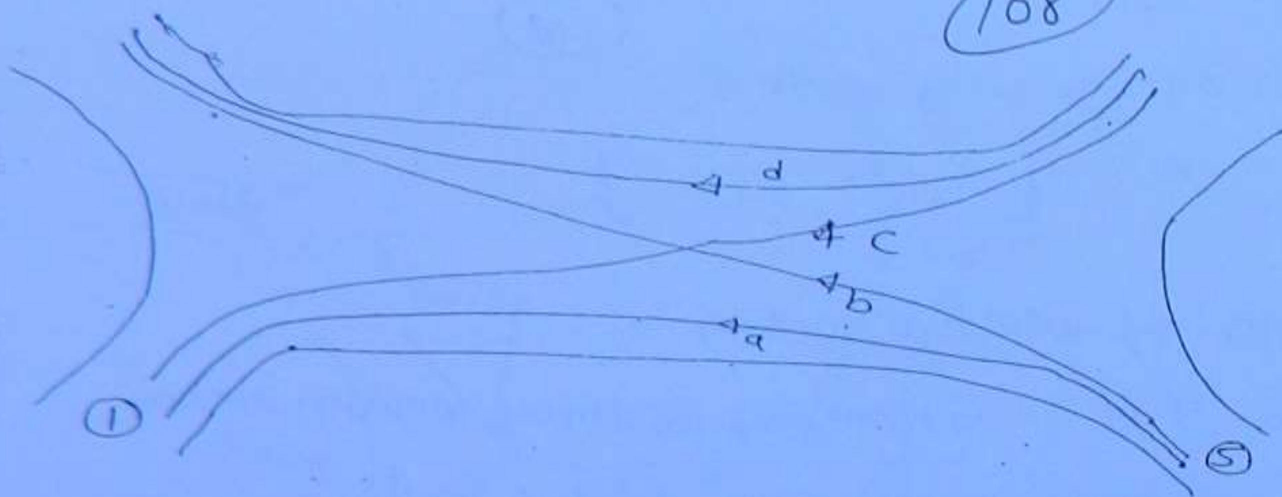

weaving ratio

$$p = \frac{b+c}{a+b+c+d}$$

Imp → only clockwise moments is possible

It is the ratio of Number of weaving traffic crossing to each other) to the total number of traffic in one weaving portion between any two leg.

Q. A road intersection has legs designated as 1, 2, 3, 4 and 5. leg 1 in N-S-direction and others are marked clockwise. The traffic volume in (PCU/hr)

V_{12} - 37	V_{31} - 466	V_{41} - 182	V_{51} = 45
V_{13} - 303	V_{32} - 122	V_{42} - 54	V_{52} - 132
V_{14} - 64	V_{34} - 47	V_{43} - 18	V_{53} - 62
V_{15} - 52	V_{35} - 657	V_{45} - 116	V_{54} - 15

- Find the weaving ratio between leg ① and ② what is the use of this value draw a sketch showing traffic volume between ① and ②.

Soln

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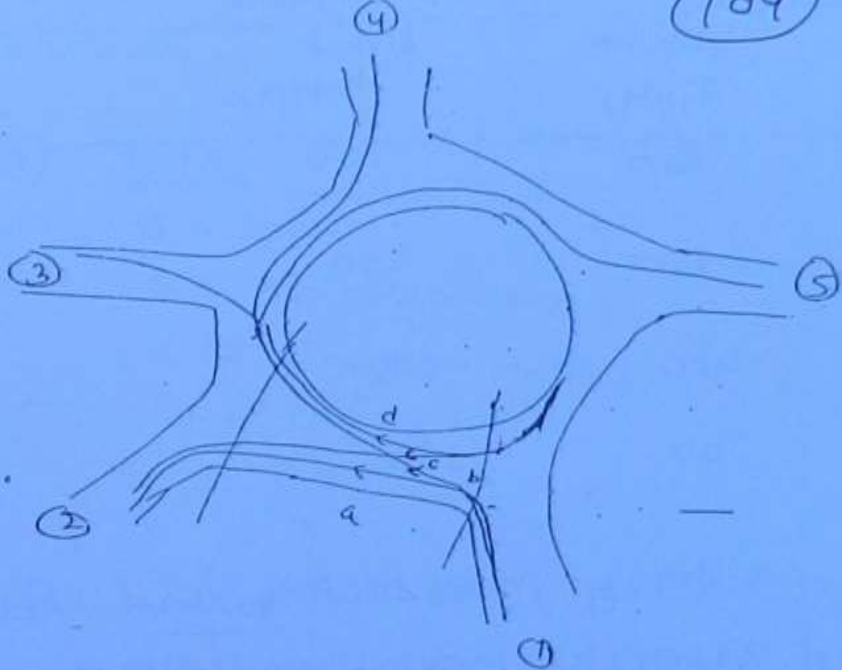
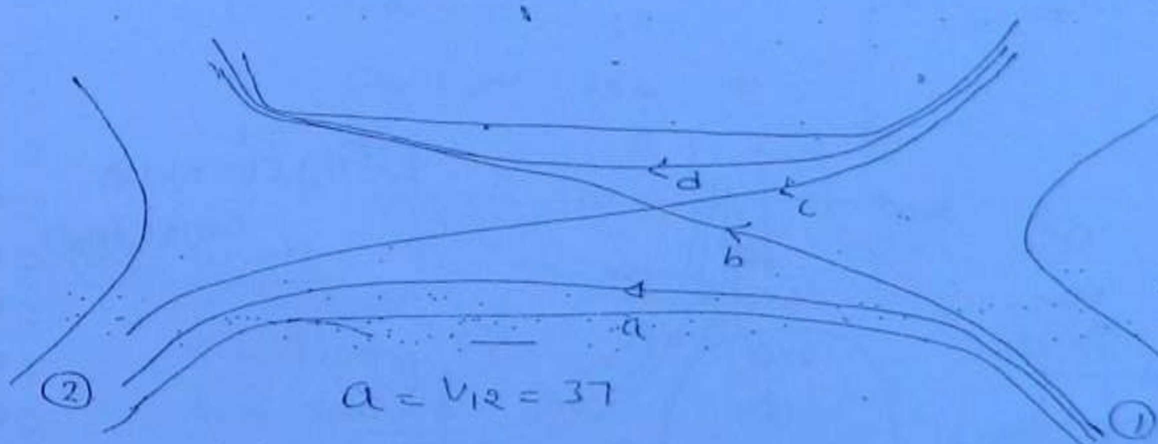


[only clockwise traffic flows]



$a = V_{12} = 37$

$b = V_{13} + V_{14} + V_{15} = 303 + 64 + 52 = 419$

$c = V_{32} + V_{42} + V_{52} = 122 + 54 + 132 = 308$

$d = V_{43} + V_{53} + V_{54}$

$= 18 + 62 + 15 = 95$

$$p = \frac{b+c}{a+b+c+d} = \frac{37+419}{37+419+308+95} = 0.846$$

16. Traffic flow in an urban area at right angle
7 intersection of two major road in the design years are given below:-

Both road = 15 m wide

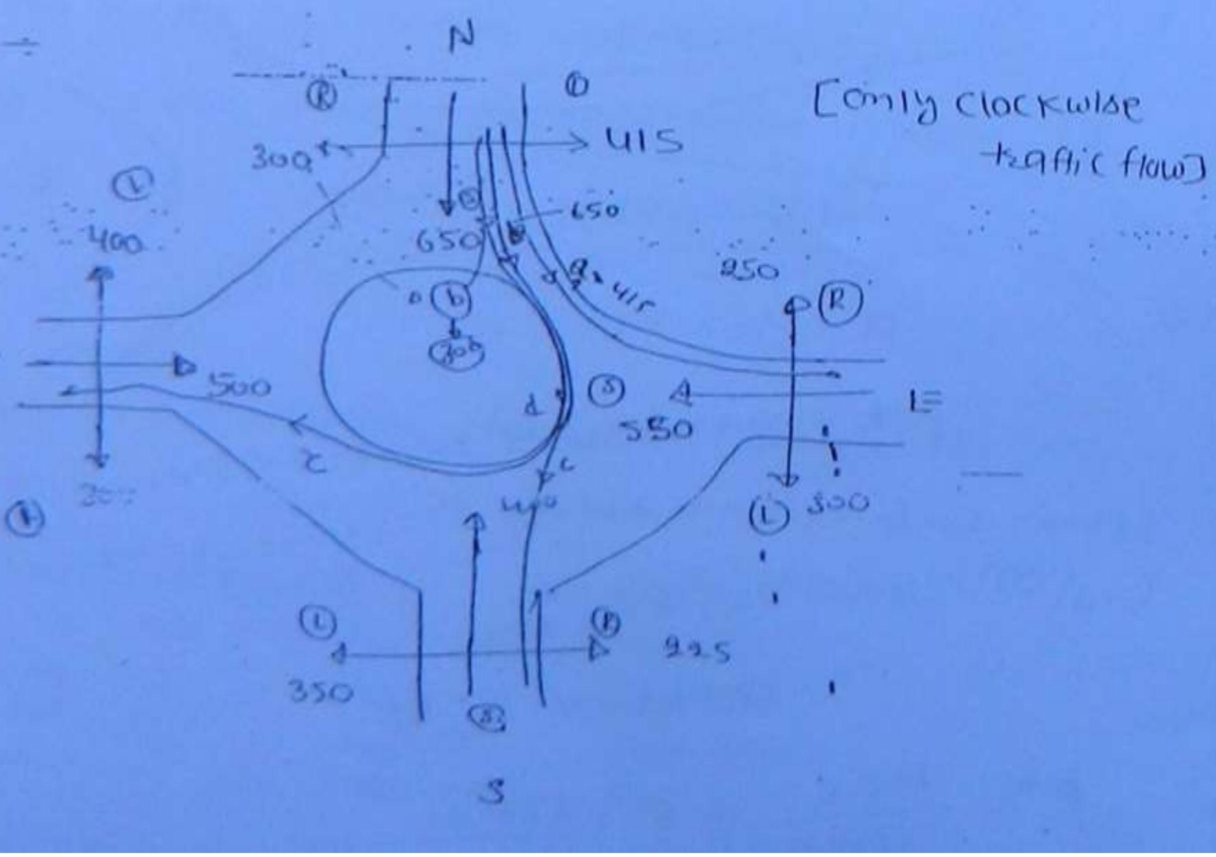
1/0

Traffic volume

Aproach Road	left turning	straight turning	Right turning.
North	415	650	300
East	300	550	250
South	350	400	225
West	400	500	300

Design a draw a rotary intersection and check for its practical capacity making suitable assumptions.

17.



Weaving Ratio between different legs

[Only clockwise traffic flow]

(1) N-E

a = 415 = 415

b = 650+300 = 950

c = 500+225 = 725

d = 300 = 300

Weaving Ratio

$= \frac{b+c}{a+b+c+d}$

$= \frac{950+725}{415+950+725+300}$

$= 0.70$

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(2) E-S

a = 300

b = 550+250 = 800

c = 650+300 = 950

d = 300

Weaving Ratio

$= \frac{800+950}{300+800+950+300}$

$= 0.745$

(3) S-W

a = 350

b = 400+225 = 625

c = 550+300 = 850

d = 250

Weaving Ratio

$p = 0.71$

(4) W-N

a = 400

b = 500+300 = 800

c = 400+250 = 650

d = 225

Weaving Ratio

$p = \frac{800+650}{400+800+650+225}$

$= 0.699$

capacity

$$Q_p = \frac{280w\left(1+\frac{e}{w}\right)\left(1-\frac{p}{3}\right)}{\left(1+\frac{w}{l}\right)}$$

[illegible] 745

Entry width $e_1 =$ 6.5 to $\left(\frac{15.0}{2} = 7.5\right)$ ← width of road

take $= e_1 = 7.50m$

(112)

width of non weaving section $e_2 = e_1 = 7.5m$

$$e = \frac{e_1 + e_2}{2} = 7.50m$$

weaving portion width

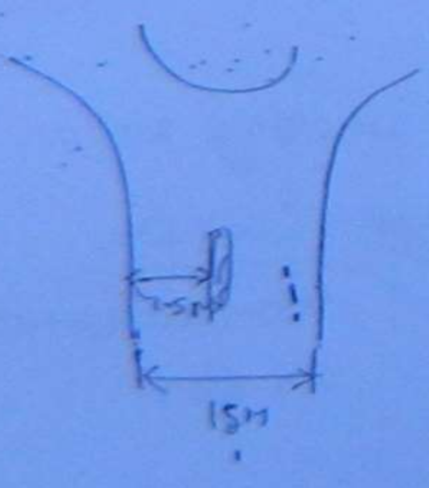
$$w = \frac{e_1 + e_2}{2} + 3.5 = 7.50 + 3.50 = 11.0m$$

Length of weaving portion $= 4w = 4 \times 11 = 44\,m$

Capacity $$Q_p = \frac{280 \times 11 \left(1 + \frac{7.5}{11}\right) \times \left[1 - \frac{.745}{3}\right]}{\left(1 + \frac{11}{44}\right)}$$

$$Q_p = 3114.9 = 3115 \text{ veh/hr}$$

$\boxed{\text{Road width}} = 15m$



$e_1 =$	7.0m	6.5m
	10.5m	7.0m
	14.0m	8.0m

Pavement design

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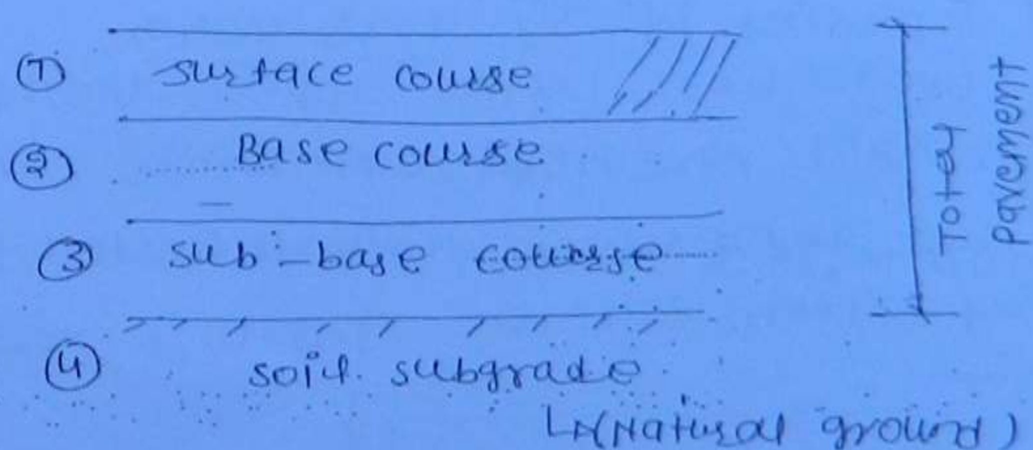
Type of pavement :-

① Flexible pavement :-

→ Flexible pavement are constructed by using stone aggregate with or without some binder material.

Ex → Earth, bitumen etc. , WBM or bituminous road are Example

→ Generally consists of four layers.



→ Load transfer is by grain to grain transfer.

→ Pavement may be deflected in the shape of bottom surface due to any localised depression.

... low or negligible flexural strength. [It can not take B.M.]

Rigid pavement :-

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- Rigid pavement are constructed by using cement concrete [PCC, RCC, PSC]

- consists of generally three layers.

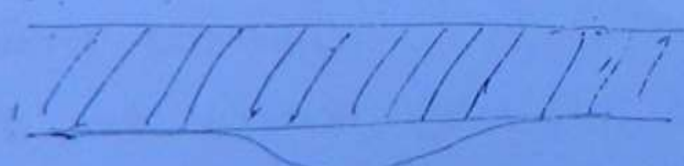
① pavement (cement concrete)

② Lean concrete [Base course 1:5:10)

③ soil subgrade

- Load transfer is by slab action.

- solid. Rigid pavement can bridge over localised depressions. Not deflected in the shape of bottom surface.



- It has sufficient flexural Rigidity. Bending stress can be resisted.

3) semi rigid pavement :-

- It binder material of better quality like soil cement, Lime, pozollanic cement are used with stone aggregate, the pavement will have better strength and rigidity than Flexible pavement. These are called semi rigid pavement.

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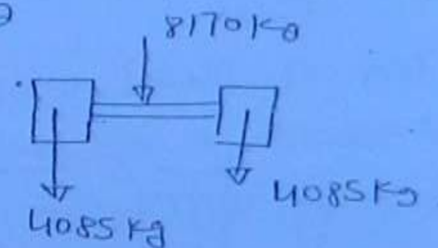
* Design of Flexible pavement :-

Some important points :-

(1) Max^m Legal axle load as per IRC

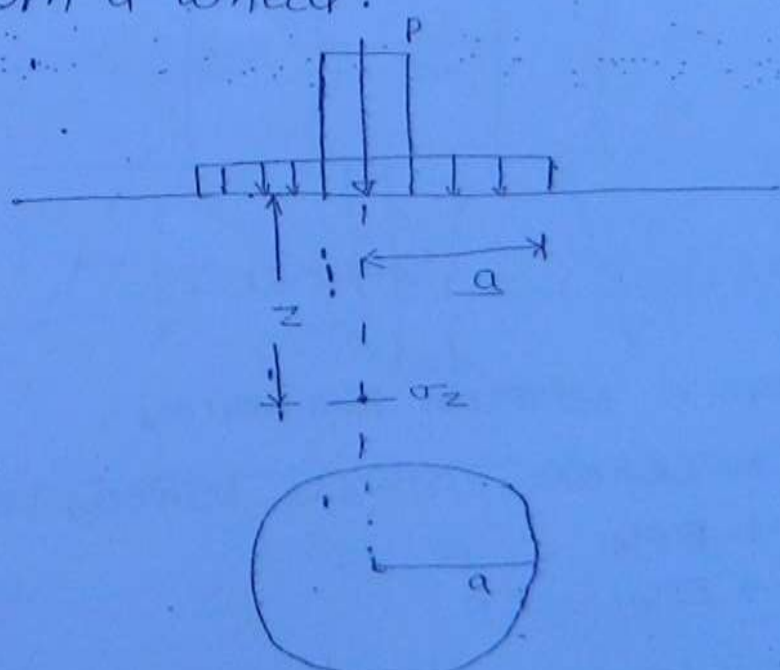
= 8170 kg



(2) Equivalent single wheel load [ESWL]

= 4085 kg.

(3) Stress at a ~~depth~~ point at z depth due to Load from a wheel:



If P = Total wheel load

a = radius of contact area

Tyre pressure

$$p = \frac{P}{A} = \frac{P}{\pi a^2}$$

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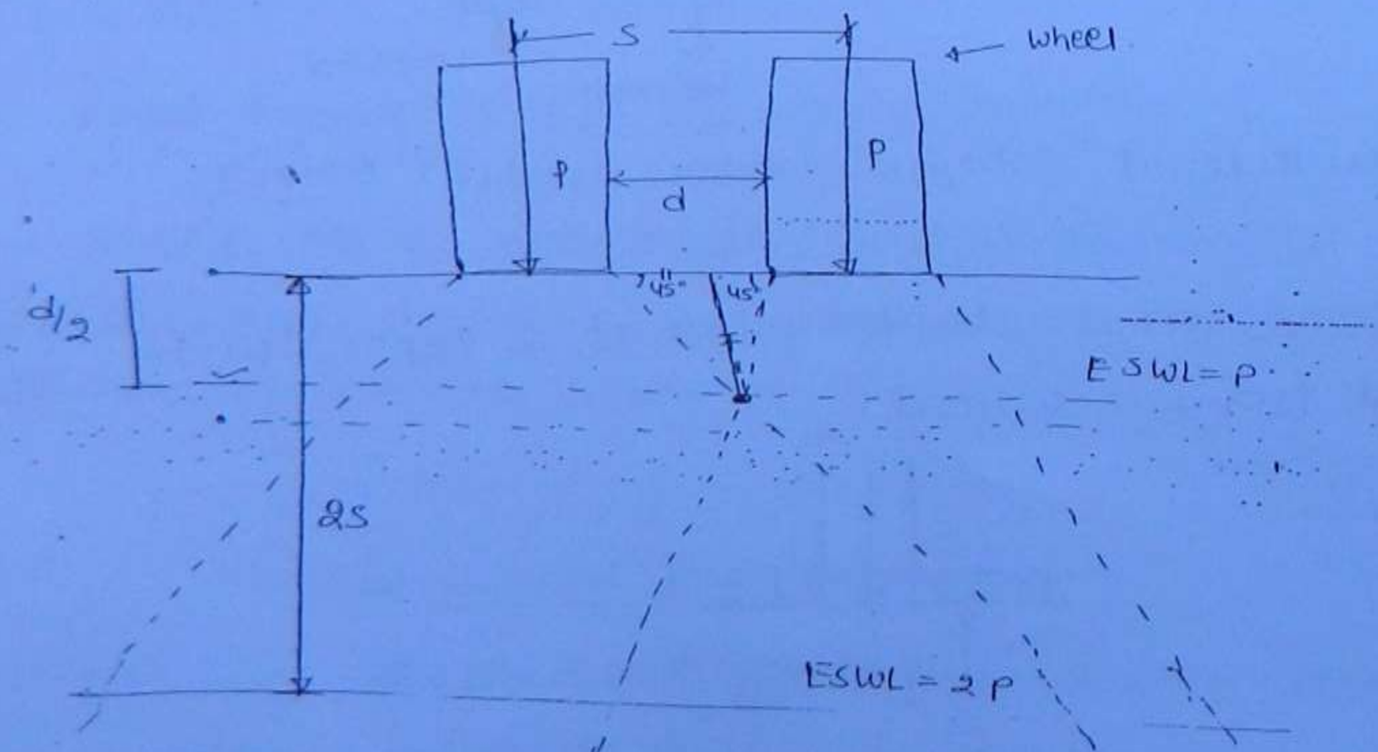
Stress at z depth below the load

Boussinesques Equation

$$\sigma_z = p\left[1 - \frac{z^3}{(a^2+z^2)^{3/2}}\right]$$

1) ESWL for a Dual wheel assembley



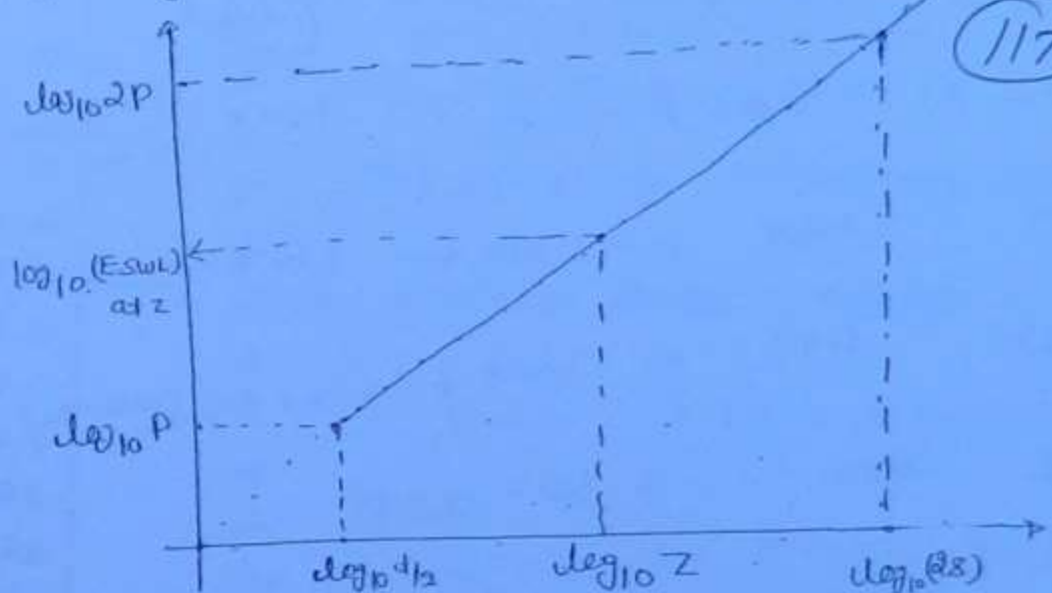
If d = clear distance between two wheels

S = Centre to Centre distance between wheels

upto d/2 depth → ESWL = P

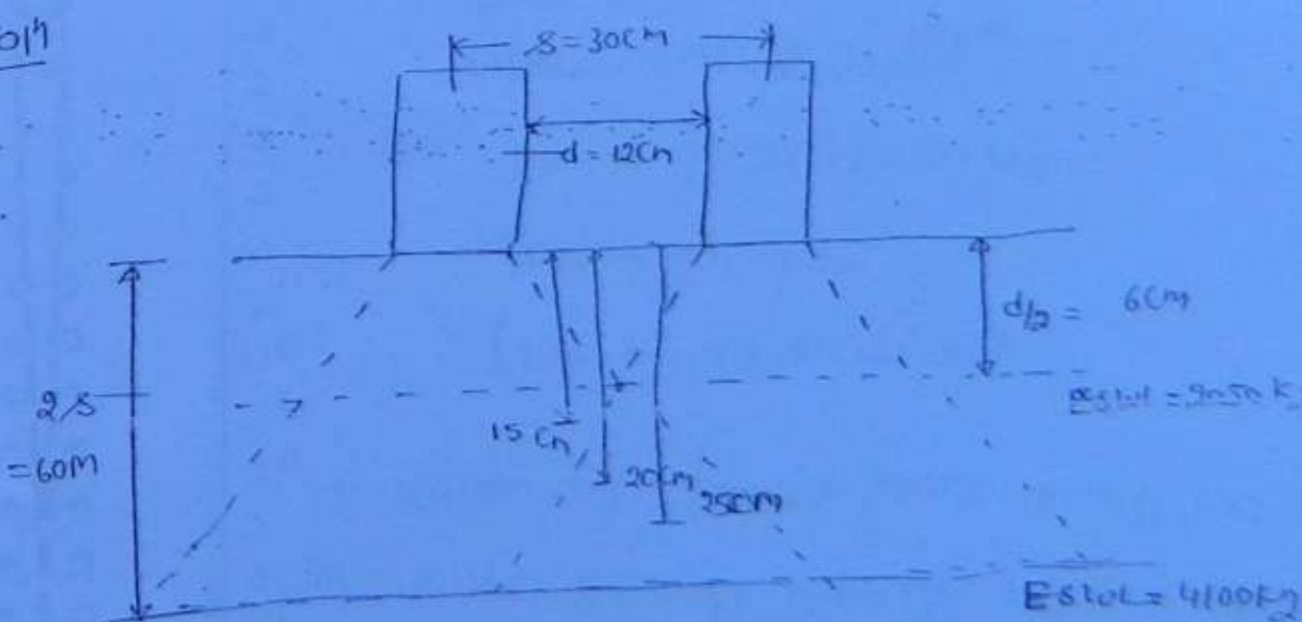
beyond 2S depth → ESWL = 2P

between $\frac{d}{2}$ and 2.8 ⇒ ESWL values can be interpolate on a log scale.



Que: Calculate ESWL value for a dual wheel Assembley carry 2050 kg each for pavement thickness of 15, 20 and 25 cm. If centre to centre distance between tyre is = 30 cm. clear distance between wall is = 12 cm.

Soln



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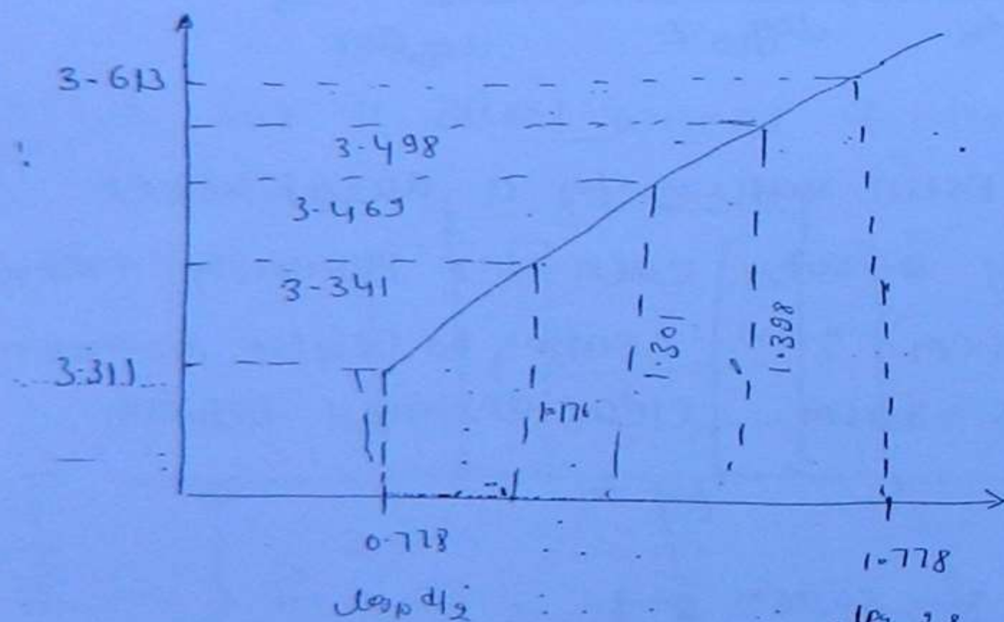
Depth	$\log_{10}$(depth)	ESWL	$\log_{10}$ESWL	Remarks
6 cm	0.778	2050	3.311	
15 cm	1.176	2699 ←	3.431 ←	$= 3.311 + \frac{3.613 - 3.311}{1.778 - 0.778}[1.176 - 0.778]$ =
20 cm	1.301	2944 ←	3.469 ←	$= 3.311 + \frac{0.302}{1}(1.301 - 0.778)$
25 cm	1.398	3149 ←	3.498 ←	$3.311 + \frac{0.302}{1}[1.398 - 0.778]$
60 cm	1.778	4100	3.613	



Methods for design of Flexible pavements:→

① Group index method :- (G.I.)

→ Group index value is used for design of of pavement required over a soil.

→ Group index value

$$G.I. = 0.2a + 0.005\,ac + 0.01\,bd$$

here

$a = P - 35 \not> 40$

$b = P - 15 \not> 40$

$c = w_L - 40 \not> 20$

$d = I_p - 10 \not> 20$

here

P = % fine of soil particles passing 0.074 mm sieve.

w_L = Liquid limit

I_p = plasticity index

$I_p = w_L - w_p$

w_p → plastic limit

→ value of group index may be 0 to

→ soil getting having higher group ind is a poor soil.

→ thickness of pavement is found as per Group index value, using tables and graphs.

→ Table :-

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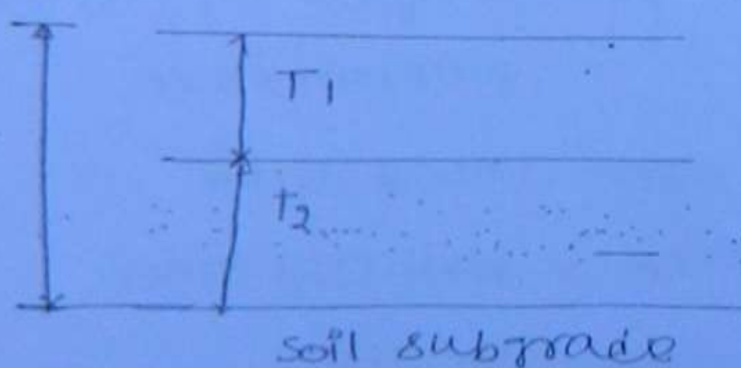
Total thickness of pavement required over a soil having G.I value →

G.I value	Base + surface (T_1)	Subbase (T_2)
0 - 4	15 cm	10 cm
5 - 9	20.5 cm	20 cm
10 - 20	30 cm	30 cm



Limitations :-

→ for all type of material used in pavement, thickness suggested same. Thickness does not depends upon quality of materials.

Que A soil subgrade has following data
(a) soil passing from 0.074 mm sieve = 60%
(b) $w_L = 45\%$, $w_p = 25\%$
calculate thickness of pavement required above the soil subgrade using Group index method use table as shown above. (12)

Soln
Percent fine $p = 60\%$

$w_L = 45\%$

$w_p = 25\%$

$I_p = w_L - w_p = 45 - 25 = 20\%$

$a = p - 35 = 60 - 35 = 25 < 40$ ok

$b = p - 15 = 60 - 15 = 45 > 40$, Take 40

$c = w_L - 40 = 45 - 40 = 5 < 20$ o.k.

$d = I_p - 10 = 20 - 10 = 10 < 20$ o.k.

Group index :- $0.2a + 0.005ac + 0.01bd$

$= 0.2 \times 25 + 0.005 \times 25 \times 5 + 0.01 \times 40 \times 10$

(G.I.) $= 9.625$ say 10

Total thickness of pavement
(1) surface + base = 30 cm
(2) Sub base = 30 cm

Total = $T = 30 + 30 = 60$ cm

CBR Method :-

(California bearing Ratio Method)

> CBR value :-

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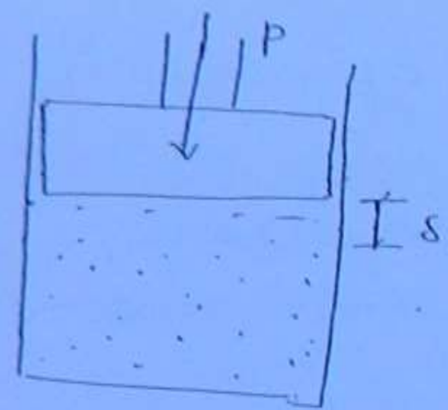
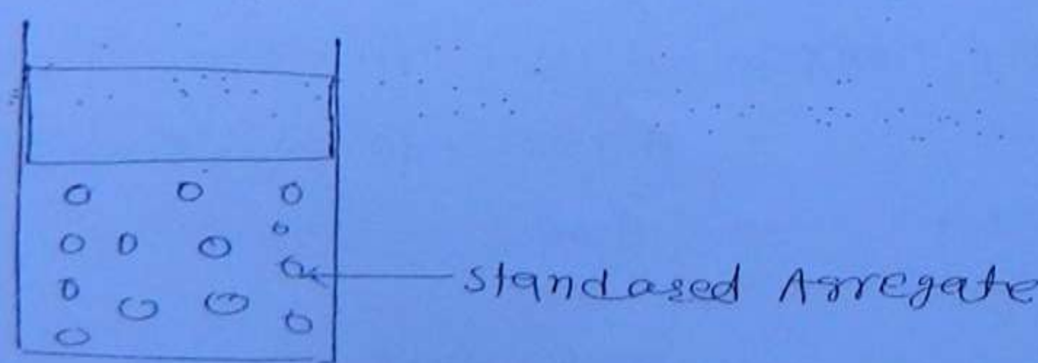


- soil sample is put into a cylinder and a piston (plunger) is penetrated using loads. load and penetration value are noted.
- The value of load required for 2.5mm penetration (P_1) and 5.0mm penetration (P_2) are compared with standard load values



standard load value are load required for 2.5mm and 5.0mm penetration over standard Aggregate.

- Standard load values are

(123)

2.5 mm penetration = 1370 kg

5.0 mm penetration = 2055 kg = 2055 kg.

(4) CBR values

$$= \frac{\text{load over soil}}{\text{standard load}} \times 100$$

for 2.5 mm $\quad CBR_1 = \frac{P_1}{1370} \times 100$

for 5.0 mm $\quad CBR_2 = \frac{P_2}{2055} \times 100$

(5) Generally 2.5 mm penetration CBR values is higher, it is accepted as CBR values.

(6) if 5.0 mm CBR value is higher,

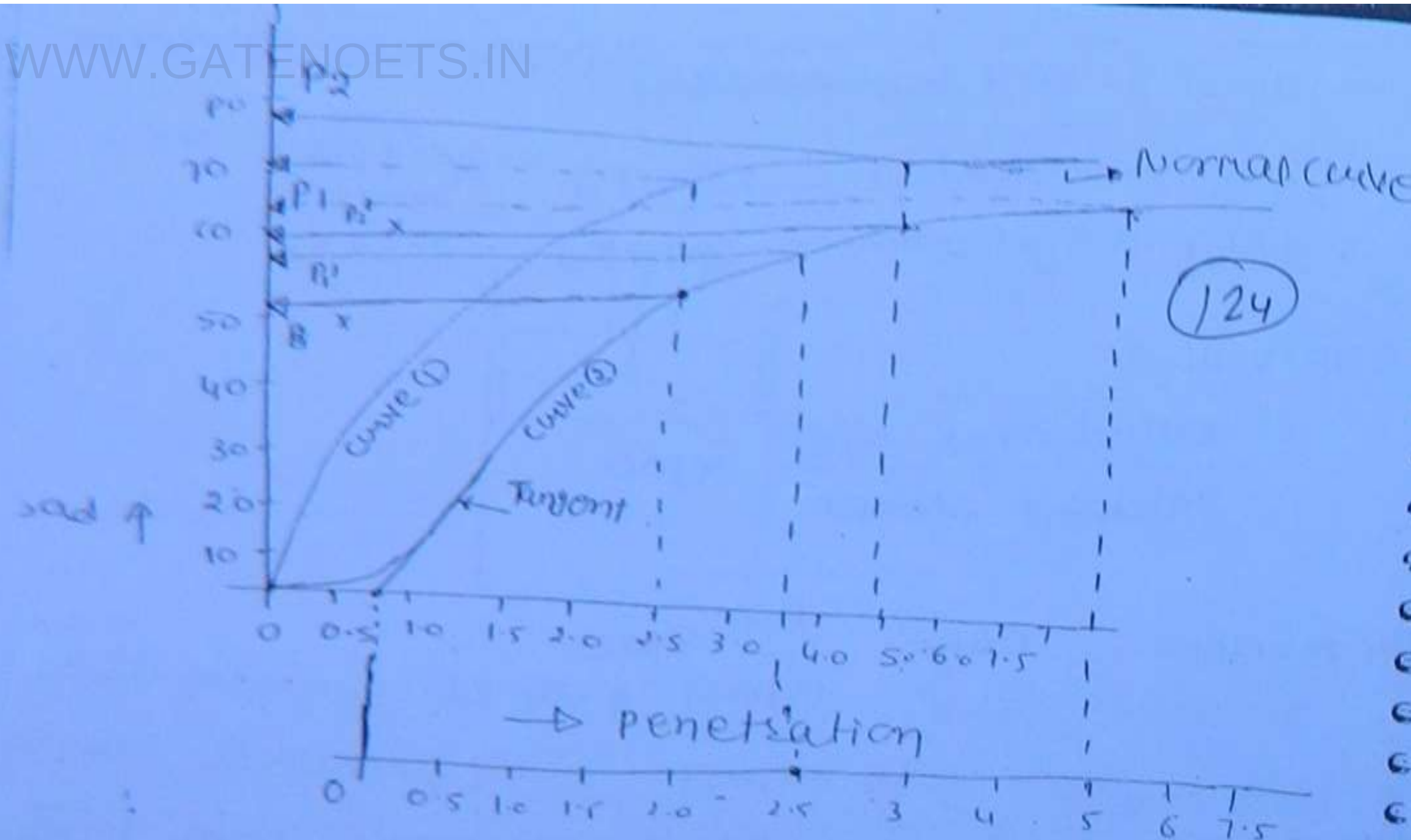
In this case test is reapeated and if same results is obtained again this 5.0 mm CBR value (higher value) is accepted as CBR value.

(7) Graph b/w load and penetration

curve - (1) Normal curve P_1 and P_2 taken for 2.5 and 5.0 mm penetration.

(2) false ~~statement~~ reading or initial concavity due to the soil compacted by hand not properly may occur. The

continue



- If there is a initial concavity in the graph (curve 2). This is due to false settlement at initial stage. In this case a tagent is drawn from the steepest point and origin is shifted to cutting point of this tangent with x-axis.
- P_1' and P_2' are read using shifted scale.

Design of pavement Based on CBR values

Thickness of pavement

$$\boxed{T = \sqrt{\frac{1.75\,P}{CBR} - \frac{A}{\pi}}}$$ Imp.

$$T = \sqrt{\frac{1.75P}{CBR} - \frac{A \times p}{\pi \times p}}$$

$$T = \sqrt{\frac{1.75P}{CBR} - \frac{P}{\pi \times p}} \qquad \boxed{A \times p = P}$$

$$T = \sqrt{P\left(\frac{1.75}{CBR} - \frac{1}{\pi p}\right)}.$$

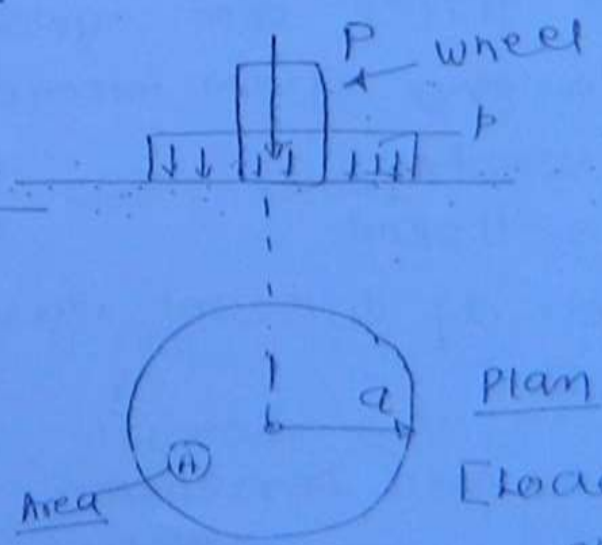
where

P = wheel load (kg)

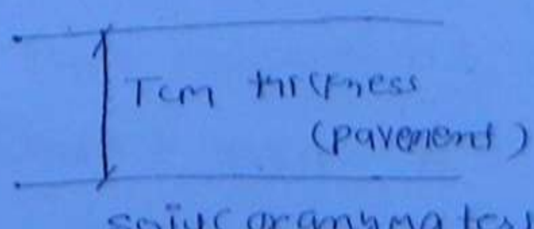
p = tyre pressure (kg/cm²)

$A = \frac{P}{p}$ = contact Area (cm²)

CBR = CBR value in %.



[Load acting on the circular Area]



Limitations:-

Quality of material used in pavement is not considered.

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Thickness can be found for a limited CBR value only. [CBR value more, than T = $\sqrt{-(\text{value})}$, $\frac{1.75P}{CBR} < \frac{P}{\pi}$]

Q: CBR test was conducted for soil subgrade and following results were obtained.

Penetration (mm)	0.5	1.0	1.5	2.0	2.5	3.0	4.0	5.0	7.5	10
Load (kg)	4.0	18.0	30.0	43	49	59	70	78	93	102

Above this soil subgrade following materials were used →

i) Compacted soil having CBR = 6.0%.
ii) Poorly graded gravel CBR = 13.0%.
iii) Well graded gravel CBR = 48.0%.
iv) Bituminous surfacing of 4cm thickness

Wheel load = 4500 kg

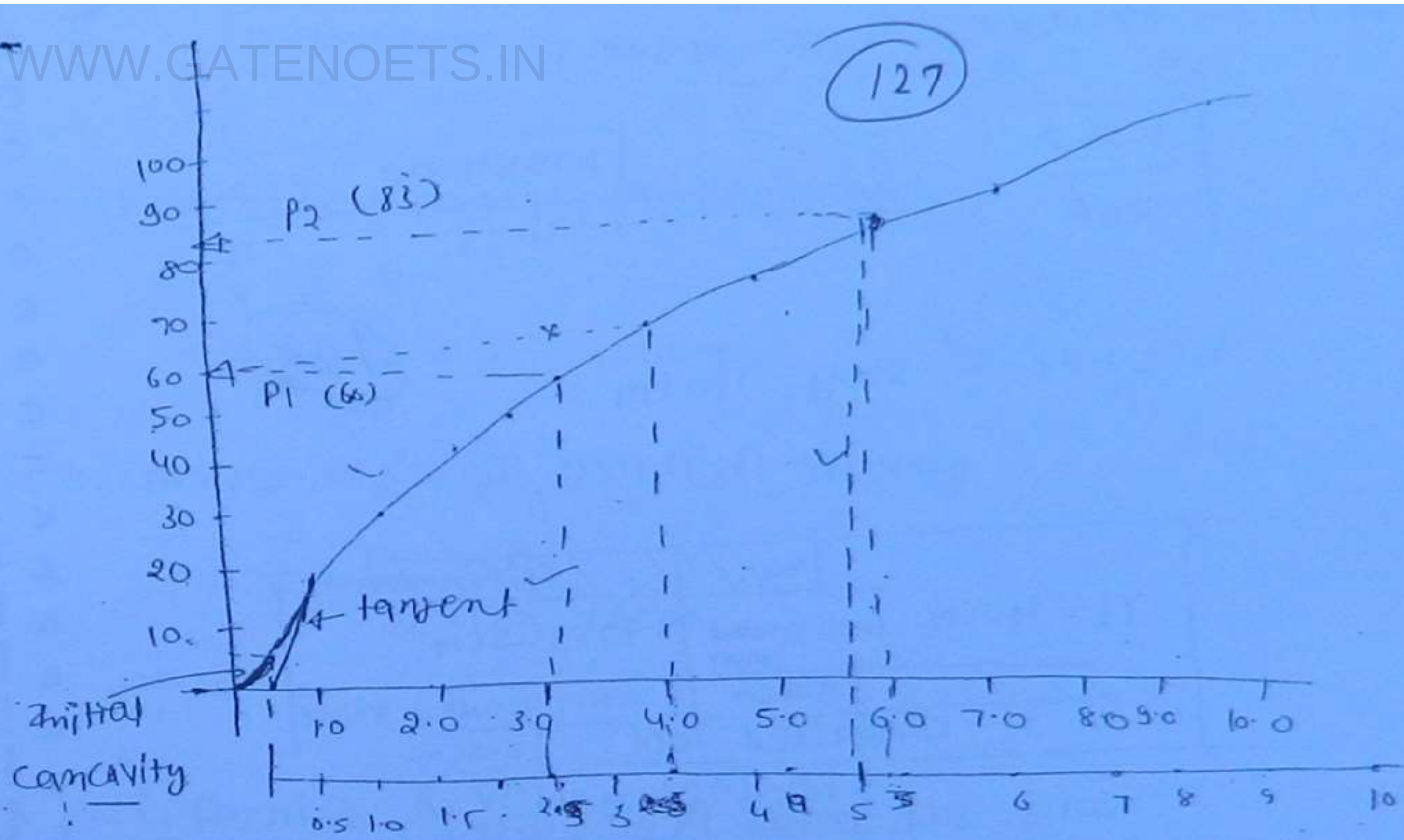
Tyre pressure = 7 kg/cm²

Calculate thickness of different layers of pavement using CBR method.

Ans:

graph b/w load and penetration

I) CBR value of soil subgrade.



$P_1 = 60 kg$
$P_2 = 83 kg$

} A/C to corrected shifted scale from curve

$$CBR(2.5) = \frac{60}{1370} \times 100 = 4.38\%$$

$$CBR(5.0) = \frac{83}{2025} \times 100 = 4.04\%$$

CBR value = 4.38%

CBR value of soil subgrade = 4.38%

wheel load $P = 4500 kg$

tyre pressure $p = 7 kg/cm^2$

Contact Area $= A = \frac{P}{p} = \frac{4500}{7} = 642.86 cm^2$

→ Total thickness of pavement required over soil subgrade (CBR = 4.38%)

$$T_1 = \sqrt{\frac{1.75P}{CBR} - \frac{A}{\pi}} = \sqrt{\frac{1.75 \times 4500}{4.38} - \frac{642.86}{\pi}}$$

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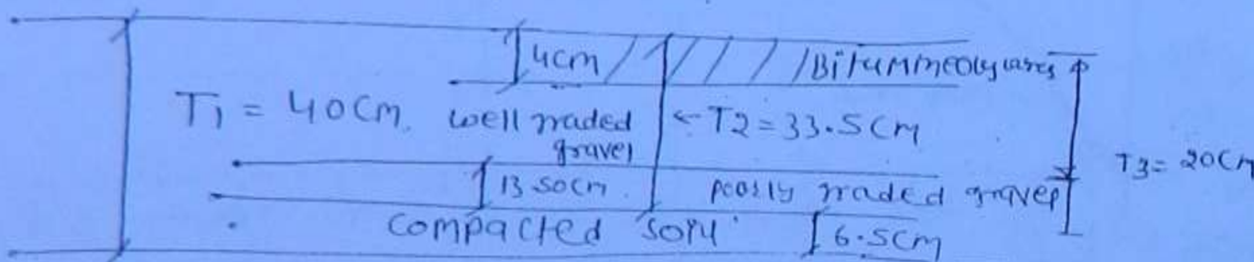
$$= 39.91 \simeq \text{say } 40\,cm$$



soil sub grade [CBR = 4.38%]

→ Thickness of pavement required above compacted soil [CBR = 6%]

$$T_2 = \sqrt{\frac{1.75 \times 4500}{6.0} - \frac{642.86}{\pi}}$$

$$T_2 = 33.28 \simeq 33.50\,cm$$

thickness of compacted soil required

$$T_1 - T_2 = 40 - 33.50 = 6.5\,cm$$

Total thickness of pavement required above poorly graded gravel [CBR 13.0%]

$$T_3 = \sqrt{\frac{1.75 \times 4500}{13} - \frac{642.86}{\pi}} = 20.03 \simeq 20\,cm$$

thickness of poorly graded gravel

$= T_2 - T_3$

$= 33.50 - 20 = 13.5\,cm$

→ Thickness of well graded gravel

$= T_3 - 4\,cm$

$= 20 - 4 = 16\,cm$

③ California R-value Method :-

(California Resistance value Method)

① thickness of pavement required

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

where

K = constant = 0.166

TI = Traffic Index

$= 1.35 (EWL)^{0.11}$

R = stabilometer R-value

C = cohesiometer C-value

EWL → yearly value of Equivalent wheel load.

axle	2	3	4	5	6	
EWL constant	330	1070	2460	4620	3040	
traffic volume	V_1	V_2	V_3	V_4	V_5	136
daily EWL value	$330V_1$	$1070V_2$	$2460V_3$	$4620V_4$	$3040V_5$	

$$\text{Total EWL value} = 330V_1 + 1070V_2 + 2460V_3 + 4620V_4 + 3040V_5$$

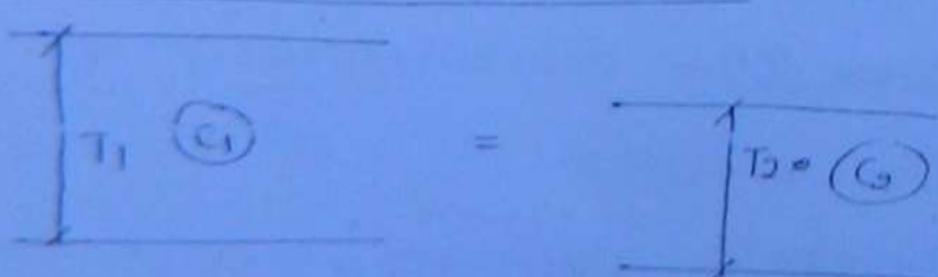
Thickness of Pavement

[illegible]

$$T = \frac{0.166 \times 1.35\,(EWL)^{0.11}\,(90-R)}{C^{1/5}}$$

$$\boxed{T = \frac{0.22\,(EWL)^{0.11}\,(90-R)}{C^{0.20}}}$$

For two Equivalent layers:



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

[if other value are constant]

Q. Calculate 10 years EWL and traffic index value using following data

Nos of Axle	AADT
2	3750
3	470
4	320
5	120

Assume 60% increase in traffic in next 10 years period calculate thickness of pavement required, if R value = 48, C = 16

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Sol^n

Yearly value of EWL [present year]

Nos of Axle	AADT (volume)	EWL constant	yearly anual EWL
2	3750	330	1237500
3	470	1070	502900
4	320	2460	787200
5	120	4620	554400
	sum =		3082000

After 10 years $= 1.60 \times 3082000$ [60% increase]

$= 4931200$

Average value (yearly value)

$$= \frac{3082000 + 4931200}{2}$$

$= 4006600$

EWL for 10 years period = 10×4006600

$= 40066000$

Traffic index

$$TI = 1.35 \times (EWL)^{0.11} = 1.35 \times (40066000)^{0.11}$$

$$TI = 9.26$$

Thickness

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$$T = \frac{0.22(TI)(90 - R)}{C^{0.20}}$$

$$= \cancel{0.22 \times 9.260 \times (}$$

$$T = \frac{K \cdot (TI)(90 - R)}{C^{1/5}}$$

$$T = \frac{0.166 \times 9.26 \times (90 - 48)}{(46)^{1/5}} = 37.08\ cm$$

Q. Calculate the Equivalent C-value of a three layer pavement having

Bituminous pavement	Thickness	C-value
	12.5 cm	62
well graded gravel	25.0 cm	180
Cement treated base	20.0	25

Sol^n

C = 62	Bituminous	12.5	
C = 180	Cement	25.0	T = 57.5 cm
C = 25	Well graded	20	

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Let us find Equivalent thickness of Each layer in terms of well graded gravel.

(1) Bituminous

$T_B = 12.5$, $C_B = 62$

$T_{w_1} = ?$ $C_w = 25$

$$\frac{T_B}{T_w} = \left(\frac{C_w}{C_B}\right)^{1/5} \Rightarrow T_w = T_B \times \left(\frac{C_B}{C_w}\right)^{1/5}$$

$$T_{w_1} = 12.5 \times \left(\frac{62}{25}\right)^{1/5} = 14.99 \text{ cm}$$

(2) Cement

$T_c = 25.0$, $C_c = 180$

$T_w = ?$, $C_w = 25$

$$T_{w_2} = T_c \times \left(\frac{C_c}{C_w}\right)^{1/5} = 25 \times \left(\frac{180}{25}\right)^{1/5} = 37.10 \text{ cm.}$$

(3) well graded gravel = 20.0 cm = T_{w_3}

Total thickness of pavement in terms of well graded

$$T_w = T_{w_1} + T_{w_2} + T_{w_3} = 14.99 + 37.10 + 20 = 72.09 \text{ cm}$$

Equivalent C - value = 25

$T_w = 72.03\text{cm}$, $C_w = 25$ for total pavement

$T_p = 57.50\text{cm}$, $C_p = ?$

Actual thickness

$$\frac{T_w}{T_p} = \left(\frac{C_p}{C_w}\right)^{1/5} \Rightarrow \frac{C_p}{C_w} = \left(\frac{T_w}{T_p}\right)^5$$

$$C_p = C_w \times \left(\frac{T_w}{T_p}\right)^5 = 25\left(\frac{72.03}{57.50}\right)^5$$

$$\therefore \boxed{C_p = 77.4}$$ Ans.

- Design procedure Based on California R-value Method :-

→ For design of pavement, it is required to satisfy three criteria

1. design based on R- value
2. design based on Expansion pressure
3. design based on Exudation pressure

▷ Exudation pressure is value of pressure required to force out water from a soil.

Step(1) Thickness based on R-value.

Thickness of pavement calculated as per

$$T_R = \frac{K\cdot(TI)\cdot(90-R)}{C^{1/5}} = \frac{0.166 \times 1.35\,(EWL)^{0.1} \times (90-R)}{C^{1/5}}$$

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Step(2) Thickness based on Expansion pressure

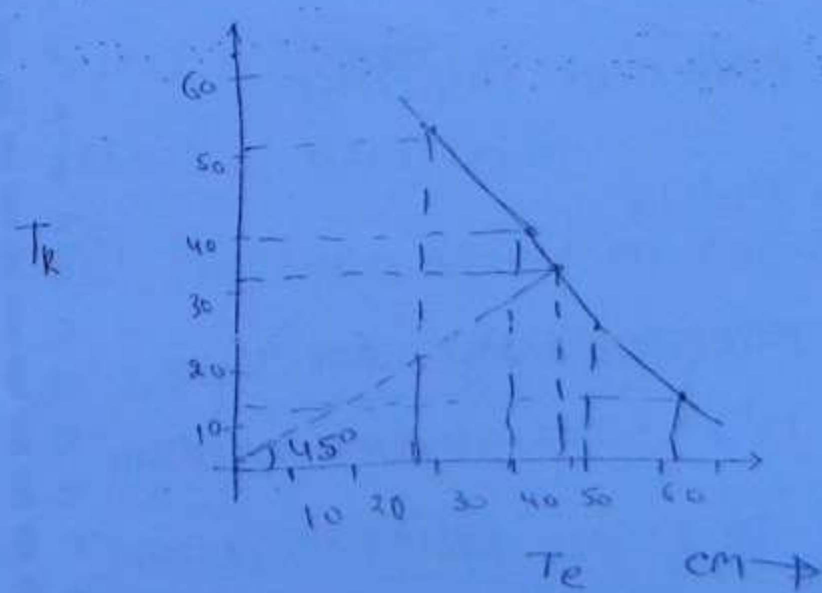
Thickness of pavement is

$$= \frac{\text{Expansion pressure } (kg/cm^2)}{\text{Ab. density of soil}}$$

$\hookrightarrow [2100\, kg/m^3 = 0.0021\, kg/cm^3]$

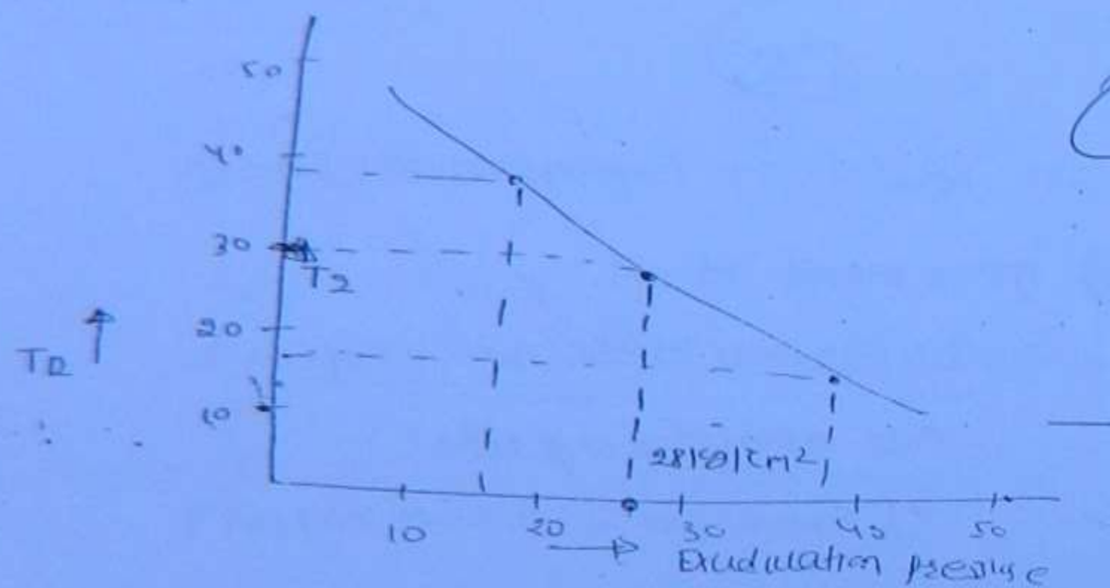
$$T_e = \left(\frac{\text{Expansion pressure}}{0.0021}\right) \text{cm}$$

Step(3) Plot T_R v/s T_e



 ... of pavement required where
$T_R = T_e = T_1$ cm | By drawing a line at 45° angle

Step (4) Plot T_R v/s Exudation pressure



(136)

→ Thickness of pavement at 28 kg/cm² Exudation pressure is found $= T_2$ cm.

Step (5): Thickness of pavement required

$= \text{Max}^m$ of T_1 and T_2

e. Design a flexible pavement using WBM base course [C-value = 15] + 7.5 cm thick bituminous surface [C-value = 62] by California R-value method.
The soil subgrade has following data [Traffic index = 9.50]

Moisture content	R-value	Expansion pressure	Exudation pressure	T_R	T_e
15%	56	0.135	36.5	31.20	64.30
18%	44	0.099	26.5	42.20	47.14
21%	25	0.055	18.0	59.60	26.20
24%	14	0.034	15.0	69.73	16.20

Sol^n step① Thickness of pavement in terms of WBM value (C = 15 value)

Thickness based on R-value

$$T_R = \frac{K \cdot TI (90-R)}{C^{1/5}} = \frac{0.166 \times 9.50 \times (90-R)}{(15)^{1/5}}$$

$$T_R = 0.9175 (90-R)$$

$T_{R(56)} = 31.20$ cm

$T_R(44) = 42.20$ cm

$T_R(25) = 59.60$ cm

$T_R(40) = 69.73$ cm

step② Thickness based on Expansion pressure

$$T_e = \left(\frac{\text{Expansion pressure}}{0.0021}\right)$$

$$T_{e(15\%)} = \frac{0.135}{0.0021} = 64.30 \text{ cm}$$

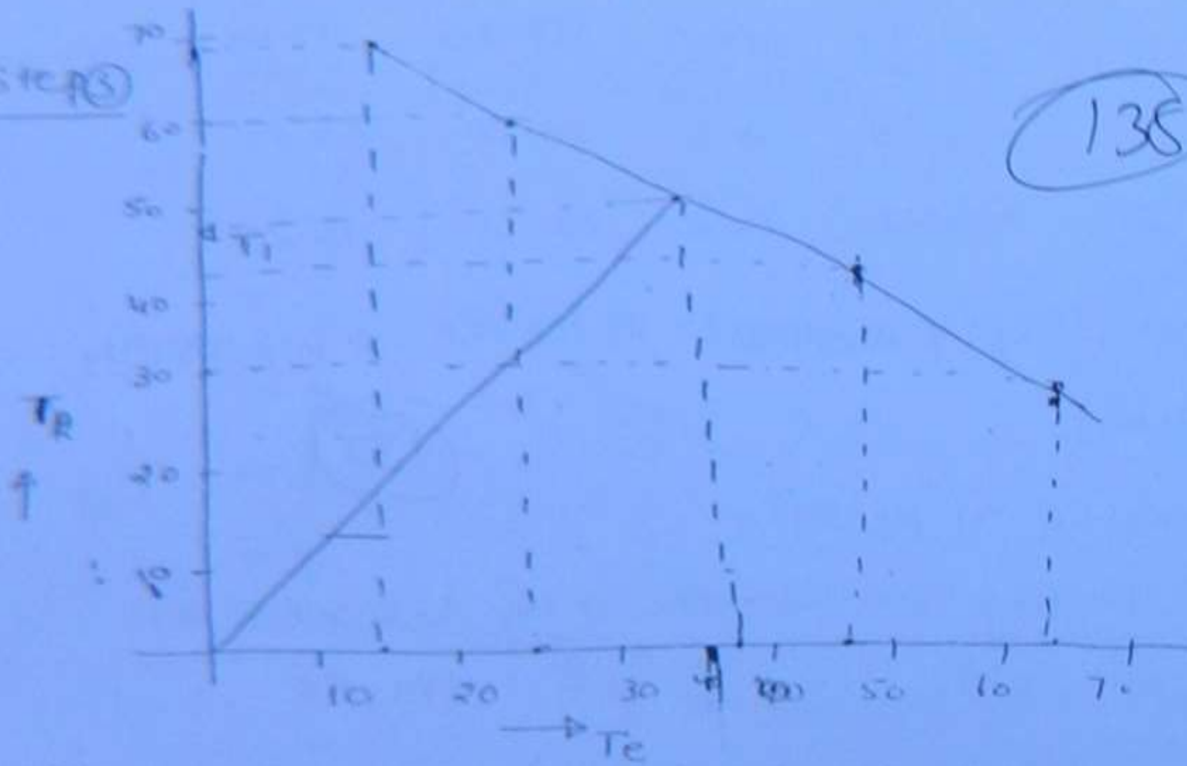
$$T_{e(18\%)} = \frac{0.099}{0.0021} = 47.14$$

$Tc(\ldots) = \dfrac{0.055}{0.0021} = 26.20$

$Tc(34.?) = \dfrac{0.034}{0.0021} = 16.20$

(138)

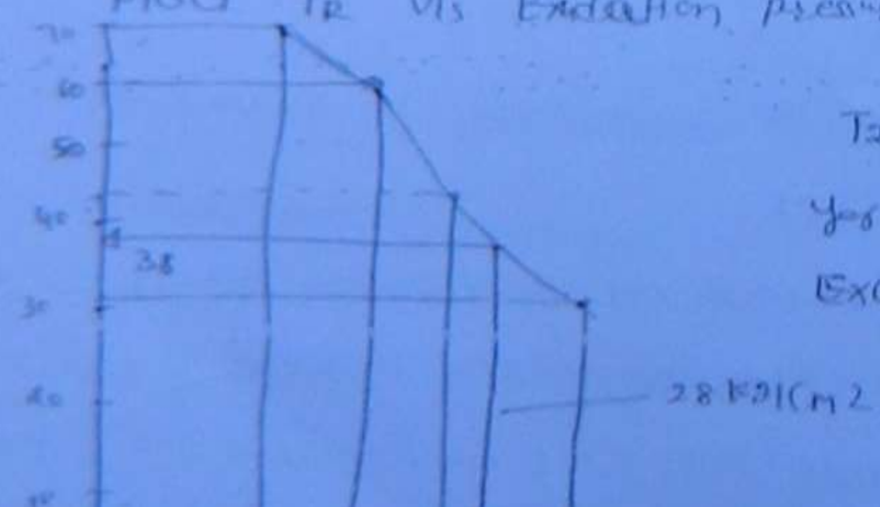
Step (3)



Thickness

Say $T_1 = 44$ cm

Step (4) Plot T_R V/s Exudation pressure



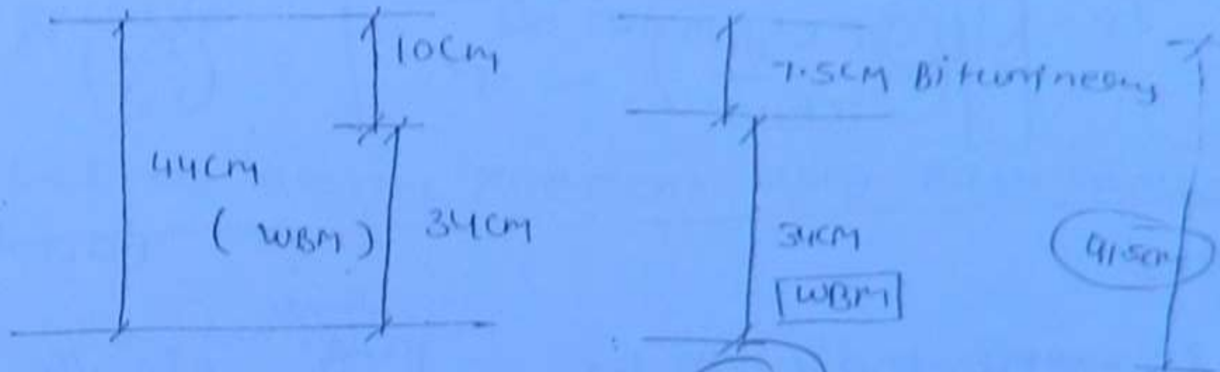
$T_2 = 38$ cm

for 28 Kg/cm^2

Exudation pressure

Step (5) Thickness of pavement

T = 44cm of WBM layer [Take max value]



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$T_B = 7.5cm$ $C_B = 62$

$T_W = ?$ $C_W = 15$

$T_W = T_B\left(\frac{C_B}{C_W}\right)^{1/5}$

$= 7.5\left(\frac{62}{15}\right)^{1/5} = 9.6cm$

say = 10cm

∴ Remaining thickness of WBM layer required = 44 - 10 = 34cm

(4) Triaxial Method :-

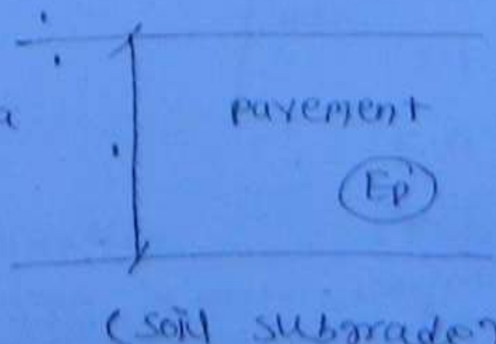
→ This Method Based on E-value

Thickness of

↳ Young Modulus of Elasticity of different layer

$E_P > E_S$

This is called a two layer system



→ $E_P > E_S$ becoz in pavement good material is provided thickness of pavement required

For a two layer system, :-> 140

$$\boxed{T_P = \left[\sqrt{\left(\frac{3PXY}{2\pi E_s \Delta}\right)^2 - a^2}\right] \times \left(\frac{E_s}{E_P}\right)^{1/3}}$$

where

Imp

$$\frac{T_1}{T_2} = \left(\frac{E_2}{E_1}\right)^{1/3}$$

P = wheel load in kg

X = Traffic coefficient

Y = Rainfall coefficient

E_s = youngs Modulus of soil subgrade (kg/cm²)

E_P = youngs Modulus of pavement (kg/cm²)

Δ = design deflection (0.25cm) 0.25cm

a = Radius of contact area (cm)

Que - design a pavement section, by triaxial method using following data :-

wheel load = 4100 kg

Radius of contact Area = 15cm

Traffic coefficient = 1.6

Rainfall coefficient = 0.7

design deflection = 0.25cm

Pavement consists of two layer ... ...

(1) Base course, $E_B = 360 \text{ kg/cm}^2$

(2) Bituminous surfacing of 6cm of, $E_{Bit} = 1200 \text{ kg/cm}^2$

Soil subgrade $= E_{SS} = 120 \text{ kg/cm}^2$ (141)

Soln

Let us design pavement using Base course material.

$E_P = 360 \text{ kg/cm}^2$

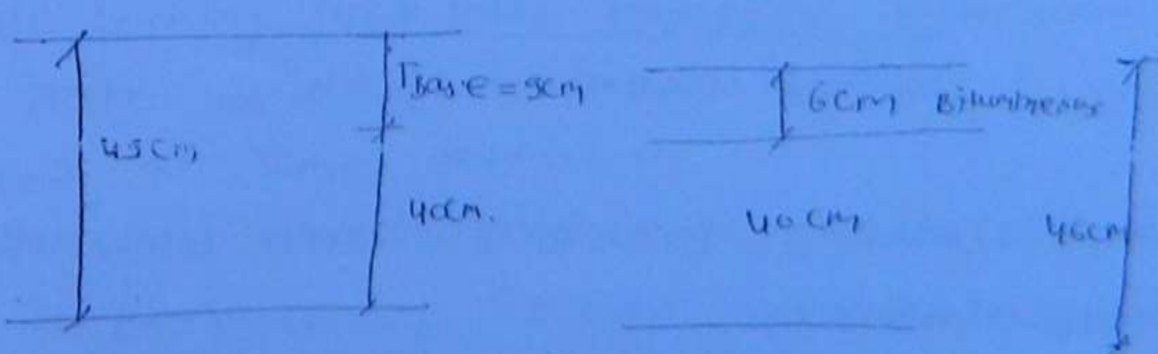
$E_S = 120 \text{ kg/cm}^2$

Thickness

$$T = \sqrt{\left(\frac{3PXY}{2\pi E_S \Delta}\right)^2 - a^2} \times \left(\frac{E_S}{E_P}\right)^{1/3}$$

$$T = \sqrt{\left(\frac{3\times 4000\times 1.6\times 0.7}{2\times\pi\times 120\times 0.25}\right)^2} \times \left(\frac{120}{360}\right)^{1/3}$$

$\therefore T = 48.33 \simeq 49\text{cm (say)}$



$T_{Bit} = 6\text{cm}$, $E_{Bit} = 1200 \text{ kg/cm}^2$

$T_{Base} = ?$ $E_{Base} = 360 \text{ kg/cm}^2$

$$\frac{T_{Bit}}{T_{Base}} = \left(\frac{E_{Base}}{E_{Bit}}\right)^{1/3}$$

$$T_{Base} = T_{Bit} \times \left(\frac{E_{Bit}}{E_{Base}}\right)^{1/3} = 6\times\left(\frac{1200}{360}\right)^{1/3} = 8.96\,cm$$

say 9cm

Remaining thickness of Base course material

$= 49cm - 9cm = 40\ cm.$

Total thickness of pavement is provided is $\approx 46cm$

$= 40+6 = 46\ cm$

Imp

5) Burmister's Method :-

→ In this method, young Modulus of Elasticity (E-value) is used for design.

→

Surface	E_1
Base	E_2
Sub-Base	E_3
soil subgrade	E_4

→ Better quality materials are used in uppers layers.

$$E_1 > E_2 > E_3 > E_4$$

(2) For Rigid Plate:-

[when In case of plate load test done over pavement or over soil subgrade]

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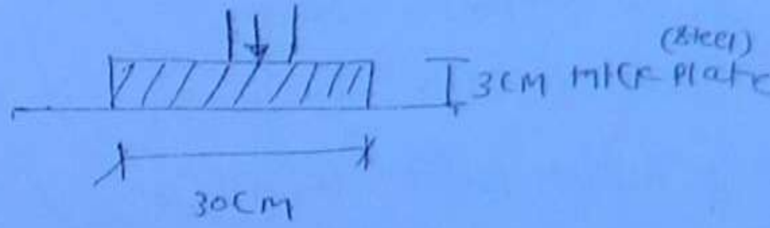


$$\boxed{\Delta = 1.18 \frac{p \cdot a}{E_s} \cdot F_2}$$

where

p = tyre pressure due to wheel load [pressure due to load over plate]

a = Radius of contact area as Radius of plate

F_2 = Factor, constant

Δ = Design deflection (cm)

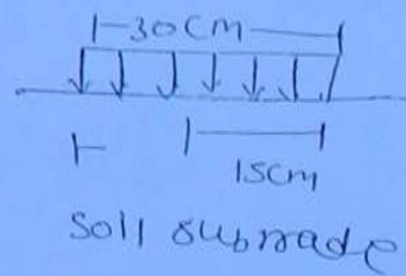
Que. plate bearing test was conducted with 30cm diameter plate on a soil subgrade yielded a pressure of 1kg/cm² at 5mm deflection.

The test carried out over 18cm base course yielded a pressure of 5kg/cm² at 5mm deflection

Design the pavement section for wheel load of 4100kg with a tyre pressure of 6kg/cm² and allowable deflection of 5mm using Burmister method.

soln

① plate bearing test on soil subgrade



Dia. of plate = 30cm

Radius of plate a = 15cm

using Rigid plate formula

$$\Delta = 1.18 \frac{p \cdot a}{E_s} \cdot F_2$$

where Δ = Deflection = 5mm = 0.5cm

p = 1 kg/cm²

a = 15cm

F_2 = 1 (Because single layer system)

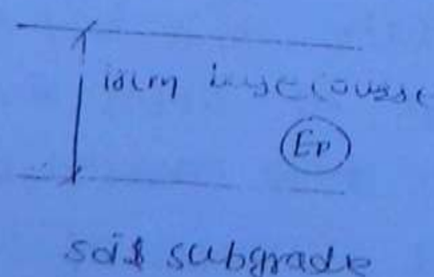
$$0.5 = 1.18 \times \frac{1 \times 15}{E_s} \times 1$$

$$E_s = 35.4 \text{ kg/cm}^2$$

② plate bearing test over 18cm thick base course

⇒ This is two layer system

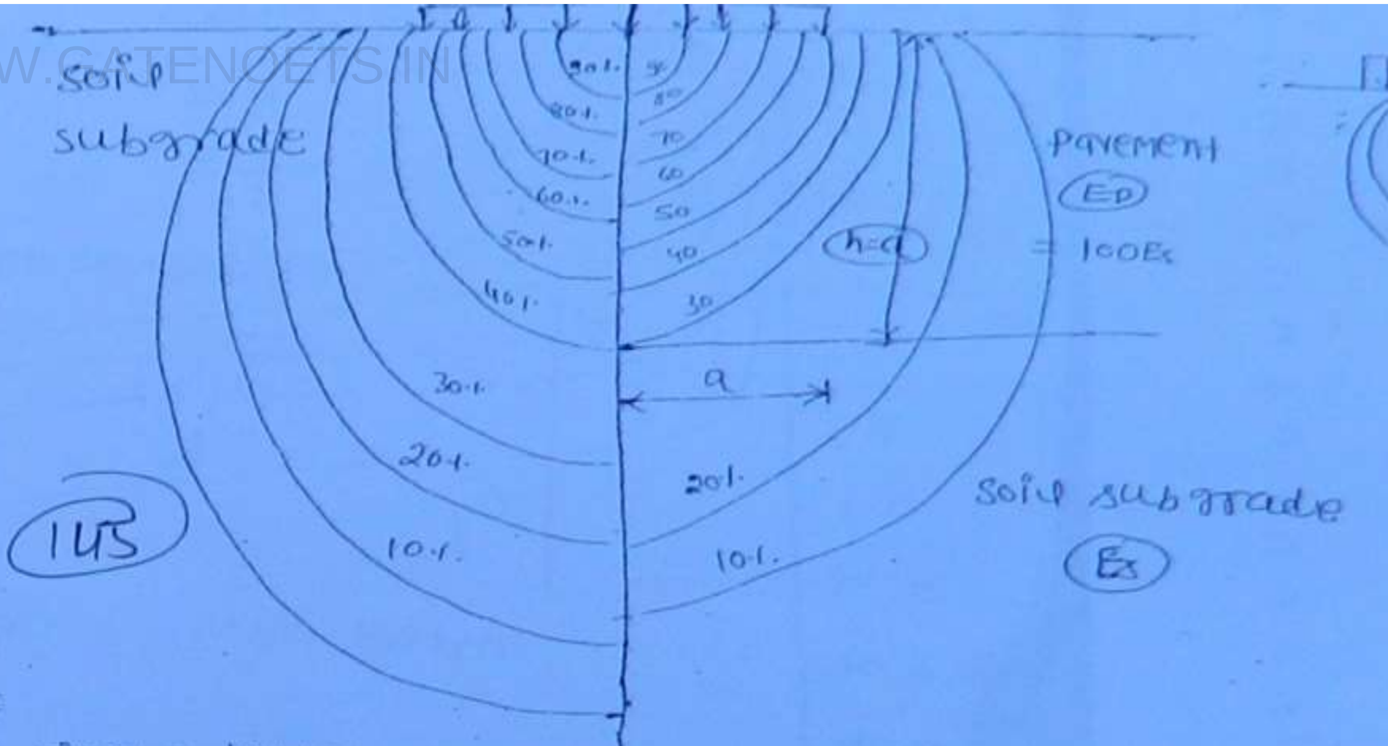
⇒ using rigid plate formula



$$\Delta = 1.18 \times \frac{p \cdot a}{E_s} \cdot F_2$$

0.5 = ~~Δ~~ E_s = 34 kg/cm²

p = 5 kg/cm² h = 18cm, a = 15cm



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single layer system
$\boxed{F_2 = 1.0}$

Two Layer system
(F2 read from c

→ In an Experiments as shown in figure →
Burminster show that

stresses are reduced by providing a layer.

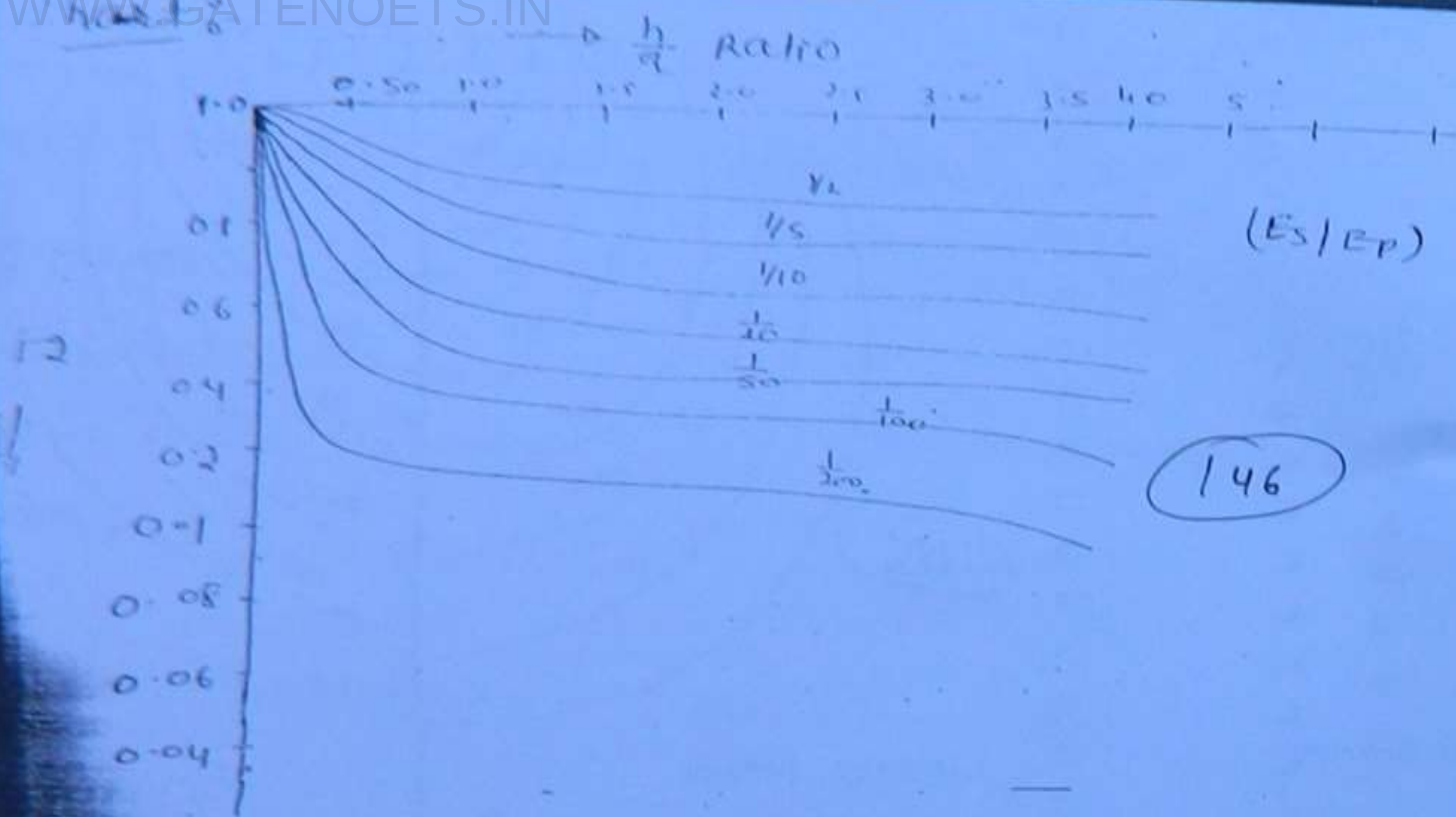
→ This is called reinforcing action of p

→ Two values are important [All line pavement / all load pavement

① Ratio $\left(\frac{h}{a}\right) = 1.0$

② Ratio $\left(\frac{E_s}{E_p}\right) = \frac{1}{100}$

→ Berminster has suggested A factor F_2 b
$\frac{h}{a}$ and $\frac{E_s}{E_p}$ ratio.



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For a single layer system (when there is no pavement)

$h = 0$

Value of $F_2 = 1.0$

Displacement relationship :-

Flexible plate :-

[Wheel load is acting over a road surface, flexible plate is to be considered]

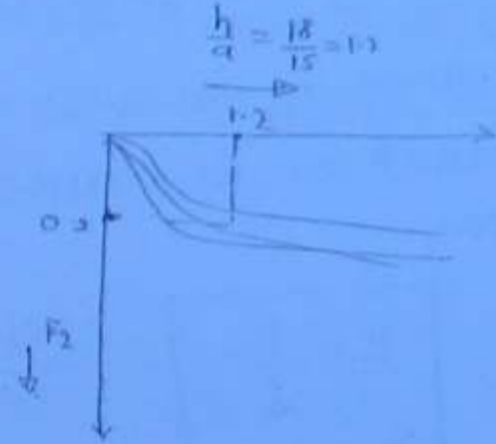
Displacement

$$\Delta = 1.5 \cdot \frac{p \cdot a}{E_s} \cdot F_2$$

$$0.5 = 1.18 \times \frac{5 \times 15}{35.4} \times F_2$$

$$F_2 = 0.2$$

From graph [given question]



$$\frac{E_s}{E_p} = \frac{1}{100}$$

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$$E_p = 35.4 \times 100 = 3540 \ kg/cm^2$$

(3) wheel over pavement
(Design of pavement)

so that consider Flexible pavement

$$\Delta = 1.5 \frac{p \cdot a}{E_s} \cdot F_2$$

$P = 4100 kg$

$p = 6 \ kg/cm^2$

$\Delta = 5mm = 0.5 cm$

$E_s = 34.5 \ kg/cm^2$

Area of contact $= A = \frac{P}{p}$

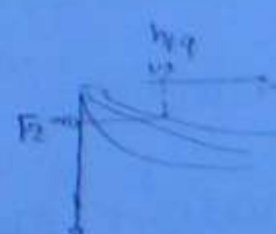
$$= \frac{4100}{6} = 683.33 \ cm^2$$

$$\pi a^2 = A \Rightarrow a = \sqrt{\frac{A}{\pi}}$$

$$a = 14.75 cm$$

$$0.5 = \frac{1.5 \times 6 \times 14.75}{34.5} \cdot F_2$$

$$\boxed{F_2 = 0.1333}$$



using these value $\frac{E_s}{E_p} = \frac{1}{100}$, $F_2 = .1333$

than from figure $\frac{h}{a} = 1.90$ say

$\boxed{h = 1.90 \times 14.75 = 28.025 \ cm.}$ thickness of

* Design of Rigid pavement :-

Importents terms :-

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1) Modully of subgrade reaction :- (K)

→ The value of pressure required for unit deflection [deformation] is called Modulus of subgrade reaction.

$$\boxed{K = \frac{P}{\delta}} \qquad \frac{Kg/cm^2}{cm} \qquad \frac{Kg}{cm^3}$$

[Apply p pressure than δ deflection]

2) Radius of Relative stiffness (l) :-

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

where

E_c → young Modulus of Elasticity of pavement (cement concrete slab)

h = thickness of slab

K = Modully of subgrade reaction for soil

μ = poissions Ratio = 0.15

Equivalent Radius of Resisting section :- (b)

→ The area effective for taking B.M.

(1) $a < 1.724\, h$

$$\boxed{b = \sqrt{1.6a^2 + h^2} - 0.675\, h}$$

(2) $a > 1.724\, h$

$$\boxed{b = a}$$

where

a = Radius of contact area (cm)

h = thickness of slab (cm)

than b = cm

Imp Stresses developed in a concrete slab:

→ There are three stresses developed

(1) Load stresses [due to load]

(2) Temperature stresses

(a) warping stress

(b) Friction stress.

Imp

(1) Load stresses: [westergaurds method] :-

→ westergaurds stress Equations

(1) Interior stress

$$S_i = \frac{0.316\, P}{h^2}\left[4 \log_{10}\left(\frac{l}{b}\right) + 1.069\right]$$

Edge stresses

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

Corner stresses

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

where

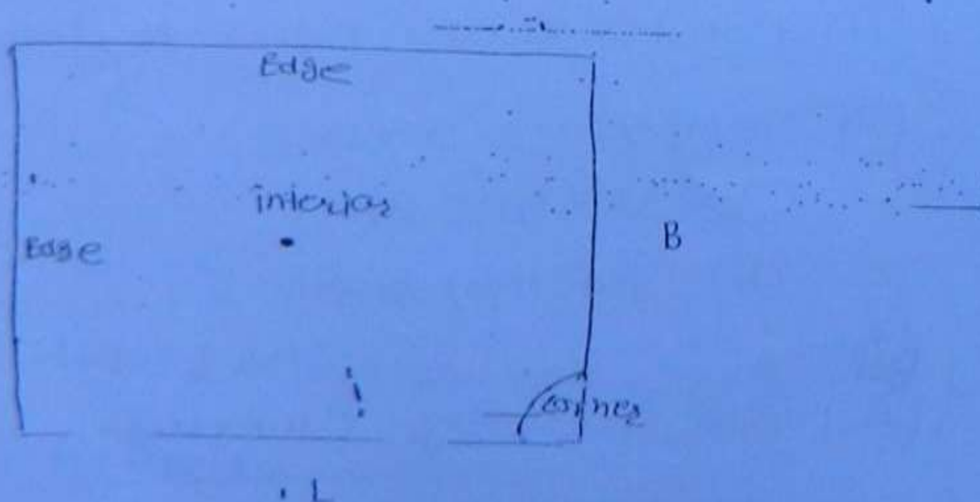
P = wheel load in (kg)

h = slab thickness in (cm)

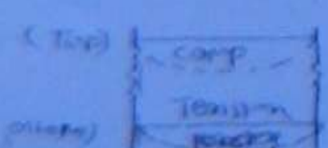
l = Radius of Relative stiffness (cm)

b = B1 - Radius of resisting section (cm)

a = Radius of contact Area.



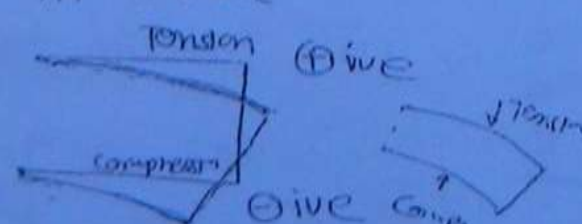
(1) Interior case / Edge



⊖ive

⊕ive

(2) At corner



⊕ive

⊖ive

ES 1997 Que. Calculate the stresses at interior, edge and corner region of a cement concrete pavement using Westergaards stress Equations, using Following data

wheel load value P = 4100 kg (15)

$E_c = 3.3 \times 10^5$ kg/cm²

$h = 18$ cm, $\mu = 0.15$, $K = 25$ kg/cm², $a = 12$ cm

Soln

① Radius of Relative stiffness

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

$$l = \left[\frac{3.3\times10^5\times18^3}{12\times25(1-0.15^2)}\right]^{1/4}$$

$l = 50.61$ cm

② Equivalent Radius of Resisting section

$a = 12$ cm, $h = 18$ cm

$a < 1.724h$

$$b = \sqrt{1.6a^2 + h^2} - 0.675h$$

$$b = \sqrt{1.6\times12^2+18^2} - 0.675\times18 = 11.4 \text{ cm}$$

③ Stresses

ⓐ Interior stress

$$S_i = \frac{0.316P}{h^2}\left[4\log_{10}\frac{l}{b} + 1.069\right]$$

$$S_i = \frac{0.316 \times 4100}{18^2}\left[4 \log_{10}\left(\frac{50.61}{11.40}\right) + 1.069\right]$$

$S_i = 14.63 \ kg/cm^2$

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) Edge stresses

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

$$S_e = \frac{0.572 \times 4100}{18^2}\left[4 \log_{10}\left(\frac{50.61}{11.40}\right) + 0.359\right]$$

$S_e = 21.34 \ kg/cm^2$

) Corner stresses

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

$$S_c = \frac{3 \times 4100}{18^2}\left[1 - \left(\frac{12 \times \sqrt{2}}{50.61}\right)^{0.6}\right]$$

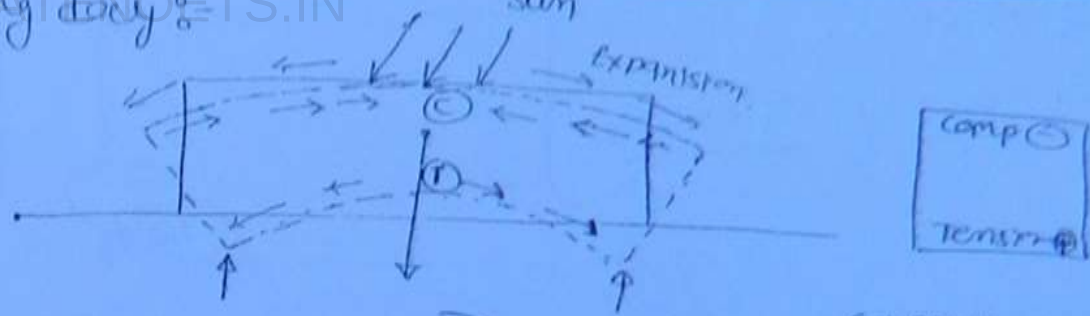
$S_c = 18.25 \ kg/cm^2$

) Temperature stress :-

1) warping stress :-

Due to variation of temperature during day/night.

(a) During Day:-



C → Comp. ⊖
T → Tension ⊕

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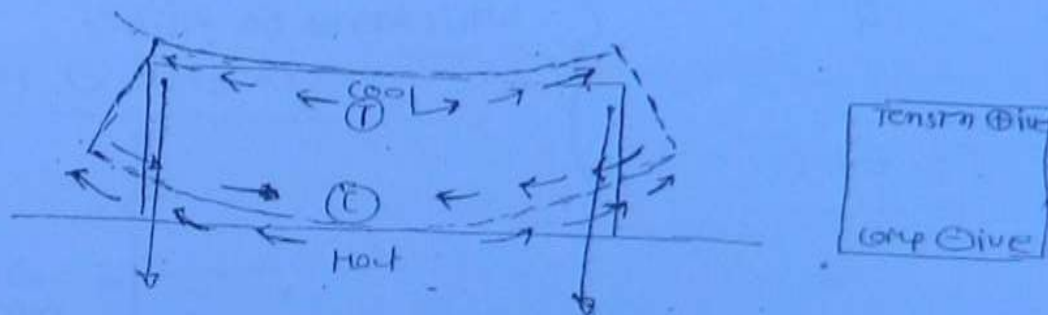
(b) During Night:-

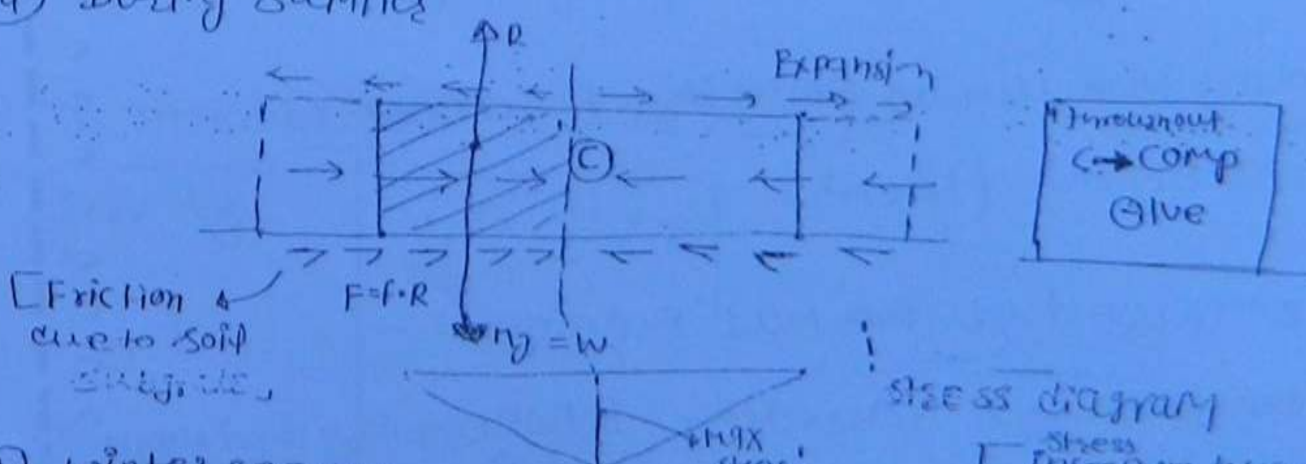


→ Max stresses occurs due to warping.

(2) Frictional stresses:-

[Due to seasonal temperature variation]

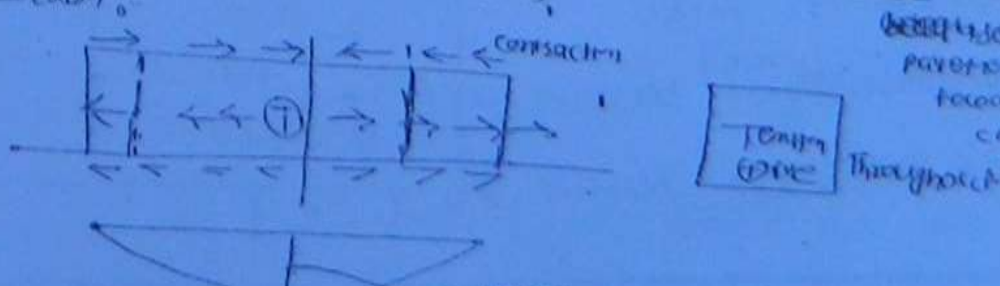
(a) During summer



stress diagram

[stress increase towards centre because wt of pavement increase towards the centre]

(b) winter season:



Warping stresses

Interior stress

$$S_{ti} = \frac{E\alpha T}{2}\left(\frac{C_x + \mu C_y}{1-\mu^2}\right)$$

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Edge stresses

$$S_{te} = \frac{C_x \cdot E\alpha T}{2}$$

or

$$= \frac{C_y \cdot E\alpha \cdot T}{2}$$

whichever is higher

Corner stresses

$$S_{tc} = \frac{E\alpha T}{3(1-\mu)}\sqrt{\frac{a}{l}}$$

Where

E = Young Modulus of Elasticity of Cement concrete pavement (kg/cm²)

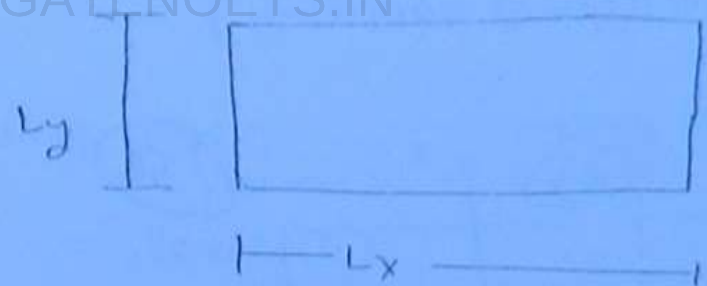
α = Coefficient of thermal Expansion

T = temperature variation between day and Night or

μ = Poissons Ratio

C_x = Coefficient based on $\left(\frac{L_x}{l}\right)$

C_y = Coefficient based on $\left(\frac{L_y}{l}\right)$



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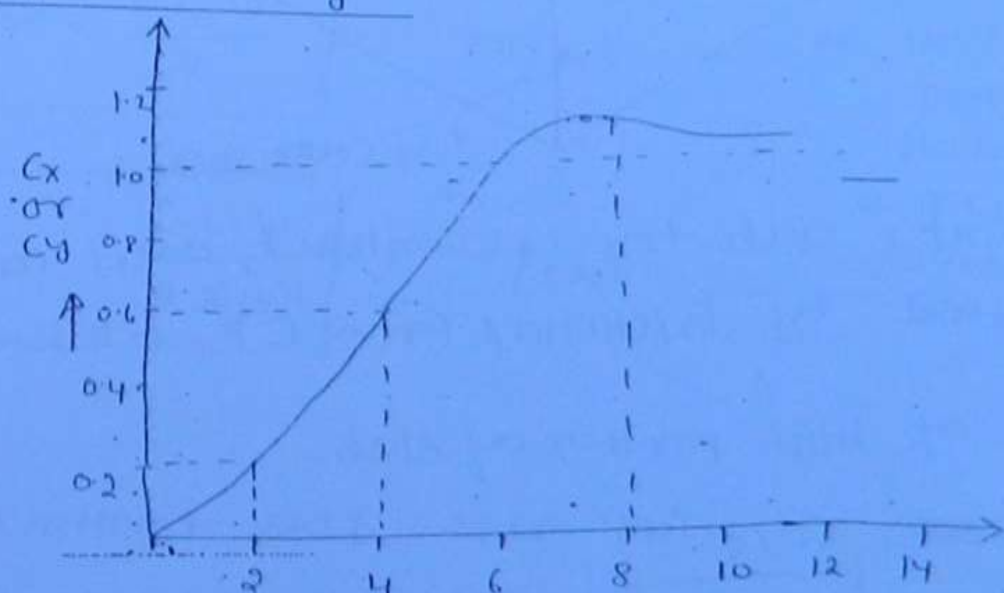
l = Radius of Relative stiffness

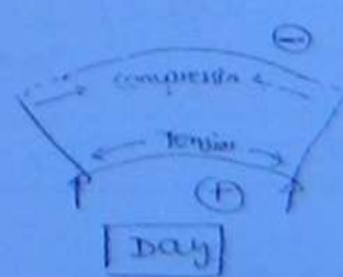
a = Radius of contact area.

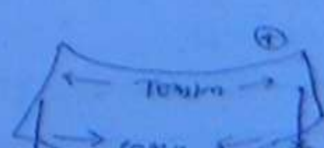
Value of Cx and Cy



$\rightarrow \left(\frac{Lx}{l}\right)$ or $\left(\frac{Ly}{l}\right)$

$\frac{Lx}{l}$ or $\frac{Ly}{l}$	Cx or Cy
2	0.2
4	0.6
8	1.1
12	1.02

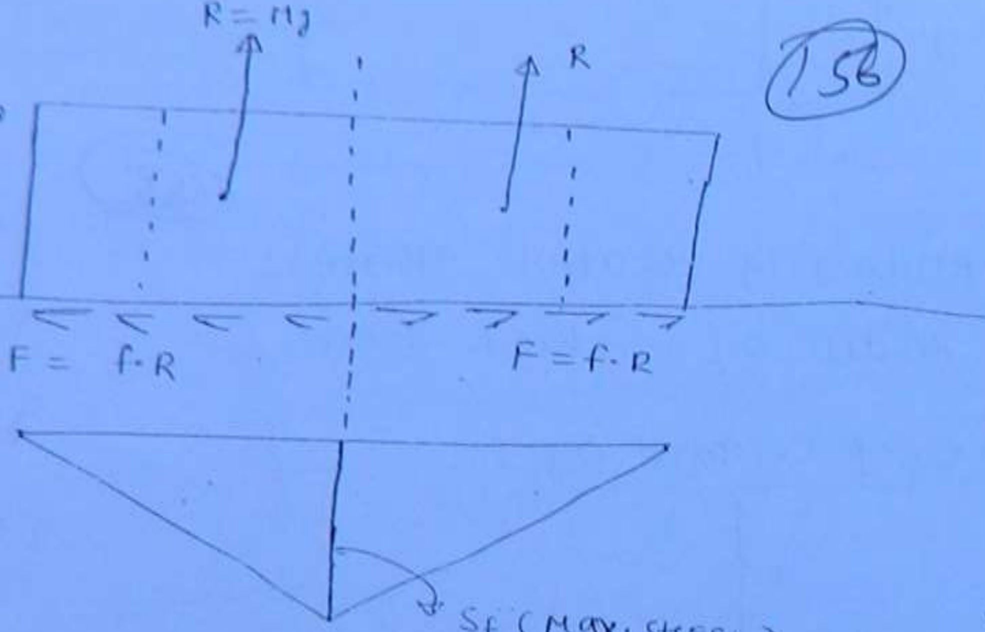




3) Frictional stresses :-

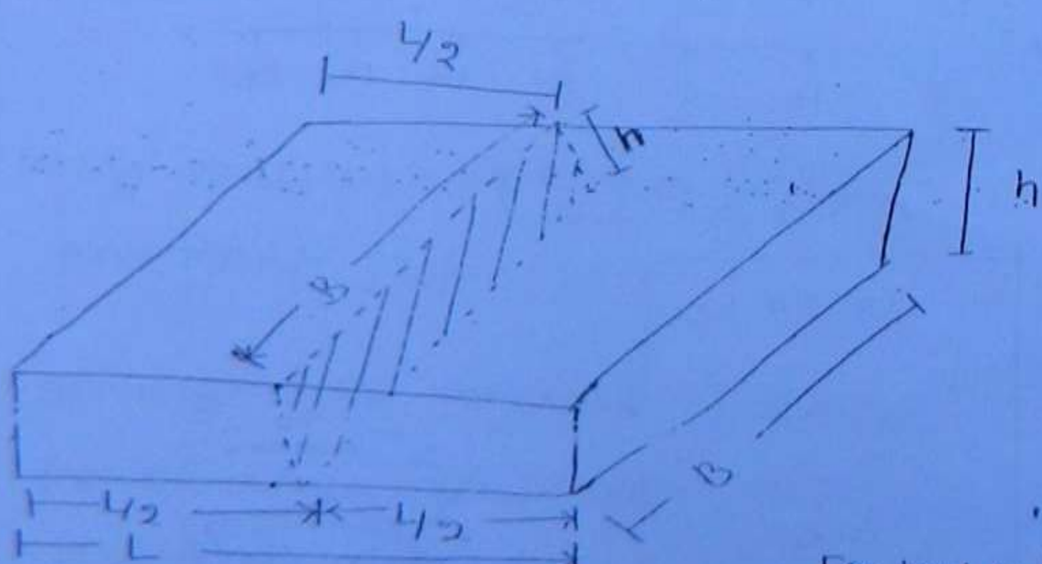
[Due to seasonal temperature variation]

[During winter] tensile stress developed, This stresses are dangerous to the comp. stress developed during summer than considered During winter]



> During winter slab try to contract, and contraction is prevented by frictional force [F = f·R]

R = wt. of half portion of slab.



For half portion of slab $\gamma = W/$

$\boxed{R = Mg} = (\frac{L}{2} \times B) \times h \times \gamma$

Frictional force

F = f·R.

[Resisting force is acts at centre on shaded area, Sf max tensile stress then F = Sf × Area = Sf × B × h

$F = f\left(\frac{L}{2} \times B\right) \times h \times W$ —— (1)

Resisting Force

$= \underbrace{S_f}_{\text{stress}} \times \underbrace{(B \times h)}_{\text{Area}}$ —— (2)

(157)

$W = kg/m^3 = \gamma$

$\boxed{W = \gamma}$

$w = mg = (B \times h) \times \underbrace{(\rho g)}_{\text{wt (v)}}$

$= (B \times h) \times W$

$\underbrace{w}_{\text{(weight)}} = (B \times h) \times \gamma$

Equating (1) and (2)

$$f \cdot \frac{L}{2} B h W = S_f \cdot B \cdot h$$

$$\boxed{S_f = \frac{f \cdot L \cdot W}{2}} \quad kg/m^2$$

W = unit wt of pavement materias

$\Rightarrow 24, 25 \, kN/m^3$

$\Rightarrow 2400 \, kg/m^3$ or $2500 \, kg/m^3$

$$\therefore \boxed{S_f = \frac{f \cdot L \cdot W}{2 \times 10^4}} \quad kg/cm^2$$

Que. A pavement slab 22 cm thick is constructed over a grannular sub base having $k = 18 \, kg/cm^3$. spacing between joint are, transverse joint = 5.50 m, longitudinal joint = 4.2 m.

Design wheel load = 4500 kg

Max. difference of temperature = 20°C

Radius of contact Area = 15 cm

$E_c = 3 \times 10^5 \, kg/cm^2$

$\mu = 0.15$, $\alpha = 12 \times 10^{-6} / °C$, $f = 1.50$

Find out best combination of stresses.

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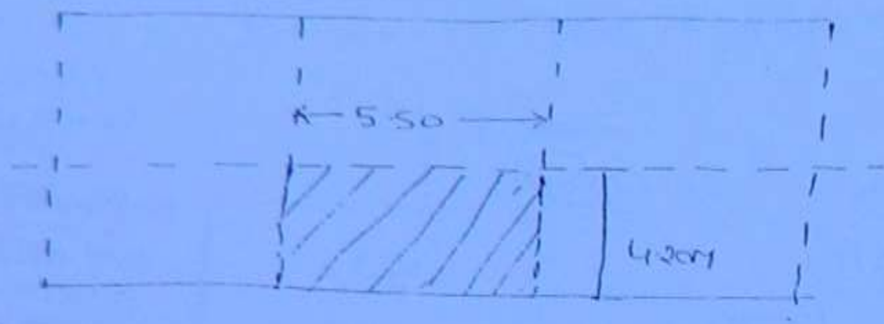

$L_y = B = 4.20m$, $L = L_x = 5.50 M$

$H = 22 cm$, $P = 4500 kg$, $T = 20°c$, $a = 15 cm$.

) Load stresses :-

* Radius of Relative stifness

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

$$l = \left[\frac{3\times10^5 \times 22^3}{12\times18\times(1-0.15^2)} \right]^{1/4} = 62.37\ cm$$

* Equivalent Radius of Resisting section

$a = 15$, $h = 22$ $(a < 1.724h)$

$$b = \sqrt{1.6a^2 + h^2} - 0.675h$$

$$b = \sqrt{1.6\times15^2 + 22^2} - 0.675\times22 = 14.20\ cm$$

) interior stresses

$$S_i = \frac{0.316P}{h^2}\left[4\log_{10}\left(\frac{l}{b}\right) + 1.069\right]$$

$$S_i = \frac{0.316\times4500}{22^2}\left[4\log_{10}\frac{62.37}{14.20} + 1.069\right] = 10.69\ kg/cm^2$$

(2) Edge stresses

$$S_e = \frac{0.572\,P}{h^3}\left[4\log_{10}\left(\frac{l}{b}\right) + 0.359\right]$$

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$$= \frac{0.572 \times 4500}{22^2}\left[4\log_{10}\frac{62.37}{14.20} + 0.359\right]$$

$$= 15.58\ \text{kg/cm}^2$$

(3) Corner stresses

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

$$S_c = \frac{3 \times 4500}{22^3}\left[1 - \left(\frac{15\sqrt{2}}{62.37}\right)^{0.6}\right]$$

$$S_c = 13.28\ \text{kg/cm}^2$$

(2) Temperature stresses

(a) Warping stresses

(i) interior

$$S_{ti} = \frac{E\alpha t}{2}\left[\frac{C_x + \mu C_y}{1-\mu^2}\right]$$

$\frac{L_x}{l}$ or $\frac{L_y}{l}$ $\quad$ C_x or C_y

$8 \rightarrow 1.10$

$12 \rightarrow 1.02$

→ Value of C_x and C_y

$$\frac{L_x}{l} = \frac{550}{62.37} = 8.82 \quad , \quad C_x = 1.10 - \frac{1.10 - 1.02}{4} \times 0.82$$

$= 1.08$

$\frac{L_y}{\ell} = \frac{420}{62.37} = 6.73$

$\frac{L_x}{\ell}$ or $\frac{L_y}{\ell}$ | C_x or C_y
$4 \rightarrow 0.6$
$8 \rightarrow 1.1$

$C_y = 0.6 + \frac{1.1-0.6}{4} \times 2.73 = 0.94$

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$i = \frac{3\times10^5 \times 12\times10^{-6} \times 20}{2} \left[\frac{1.08 + 0.15 \times 0.94}{1-0.15^2} \right]$.

$i = 44.97 \text{ kg/cm}^2$

Edge stresses

$S_{te} = \frac{C_x \cdot E\alpha T}{2}$ or $\frac{C_y \cdot E\alpha T}{2}$

$C_x > C_y$.

$S_{te} = \frac{C_x \cdot E\alpha T}{2} = \frac{1.08 \times 3\times10^5 \times 12\times10^{-6} \times 20}{2}$

$= 38.88 \text{ kg/cm}^2$

Corner stresses

$S_{tc} = \frac{E\alpha T}{3(1-\mu)} \sqrt{\frac{a}{\ell}}$

$= \frac{3\times10^5 \times 12\times10^{-6} \times 20}{3\times(1-0.15)} \sqrt{\frac{15}{62.37}}$

$S_{tc} = 13.88 \text{ kg/cm}^2$

(3) Frictional stress

$$S_f = \frac{f \cdot L \cdot W}{2 \times 10^4}$$

W = unit wt. of pavement material = 2400, 2500 kg/m³ or 24 or 25 kN/m³

(161)

$$S_f = \frac{1.5 \times 5.50 \times 2500}{2 \times 10^4} = 1.03 \text{ kg/cm}^2$$

Worst combination

At interior = $S_i + S_{ti} + S_f$ = 10.69 + 44.97 + 1.03 = 56.69 kg/cm²

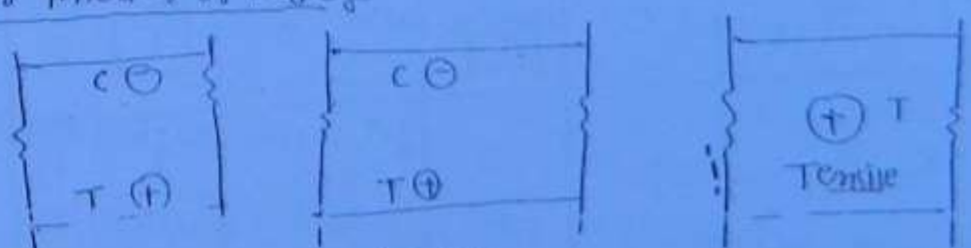
At Edge = $S_e + S_{te} + S_f$ = 15.58 + 38.38 + 1.03 = 55.43 kg/cm²

Worst case at corner; At top = $S_c + S_{tc} + S_f$

= 13.28 + 13.84 + 1.03 = 28.15

* Worst combination :-

For interior or Edge :-

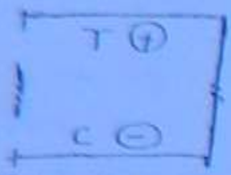


(Load stress)   Warping (Day time)   (During winter)   Frictional stress

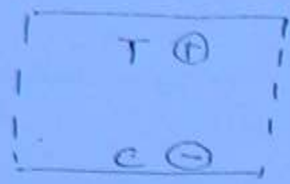
$\boxed{\text{At interior} = S_i + S_{t_i} + S_f}$ (At bottom)

At Edge = $S_e + S_{te} + S_f$ (At bottom)

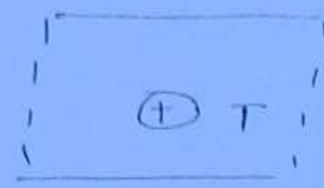
Worst case at corner.



(Load stresses)



Warping stresses (Night)



Frictional stresses (winter)

$$\boxed{\text{At top} = S_c + S_{tc} + S_f}$$

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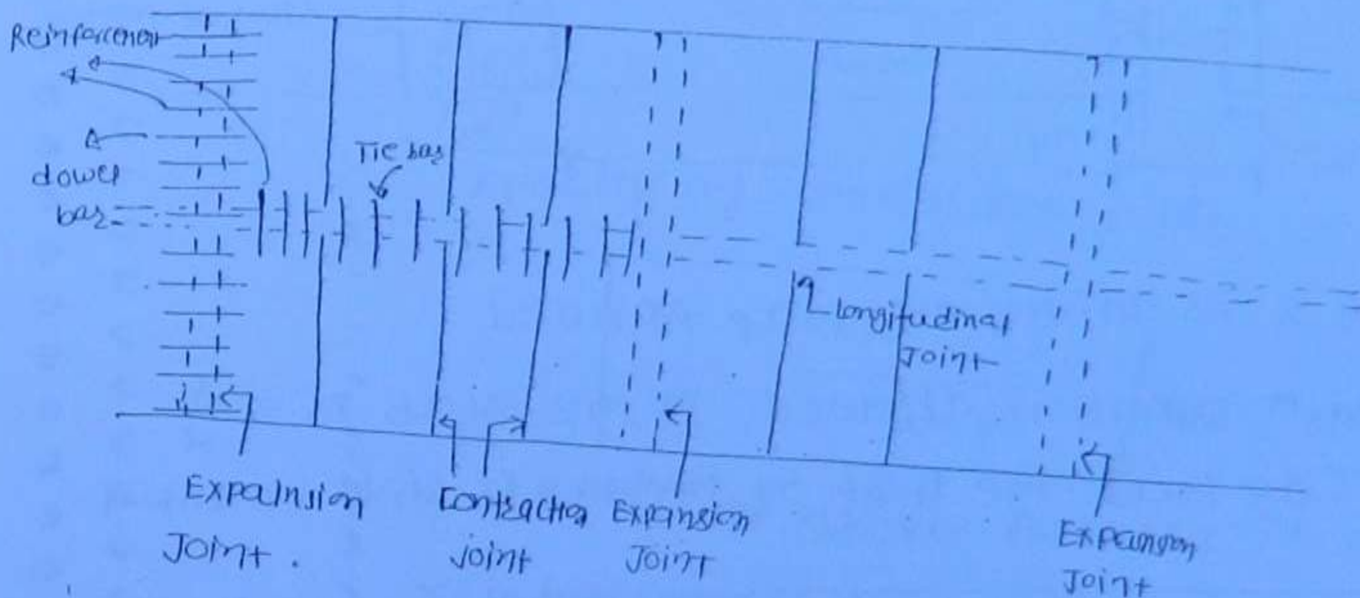
→ Worst combination of stresses (Table) :-

—		Load stresses	Warping stress		Frictional stresses	
			Day	Night	Summer	Winter
Interior stresses	Top	C ⊖	C	T	C	T
	Bottom	$\boxed{\text{T ⊕}}$	$\boxed{\text{T}}$	C	C	$\boxed{\text{T}}$
Edge stresses	Top	C ⊖	C	T	C	T
	bottom	$\boxed{\text{T ⊕}}$	$\boxed{\text{T}}$	C	C	$\boxed{\text{T}}$
Corner stress	$\boxed{\text{Top}}$	$\boxed{\text{T ⊕}}$	C	$\boxed{\text{T}}$	C	$\boxed{\text{T}}$
	bottom	C ⊖	T	C	C	T

Worst combination :- In Edge and interior stresses
→ at bottom during day during winter
Corner → at top during During Night During winter

V.V. Imp

Design of joints :-



(1) Expansion joints :-

→ A clear gap of δ width is provided at Expansion joints

→ To Allow Expansion of slab, due to temperature increase

→ Max^M spacing b/w joints = 140 M.

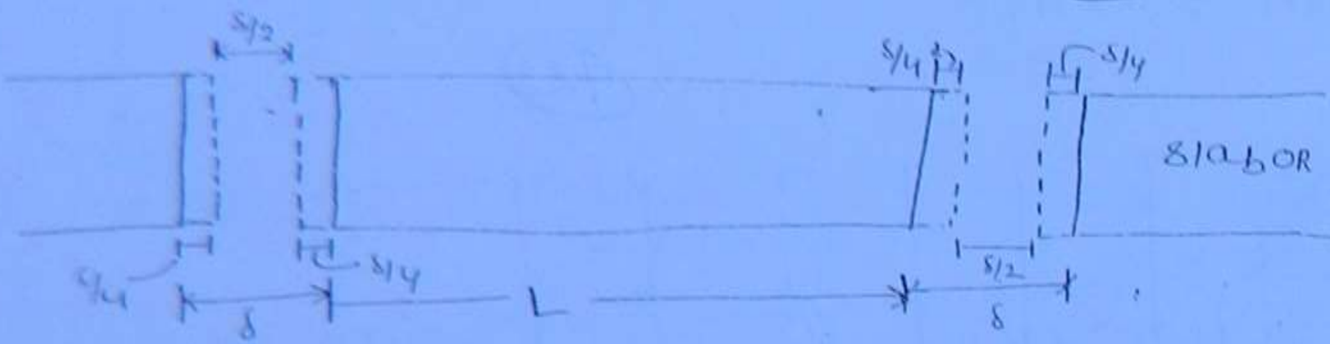
(2) Contraction joint :-

→ To allow contraction of slab due to to decrease of temperature.

→ Paper thick joint are provided

→ Max^M spacing = 4.5 M

Design of Expansion joints :-



→ if δ is width of gap provided

Max^{m} Expansion allowed in the slab is = $\frac{\delta}{2}$

[so that the half of the gap is still vacant.]

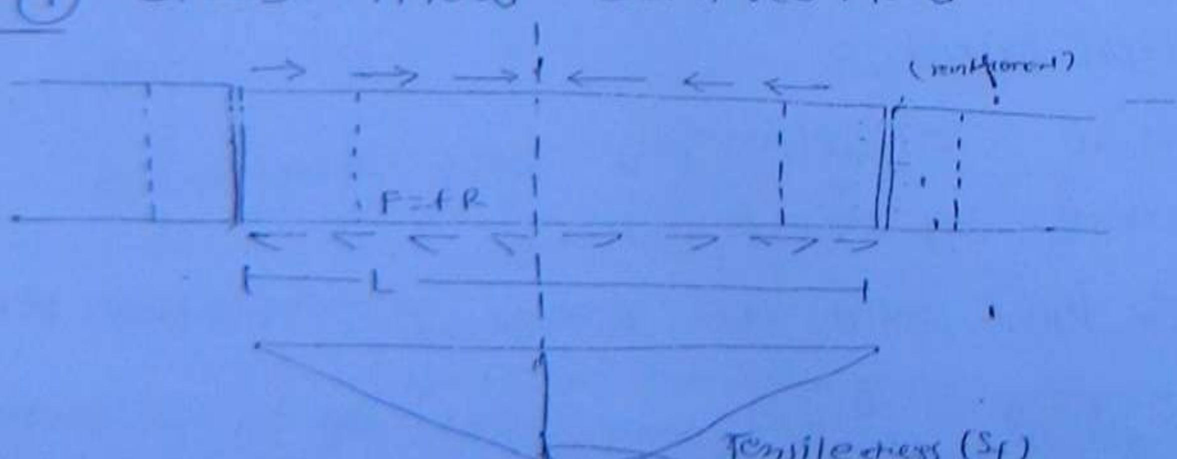
$$\boxed{\frac{\delta}{2} = L \cdot \alpha \cdot (T_2 - T_1)}$$

spacing of Expansion joints

$$\boxed{L = \frac{\delta}{2 \cdot \alpha \cdot (T_2 - T_1)}}$$

Design of contraction joint :-

case (1) slab without reinforcement.



Tensile stress developed at contrac

$$S_f = \frac{WLf}{2\times10^4} \quad kg/cm^2$$

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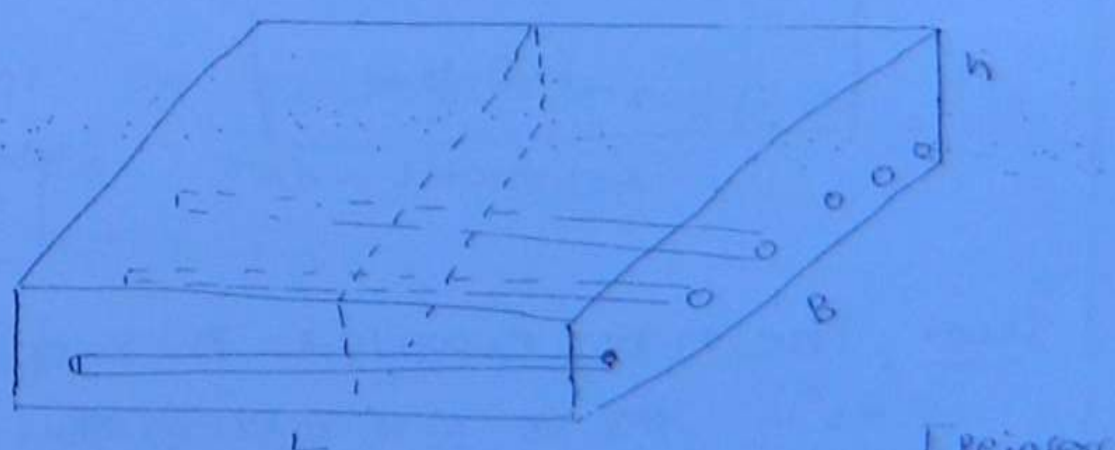
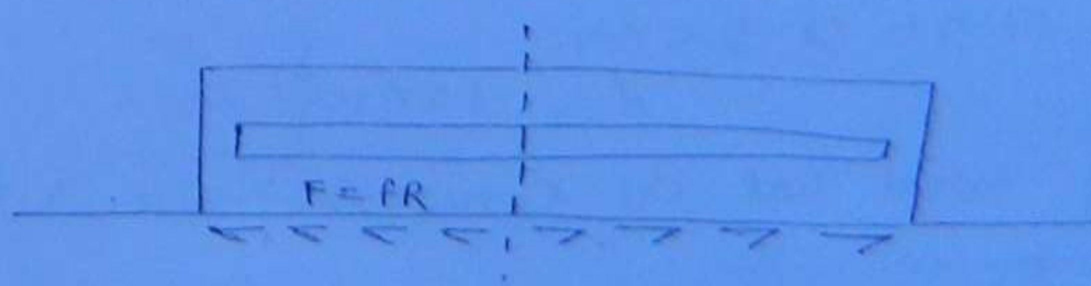
spacing of contraction joint

$$\boxed{L = \frac{2\times10^4 \cdot S_f}{W \cdot f}}$$

All above formula is used when no reinforcement has been provided in

Case ② when reinforcement are prov. resist tensile stresses:-





In this case all tensile stresses are taken by steel alone; concrete is free.

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→ if Area of steel is $= A_{st}$

Max^m permissible stress in tension for steel $= \sigma_{st}$

Total ~~tens~~ force of tension $= A_{st} \cdot \sigma_{st}$ —— (1)

Force of friction $= F = f \cdot R$

$$F = f \cdot \left(\frac{L}{2} \times B \times h \times W\right) \quad —— (2)$$

Equating (1) and (2)

W → unit wt. of pavement material in kg/cm² [= S2 = r]

$$A_{st} \cdot \sigma_{st} = f \cdot \frac{L}{2} \times B \cdot h \cdot W$$

spacing of contraction joints

$$\boxed{L = \frac{2 A_{st} \cdot \sigma_{st}}{f \cdot B \cdot h \cdot W}}$$

B → width

h → height

given

$$\boxed{A_{st} = \left(\frac{B}{h}\right) \times \frac{\pi}{4} \times \phi^2}$$

Que. The Max. Expected increase in temperature is 26°C for a C.C. pavement, calculate spacing of Expansion joint if gap of Expansion joint is 2.5 cm.

$$\alpha = 15 \times 10^{-6} / °C$$

unit wt of concrete = 2400 kg/m³

Sol^n

Max^M Expansion allowed = $\delta/2$

$$= \frac{2.50}{2} = 1.25\ cm$$

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$$L \cdot \alpha \cdot T = \frac{\delta}{2}$$

$$L = \frac{1.25}{15 \times 10^{-6} \times 26^{\circ} \times 100}$$

$$\boxed{L = 32.05\ m}$$

Que. A cement concrete pavement has 4.5m width and thickness of 25cm. Design contraction joints spacing for

(i) if No reinforcement is given

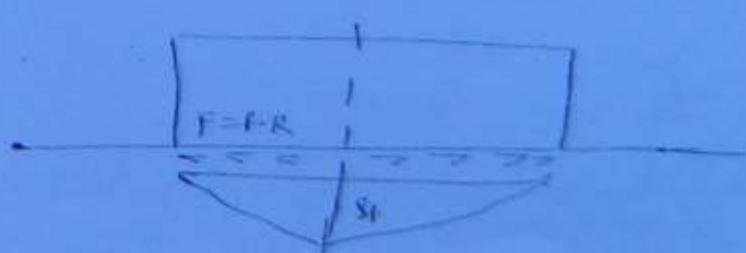
PCC Max^M permissible stress of Concrete in tension = 0.8 kg/cm2

(ii) if reinforcement of 12mm ϕ @ 300 mm c/c are used. Mild steel used. $\sigma_{st} = 1400\ kg/cm^2$

Coefficient of friction f = 1.5

RCC

Sol^n :- (i) PCC (No steel used)



$F = S_f \cdot (B \cdot h)$

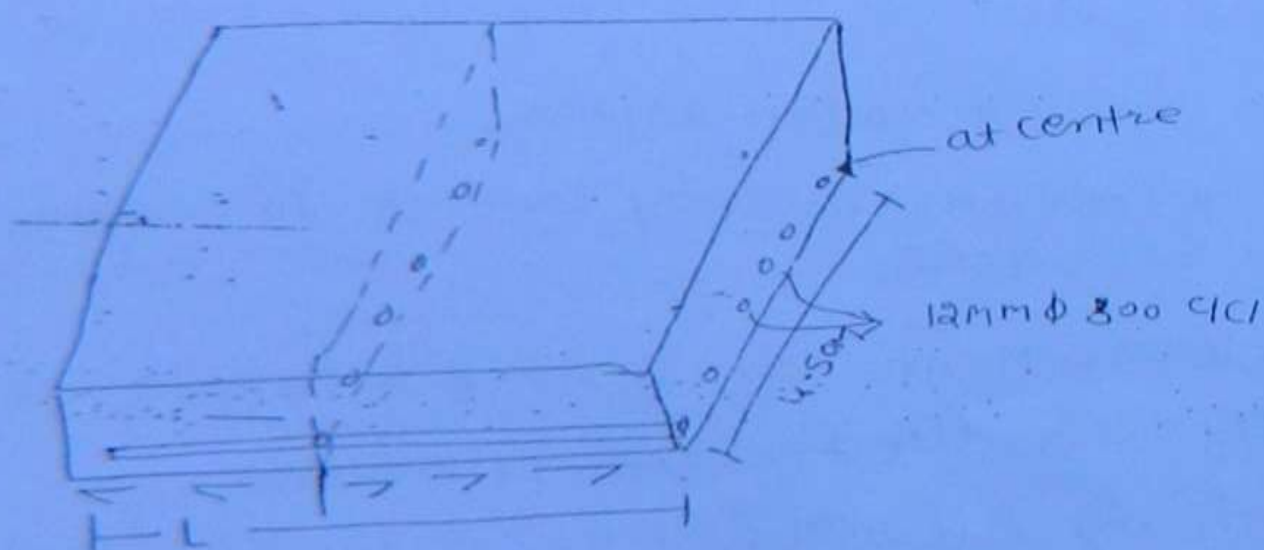
$f \cdot \frac{L}{2} \cdot B \cdot h \cdot W = S_f \cdot B \cdot h$

$S_f = \frac{f\,L\,W}{2}$ kg/m²

$S_f = \frac{f\,L\,W}{2\times10^4}$ kg/cm²

$L = \frac{2\times10^4\,S_f}{f\cdot W} = \frac{2\times10^4\times0.8}{1.5\times2400} = 4.44\,M.$

) steel is used [RCC]



$F = f\cdot R = A_{sd}\cdot\sigma_{sd}$

$f\cdot\frac{L}{2}\times B h\cdot W = A_{sd}\cdot\sigma_{sd}$

$L = \frac{2A_{sd}\cdot\sigma_{sd}}{f\cdot B\cdot h\cdot W} =$

$$Ast = \left(\frac{B}{h}\right)\frac{\pi}{4}\times\phi^2$$

$$= \left(\frac{4500}{300}\right)\times\frac{\pi}{4}\times 12^2 \times \frac{1}{100}$$

For change in cm

$Ast = 16.9646\, cm^2$

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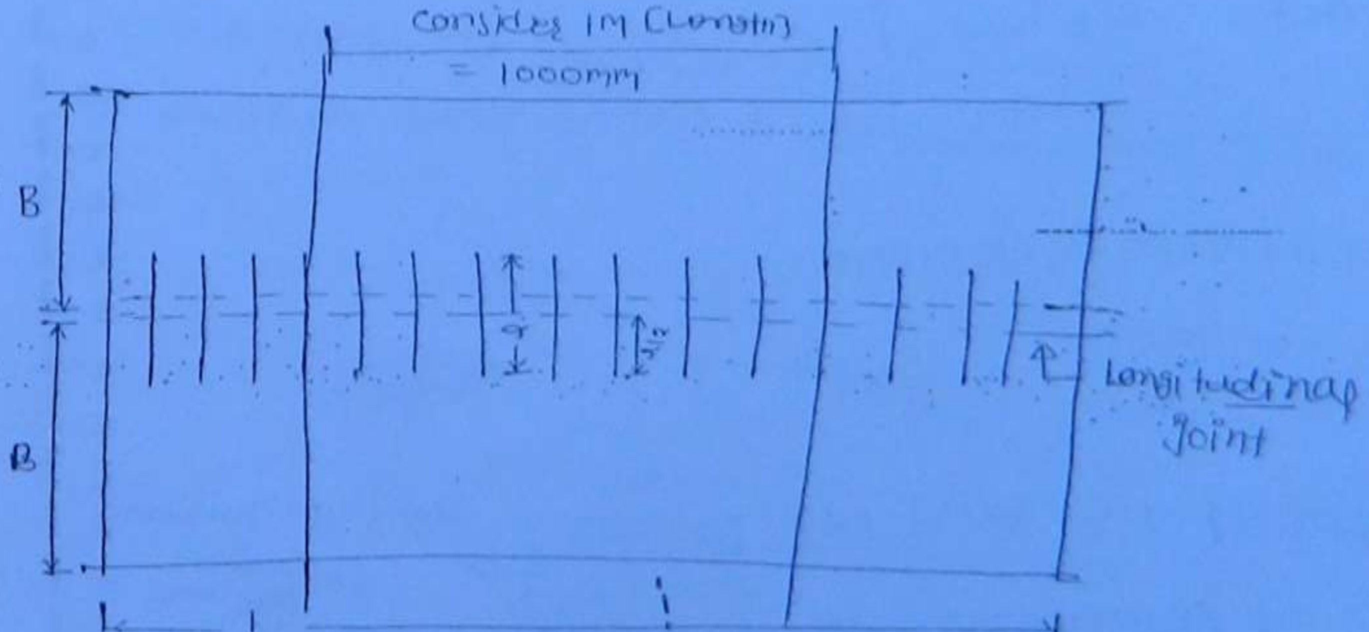
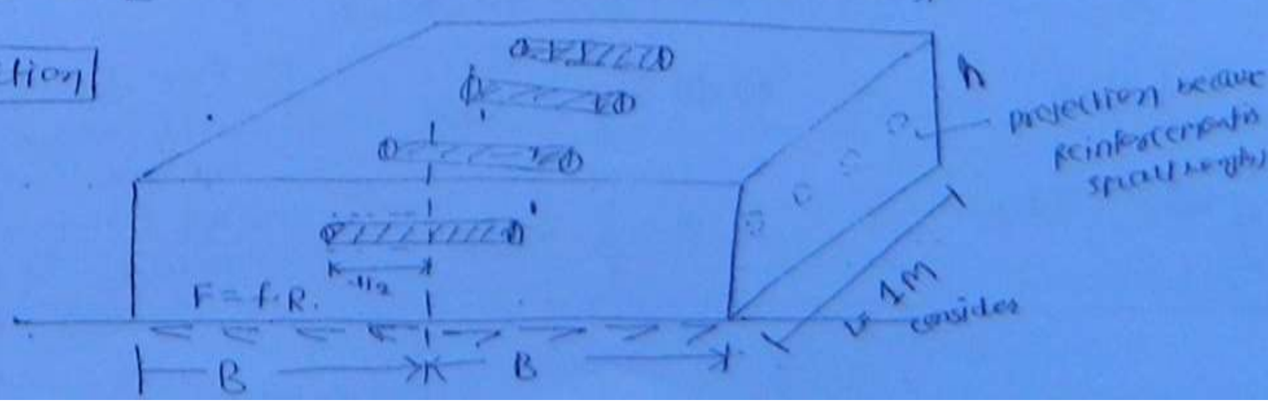
$$L = \frac{2\times 16.9646\times 1400}{1.5\times 4.50\times 0.25\times 2500} = 11.25\,m$$

$$\boxed{L = 11.25\,m}$$

* Design of tie bar :-



Cross section



of friction

$F = f \cdot R = f \cdot$ [weight of half portion of slab]

$F = f \cdot [\underbrace{\underbrace{(B \times 1)}_{\text{Area}} \times h}_{\text{volume}} \times W]$ ——— (1)

[$W \rightarrow$ unit wt. of pavement] $\boxed{W = \rho g} = \gamma$

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Force of Resistance by steel

$= A_{st} \cdot \sigma_{st}$ ——— (2)

Equations (1) and (2)

$f \cdot B \cdot h \cdot W = A_{st} \cdot \sigma_{st}$

Area of steel required (for 1m width)

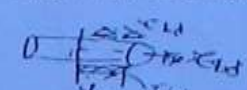
$$\boxed{A_{st} = \frac{f \cdot B \cdot h \cdot W}{\sigma_{st}}}$$ ——— (A)

Spacing of reinforcement

$$= \frac{1000}{A_{st}} \cdot \frac{\pi}{4} \times \phi^2$$

Length of tie bars (l) :-

$\pi \phi = \pi D =$ Circumference



Force of Resistance = strength in bond

$A_{st} \cdot \sigma_{st} = (\pi \phi) \times \frac{l}{2} \times \tau_{bd}$

$\frac{\pi}{4} (\phi)^2 \cdot \sigma_{st} = \pi \phi \cdot \frac{l}{2} \cdot \tau_{bd}$

[Take $\frac{l}{2}$, bcoz tie bar one side fail than so the that fail both side of pavement]

$$\boxed{l = \frac{2 \cdot \phi \cdot \sigma_{st}}{4 \cdot \tau_{bd}}}$$

→ Length of ties bar is Equal to twice of development Length (Ld)

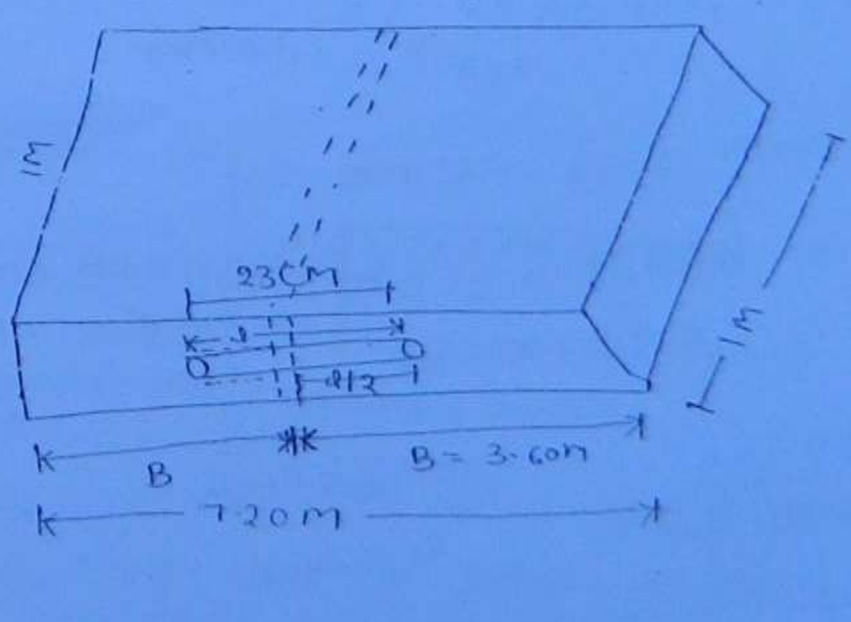
$$\boxed{l = 2L_d}$$ $\because L_d = \frac{\phi \cdot \sigma_{st}}{4 \cdot \tau_{bd}}$

(176)

Que (ES 1996) A cement concrete pavement has a thickness of 24 cm and has two lanes of total width 7.2 m with a longitudinal joints. design the dimensions and spacing of bars (tie bar) using following data.

Allowable stress in steel in tension = 1400 kg/cm²
Unit weight of concrete = 2400 kg/m³.
Coefficient of friction = f = 1.5
Allowable bond stress in concrete = 24.6 kg/cm²

soln



Total width of slab = 7.20m

Half width = B = 3.60m

consider 1m length of slab

$h = 24cm = 0.24m$

Area of steel

$$A_{st} \cdot \sigma_{st} = f \cdot B \cdot h \cdot 1 \cdot W$$

$$A_{st} = \frac{f \cdot B \cdot h \cdot W}{\sigma_{st}} = \frac{1.5 \times 3.60 \times 0.24 \times 2400}{1400 \ kg/cm^2}$$

$$A_{st} = 2.2217 cm^2$$

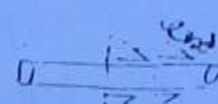
$$= 222.17 mm^2$$

using 10mm ϕ bars

$$\text{Spacing} = \frac{1000}{222.17} \times \frac{\pi}{4} \times 10^2 = 353.5mm$$

$$\text{using } 8mm = 353.3 \times \frac{8^2}{10^2} = 226mm$$

provide 8mm ϕ @ 220mm c/c



Length of tie bars:- [when the bar in fail in one side slab than assume will be fail on both side]

$$A_{st} \cdot \sigma_{st} = \frac{l}{2} \pi \phi \times \tau_{bd}$$

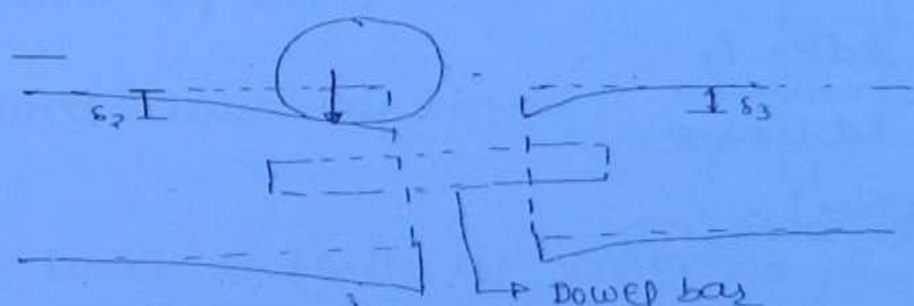
$$l = \frac{2\phi \sigma_{st}}{4 \times \tau_{bd}} = \frac{2 \times 0.8 \times 1400}{4 \times 24.6} = 22.76cm$$

$$\boxed{l = 23 \ cm}$$

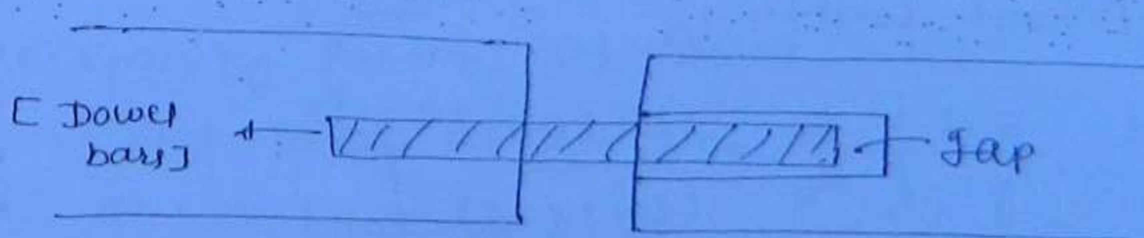
* Dowel bars :-

→ provided at Expansion joints

differential deflection $= \delta_1$



Differential deflection $= \delta_2 - \delta_3$



[At Expansion joint]

→ Dowel Bars is fixed one side of the pavement and provided other side a gap. because Dowel bar provided at Expansion joint so that Expansion of the joint is allowed so that provide gap.

→ when gap not provided than Expansion is not allowed

Design of Dowel bars :-

- Dowel bar are designed based on Bradbury analysis :- (As per IRC)

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) Load carrying capacity of a single dowel bars
) is minm of following :-

1) Strength in shear

$$P' = \frac{\pi}{4} \times d^2 \cdot f_s$$

b) Strength in bending

$$P' = \frac{2d^3 \cdot f_f}{L_d + 8.8\delta}$$

c) Strength in bearing

$$P' = \frac{L_d^2 \cdot d \cdot f_b}{12.5\,(L_d + 1.5\delta)}$$

Development Length L_d

$$L_d = 5d\left[\frac{f_f}{f_b} \times \frac{(L_d + 1.5\delta)}{(L_d + 8.8\delta)}\right]^{1/2}$$

→ Solve by trial and error.

where

d = Dia of bar (cm)

δ = gap or Expansion joint width in (cm)

- f_s = max^m permissible stresses in shear
- f_f = max^m permissible stresses in bending
- f_b = max^m permissible stresses in bearing

} kg/cm²

(175)

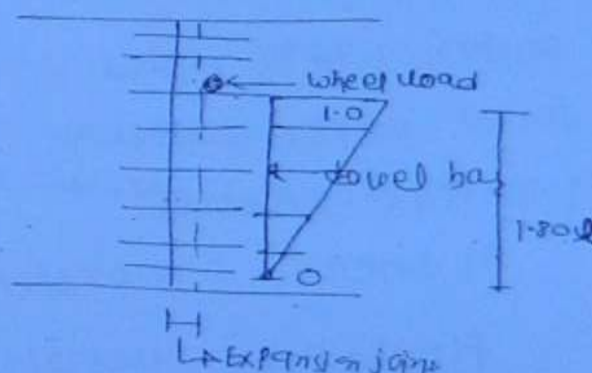
Design steps:-

① Length of dowel bars

$$= (L_d + \delta)$$

② Load capacity of dowel group system

= 40% of wheel load



③ Required load capacity factor

$$= \frac{\text{Load capacity of dowel group}}{\text{Load capacity of single dowel bar}}$$

$$= \frac{0.40 \times P}{P'}$$

④ Capacity factor of dowel bars

just below load = 1.0

at 1.80 l distance = 0

Now total capacity factor is calculated.

$$= 1.0 + \left(\frac{1.80l - s}{1.80l}\right) + \frac{(1.80l - 2s)}{1.80} + \cdots$$

$$\nless \frac{0.40P}{P'}$$

spacing should be selected such that above condition is satisfied.

l = Radius of the Relative stiffness.

Que Design a dowel bar system for pavement thickness = 2.5cm.

Radius of Relative stiffness = 80cm

Design wheel load = 5100kg

joint width = 2.4cm

Permissible stresses —

in shear = 1200 kg/cm² = f_s

flexure = 1400kg/cm² = f_f

Bearing = 120 kg/cm² = f_b

use Diameter of dowel bar = 20mm

Soln Development length required

$$L_d = 5d\left[\frac{f_f}{f_b} \times \frac{L_d + 1.5\delta}{L_d + 8.8\delta}\right]^{1/2}$$

$$= 5 \times 2.0\left[\frac{1400}{120} \times \frac{L_d + 1.5 \times 2.4}{L_d + 8.8 \times 2.4}\right]^{1/2}$$

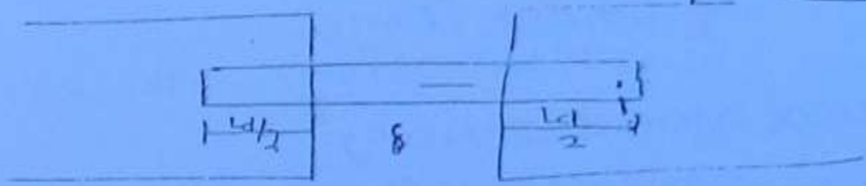
$$L_d^2\left[\frac{L_d + 21.12}{L_d + 3.6}\right] = 1166.67$$

by trail and error

$L_d = 27.27 cm$.

Total length of bar = $L_d + S = 27.27 + 2.4 = 29.67$

say = 30 cm



② Load capacity of single dowel bars

① In shear

$= \frac{\pi}{4} d^2 \times f_s = \frac{\pi}{4} (2)^2 \times 1200 = 3769.9 kg$

② In bearing

$$= \frac{f_b \cdot L_d^2 \cdot d}{12.5 [L_d + 1.5 S]}$$

$$F_b = \frac{120 \times 27.27^2 \times 2.0}{12.5 [27.27 + 1.5 \times 2.4)}$$

$= 462.50 kg$

② Strength in flexure or bending

$$F_f = \frac{f_f \times 2d^3}{L_d + 8.8 S} = \frac{1400 \times 2 \times 2^3}{[27.27 + 8.8 \times 2.4]}$$

$= 462.90 kg$

 single dowel bars.

$P' = 462.50$ kg

) Load capacity of dowel groups systems

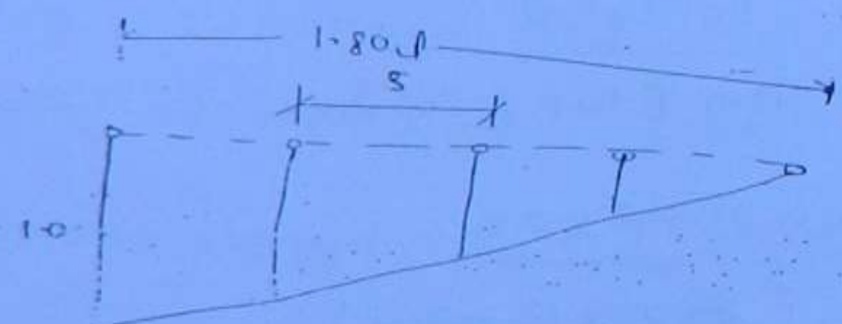
$= 40\%$ of wheel load

$= 0.40 \times 5100 = 2040$ kg

) Required Load capacity factor

$$= \frac{\text{Load capacity of group}}{\text{Load capacity of single dowel bar}}$$

$$= \frac{2040}{462.50} = 4.41$$



Assume spacing

$1.80\, l = 1.80 \times 80 = 144$

capacity factor of group = By similar triangle

$$1 + \frac{144-30}{144} \times 1 + \frac{144-2\times30}{144} \times 1 + \frac{144-3\times30}{144} + \frac{144-4\times30}{144}$$

SURVEYING

Introduction :-

→ Earth is an Oblate Spheroid.

Polar Axis = 12713.80 KM

Equatorial Axis = 12756.75 KM

difference = 42.95 KM

Average Radius = 6370 KM

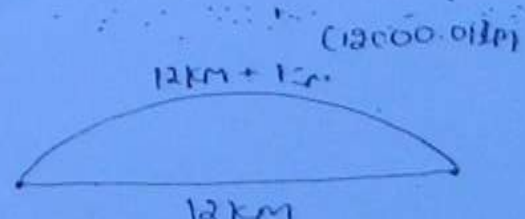
→ Plain Surveying :-

→ Earth curvature is not considered.

* Geodetic survey :- Earth curvature is considered for large Area.

Example :-

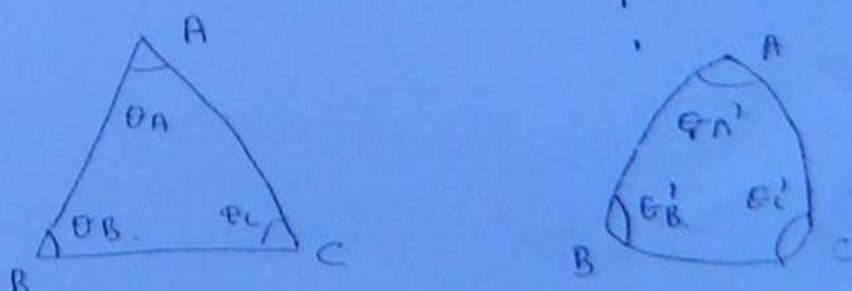
(1)



→ For a 12 KM long line

diff = 1.0 cm only

(2)



for an area = 195 km²

$= 2.9$

[Pivoting method ?? calculating max spacing] ... are more than these value 180

$\Rightarrow \dfrac{144 \times \underline{5} - [30 + 60 + 90 + 120]}{144}$

$\Rightarrow$ Assume spacing = 20 cm

Capacity factor

$= \dfrac{144 \times \underline{8} - [20 + 40 + 60 + 80 + 100 + 120 + 140]}{144}$

$= 4.11$

$\Rightarrow$ Spacing = 18 cm

$\dfrac{144 \times 8 - (18 + 36 + 54 + 72 + 90 + 108 + 126]}{144} = 4.50 > 4.44$ (o.k.)

$(\theta_A' + \theta_B' + \theta_C') - (\theta_A + \theta_B + \theta_C) = 1$ second.

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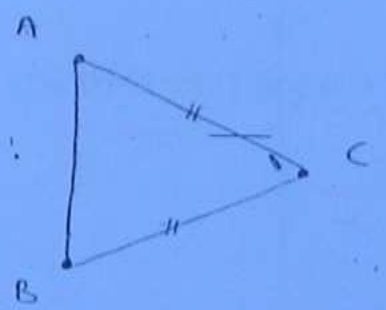
$= 0^\circ 0' 1''$ or $0^\circ 0' 1''$

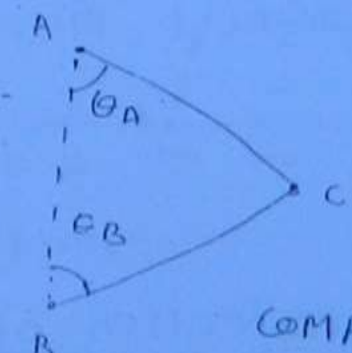
Principle of surveying :-

① Location of a point by measurement from two reference point.

A, B → Reference point

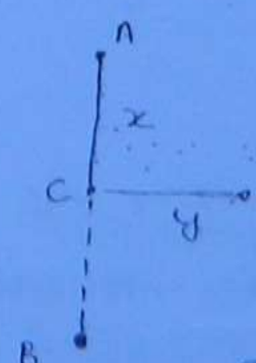


chain survey



compass surveying

Traversing



chain survey
[offset method]

Imp
) working whole to part →

→ First major control points are fixed and measured with higher accuracy. minor details can be taken later

Even with less precision. Error involved in minor details will not be reflected in major measurement.

* Accuracy and Error :-

① Precision :-

- Degree of perfection used in measurement is called precision.

[using correct instruments, correct manner of reading]

② Accuracy :-

Degree of perfection obtained in measurement is called accuracy.

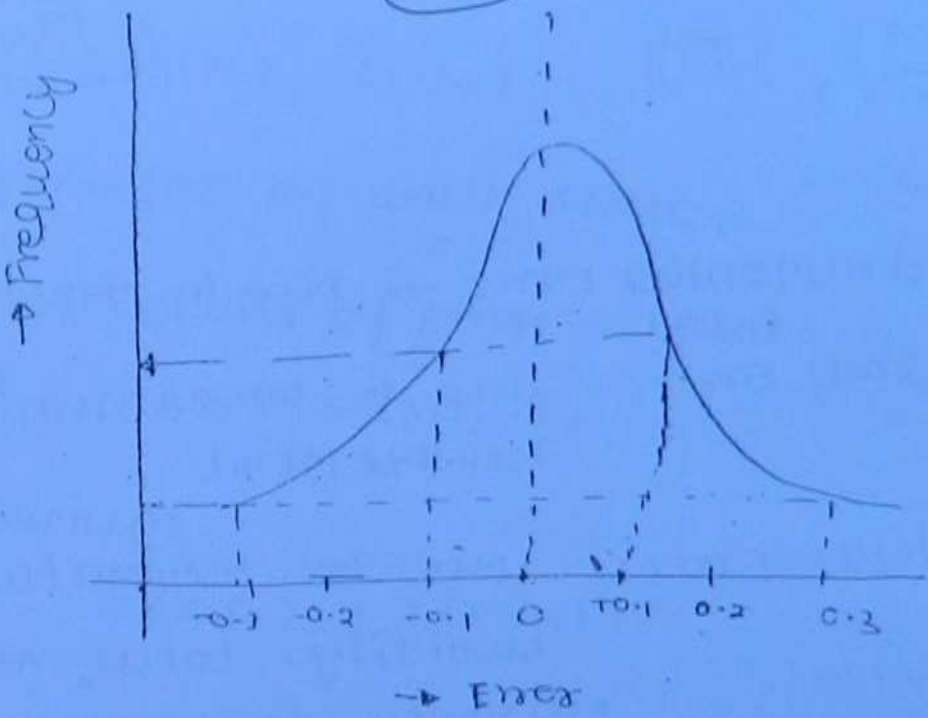
③ True Error :-

Difference between the exact true value of a quantity and measured error is called true error.

④ Descrepancy :-

Difference between two measured value of the same quantity is called descrepancy.

* Theory of probability [For Accidental Errors] :-



→ Accidental Errors follow a definite Rule. It is called Law of probability.

As per this law

① Small Error are more frequent than Large Error
[because frequency large in -0.1 to +0.1]

② positive and Negative error of same size has Equal frequency so they are Equally probable

* Principal of Least square :-

→ The most probable value (MPV) is one for which sum of square of all errors is minimum

Most probable value (MPV) :-

→ The value of a quantity which has more cha of being the correct value of a quantity is called most probable value.

Errors :-

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Types

① Instrumental Error → Due to faulty instrument

② Personal Error → Due to wrong reading of a measurement

③ Natural Error → Due to temperature, wind, humidity, Local Attraction, Magnetic declination.

Kind :-

① Accumulative Error :- [Systematic Error]

→ Always occurs in same direction.

② Compansating Error [random Errors / Accidental Errors]:-

→ occurs some time in one direction and some time in other direction

→ value occurs ⊕ive and ⊖ive Errors.

→ ⊕ive and ⊖ive errors will compensate each other.

Case-① $x_1, x_2, x_3 \ldots x_n$ are measurement with unit weight. [Means one value occurs at one time]

if x is most probable value

Errors $= (x-x_1), (x-x_2), \ldots (x-x_n)$

∴ As per principle of least square

sum of squares of Errors = Least

$y = (x-x_1)^2 + (x-x_2)^2 + (x-x_3)^2 + \ldots$

for y minimum

$$\frac{dy}{dx} = 0 = 2(x-x_1) + 2(x-x_2) + \ldots = 0$$

$$nx - [x_1 + x_2 + x_3 + \ldots x_n] = 0$$

$$\boxed{x = \frac{x_1 + x_2 + x_3 + \ldots x_n}{n}}$$

> Most probable value is the average value of all measurement.

Case ② Having Different Weightage

	MPV	Errors	Square of Errors
$x_1 = w_1$		$(x-x_1)$	$(x-x_1)^2 \times w_1$
$x_2 = w_2$	x	$(x-x_2)$	$(x-x_2)^2 \times w_2$
$x_3 = w_3$		$(x-x_3)$	$(x-x_3)^2 \times w_3$
⋮		⋮	⋮

As per principle of least square

$$y = w_1 (x-x_1)^2 + w_2 (x-x_2)^2 + \cdots$$ 186

$$\frac{dy}{dx} = 2w_1 (x-x_1) + w_2 (x-x_2) + \cdots = 0$$

$$x(w_1 + w_2 + w_3 \cdots) = w_1 x_1 + w_2 x_2 + \cdots w_n x_n$$

$$\boxed{x = \frac{w_1 x_1 + w_2 x_2 + \cdots w_n x_n}{w_1 + w_2 + \cdots w_n}}$$

→ called weightage average.
[This is most probable value]

① * Probable Error of single observation :

$$E_s = \pm 0.6745 \sqrt{\frac{\Sigma v^2}{(n-1)}}$$

where

$v = (x - x_1)$ [difference b/w any single
$(x - x_2)$ measurement and mean of
$(x - x_3)$ the seriese.]

* Probable Error of single observation unit wt. (weighted given)

$$E_s = \pm 0.6745 \sqrt{\frac{\Sigma w v^2}{(n-1)}}$$

② Probable Error of Mean of the seriese :-

$$E_m = \pm 0.6745 \sqrt{\frac{\Sigma v^2}{n(n-1)}}$$ 187

$$\boxed{E_m = \frac{E_s}{\sqrt{n}}}$$

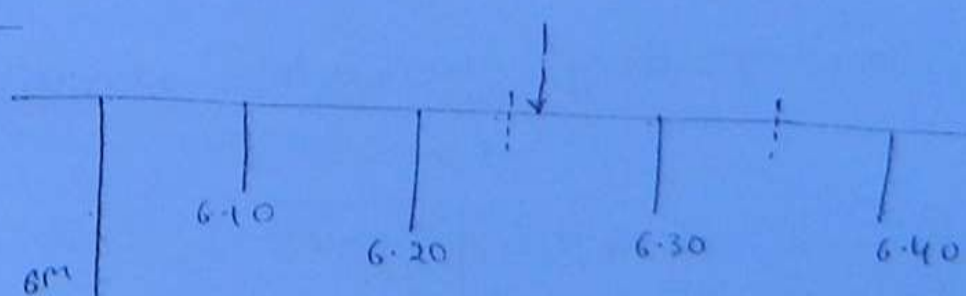
* Significant Figure in a Measurement :-

6.147

6.14

→ If there are n-figures in a measurement (n-1) figures are called certain figures. Last figure is called uncertain figures.

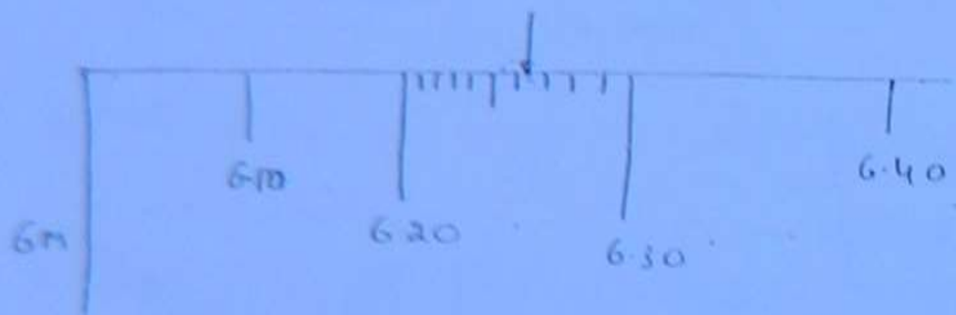
→ chances of Errors are in uncertain figure.

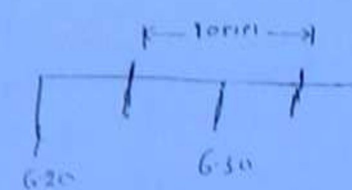


→ read 6.3

Max^m Error = 0.05m

Probable Error = 0.025 m ($\frac{\text{max}^m \text{ Error}}{2}$)





Reading = 6.26

Max^m Error = 0.005m

Probable Error = 0.0025 m

3. The probable Error of weighted arithmatic mean :-

$$E_s = \pm 0.6745 \sqrt{\frac{\Sigma (wv^2)}{(\Sigma w)(n-1)}}$$

4. Probable Error of any observation of weighted w

$$= \frac{E_s}{\sqrt{w}} = \pm 0.6745 \sqrt{\frac{\Sigma w v^2}{w(n-1)}}$$

Errors in computed results:-

Significant figure

if a measurment has n digits.

initial (n-1) figures = certain figure

Last figures → uncertain figure

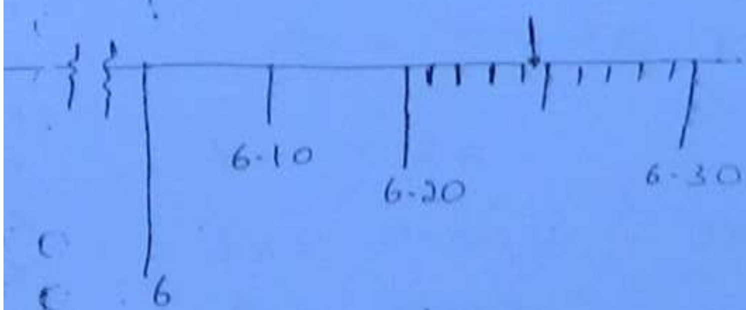
6.94 m

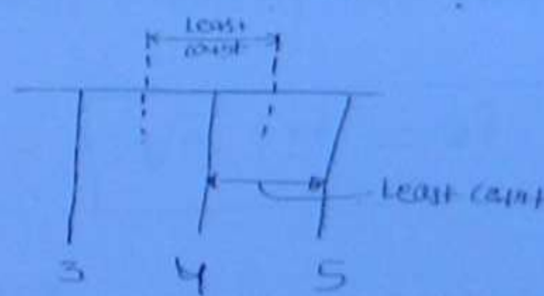
certain, uncertain

For this measurment

① Max^n Error = 0.005 m

[Half of leastcount]





② Probable Error = Half of Max^n Error

= 0.0025 m

Summation of Errors:-

Max^n Error:- sum is simple algebric.

$$e_t = e_1 + e_2 + e_3 + - - -$$

Probable Error:- In this case accumulation is root mean square

$$e_t = \sqrt{e_1^2 + e_2^2 + e_3^2 + \cdots}$$

① Sum:- (S)

$$S = x + y$$

$$ds = 1 \cdot dx + 1 \cdot dy$$

① For Max^M Error

Max^M Error in (x) $= \delta x$

Max^M Error in (y) $= \delta y$

Max^M Error in (S) $= \delta s$

For S
$1 \cdot dx$
$1 \cdot dy$

$$\boxed{\delta s = \delta x + \delta y} \quad \text{—— ①}$$

② Probable Error

Probable error in $x = e_x$

Probable Error in $y = e_y$

Probable Error in $S = e_s$

For S
$1 \cdot e_x$
$1 \cdot e_y$

$$\boxed{e_s = \sqrt{e_x^2 + e_y^2}} \quad \text{—— ②}$$

② Deduction :-

$$S = x - y$$

$$\boxed{\frac{e_s}{s} = \sqrt{\left(\frac{e_x}{x}\right)^2 + \left(\frac{e_y}{y}\right)^2}}$$

Que. if $s = x + y$, $x = 3.4$, $y = 6.26$

Find out Max^m and probable Errors in computed value of s.

Sol^n $x = 3.4$

$\delta x = 0.05$ Max^m Error → Half of least count

$e_x = 0.025$ probable Error [Half of Max^m Error]

$y = 6.26$

$\delta y = 0.005$ Max^m Error

$e_y = 0.0025$ probable Error

$s = x + y$

$ds = dx + dy$

For max^m ~~probable~~ Error for (s)

$\delta s = \delta x + \delta y$

$\delta s = 0.05 + 0.005$

$\delta s = 0.055$

$s = x + y = 3.4 + 6.26 = 9.66$

Max^m range of s

$= s + \delta s = 9.66 + 0.055 = 9.715$

$= s - \delta s = 9.66 - 0.055 = 9.605$

Probable Error for (s)

$e_x = \sqrt{e_x^2 + e_y^2}$

$e_x = \sqrt{0.025^2 + 0.0025^2} = 0.025124$

Range of probable value for (s)

$$ds = \left(\frac{1}{y}\right)dx - \left(\frac{x}{y^2}\right)dy$$

(i) For Max^m Error

in $x = \delta x$ for (S) $= \frac{1}{y} \cdot \delta x$

in $y = \delta y$ for (S) $= \left(-\frac{x}{y^2}\right)(\delta y) = \frac{x}{y^2}\delta y$

Max^m Error $s = \delta s$

$$\boxed{\delta s = \frac{1}{y} \cdot \delta x + \frac{x}{y^2}\delta y}$$

(ii) Probable Error

in $x = e_x$ for (S) $= \left(\frac{1}{y} \cdot e_x\right)$

in $y = e_y$ for $s = \left(\frac{x}{y^2} \cdot e_y\right)$

Probable Error for $s = e_s$

$$e_s = \sqrt{\left(\frac{1}{y}e_x\right)^2 + \left(\frac{x}{y^2} \cdot e_y\right)^2}$$

$$e_s = \frac{x}{y}\sqrt{\left(\frac{y}{x} \times \frac{1}{y}e_x\right)^2 + \left(\frac{y}{x} \times \frac{x}{y^2} \cdot e_y\right)^2}$$

$$e_s = s\sqrt{\left(\frac{e_x}{x}\right)^2 + \left(\frac{e_y}{y}\right)^2}$$

$ds = dx - dy$

$ds = 1 \cdot dx + (-1)\, dy$

(1) Max^m Errors

[For Max^m value of Error one value take (+)ive and other take (−)ive, so (−)×(−) is (+)ive]

Max^m Error in S = $\boxed{\delta_s = \delta x + \delta y}$

$(+\delta y)$ $(-\delta y)$

$\delta_s = (\delta x) - (-\delta y)$

$\boxed{\delta_s = \delta x + \delta y}$

$$\boxed{\delta_s = \delta x + \delta y}$$

(2) Probable Error in S

$$\boxed{e_s = \sqrt{e_x^2 + e_y^2}}$$

3 Multiplication :-

$S = x \times y$

$ds = x \cdot dy + y \cdot dx$

(1) Max^m Error

Max^m Error in $x = \delta x$

Max^m Error in $y = \delta y$

For (S)

$y \cdot \delta x$

$x \cdot \delta y$

Max^m Error in S :

$$\boxed{\delta s = y \cdot \delta x + x \cdot \delta y}$$

(3) Probable Error

Probable Error in $x = e_x$ — For (S): $y \cdot e_x$

Probable Error in $y = e_y$ — $x \cdot e_y$

Probable Error in $s = e_s$

$$\boxed{e_s = \sqrt{(y \cdot e_x)^2 + (x \cdot e_y)^2}}$$

$$= \sqrt{\left[(y \cdot e_x)^2 + (x \cdot e_y)^2\right] \frac{x^2y^2}{x^2y^2}}$$

$$e_s = xy \sqrt{\left(\frac{y \cdot e_x}{x \cdot y}\right)^2 + \left(\frac{x \cdot e_y}{xy}\right)^2}$$

$$\boxed{xy = s}$$

$$\boxed{e_s = s\sqrt{\left(\frac{e_x}{x}\right)^2 + \left(\frac{e_y}{y}\right)^2}}$$

$$\boxed{\frac{e_s}{s} = \sqrt{\left(\frac{e_x}{x}\right)^2 + \left(\frac{e_y}{y}\right)^2}}$$

(4) Division:-

$$s = \frac{x}{y}$$

$$ds = \frac{y\,dx - x\,dy}{y^2}$$

Q. Following are the observed value of an angle and their weightage

Angle	weightage
30° 24' 20"	2
30° 24' 18"	2
30° 24' 19"	3

Find

1) Probable Error of single observation of unit weight.
2) Probable error of weighted arithematic mean.
3) Probable Error of single observation of weight 3

Sol.)

Angle	Diff (x)	wt		$V = (\bar{x} - x)$	V^2	wV^2
30° 24' 20"	20"	2	40"	1"	1	2
30° 24' 18"	18"	2	36"	1"	1	2
30° 24' 19"	19"	3	57"	0"	0	0
			133"			4

n = No. of measurement = 3

Average value be

$$\bar{x} = \frac{133}{2+2+3} = 19'' = \bar{x}$$

1) Probable error of single observation

$$= \pm 0.6745 \sqrt{\frac{\Sigma wv^2}{(n-1)}} =$$

$$= \pm 0.6745 \sqrt{\frac{4}{(3-1)}} = 0.954$$

(2) Probable Error of weighted Arithmatic mean.

$$E_s = \pm 0.6745 \sqrt{\frac{\Sigma w \cdot v^2}{(\Sigma w)(n-1)}}$$

$$= \pm 0.6745 \sqrt{\frac{4}{7(3-1)}}$$

$$= \pm 0.3605$$

(3) Probable Error of single observation of weight 3. , where = w = wt. given = 3

$$= \pm 0.6745 \sqrt{\frac{\Sigma w \cdot v^2}{w \cdot (n-1)}}$$

$$= \pm 0.6745 \sqrt{\frac{4}{3(3-1)}}$$

$$= 0.5507$$

$= S + e_s = 9.66 + 0.025124 = 9.685$

to $\quad S - e_s = 9.66 - 0.025124 = 9.635$

Q.2 $\quad$ if $\quad S = \frac{96.83}{4.9} = \frac{x}{y}$

$x = 96.83 \qquad y = 4.9$

$\delta x = 0.005 \qquad \delta y = 0.05$

$e_x = 0.0025 \qquad e_y = 0.025$

Max^M Error

$$ds = \frac{y\,dx - x\,dy}{y^2}$$

For S

$$= \left(\frac{1}{y}\right)dx - \left(\frac{x}{y^2}\right)dy$$

In $x = \left(\frac{1}{y} \cdot \delta x\right)$

In $y = \left(\frac{x}{y^2} \cdot \delta y\right)$

$$\delta_s = \frac{1}{y} \cdot \delta x + \frac{x}{y^2} \cdot \delta y$$

$$\delta_s = \frac{1}{4.9}(0.005) + \frac{96.83}{4.9^2} \times 0.05$$

$$\delta_s = 0.20267$$

Max Range for S

$$S = \frac{96.83}{4.9} = 19.762$$

$= S + \delta s = 19.761 + 0.20267 = 19.964$

$= S - \delta s = 19.761 - 0.20267 = 19.558$

(2) Probable Error

$$\frac{e_s}{s} = \sqrt{\left(\frac{e_x}{x}\right)^2 + \left(\frac{e_y}{y}\right)^2}$$

$S = 19.761$

$$e_s = S\sqrt{\left(\frac{0.0025}{96.83}\right)^2 + \left(\frac{0.025}{4.9}\right)^2}$$

$\therefore e_s = \pm 0.1008$

Range of (S)

$S + e_s = 19.761 + 0.1008 = 19.862$

$S - e_s = 19.761 - 0.1008 = 19.6604$

Linear Measurement

(i) scales :-

→ scale is the Ratio of map distance to ground distance.

$$\text{scale} = \frac{\text{Map distance}}{\text{Ground distance}}$$

Example scale → 1cm = 500m

$$\text{Ratio} = \frac{1\,cm}{500 \times 100\,cm} = \frac{1}{50,000}$$

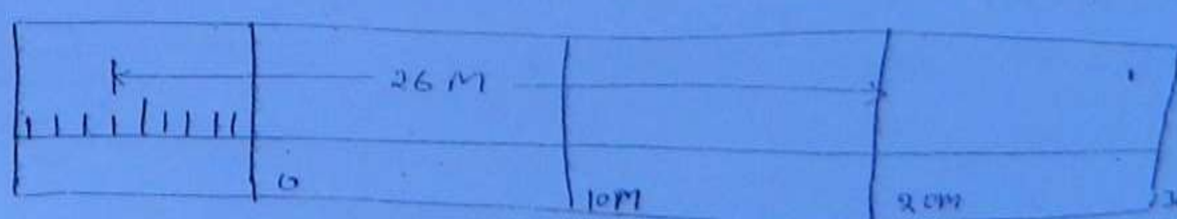
scale = (1 : 50000) ← R.F.
↓
Representative fraction

Types :-

1) Plain scale :-

Measure upto two Dimensions only.

→ Let us make scale 1cm = 4m



Scale 1cm = 4m

Take 10cm long line

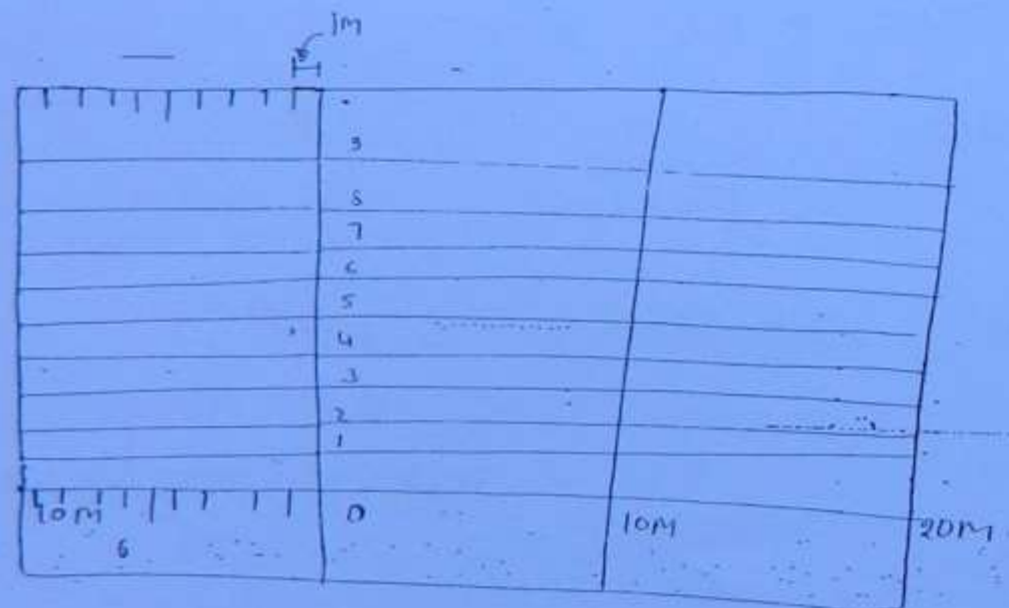
In this case, Read two Dimension

① Decameter (= 10m)

② meter.

② Diagonal ~~vernier~~ scale :-

→ Measure upto three dimensions.



In this case, Measure three dimensions

① 10m → Decameter

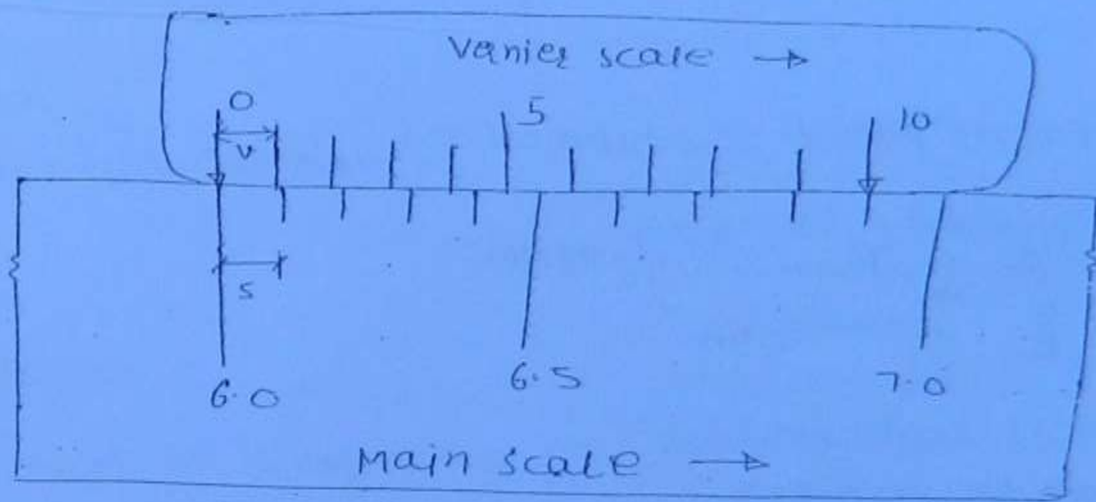
② meter → meter

③ 0.1 meter (10cm) → decimeter

③ Vernier scale:-

→ Also Read three Dimensions

(I) Direct vernier



(1) Vernier scale is in same direction as that of main scale.

(2) (n-1) divisions of main scale is divided into n division of vernier scale

$$(n-1)s = n \cdot v$$

$$\boxed{v = \left(\frac{n-1}{n}\right) \cdot s}$$

Least count:-

Smallest measurement that can be read by the scale

$= s - v \qquad (s > v)$

$$= s - \left(\frac{n-1}{n}\right)s = \frac{ns - ns + s}{n}$$

$$\boxed{\text{Least count} = \frac{s}{n}}$$

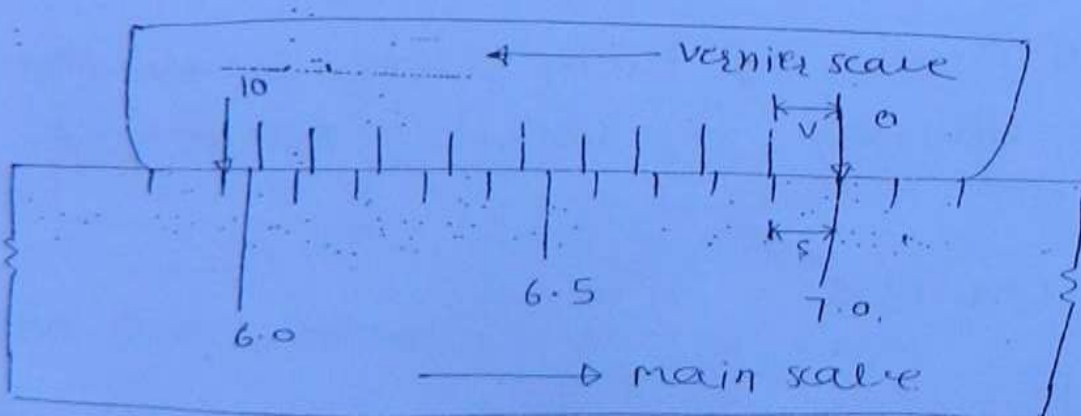
202

In this case Read, 3 Dimensions, say = $\overline{6.67}$.

$6.\ 6\ 7 \leftarrow \frac{1}{10}$ of mm.

6 → cm, 6 → mm

② Retrograde vernier:-



① Vernier scale moves in opposite direction to main scale.

② (n+1) division of main scale is Equal to n division of vernier scale.

⇒ If a drawing has shrunk. The scale of the drawing will change

203

Shrunk scale (New scale) = [Shrinkage factor] × (original scale)

where

$$\text{shrinkage factor} = \frac{\text{shrunk length}}{\text{original length}}$$

Example:-

if a 10 cm long line on drawing has shrunk to 9.5 cm.

$$\text{shrinkage factor} = S.F. = \frac{\text{shrunk length}}{\text{original length}}$$

$$= \frac{9.5}{10}$$

$$\boxed{S.F. = 0.95}$$

$$\text{shrunk scale} = \text{original scale} \times S.F.$$

$$= \frac{1}{5000} \times 0.95$$

$$= \frac{1}{5263.16}$$

New scale

1 cm = 5263.16 cm

1 cm = 52.6316 m

$-(n+1)s = n \cdot v$

$$v = \left(\frac{n+1}{n}\right) \cdot s$$

204

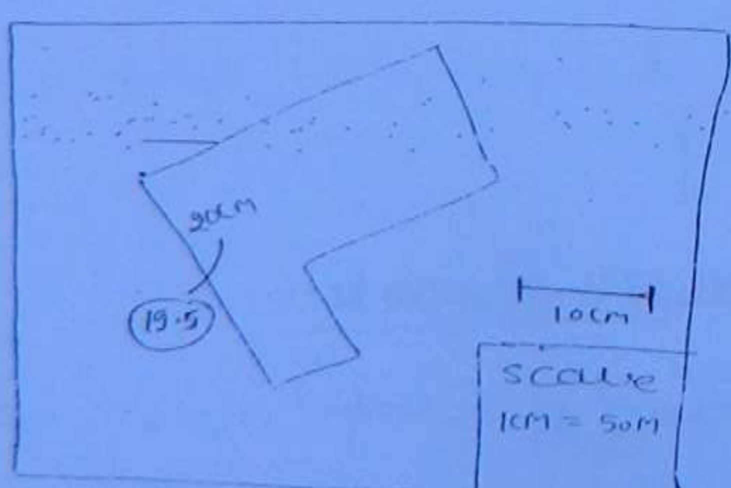
Least count $= v - s \quad (v > s)$

$$= \left(\frac{n+1}{n}\right) \cdot s - s$$

$$= \frac{s}{n}$$

$$\boxed{\text{Least count} = \frac{s}{n}}$$

* shrunk scale :-



Now scale

9.5 cm = 50×10 = 500 m

Shrunk scale 1 cm = $\frac{500}{9.5}$ = 52.6316 m if an area of 250 cm^2 is measured on drawing. How much is represent on ground

$$A = 250 \times (52.6316)^2$$

205

$$A = 692521.33\ m^2$$

* Error due to incorrect length of chain/Tape:-

L = Designated length of tape
[True length should be] (30m)

L' = wrong length of tape (Actual)
(30.10m)

If l' = length of line measured (600m)

l = True length of ~~wire~~ line.

$$\boxed{\text{True} \times \text{True} = \text{wrong} \times \text{wrong}}$$

$$L \times l = L' \times l'$$

True length of line

$$\boxed{l = \frac{L' \times l'}{L} = \frac{L'}{L} \times l'}$$

Ex:- $u = \frac{30.10}{30} \times 600 = 602M$

For Area

$$A = \left(\frac{L'}{L}\right)^2 \times A'$$

206

For volume

$$V = \left(\frac{L'}{L}\right)^3 \times V'$$

* Measured value = 600M

correction = + 2M

corrected value = 602 M

→ Error is Negative

Actual Length on Ground	Measured value [Noted value]	Error	correction
more (30.10)	Less 30M	(−)ive	(+)ive
Less (29.50M)	more 30M	(+)ive	(−)ive

(2) Correction due to slope :-

Correction Due to slope

$$C_s = AB - AC$$

$$= l - \sqrt{l^2 - h^2}$$

$$= l - l\left[1 - \left(\frac{h}{l}\right)^2\right]^{1/2}$$

$$= \frac{h^2}{2l} + \cdots = \frac{h^2}{2L}$$

Correction Due to slope = $\frac{h^2}{2L}$

→ This correction always ⊖ive.

(3) Correction Due to Alignment :-

Correction Due to wrong Alignment

$$C_{al} = l - \sqrt{l^2 - h^2}$$

$$C_{al} = \frac{h^2}{2L}$$ → correction always ⊖ive

Tape corrections :-

1) Correction due to standard length of tape/chain :-

Correction required per chain length = c

Total correction required for l' length measured

$$C_a = \left(\frac{c}{L}\right) \times l'$$

L = Designated length of tape

l' = Incorrect length of line measured.

Ex: $L = 30\,m$, $L' = 30.10\,m$, $l' = 600\,m$

Correction required per chain length

$$c = L' - L = 30.10 - 30 = (+)\ 0.10\,m$$

Total correction

$$= \frac{c}{L} \times l' = \frac{0.10}{30} \times 600 = +2.00\,m$$

Corrected length of line

$= l' +$ correction

$= 600 + 2.0$

$= 602\,m$

(4) Correction due to temperature :-

$$C_t = l' \alpha (T_m - T_o)$$ (209)

l' = length of line Measured

α = Correction of thermal Expansion

T_m = Temperature at the time of Measurement

T_o = Temperature at the time of Standardization of Tape

(5) correction Due to pull :-

$$C_p = \frac{(P_m - P_o) l}{AE}$$

P_m = Pull at the time of Measurement

P_o = pull at the time of standardization

l = length of line

A = cross section area of tape

E = young modulus of tape/chain

210

(6) Sag Correction :-

$$\text{sag correction} = S_g = \frac{(w l)^2 \cdot l}{24 \cdot P_m^2}$$

$$S_g = \frac{W^2 \cdot l}{24 \cdot P_n^2}$$

W = weight of tape

l = length of line

Pm = pull at the time of measurement