9

(2.10)

(210)

-: HAND WRITTEN NOTES:-

OF

CIVIL ENGINEERING

(1)

-: SUBJECT:-

HIGHWAY ENGINEERING

9

2

(10)

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 year Road plan → 1961-81
   [Bombay Road plan]

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

⑨ National highway Act → 1956

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Jaykar Comittee recommendation :- (4)

In 1928 Jaykar committe 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 instited to carry out research and development works. Results [CRRI - 1950]

Road plans :-

	1st	2nd	3rd
① Year	1943 - 63	1961-81	1981 - 2001
② Vanue	Nagpur	Bombay	Lucknow
③ Target	16 Km/100 sq 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

(6) Other points

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

Added

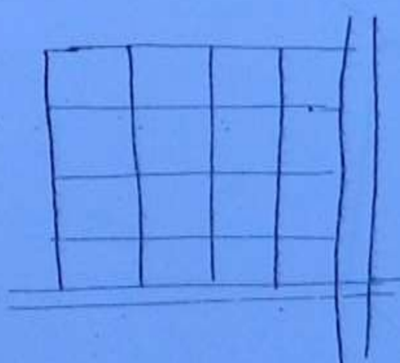
(1) 1600 Km of Expressway
(2) 5% allowance for future develement

Classification

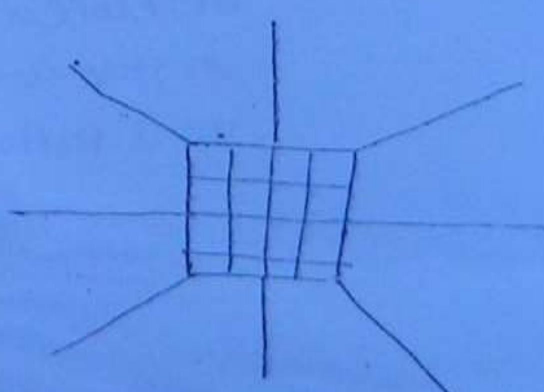
(1) Primary
(i) Expressway
(ii) NH
(2) Secondary
(i) SH
(ii) MDR
(3) Tertary
(i) ODR
(ii) VR

* Different Road pattern :-

(1) Rectangular and Block Pattern :-

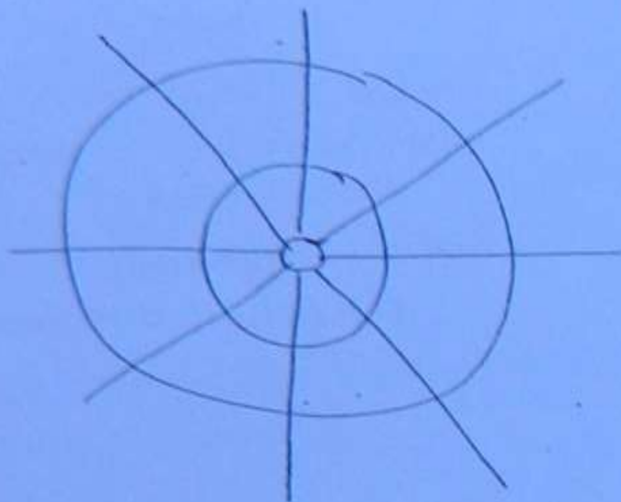


(2) Star and Block pattern :-



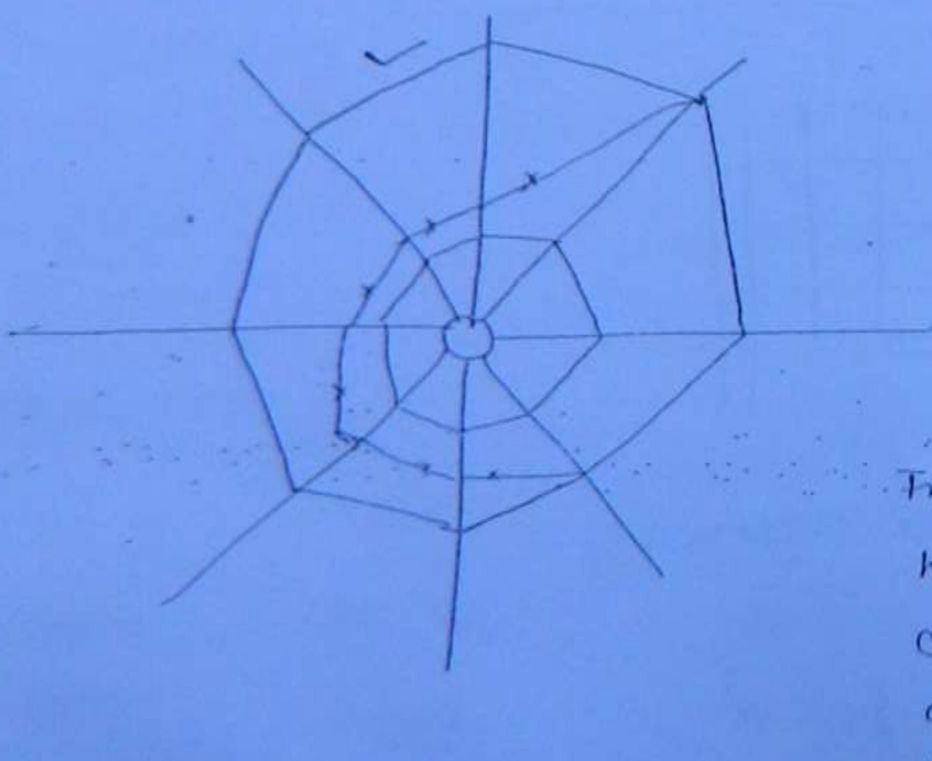
) Star and circular :-

(6)



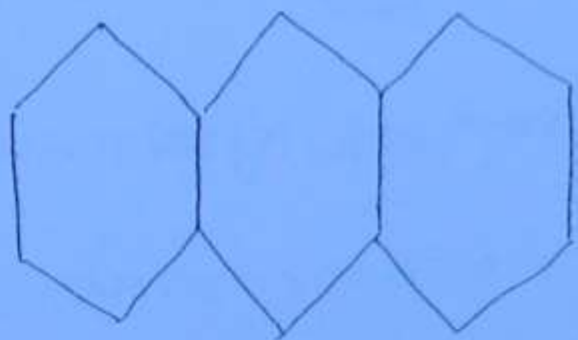
C. P.

1). Star and Grid pattern :-



Indian Road have been developed on star and Grid pattern

5) Hexagonal :-



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Geometrical design

1) Terrain classification :-

Types	Cross slope of terrain
steep terrain	> 60 %
Mounteneous 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

1) Max^{m} length :

① single unit with two axle = 10.7 M

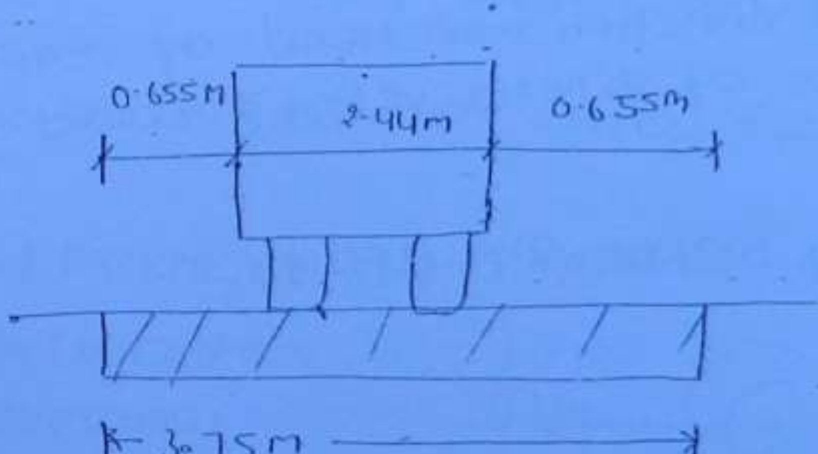
(2) single unit > 2 axle = 12.2 m

(3) Tractor + Trailor = 18.3M

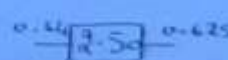
(1) Carriage way width

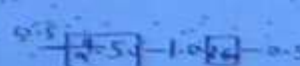
Single lane road = 3.75m

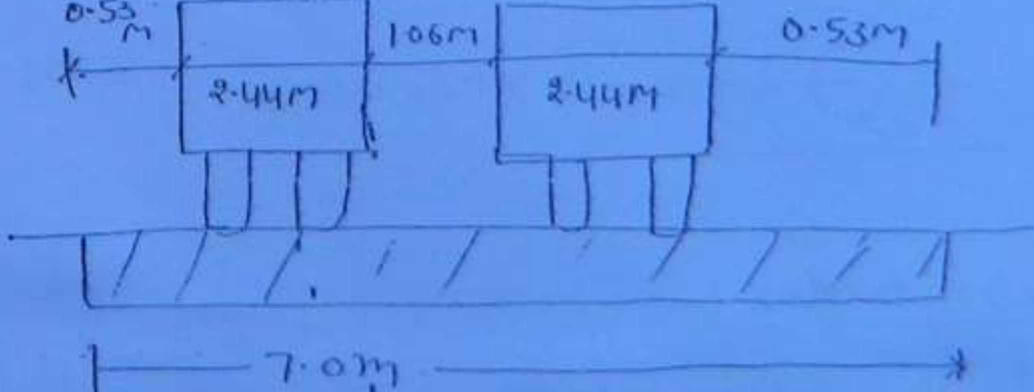
Two lane road = 7.00 m



Single lane







Double lane

③ Pavement surface charecteristics :-

① Friction :-

(10)

There are two types

ⓐ longitudinal coefficient of friction

$\mu = f = 0.35$

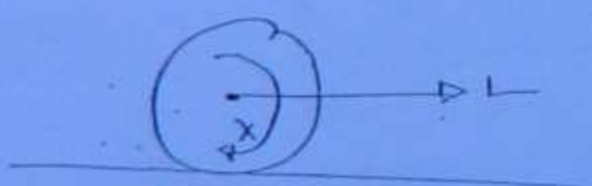
Applicable
[During application of brakes]

ⓑ 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) satisfactory	250 cm/km
(3) unsatisfactory [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
00	80	80	65	50	40	40	30

pavement design done for Rulling speed.]

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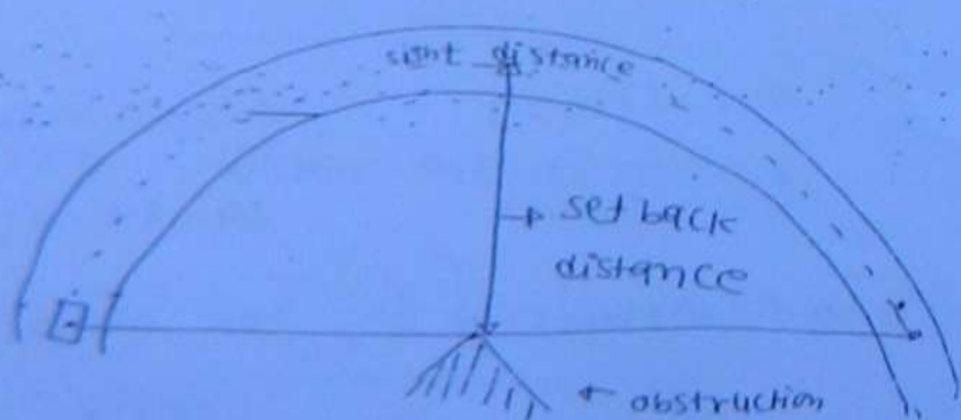
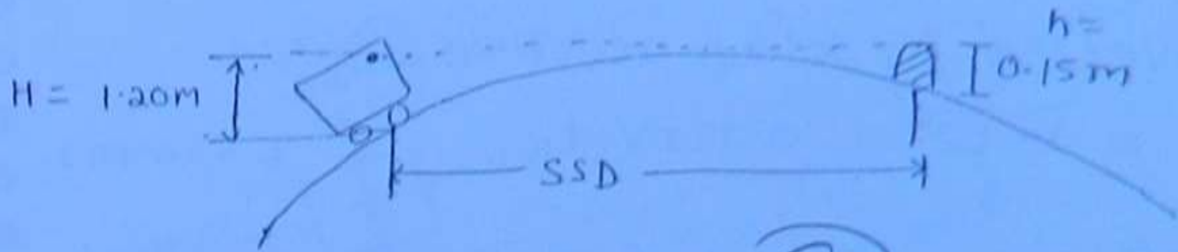
ight distance :-

As per IRC signt distance requirement

i) on Horizontal curve :-



ii) on vertical curve :-



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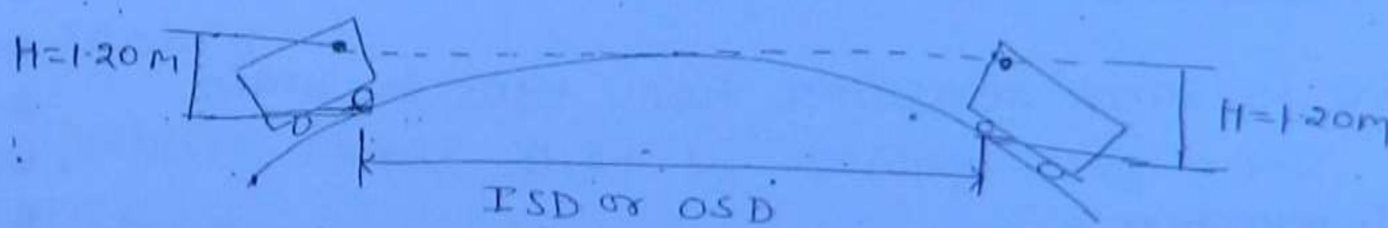
For stopping sight distance

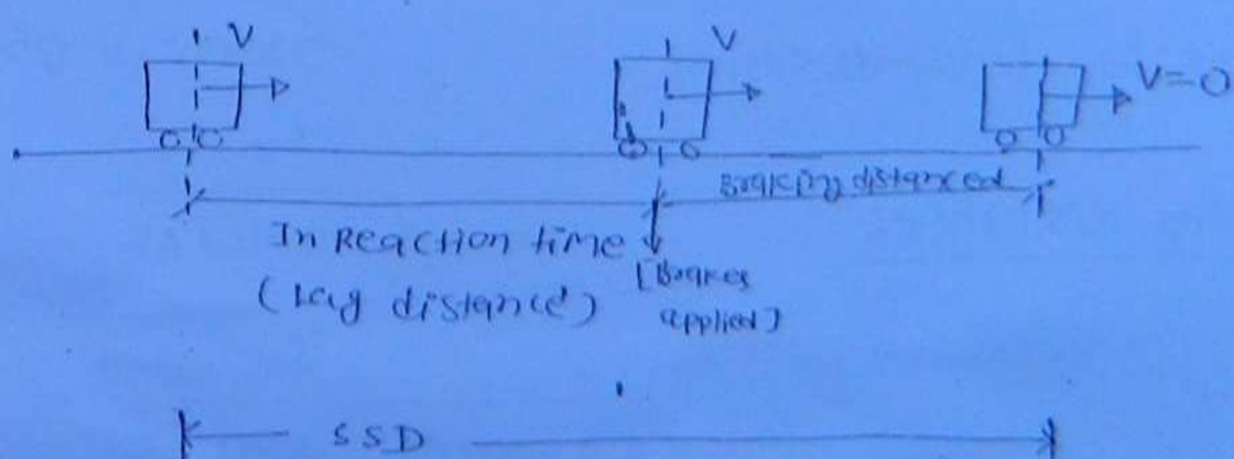


For intermediate or overtaking sight distance

① <u>stopping sight distance:-</u>

→ 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 sand sensation from eyes to brain

I- Intellaction :-

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

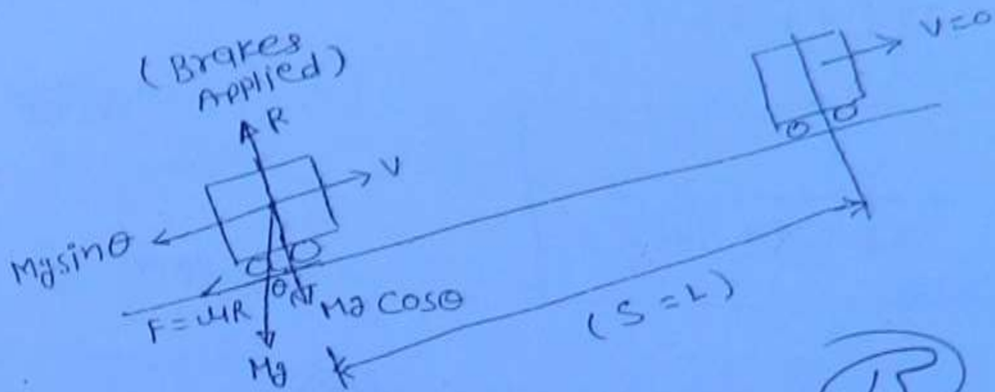
) E → Emotion :-

Time elapsed in emotional sensation.

) V → Volition :-

Time for final decision.

) Braking distance:-



(15)

Assumptions:-

① Brakes are fully applied wheels are fully jammed.

② Vehicle moves just by skiding over road surface.

K·E· Lost = work done

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

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

= $(mg\sin\theta + f.mg\cos\theta)\,S$ — μ = f, R = Mg cosθ

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

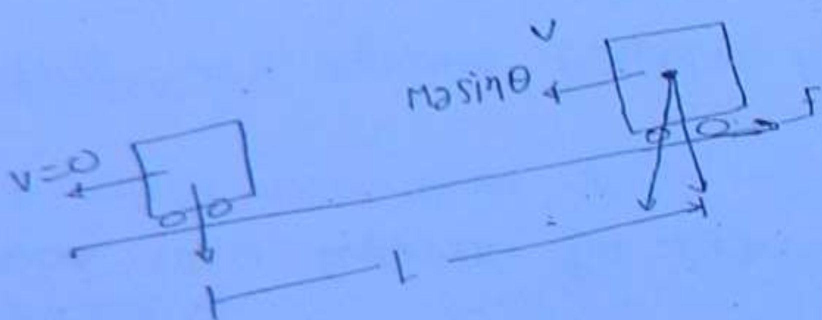
$$S = \frac{V^2}{2g[f + S\%]}$$

[S = L] distance

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

S% → slope

when movement is downward (16)



In this case

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

Total stopping sight distance

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

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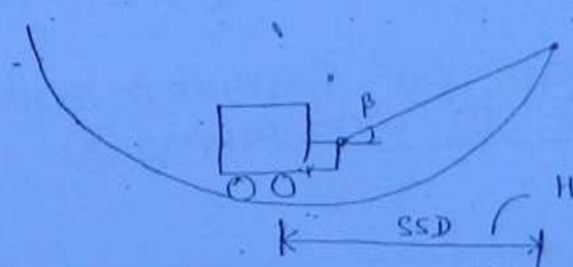
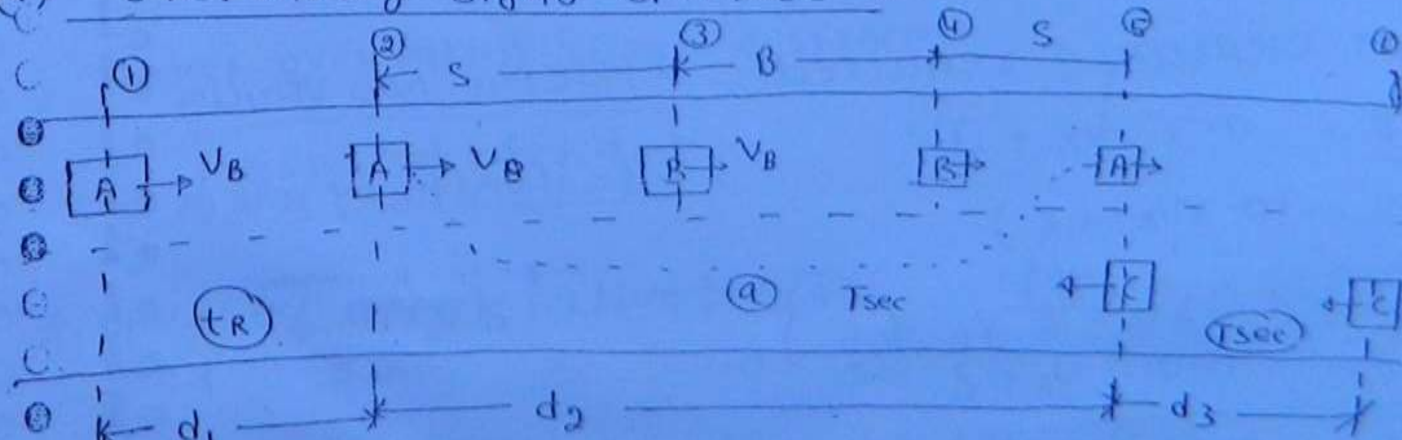
Cases	Total sight distance
① One way road (one way traffic)	SSD
② One lane road (Two way traffic) [Also called intermediate sight distance or meeting sight distance]	2 SSD
③ Two lane road (Two way traffic)	SSD
④ Head light sight distance	SSD



(2) Overtaking sight distance :-



a = acceleration

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speed of (A) (overtaking vehicle) = V_A

speed of overtaken vehicle (B) = V_B

speed of opposite side vehicles (C) = V_c

) 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)]

$d_1 = V_B \cdot t_R = 0.278\, V_B \cdot t_R$ —— (1)

t_R = Reaction time. (2.5 to 3.0 sec)

Distance (d_2) :-

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

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

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

minimum clearance required between two vehicles

$S = 0.7 \cdot V_B + l$

$S = (0.7 V_B + 6)$

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

$S = 0.20\, V_B + 6$

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

l = length of vehicle

0.7 = t_R - Reaction time

$t_R \cdot V_B$ = Distance

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

(19)

distance d_2 = 2s + B (B → distance travelled by vehicle B (v_B))

$$d_2 = 2s + V_B \cdot T$$ —— (3)

Equating (2) and (3)

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

$$T = \sqrt{\frac{4s}{a}}$$ —— (4)

(3) Distance (d_3) :-

Distance travelled by opposite side vehicles (C)

$$= V_C \cdot T$$

$$d_3 = 0.278\ V_C \cdot T$$ —— (5)

Total over taking sight distance

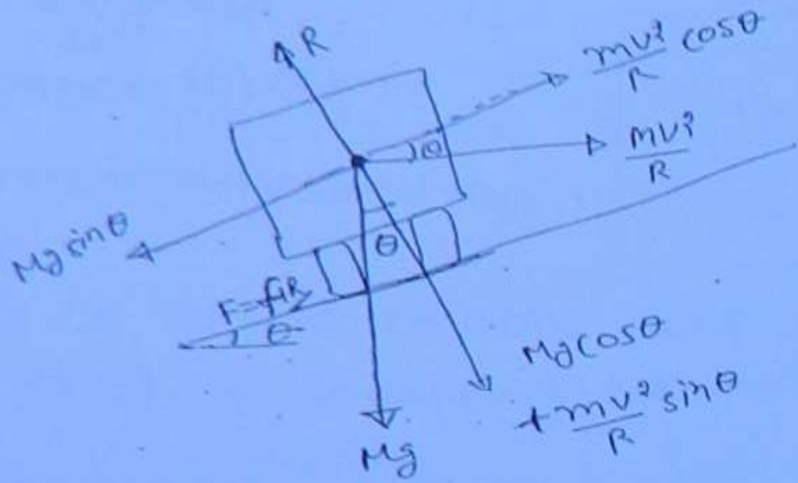
$$OSD = d_1 + d_2 + d_3$$

* 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.



(20)

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.)

(21)

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

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

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

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 :-

I. 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 = cambar slope

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 $e_{cal.} > e_{max}$

then limit e value to e_{max}

and check value of f considering full design speed.

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

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

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

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) <u>special case :-</u>

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

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

<u>Minimum Radius of curve</u>

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

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

Extra widening :-

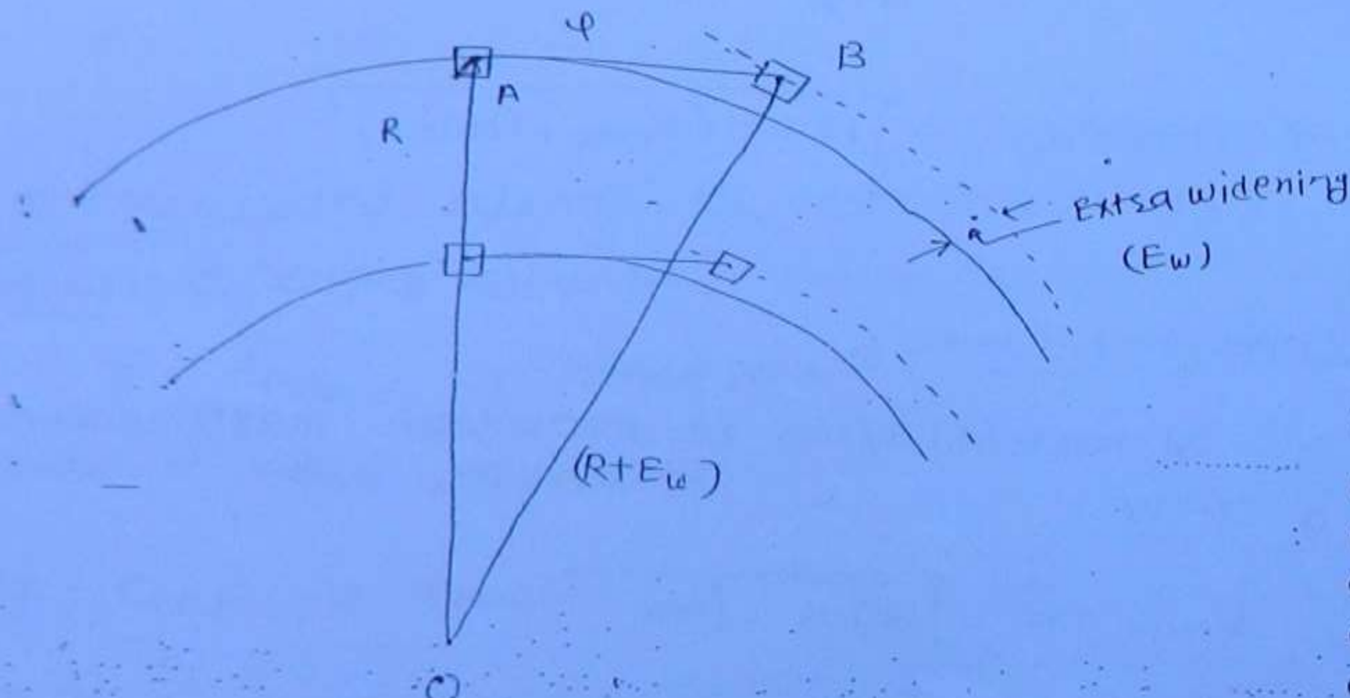
Extra widening is required on curve.

Purpose :-

Mechanical widening (24)

Psychological widening

Mechanical widening :-



In traingle OAB

$$R^2 + \ell^2 = (R+E_w)^2$$

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

$$\ell^2 = E_w(E_w + 2R)$$

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

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

if n = number of lanes

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

(2) Psychological widening :-

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

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

same for one lane or more lan.

V = Kmph

Total Extra widening

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

Transistion curve :-

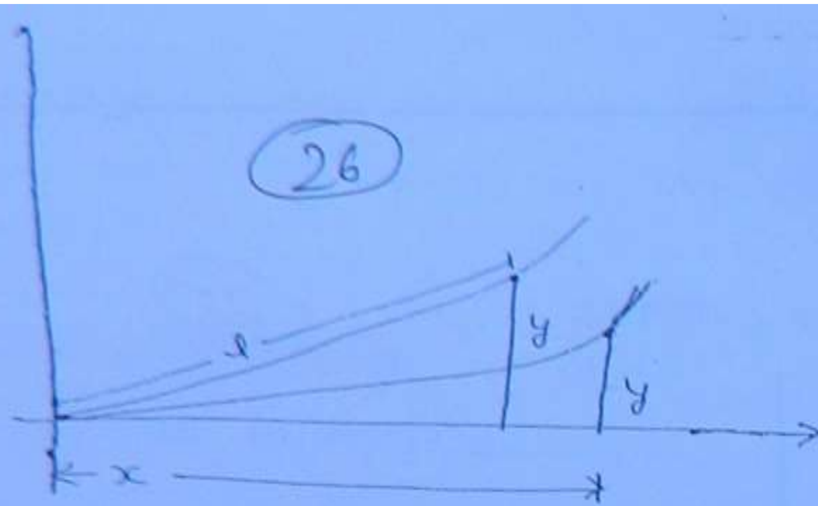
→ For Highway Transition curve → spiral is used

(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

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

v = speed in m/sec.

C = Rate of change of Radial Acceleration (m/sec²/sec)

R = Radius in meter

value of c

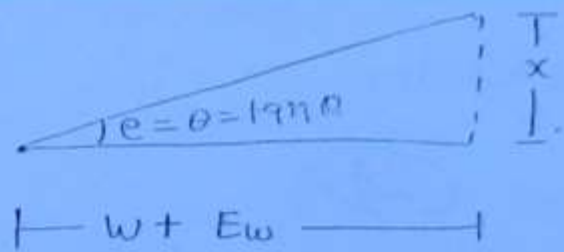
$$C = \frac{80}{75 + V}$$

value lies

$$0.50 \leq C \leq 0.80$$

2) Based on Rate of change of superelevation:-

i) if pavement is roteted about edge



Rise of outer edge

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

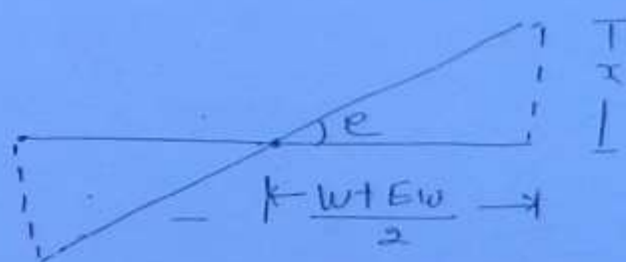
$x = (W + E_w) e$

W = width of Road

Length of Transition curve

$$L = N \cdot x$$

(ii) if pavement is rotated about centre



Raise of outer edge

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

T.C = Transition 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

R = in meter.

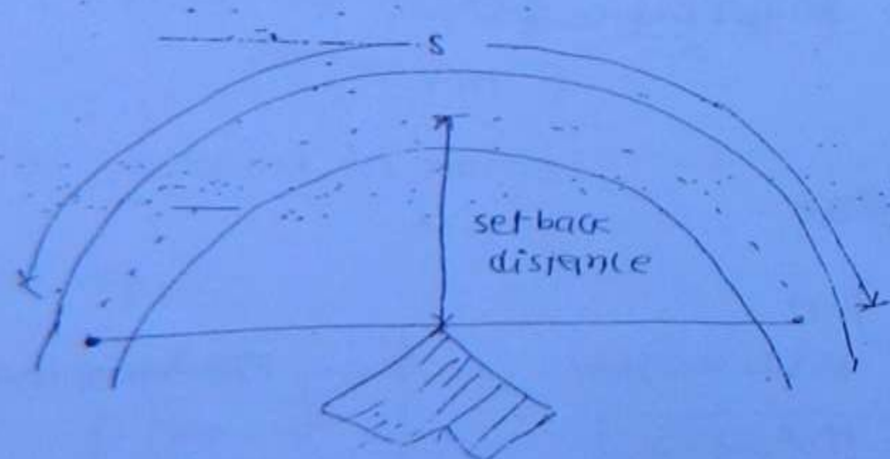
mountaneous and steep

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

Shift of curve :-

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

Set 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.

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

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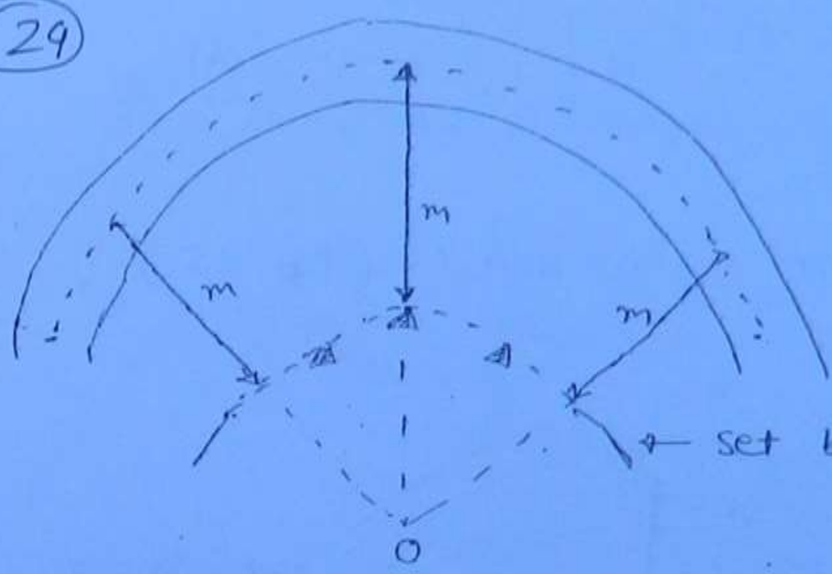
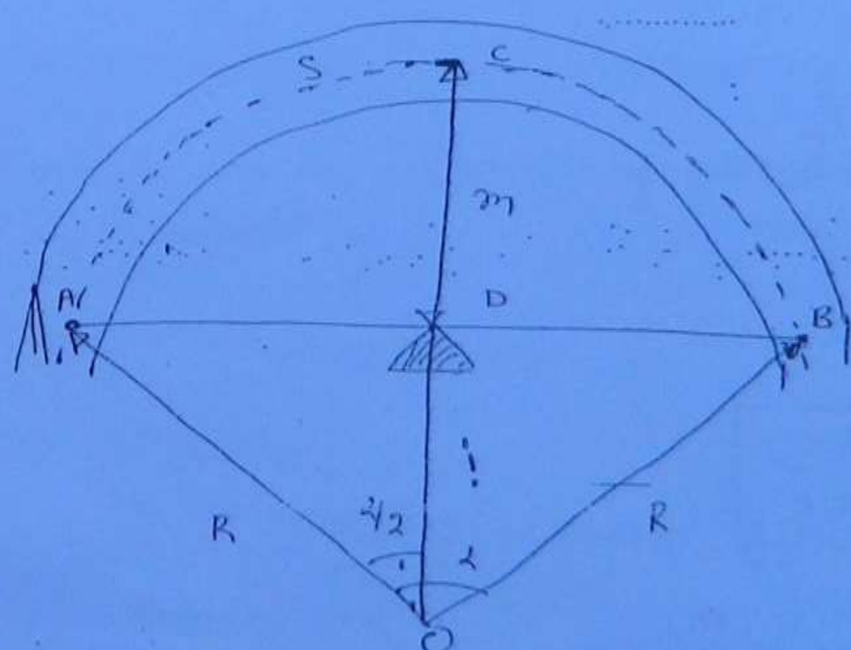


Case ①

if length of curve (L_c) > sight distance

one lane Road ($L_c > S$)



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

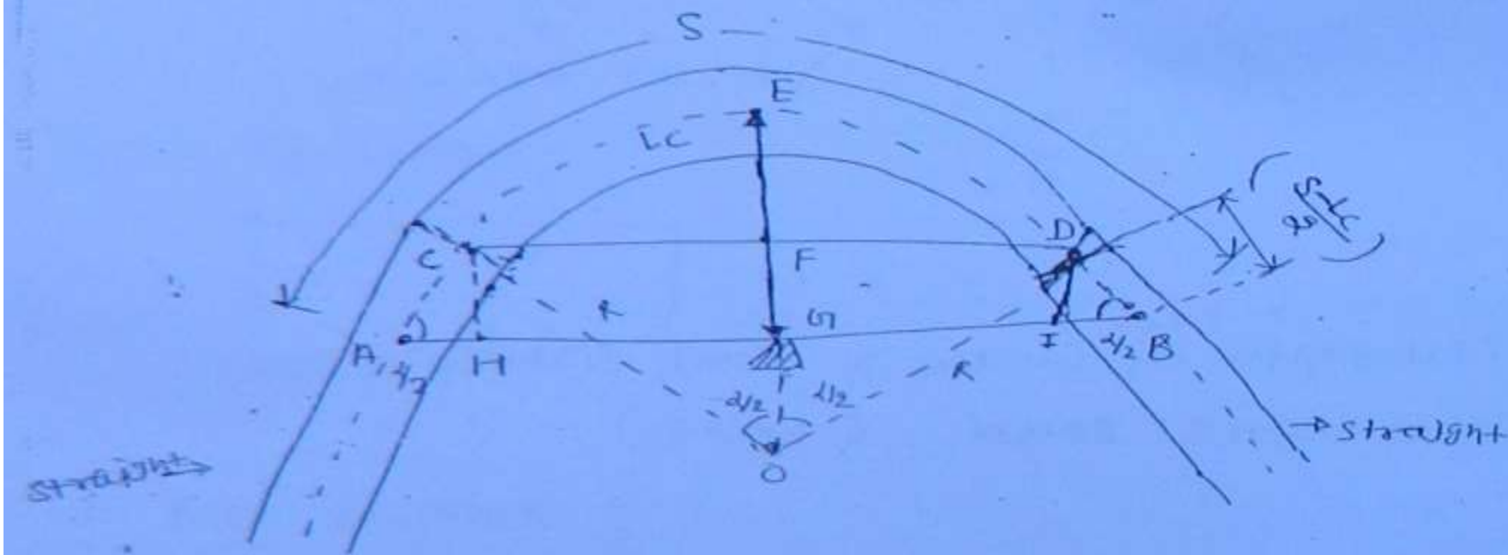
$$\alpha = \frac{360\,S}{2\pi R} \Rightarrow \frac{\alpha}{2} = \frac{180\,S}{2\pi R}$$

set Back distance

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

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

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



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

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

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

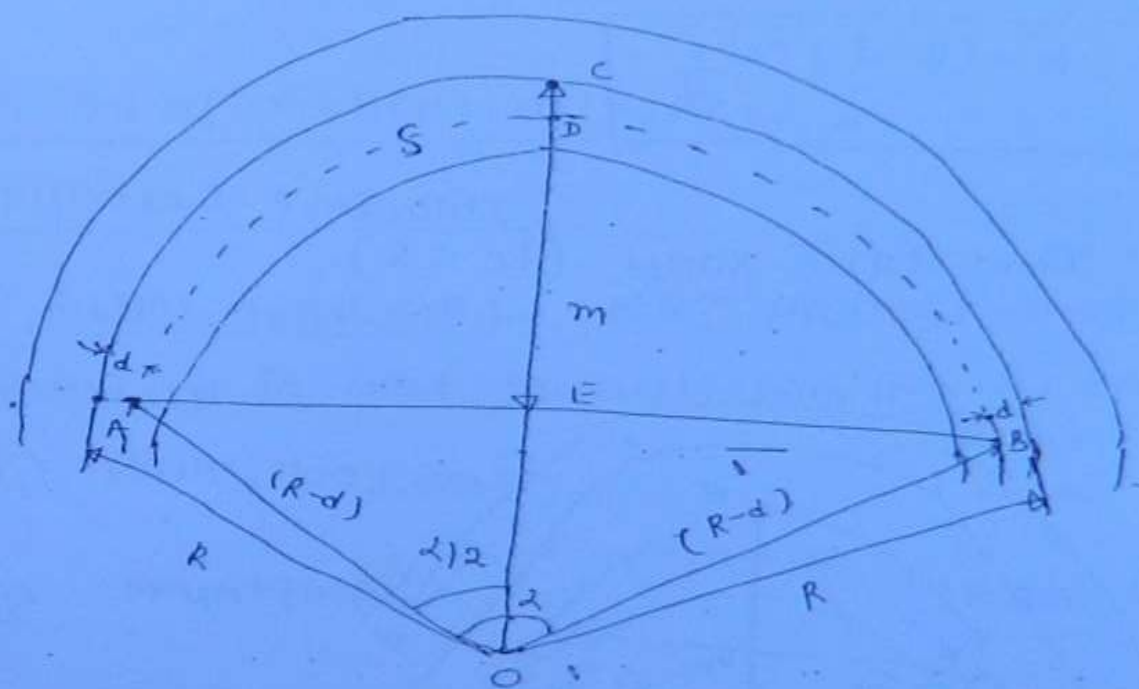
set back distance (m)

$m = EG = EF + FG$

$m = (OE - OF) + DI$

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

<u>case-3</u> 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.

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

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

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

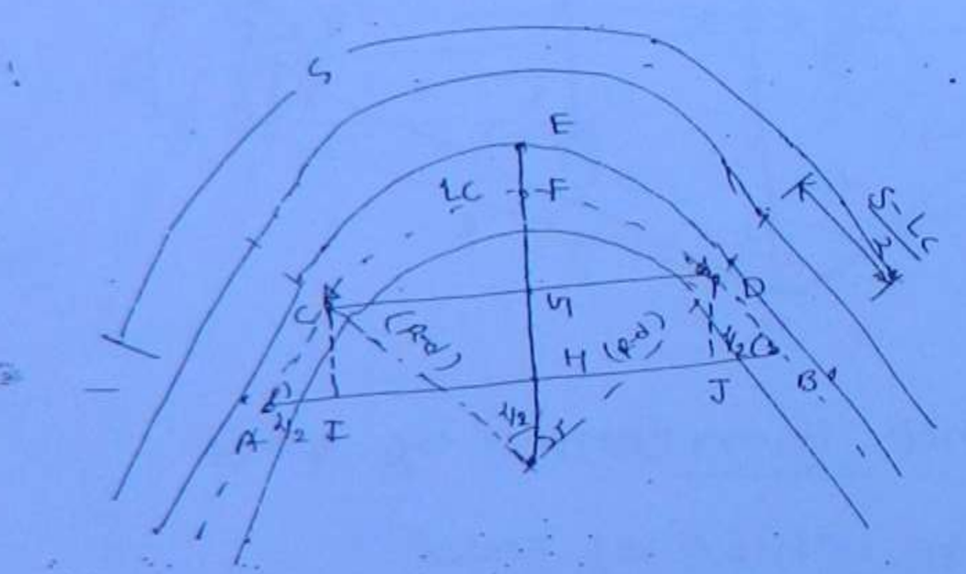
set back distance (32)

$m = CE$

$= OC - OE$

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

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



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

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

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

set back distance

$m = EH$

$= EG + GH$

$= (OE - OG) + DJ$

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

Design of vertical alignment :-

Different gradients

(A) **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

(B) **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.

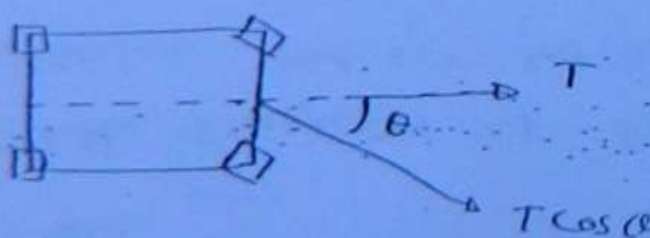
Plain and rolling	1 in 15
Mountainous	1 in 14.3
Steep	1 in 12.5

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

$= T\cos\theta$

in the direction of movement

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

Grade compansation :-

Reduction of grade at the location of curve

Grade compansation

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

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

Ex. For a mountaneous region at the location of a curve, of $R = 120\,m$, what Max^m Rulling gradient can be provided.

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

Grade compansation

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

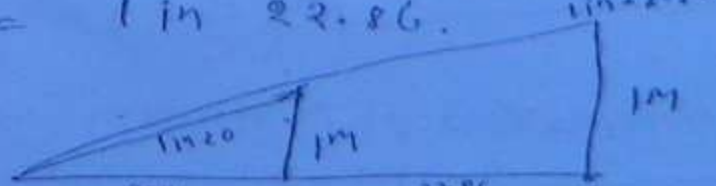
Max^M $\frac{75}{R} = \frac{75}{120}\ \% = 0.625\%$

$$= \frac{0.625}{100} = 6.25\times10^{-3}$$

Compansated gradient

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

$= 1$ in 22.86.



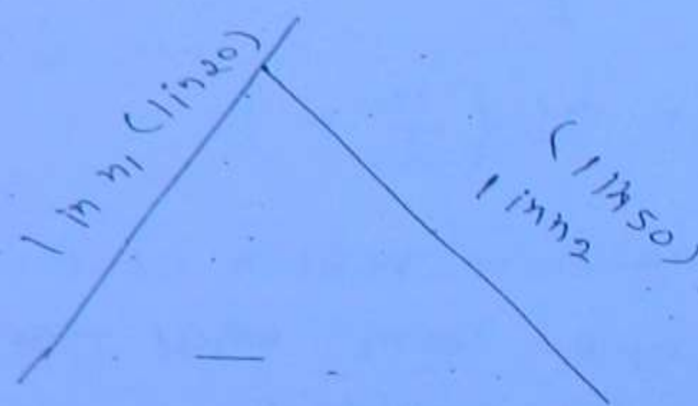
ertical curve :-

1) summit curve

2) valley curve

(36)

hange in gradient :- (N)



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

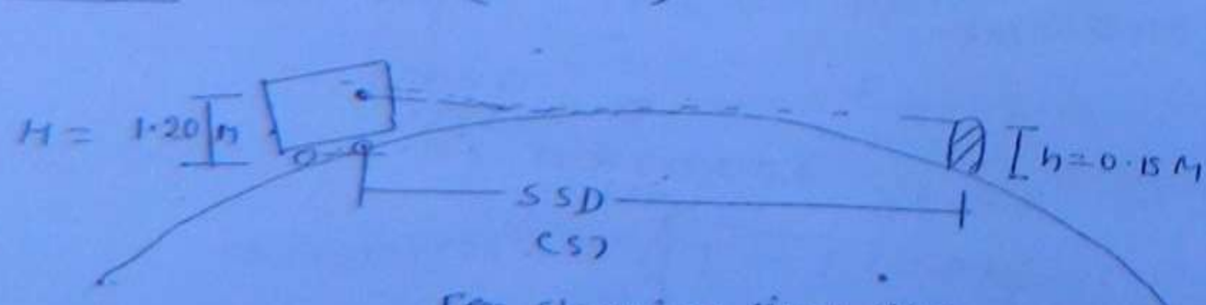
general formula

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

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

Summit curve :- (simple parabola)

ase 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.

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

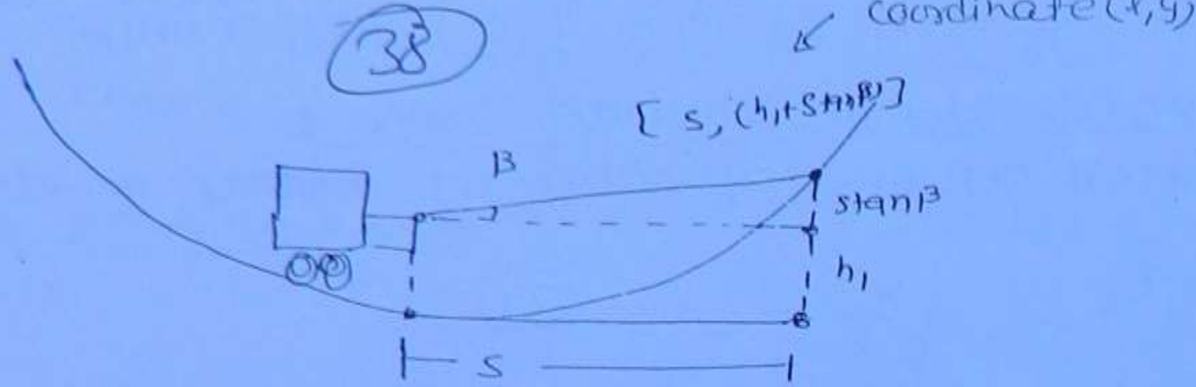
Length of valley curve

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

N = Total change in gradient

V = m/sec . C = m/sec³

) Head light sight distance:-



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 $L > s$)

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

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

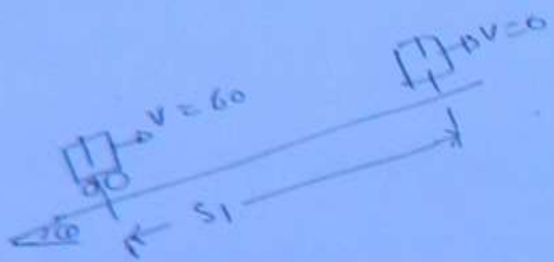
(2) if length L<S

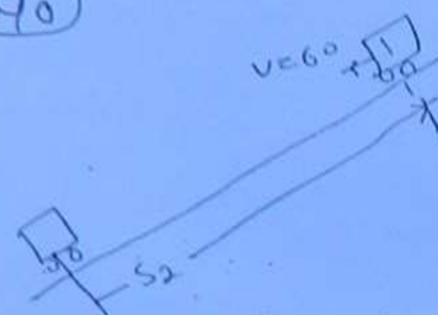
Length of valley curve

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

-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)





$(\theta = S\%)$

$S_1 = S_2 - 9$

$S_1 = \dfrac{V^2}{2g(f + S\%)}$

$S_2 = \dfrac{V^2}{2g(f - S\%)}$

$S_2 - S_1 = 9$

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

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

$\dfrac{1}{0.4 - s} - \dfrac{1}{0.4 + s} - \dfrac{9}{14.18}$

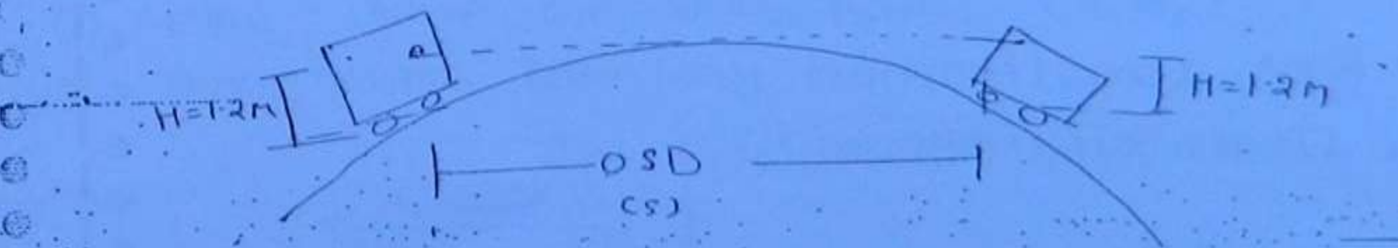
Length of curve required to fulfill IRC condition

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

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

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

For OSD or ISD



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 ($L_c \ngtr S$)

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

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

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

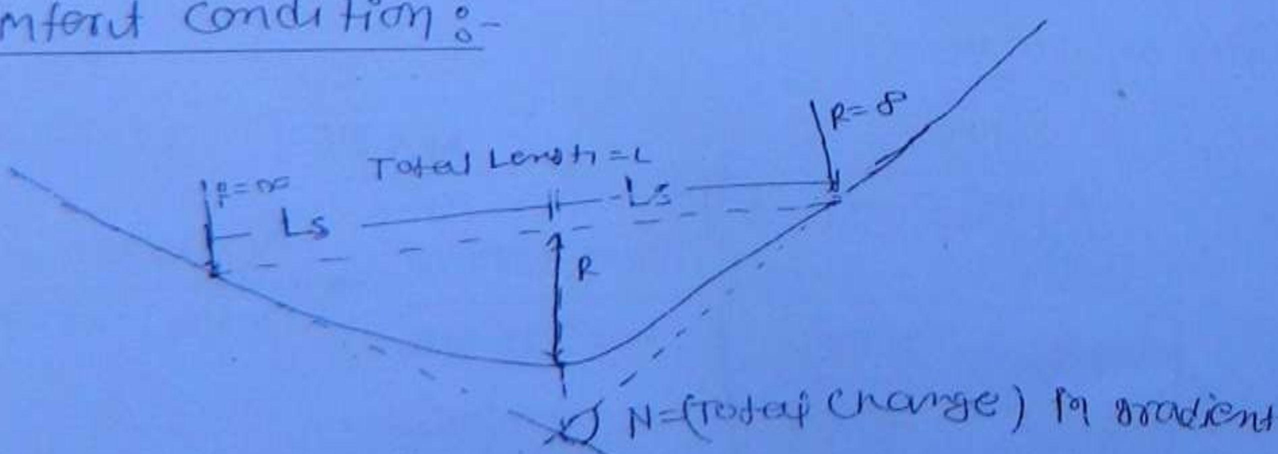
For OSD - $$L = 2S - \frac{9.6}{N}$$

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)

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

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

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

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

Q.2
CS 2010

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

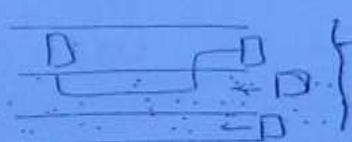
$a = 2.5$ kmph/sec.

Calculate safe passing distance.

(1) single lane one way traffic (d_1+d_2)

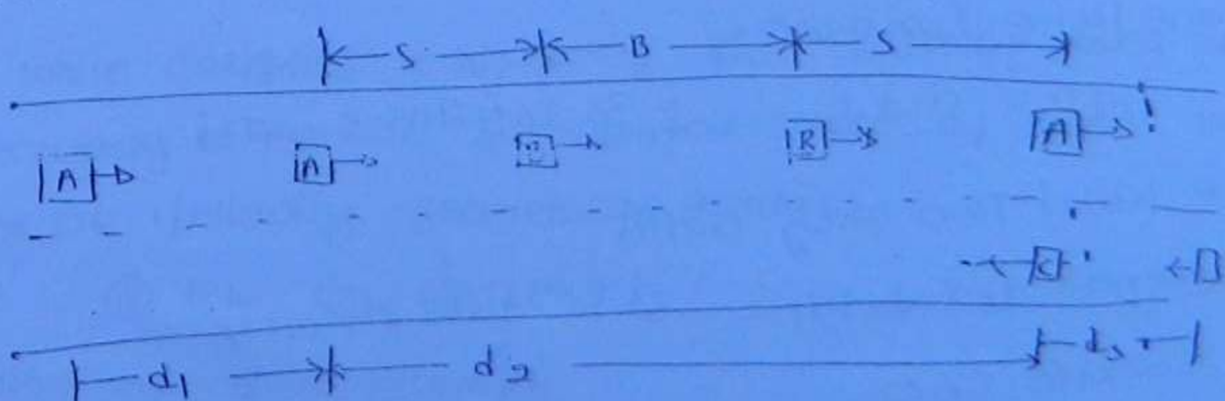
(2) Three lane both way traffic $(d_1+d_2+d_3)$

Reaction time 2 sec



** when speed of opposite side not given then 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

$s = 0.2 V_B + 6$

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

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

↳ 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

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

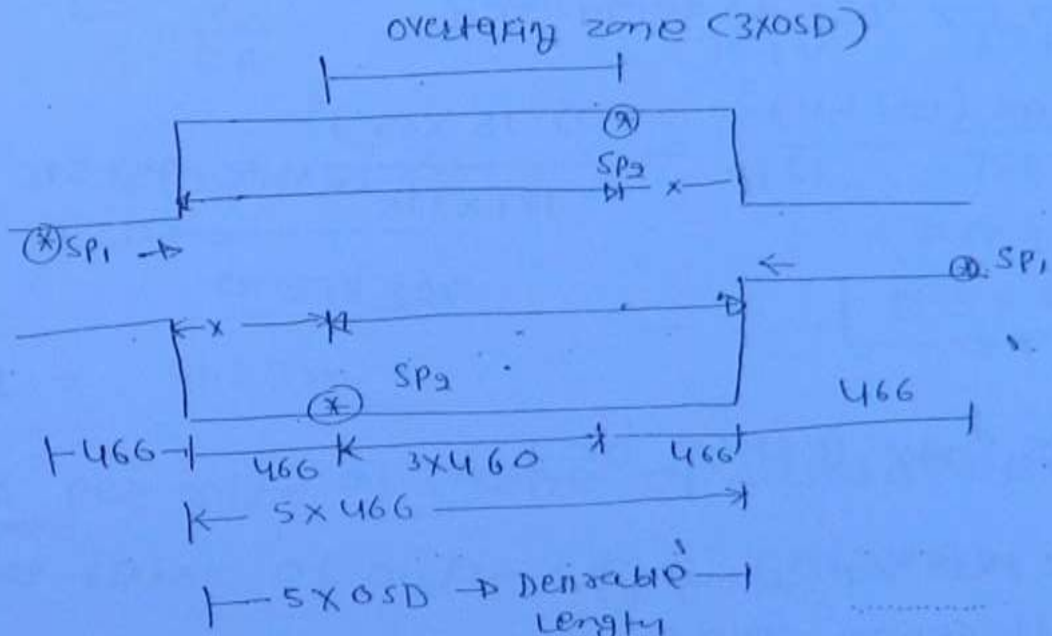
$= 465.56M$

For Total OSD = 466M

* Min length of overtaking zone

= 3 X OSD = 3 X 466 = 1398M

* Desirable length = 5 X OSD = 5 X 466 = 2330



HOMWORK

① 1 © ② 1995 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

Sol^n –

$R = 325m$

$V = 65 kmph$

$l = 6.1m$

$W = 10.5m$

(46)

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~~ of both values

S-E = 5.75%

(2) Extra widening

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

$$= 0.55m$$

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

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

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

$$= 0.57$$

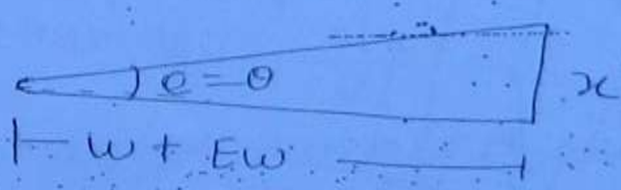
$$\boxed{0.5 \le C \le 0.8}$$

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

$L = 31.85\,m$

(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

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

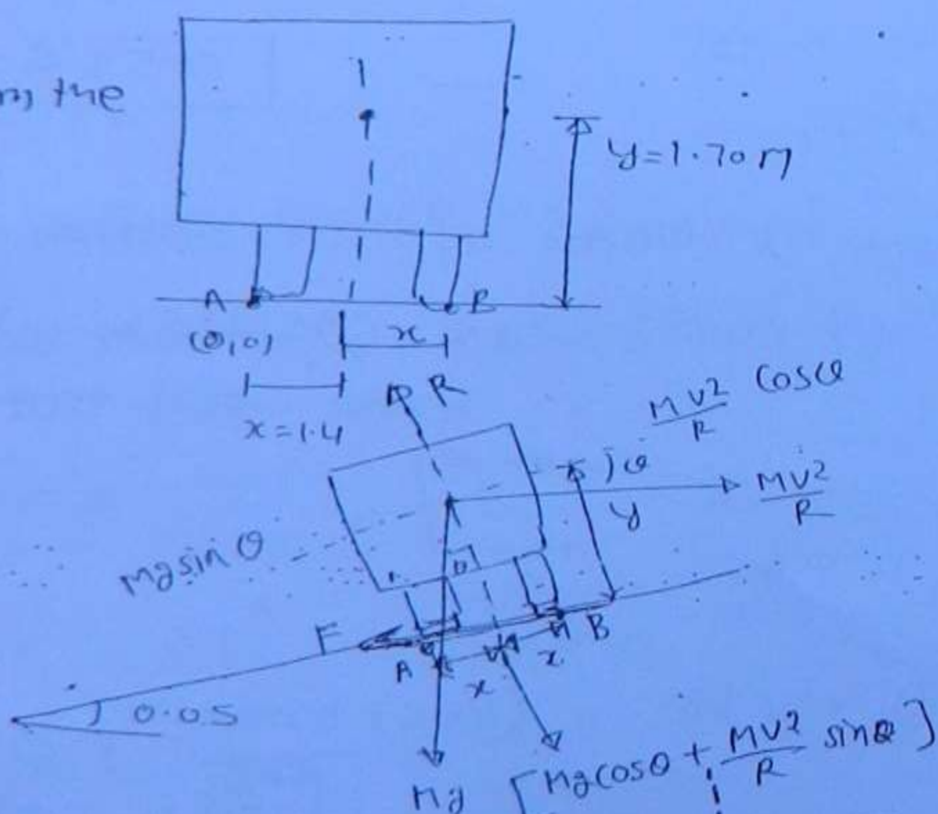
ength of T.C. = 64m

Take Max. value

6. A truck with c.g. at x = 1.4m and y = 1.7m is traveling 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.

and y from the wheel



) 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.

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

$$V = 19.88 \text{ m/sec} = 71.52 \text{ Kmph}$$

(2) For overturning

vehicle may overturn about point B.

Equating moment of all forces about B

$$\frac{mv^2}{R}\cos\theta \times y = mg\sin\theta\, y + \left(mg\cos\theta + \frac{mv^2}{R}\sin\theta\right) x$$

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

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

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

(50)

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

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

$$V_{max} = \sqrt{\frac{(1.4+0.05\times1.7)}{(1.7-0.05\times1.4)} \times 9.81\times200}$$

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

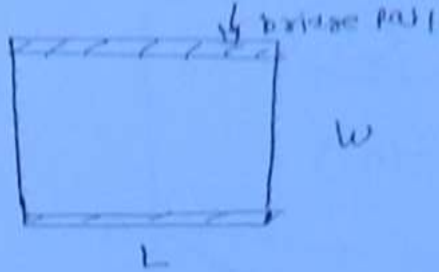
max speed will be allow take minimum

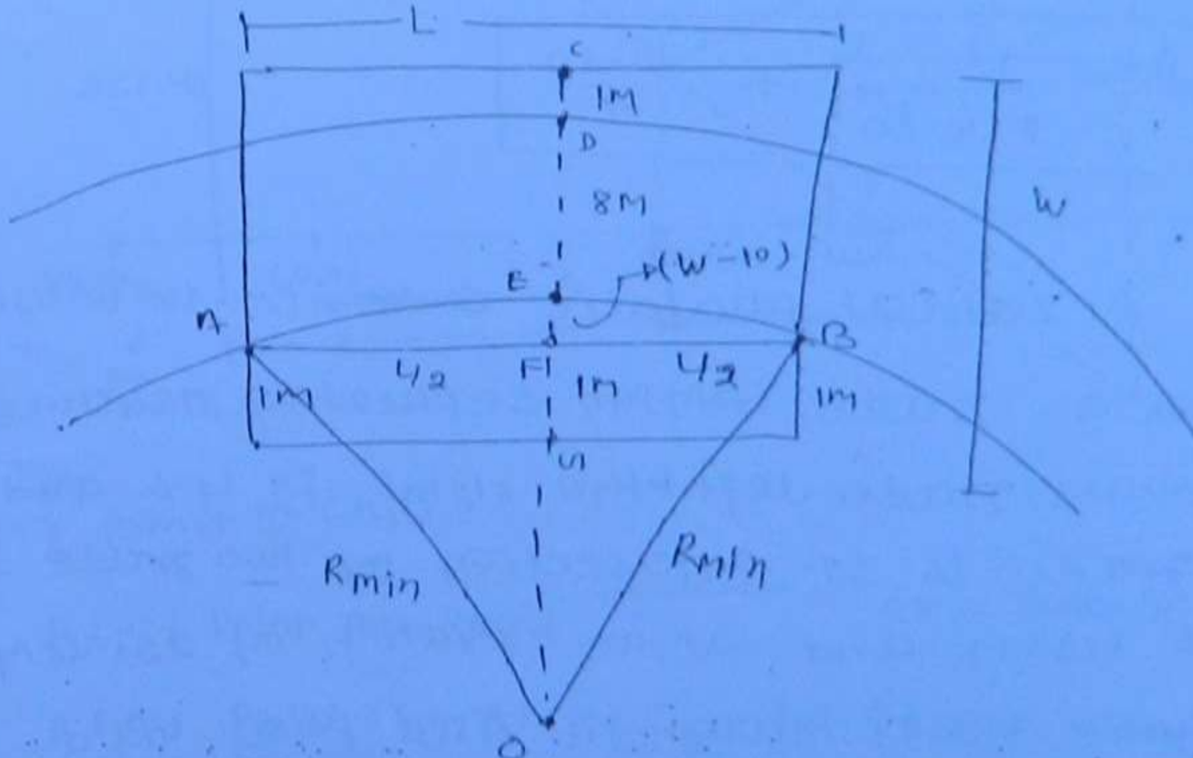
$$\boxed{V_{max} = 71.52\ KMph}$$

5 Ex.

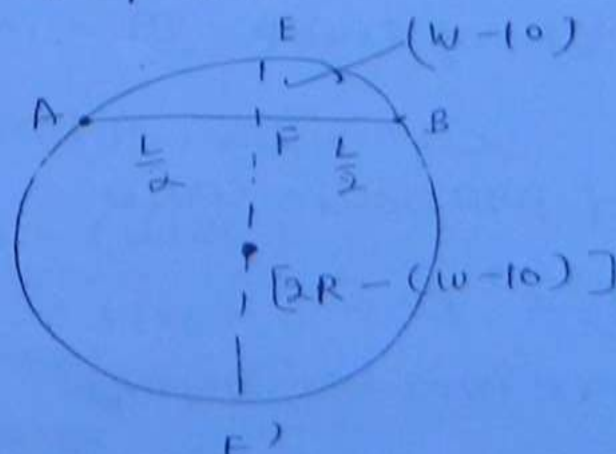
A rectangular bridge span of length L and width w, is used on a Horizontal curve. If the roadway is 8m wide, and minimum clearance of 1m is desired b/w the edge of pavement and bridge rail show that minimum radius of curvature

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





using property of circle



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

$$\frac{1}{2} \times \frac{1}{2} = (W-10)\,[\,2R - (W-10)\,]$$

(2)

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

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

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

Que. 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 at a chainage of 460m and RL of 260m.

Find the length of curve.

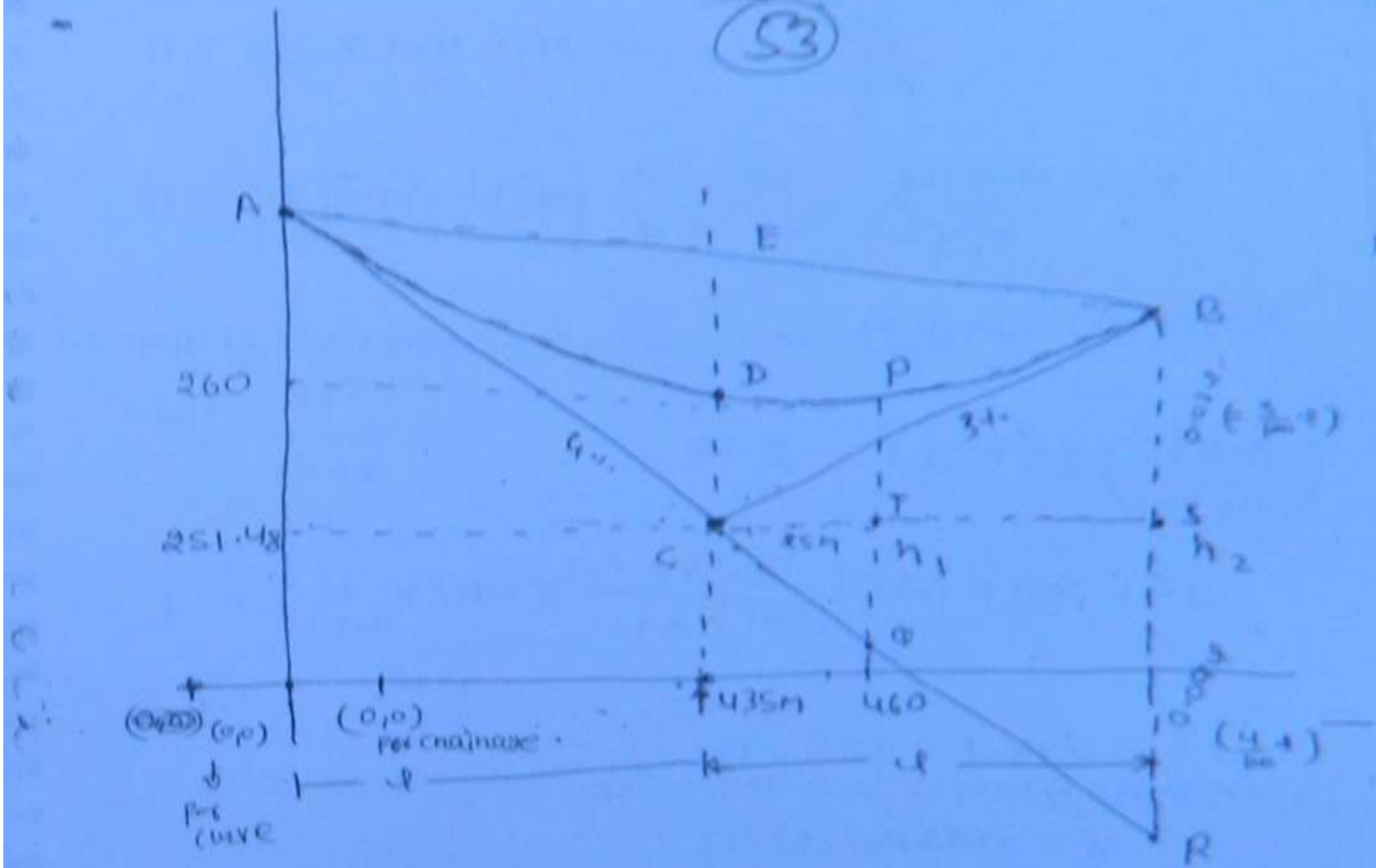
Soln

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   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

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

$h_2 = kx^2 = k(2l)^2 = 0.07l$

↳ for point B (x = 2l)

$k = \frac{0.07l}{4l^2} = \frac{0.07}{4l}$ — (2)

from (1) and (2)

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

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

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

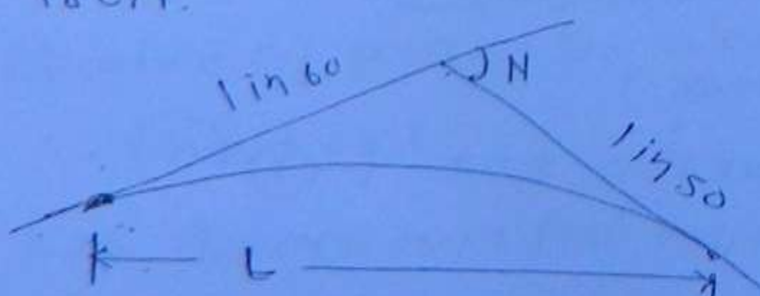
$l = ~~492~~\ 492.73$

Total length of curve

$L = 2l = 985.46\,m$

Ques. 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.

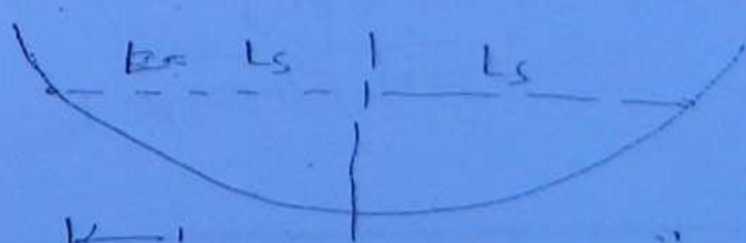
ES 2008 Que. A valley curve of a straight Highway is formed by a down gradient 1 in 20 meeting an up gradient 1 in 30. Design the length of valley curve to fulfill both comfort condition and head light sight distance condition.

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

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)

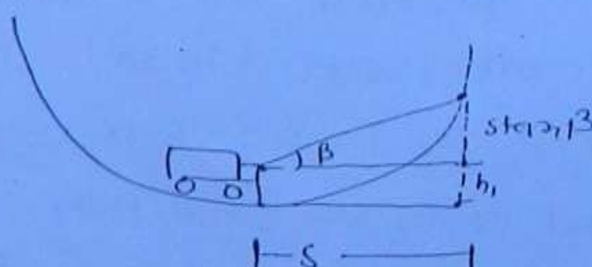
$$N = \left(\frac{1}{N_1} - \frac{1}{N_2}\right) = \left|-\frac{1}{20} - \frac{1}{30}\right| = \frac{50}{600}$$

$$L = 2\times\left[\frac{\frac{50}{600}\times(0.278\times 80)^3}{0.60}\right]^{1/2}$$

$L = 782\ m$

(2) Head light side distance

[Exp: $S\% = 0$ because half upward and half down gradient]



Assuming $L_c > S$

S = stopping sight distance

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

[$S\% = 0$]

$$S = 0.278\times 80\times 2.5 + \frac{(0.278\times 80)^2}{2\times 9.81\,(0.35 \pm 0)}$$

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

(57)

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

= 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
- → Informatary sign → Just for information

Imp ✓ → Traffic signal

→ Traffic Island

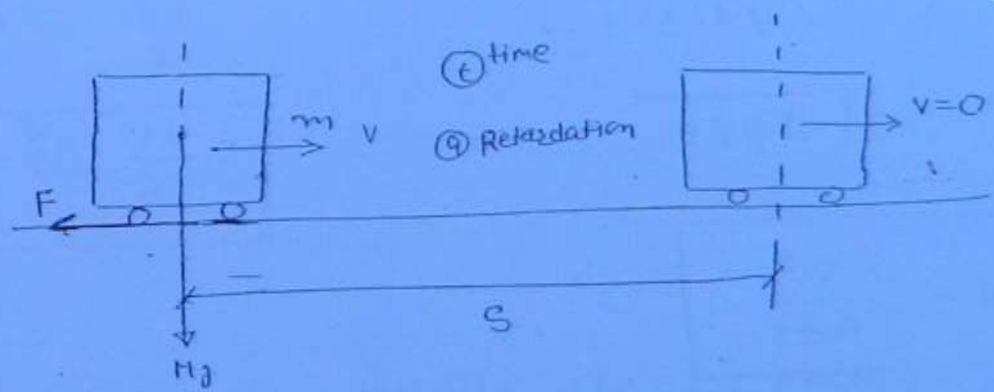
- Imp → Rotary design
  → Design of intersection & grade separation
  → Parking and lighting

(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.

K.E. lost = work done

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

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

$F = f \cdot mg$

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

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

$$v = \sqrt{2gfs}$$

$$\boxed{f_{observed} = \frac{v^2}{2gs}}$$

If time taken = t sec.

retardation = a

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

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

a = -ive = 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.

(61)

$$\boxed{f = \frac{a}{g}}$$

f = average skid resistance

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

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

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

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

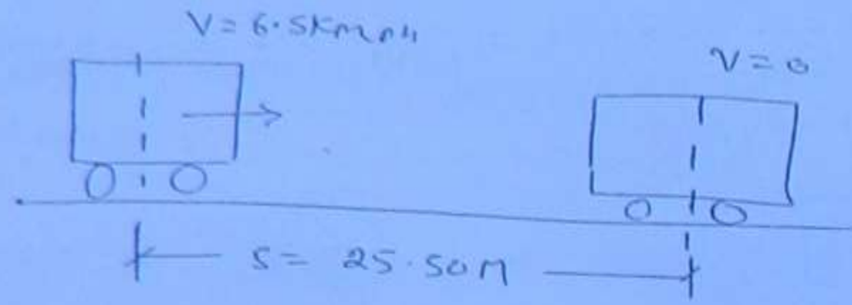
$$\boxed{S = \frac{vt}{2}}$$

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.



$V = 25.50m$

$V = 65 \text{ Kmph} = 0.278 \times 65 = 18.07 \text{ m/sec}$

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

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

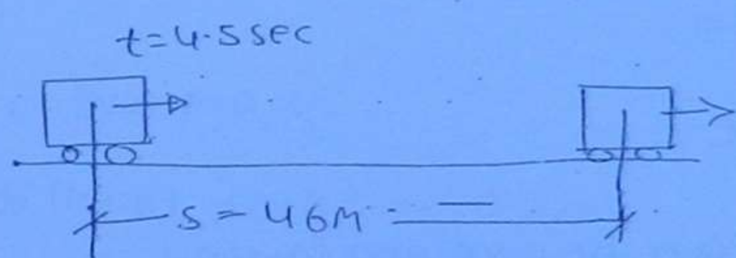
$a = \frac{V}{t} = \frac{18.07}{2.82} = 6.40 \text{ m/sec}^2$

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

1. Initial speed of vehicle
2. Average skid Resistance
3. retardation.

(63)

Soln



(1) s = 46m , (2) t = 4.5sec

(1) Initial speed (V)

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

$$V = \frac{2S}{t} = \frac{2\times46}{4.5} = 20.444\ m/sec$$

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

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

$$= \frac{(20.444)^2}{2\times9.81\times46} = 0.463$$

(3) Retardation

$$a = gf$$

$$= 9.81\times0.463 = 4.54\ m/sec^2$$

raffic study :-

raffic volume :-

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, AutoRicshaw	1.0
② Bus, truck, Agricultural tractor - trailer unit	3.0
③ Motor cycle, scooter, pedal cycle —	0.5
④ cycle Rikshaw	1.5
⑤ Horse drawn vehicles	4.0
) small bullock cart and Hand cart	6.0
) Large bullock cart	8.0

(2) Trend Chart :-

showing volume trends over a period of years.

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

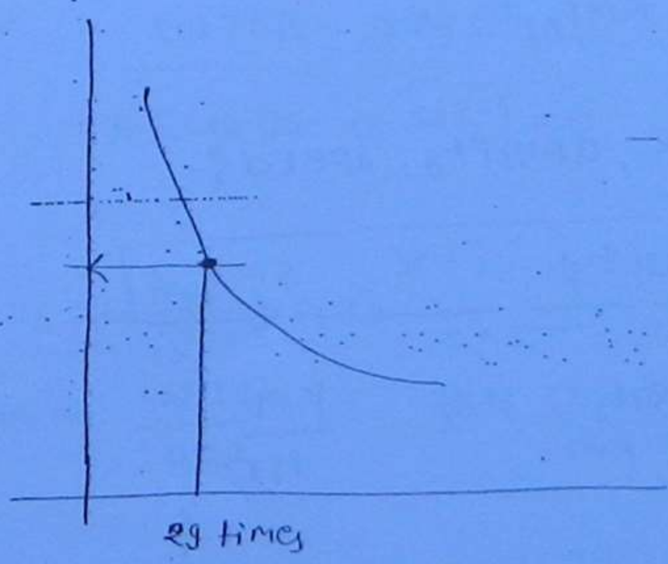
(3) Variation Charts :-

showing variation of volume.

(4) Traffic flow maps:-

— : on different routs.

(5) 30^{th} higest hourly volume

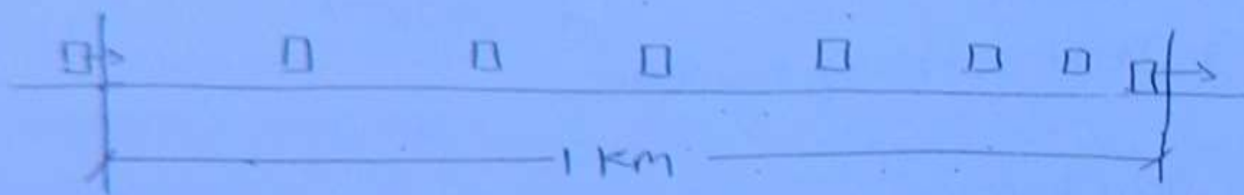


The value that has been Exceeded 29times is called 30^{th} higest hourly volume.

Traffic density:-

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

(66)



unit = vehicle/km

speed of vehicle = km/hr

Relation b/w volume, density, speed:-

| volume = density × 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)

Soln

$$v = 42.76 - 0.22K$$

capacity of road
(volume that can be accomodated on road)

C (volume) = density × speed

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

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

For C = 0

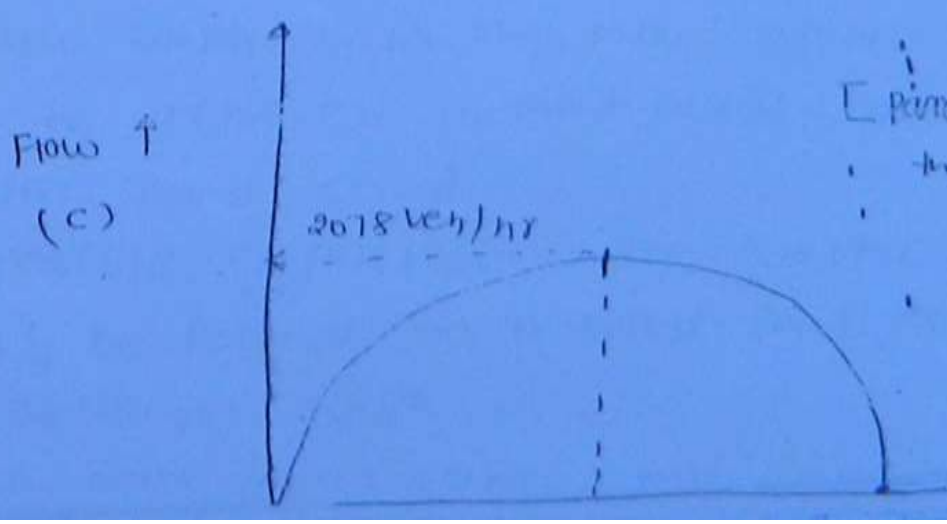
$$42.76K - 0.22K^2 = 0$$

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

$$K = 0$$

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

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



[parabolic Equation from parabolic variation]

For c to be Max^m

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

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

(68)

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

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

$$= 2.78 \text{ km/hr}$$

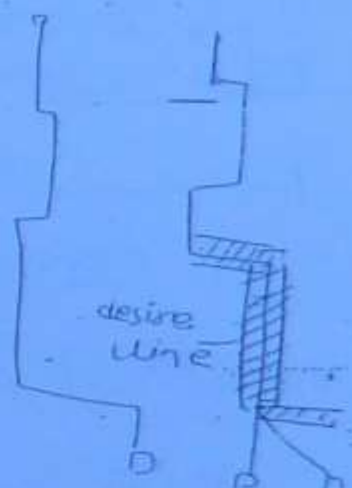
1) origin and destination study :- (O and D study)

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

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 cond - Basic capacity.

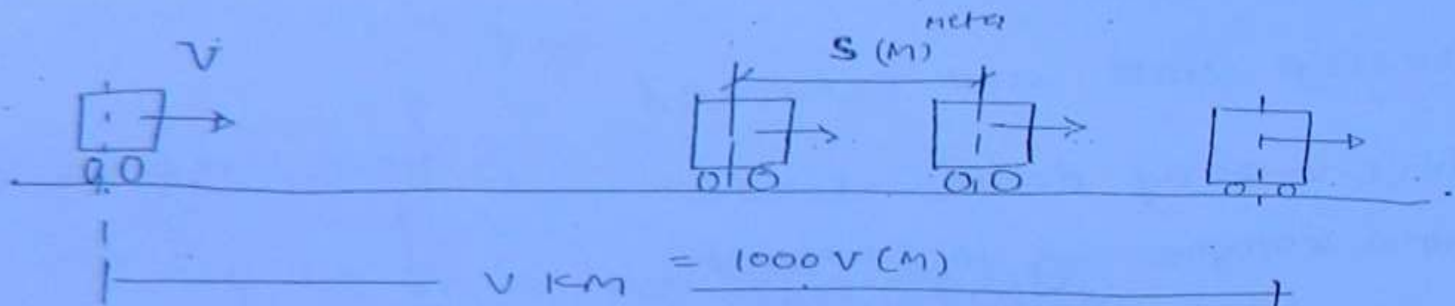
$0 \leq$ Posible Capacity $\leq$ Basic capacity

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 hours.

theoritical Max. capacity

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

V = Speed in Kmph

S = Minimum distance b/w two vehicles

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

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

$= (0.2V + 6)$

0.7 sec = perception reaction time

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

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

one vehicle pass in t_h sec.

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 head way b/w two vehicles = 2.5 sec.

Soln

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

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

$= 0.2 \times 65 + 5.2 = 18.20$

theoritical capacity (max^m)

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

(2) As per time headway = 2.5 sec

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

(5) Accident study :-

Type :-

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

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

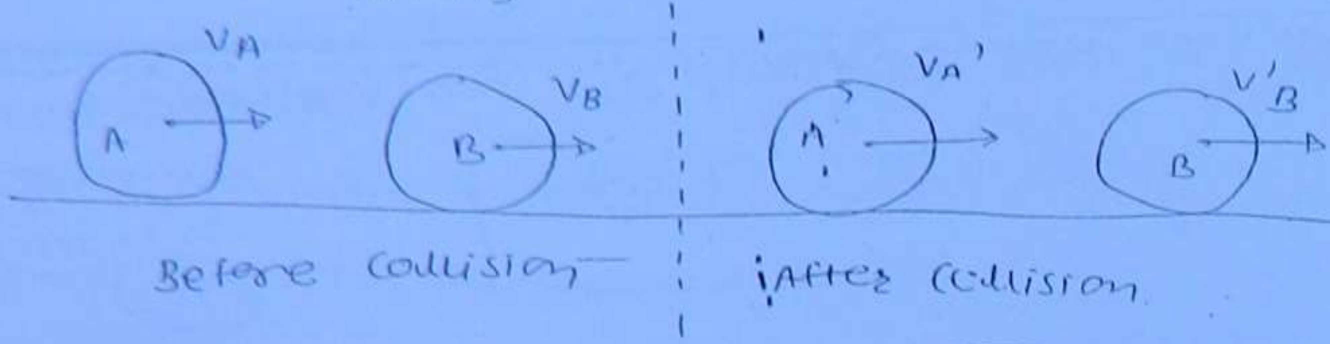
(3) A moving vehicle collide with any object

(4) Head on collison

... of two bodies :-

$V_B' > V_A'$

$V_A > V_B$



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For collision $V_A > V_B$

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 bears 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

$e = 1.0$

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

$$(V_B' - V_A') = (V_A - V_B)$$

(2) perfectly plastic collision

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

$$V_B' - V_A' = 0$$

$$V_B' = V_A'$$

it means both body will move without seperation

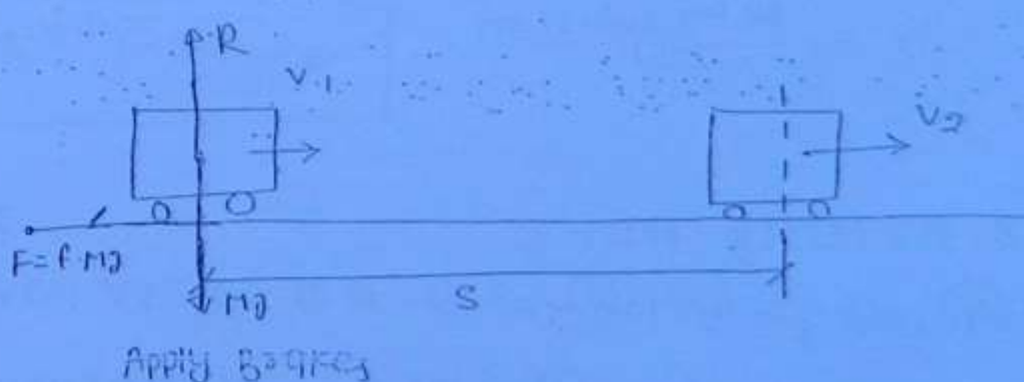
momentum Equation :-

: (As per conservation of energy)

Total momentum befor collision

= Total momentum after collision

$$m_A \cdot V_A + m_B \cdot V_B = m_A \cdot V_A' + m_B \cdot V_B'$$



→ movement of vehicle when brakes are applied

Brake efficiency = 100%

K.E lost = work done

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

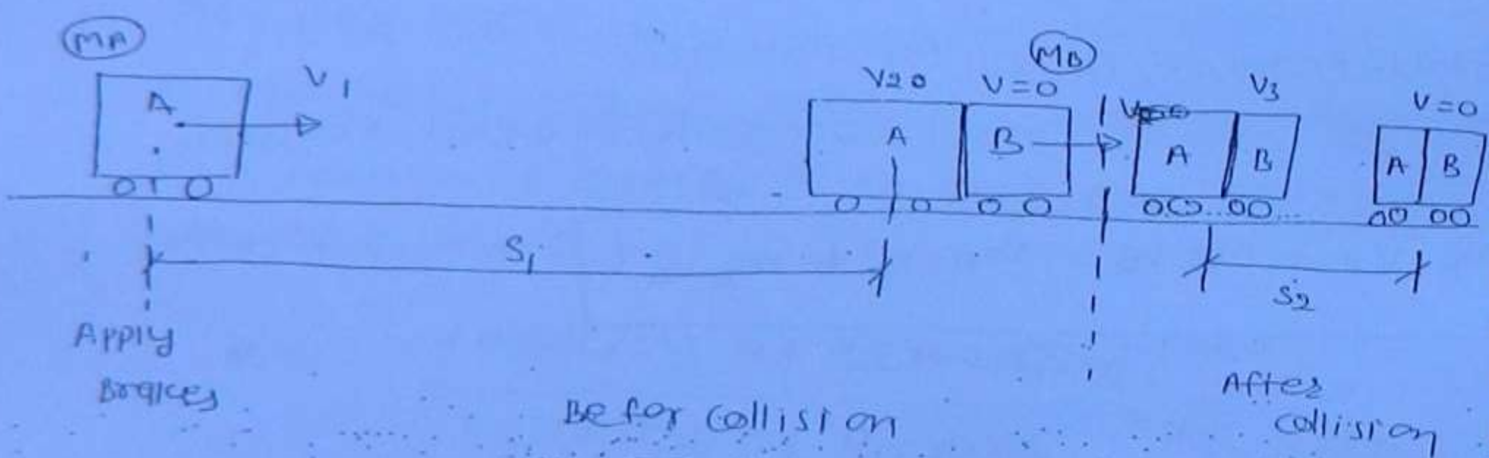
$$= f \cdot mg \cdot S$$

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

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

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

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



Assumption:-

1) Collision is perfectly plastic
2) Brake efficiency is 100 %.

Befer 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 :-

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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:-

(a) Given values (1) S_1 (2) S_2 (3) m_A (4) m_B (5) f

(1) calculate v_3 from Eq (3)

(2) calculate v_2 from Eq (2)

(3) calculate v_1 from Equation (1)

Ques- A vehicle apply brakes and skid through
2016
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 steps and assumptions in each step.

Ans

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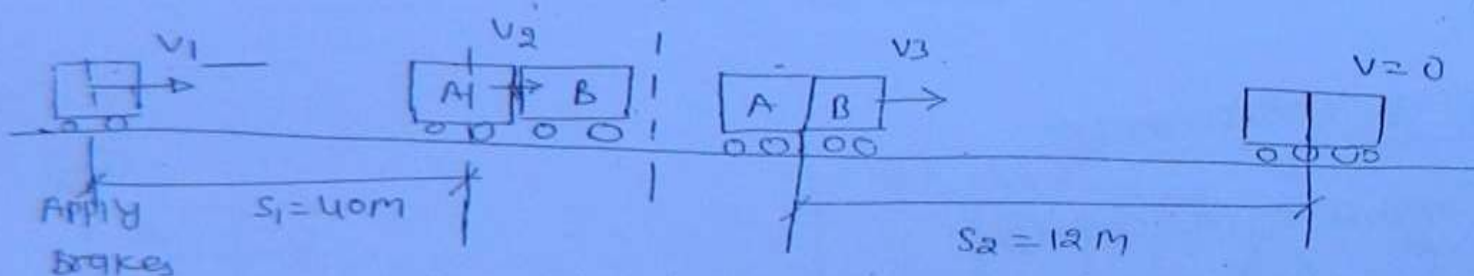

$W_B = 0.60 W_A$

$M_B = 0.60 M_A$

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

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

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

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

③ before collision for (A)

$$v_1^2 - v_2^2 = 2gfs_1$$

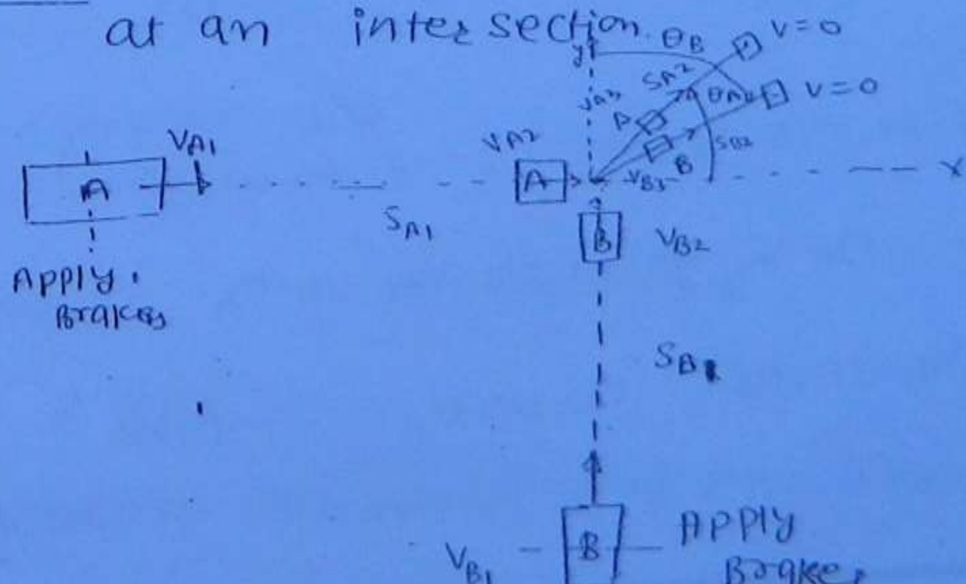
$$v_1 = \sqrt{v_2^2 + 2gfs_1}$$

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

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

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

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 :-

(78)

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)

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

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

(3) 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)

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

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

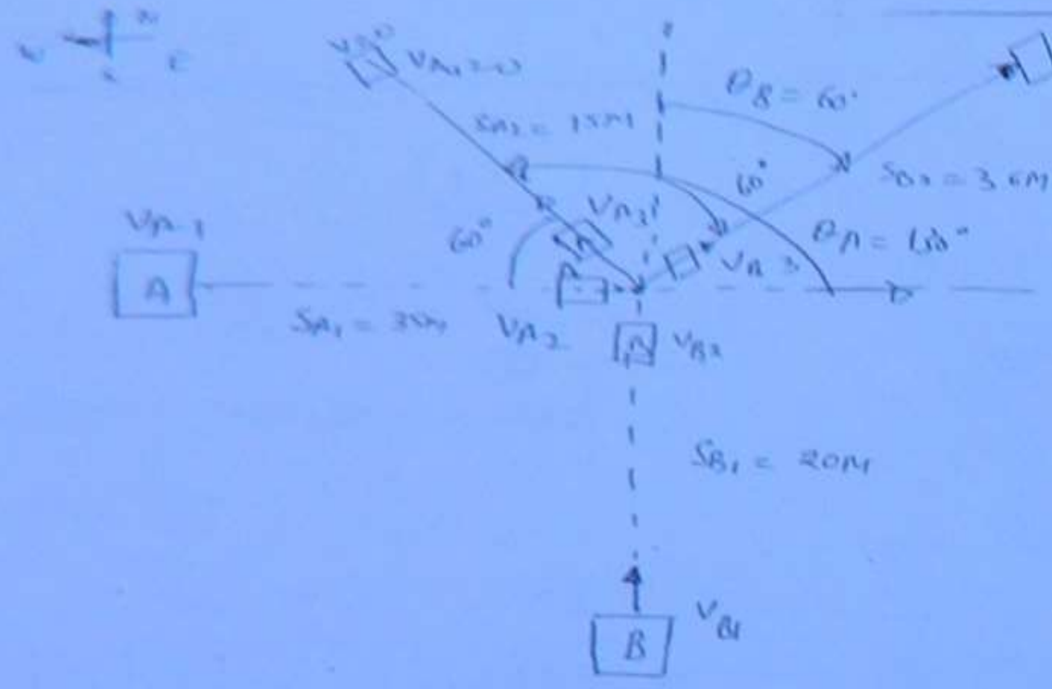
SA 96

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

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

for B $V_{B3} = \sqrt{2 \times 9.81 \times 0.55 \times 36} = 19.71\ M/sec.$

momentum Equation

$\theta_A = 130°, \quad \theta_B = 60°$

In the dirn of (A) → x-dirn

$M_A \cdot V_{A2} + M_B \cdot 0 = M_A\, V_{A_3} \cos\theta_A + M_B \cdot V_B \cdot \sin\theta_B$

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

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

$V_{A2} = 14.58\ M/sec.$

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

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

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

(81)

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

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

(3) before collision

for (A)

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

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

$= 87.35$ kmph.

For B

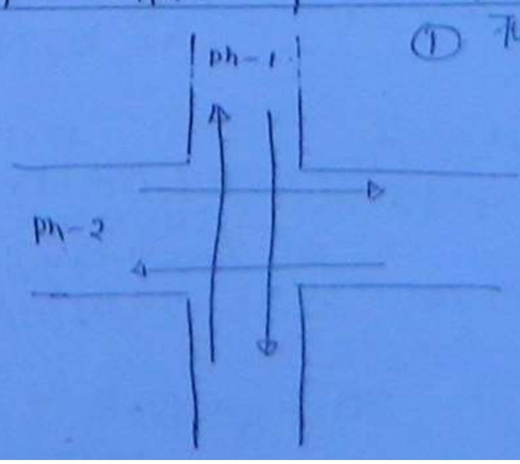
$V_{B1} = \sqrt{V_{B2}^2 + 2gf \cdot S_{B1}} = \sqrt{(17.16)^2 + 2 \times 9.81 \times 0.55 \times 20}$

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

* Design of signal timing :-

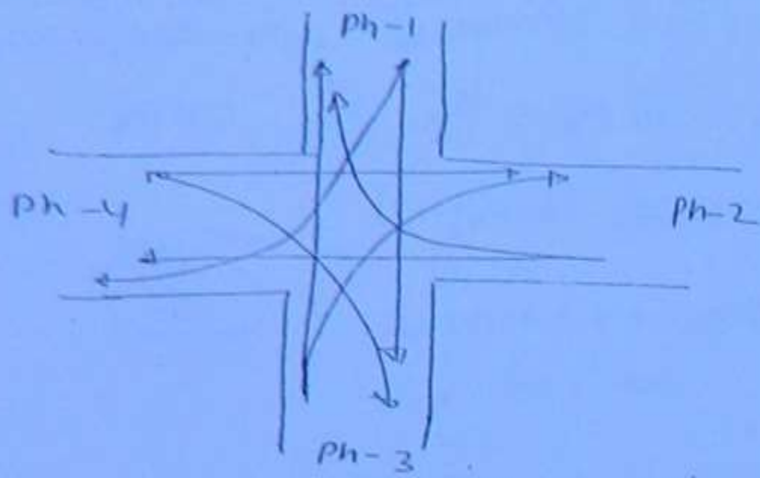
General principle of signal design:-

Types:- (1) Twophase system:-

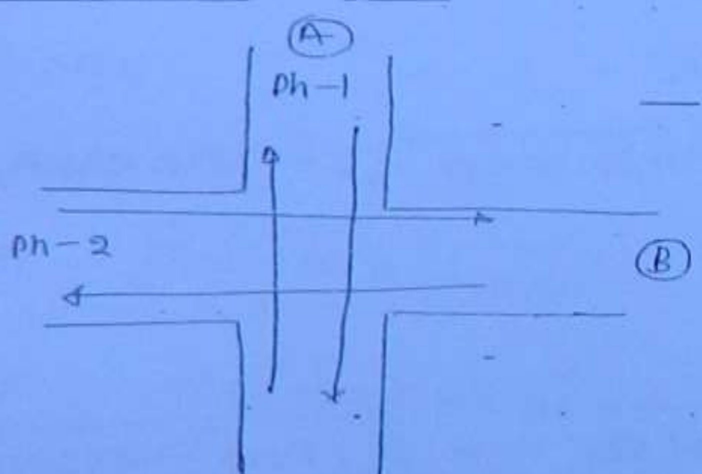


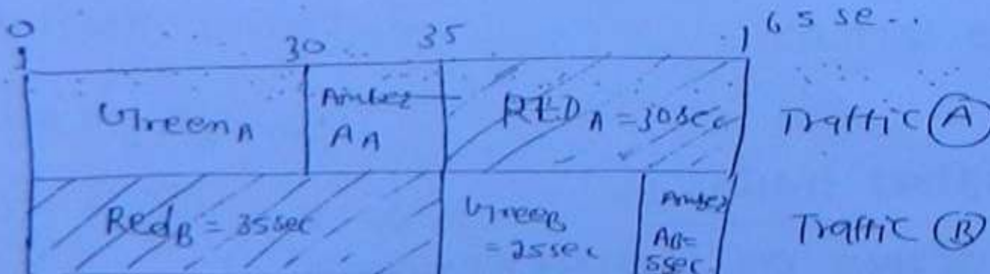
Ph – Phase

② Four phase system:-



For Two phase system:-





Properties:-

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

$R_A = G_B + A_B$

$R_B = G_A + A_A$

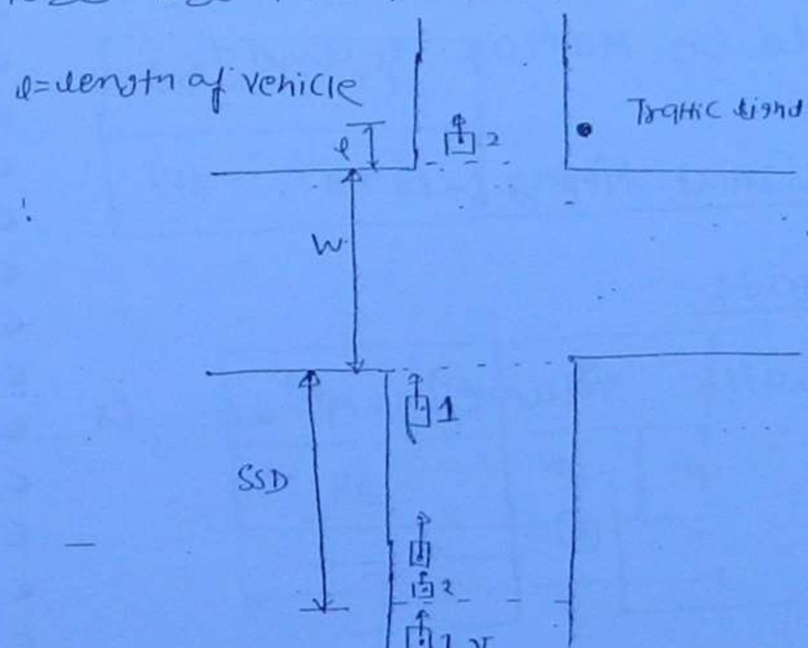
2)- Green time on two roads is decided as per traffic volume on two roads

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

(83)

(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)

(Min^m time required to stop the vehicle (Amber time required)

t_R = perception Reaction time

$= t_R +$ Braking time $= t_R + \frac{v}{a}$

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

to allow all these vehicle that are in danger area (within SSD line) to go

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

$$\text{time} = \frac{\text{Total distance}}{\text{velocity}} = \frac{(SSD + W + L)}{V}$$

$$t_2 = \left(\frac{SSD + W + L}{V}\right)$$

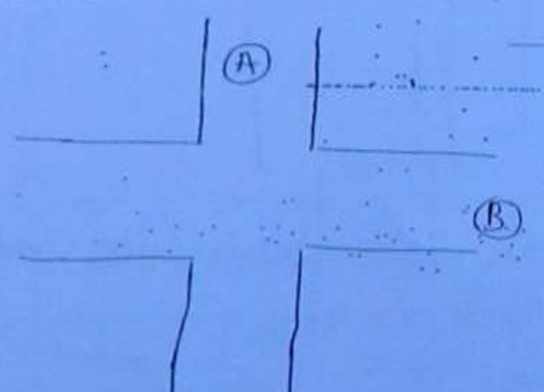
(84)

Amber time should be Max^m of t_1 and t_2.

<u>Methods for design signal timing :-</u>

<u>1) Trial cycle method :-</u>

- 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

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

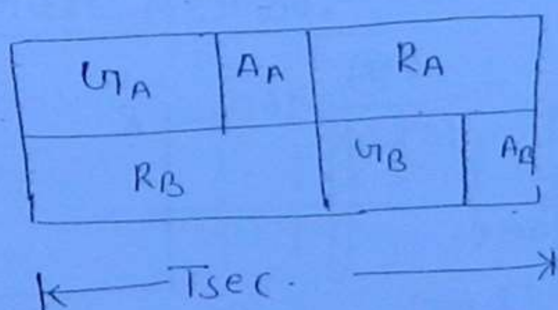
$$x_B = \frac{n_B}{15 \times 60} \times T$$

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

→ Green time required on two roads

$$G_A = x_A \times t_h$$

$$G_B = x_B \times t_h$$



→ 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.

ex- 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.

(86)

Sol

$n_A = 150$ veh / 15 min / lane

$n_B = 120$ veh / 15 min / lane

Trail ①

Assume cycle time = 60 sec.

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

$$\therefore x_A = \frac{n_A}{15 \times 60} \times T = \frac{150}{15 \times 60} \times 60 = 10$$

$$x_B = \frac{n_B}{15 \times 60} \times 60 = \frac{120}{15 \times 60} \times 60 = 8$$

Time headway = t_h = 2.5 sec.

Green time required

$G_A = 10 \times 2.5 = 25$ sec.

$G_B = 8 \times 2.5 = 20$ sec.

Total cycle time

$= (G_A + t_m) + (G_B + t_B)$

$= (25+5) + (20+5) = 55$ sec.

2nd Method

Question No Homework = $n_A = 300$, $n_B = 180$

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

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

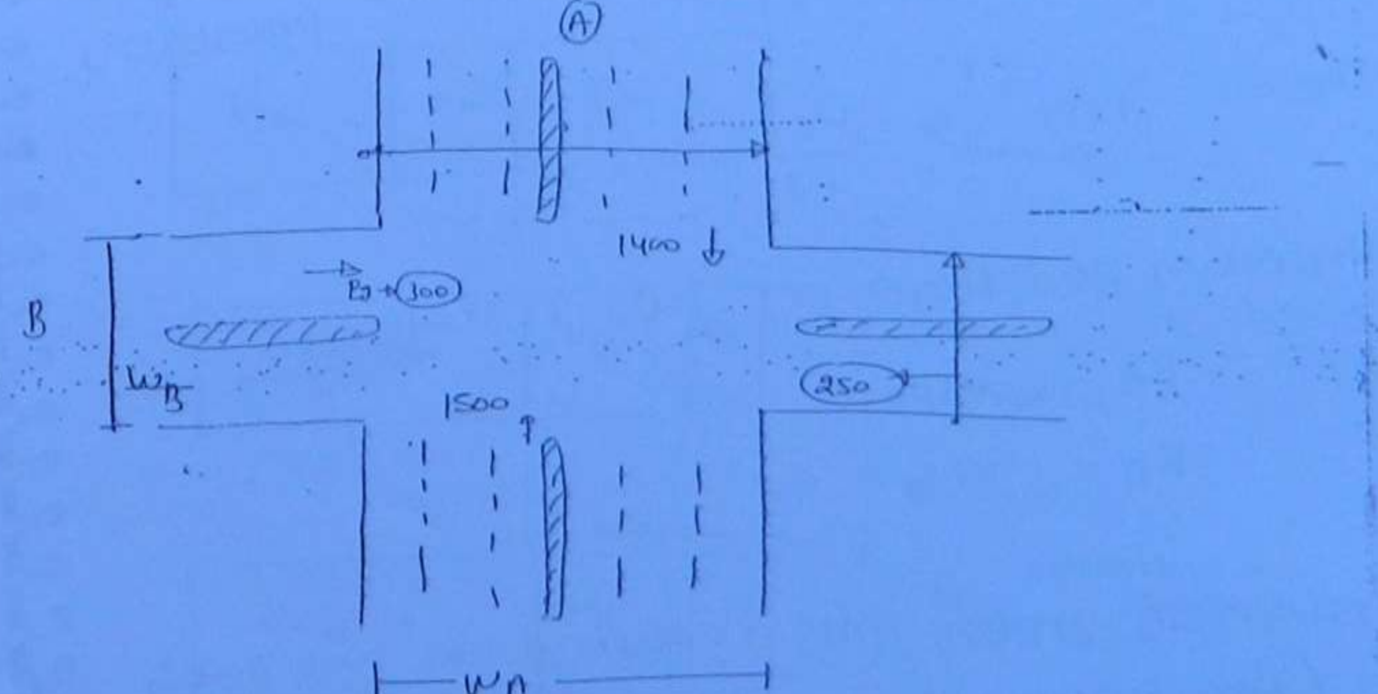
$$= \left(\frac{n_A}{15 \times 60} \times T \times t_h\right) + 5 + \frac{n_B}{900} \times T \times t_h + 5$$

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

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

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

(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.

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

↓

(initial walk period)

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

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

minimum Red time on two roads.

$R_A = G_{PA}$

$R_B = G_{PB}$

Minimum green time required on two Roads (for traffic)

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

$R_B = G_A + A_A \Rightarrow G_A = R_B - A_A$

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

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

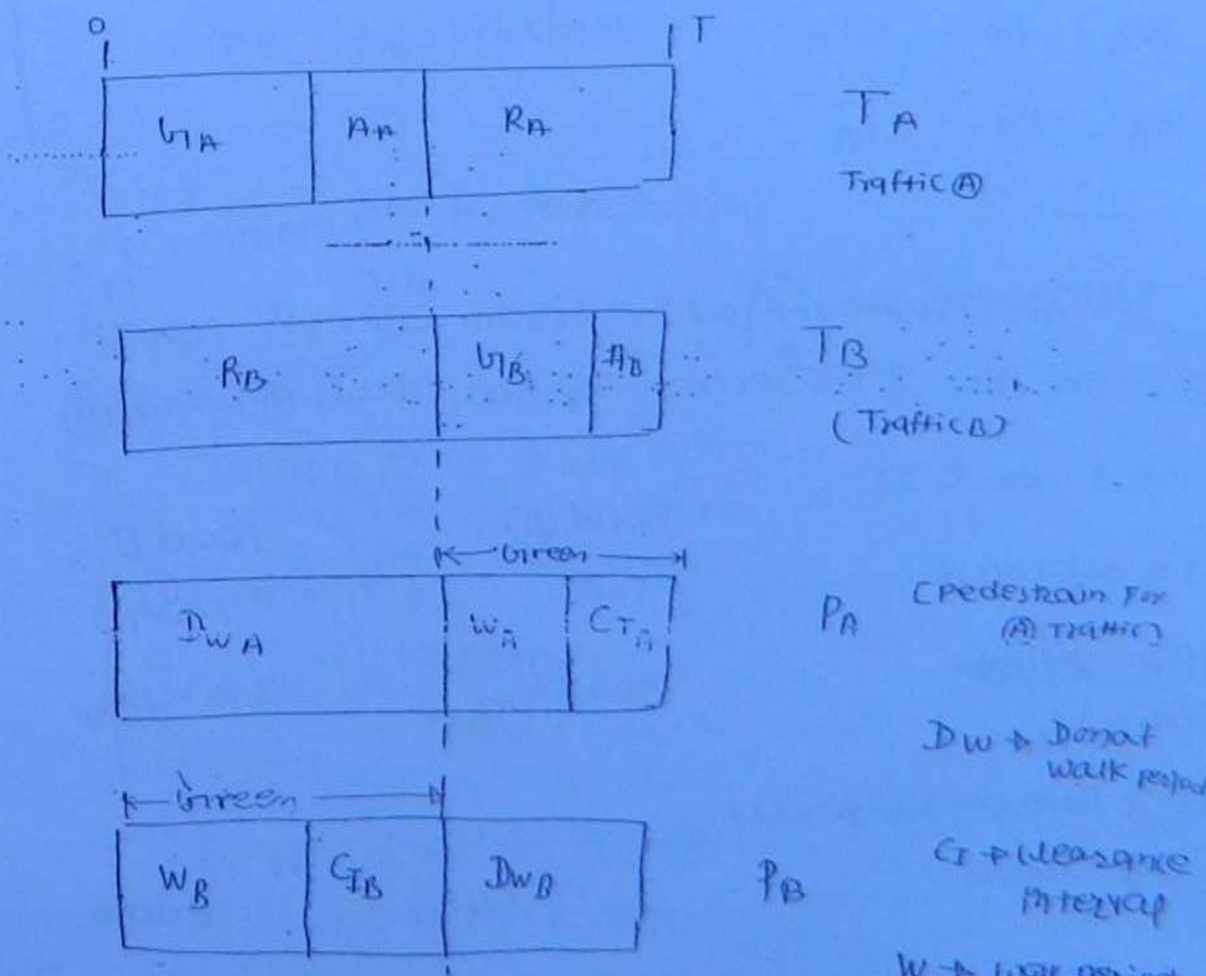
[Maxm of G_A and G_B is choosen]

If G_B is consider than G_A calculate

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

(5) Total cycle time

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



i) - $R_A = G_B + A_B$

$R_B = G_A + A_A$

7) Do not walk period [pedestrain signal]

$DW_A = G_A + A_A$

$DW_B = G_B + A_B$

(96)

8) Clearance interval

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

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

i) walk period on two roads

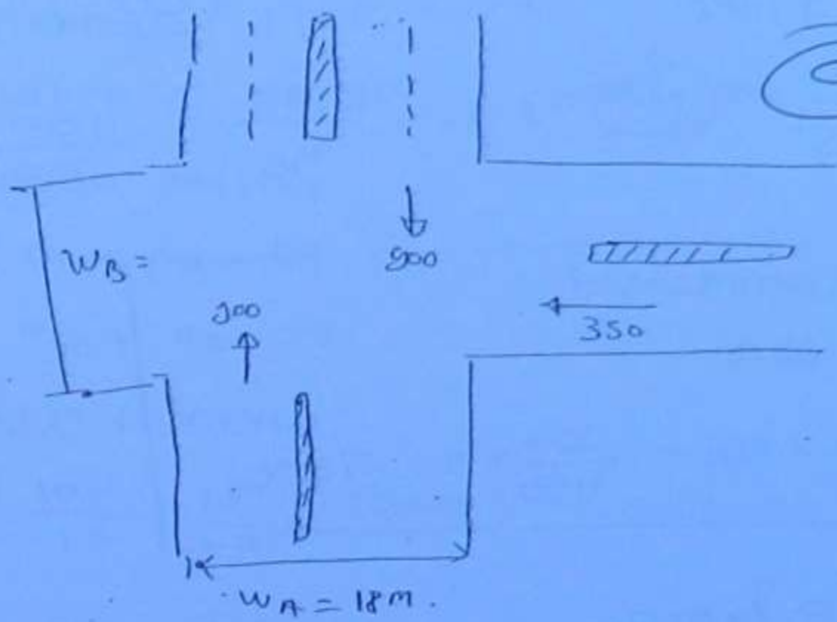
$W_A = R_A - CI_A$

$W_B = R_B - CI_B$

<u>ues.</u> Using Approximate method, design signal timing on an intersection of two roads (A) and (B)

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

Sol



Design vol/lane on two roads

n_A = 50 v/hr/lane

n_B = 350 v/hr/lane.

Step
(1) minimume for pedestrain

$G_{PA}\ \frac{W_A}{1.2} \Rightarrow 7 + \frac{18M}{1.2} = 22sec.$

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

(2) minimue on traffic

22sec.

14sec.

(3) minimme on traffic

G 14-5 = 9sec.

G 17 sec.

Let us consider max^m

$u_{TB} = 17sec$

$$\frac{u_{TA}}{u_{TB}} = \frac{n_A}{n_B} \Rightarrow u_{TA} = \frac{u_{TB}\, n_A}{n_B} = \frac{450}{350} \times 17 = 21.86$$

$\approx 22sec$

If u_{TA} is considered

$u_{TA} = 9sec.$

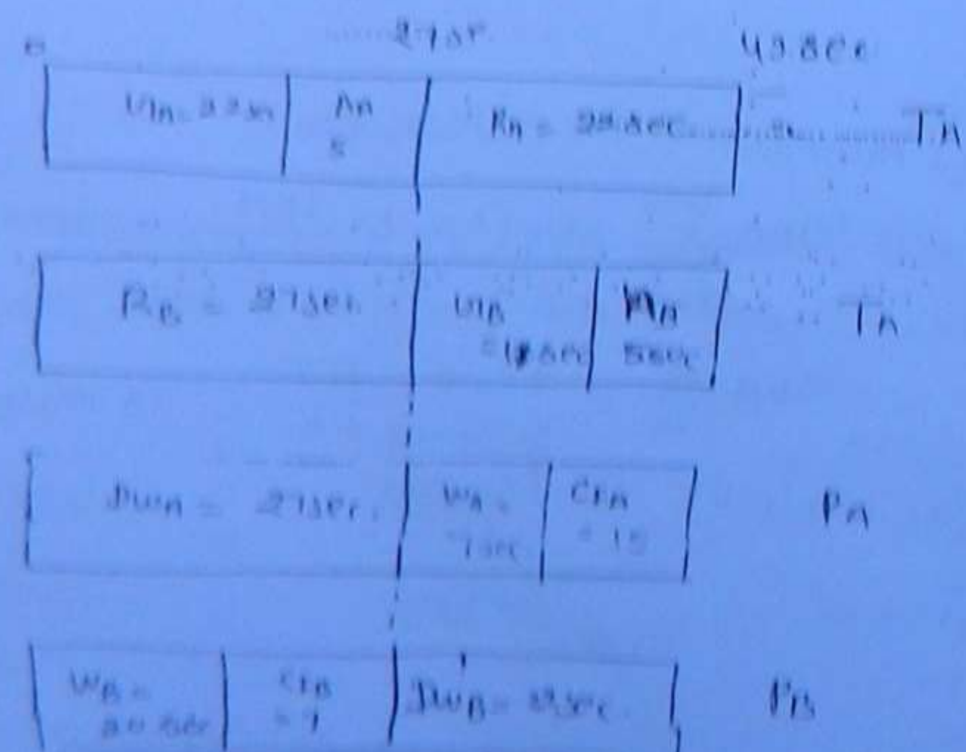
$$u_{TB} = \frac{n_B}{n_A} \times u_{TA} = \frac{350}{450} \times 9 = 7sec$$

) Total cycle time

$T = (u_{TA} + m_A) + (u_{TB} + m_B)$

$= (22+5) + (17+5)$

$= 49sec.$



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

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

(7) Do not walk period

$DW_A = G_A + A_A = 27$

$DW_B = G_B + A_B = 22$

(8) Clearance interval

$CT_A = \frac{W_A}{1.2} = \frac{18}{1.2} = 15\,sec$

$CT_B = \frac{W_B}{1.2} = \frac{7.5}{1.2} = 6.25 \simeq 7\,sec.$

(9) Walk period

$W_A = 22 - 15 = 7\,sec$

$W_B = 27 - 7 = 20\,sec.$

3) Websters Method :-

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	5.0
S (saturation flow)	1850	1890	1950	2250	2550

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.

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

(4) Green time required on two Road

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

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

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

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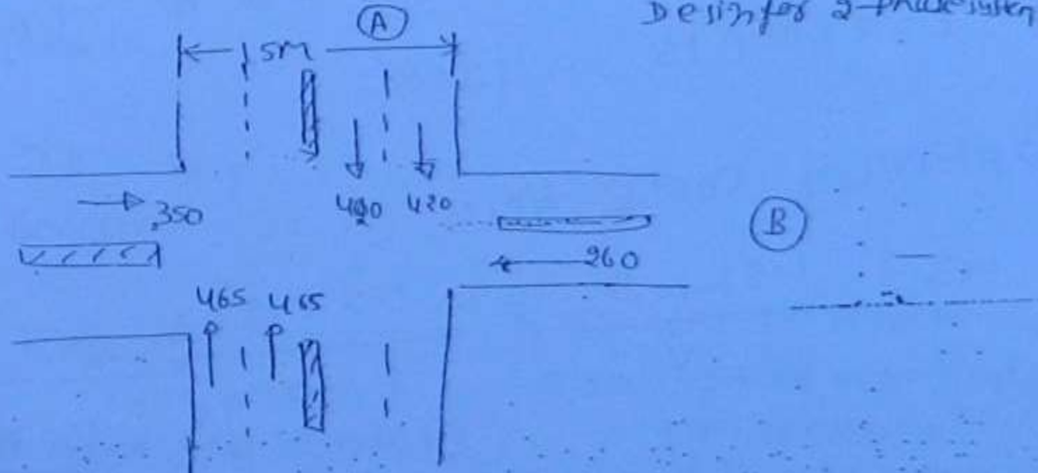
	Road (A)	Road (B)
width of road	15 m	8 m
Nos of Lanes	4 M	2 M
Normal flow in one direction	465 veh/hr/lane	350 veh/hr/lane
In opposite dirn.	420 veh/hr/lane	260 veh/hr/lane

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

Soln



(1) 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.

∴ $L = 2n + R$; ∵ no. of phase - ② [R = 15 sec, given] Standard]

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

) optimum cycle time

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

$= 58$ 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.

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

$\simeq 17$ sec.

total cycle time = $G_A + A_R + G_B + A_R$ = 22.5 + ...

(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

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

(2) on Road B for x_B vehicle

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

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

$G_{Amin} < G_A$ Hence O.K.

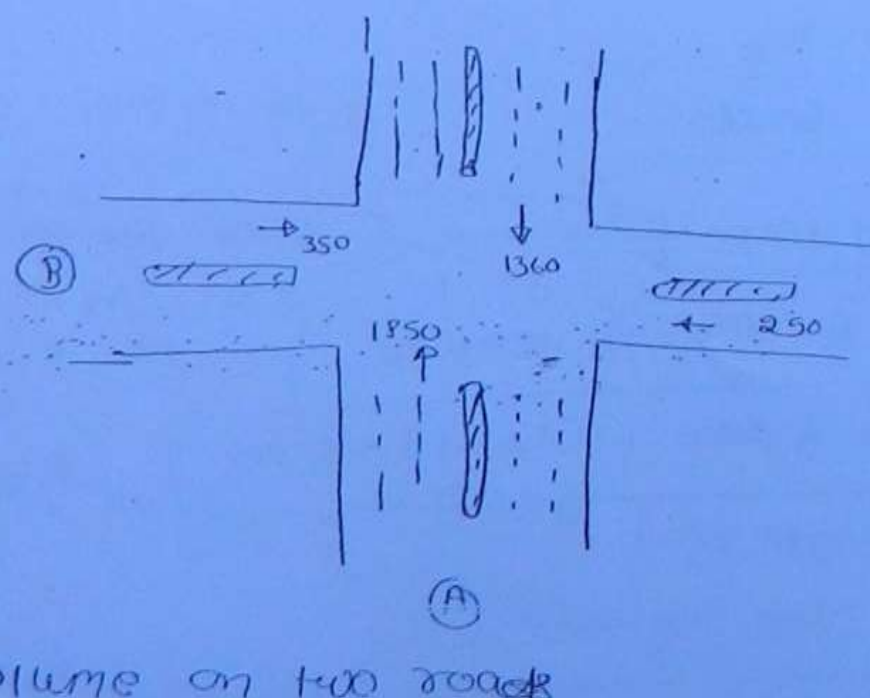
G_{Bmin} ...

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 dir^n	1850 veh/hr	350 veh/hr
other direction	1360 veh/hr	290 veh/hr
Amber time	5 sec.	5 sec.

Sol^n



1) 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 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 Road 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.

∴

Websters 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 part 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

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

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

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

Total loss time

$$L = 2n + R$$
$$= 2\times2 + 16 = 20\ sec.$$

Optimum cycle time

$$C_o = \frac{1.5L+5}{1-y} = \frac{1.5\times20+5}{1-0.476} = 67\ sec.$$

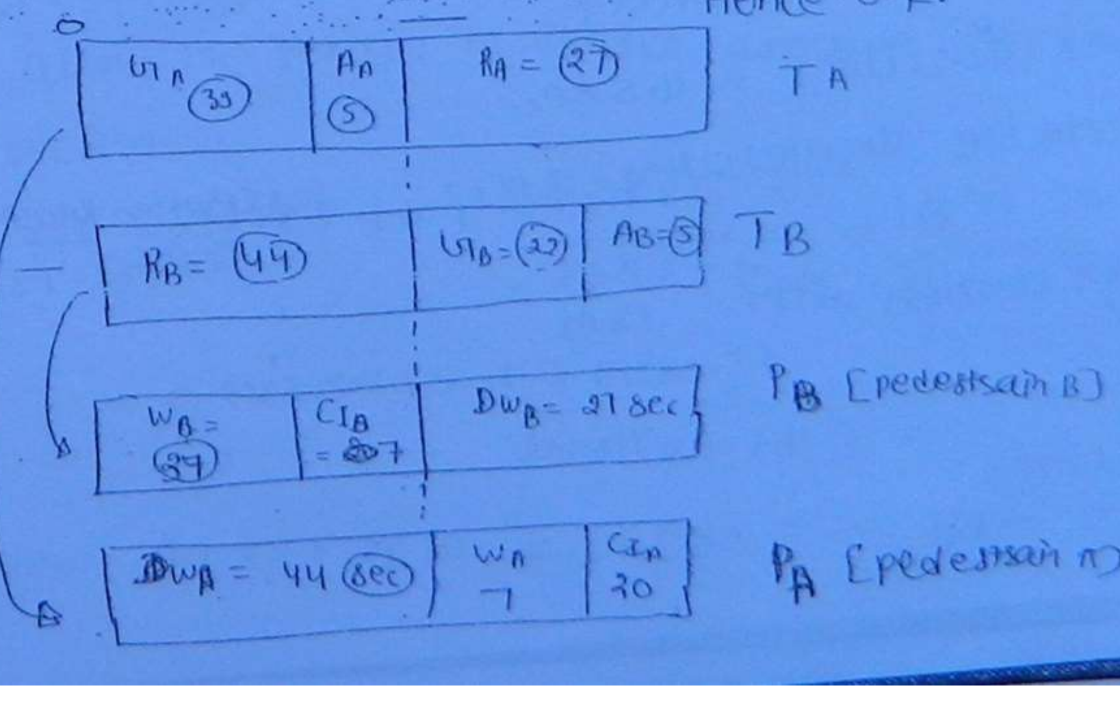
$$\therefore G_A = \frac{y_A}{y}(C_o - L) = \frac{0.294}{0.476}(67-20) = 29\ sec.$$

$< G_A\ (39)$ hence o.k

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

$= 18\ sec < 22\ sec, (G_B)$

Hence o.k.



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

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

Donal walk period

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$DW_A = G_A + A_A = 44$ sec.

$DW_B = G_B + A_B = 27$ sec.

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

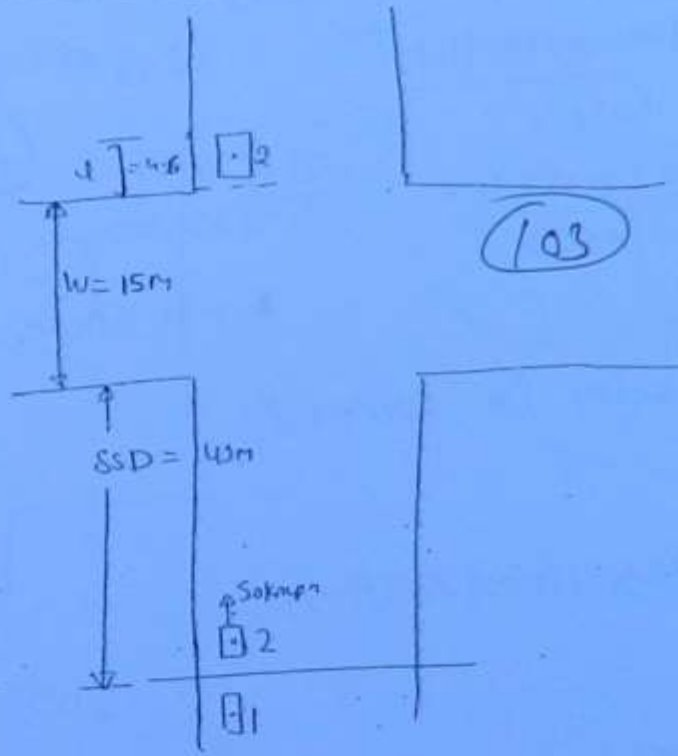
mber duration = 4.5 sec.

mfortable deceleration = 3 m/s2

Perception Reaction time(t_R) = 1.5 sec.

car length = 4.6m

Intersection width = 15 m



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

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

Consider $S = 0$

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

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

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

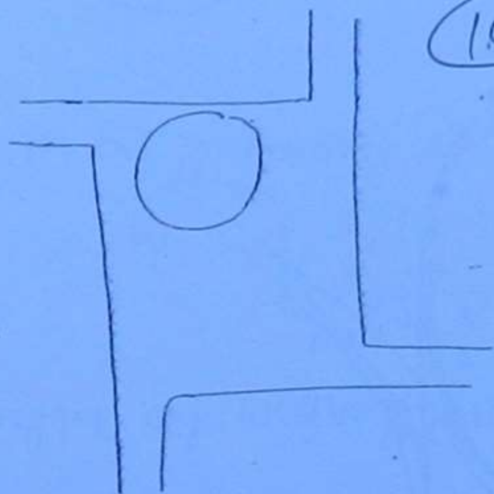
Design of Rotary intersection :-

Types:-

) Circular Rotary.

Elliptical Rotary

3- Turbine Rotary :- (4) Tangential Rotary



(2) Design speed :-

Rural Area = 40 Kmph

urban area = 30 kmph

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

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

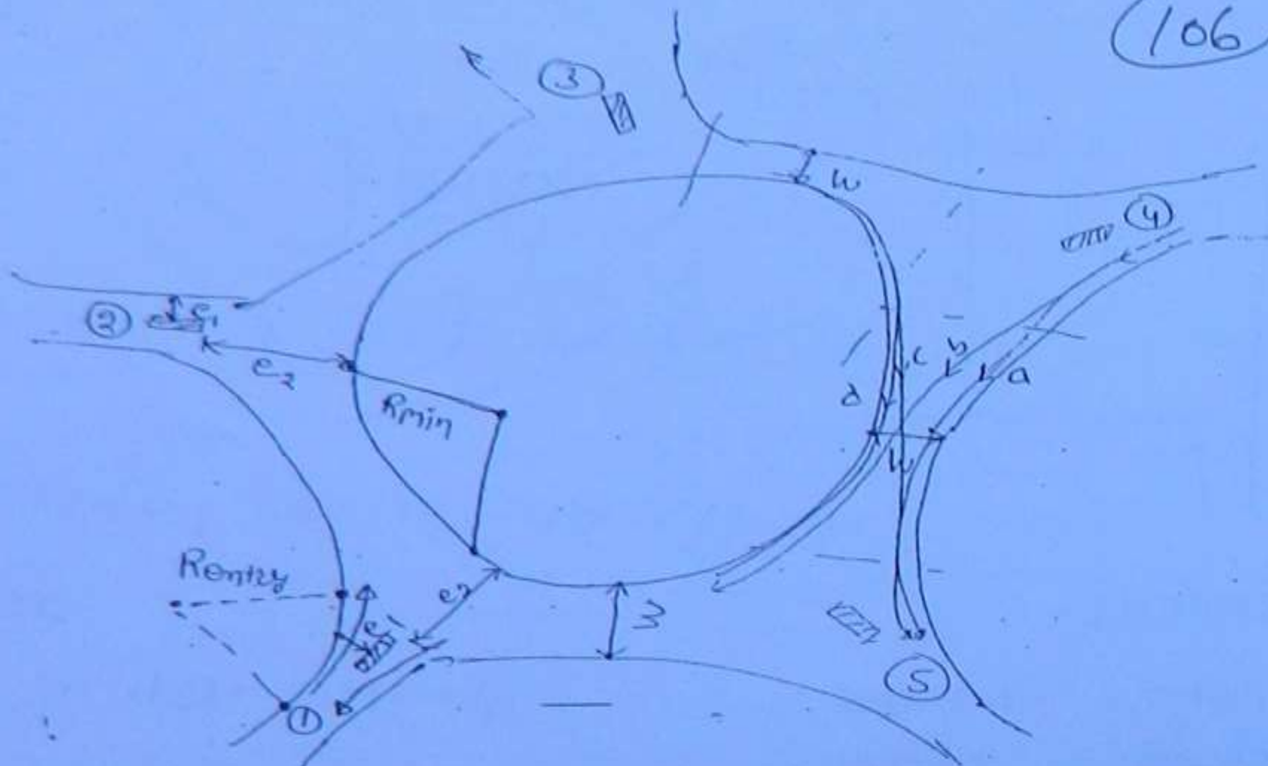
$e = 0$

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

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

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

f = 0.47 → Urban Area [30 kmph]



4) As per IRC

Radius of entry [Rentry]

Rural area = 20 to 35 m (40 kmph)

Urban area = 15 to 25 m (30 kmph)

- Minimum Radius of Central Island

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

) Width of carriageway

1) At entry e_1

Minimum = 5.0 m

As per Approach road width | e_1

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

(2) At non weaving section (e_2)

= e_1 [if no value suggested or given]

(3) width of weaving section

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

(4) Length of weaving section

L = 4·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

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

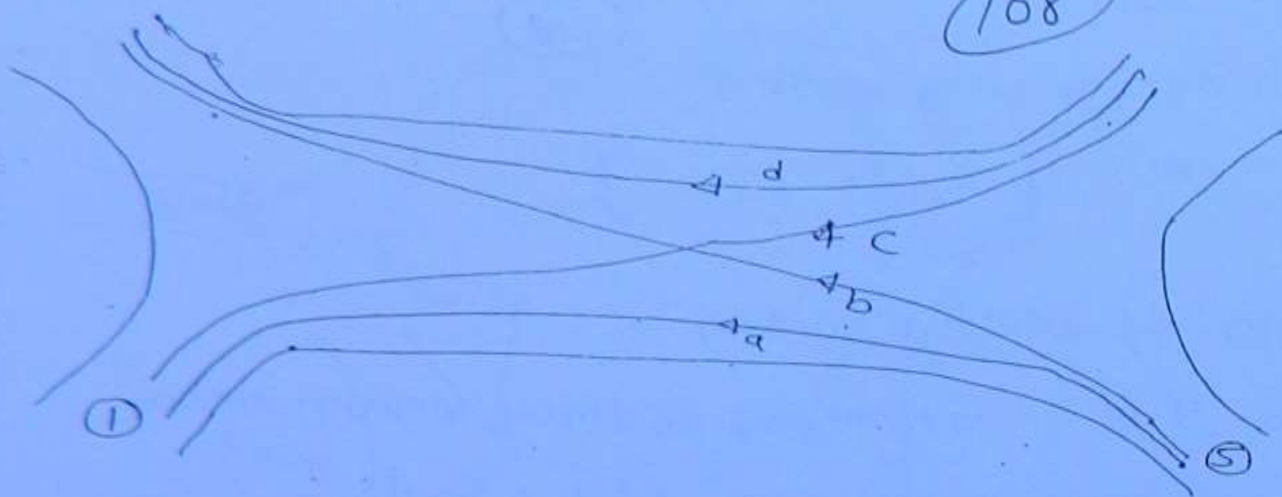
$$e = \frac{e_1 + e_2}{2}$$

L = Length of weaving section

p = weaving ratio

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

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



Weaving ratio

- Imp → only clockwise moments is possible

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

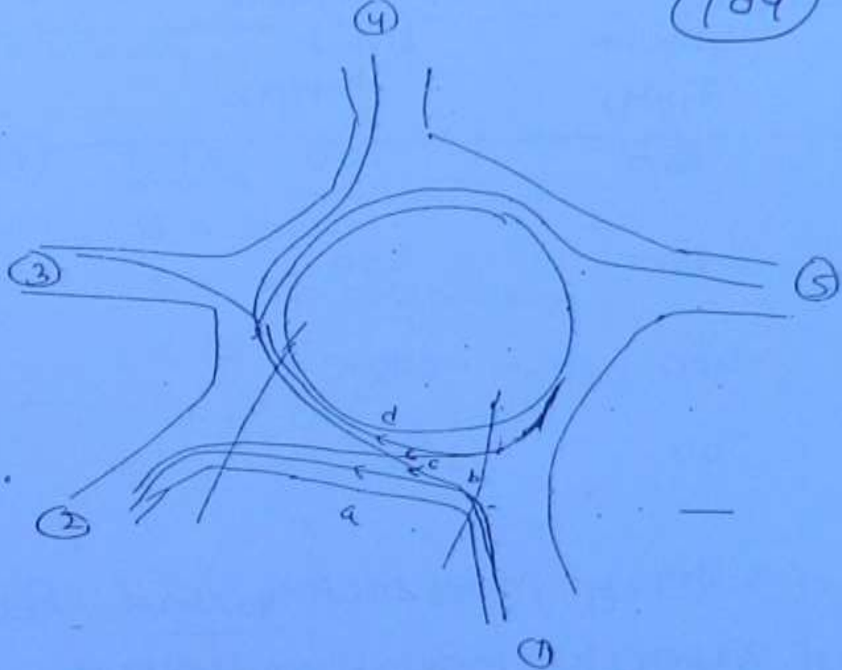
It is the ratio of Number of weaving traffic (crossing to each other) to the total Number of traffic in one weaving portion between any two leg.

e. 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 (PCC/hr)

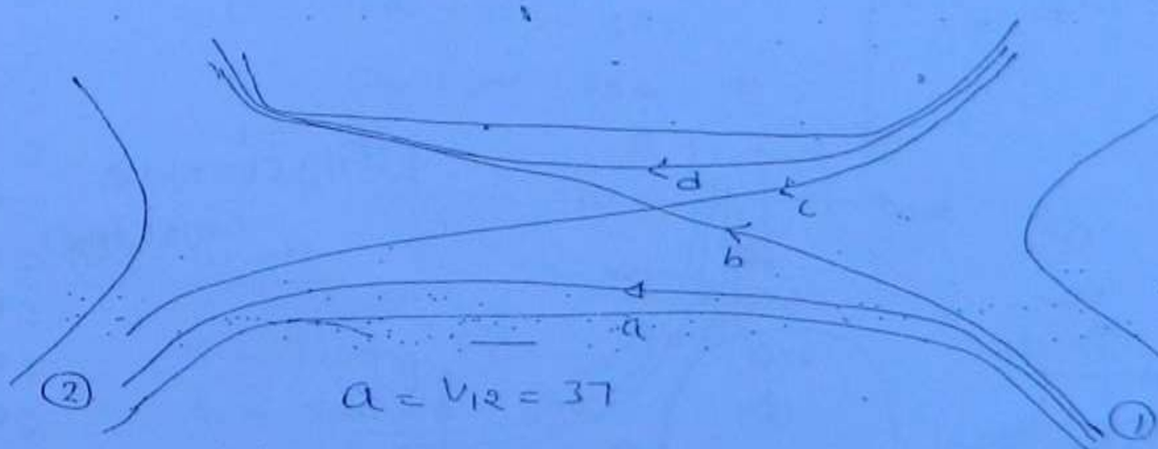
V_{12} – 37	V_{31} – 466	V_{41} – 182	V_{51} = 45
V_{13} – 303	V_{32} – 122	V_{42} – 54	V_{52} – 132
V_{14} – 64	V_{34} – 47	V_{43} – 18	V_{53} – 62
V_{15} – 52	V_{35} – 657	V_{45} – 116	V_{54} – 15

- 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



[only clockwise traffic flows]



$a = V_{12} = 37$

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

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

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

$= 18 + 62 + 15 = 95$

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

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

1/0

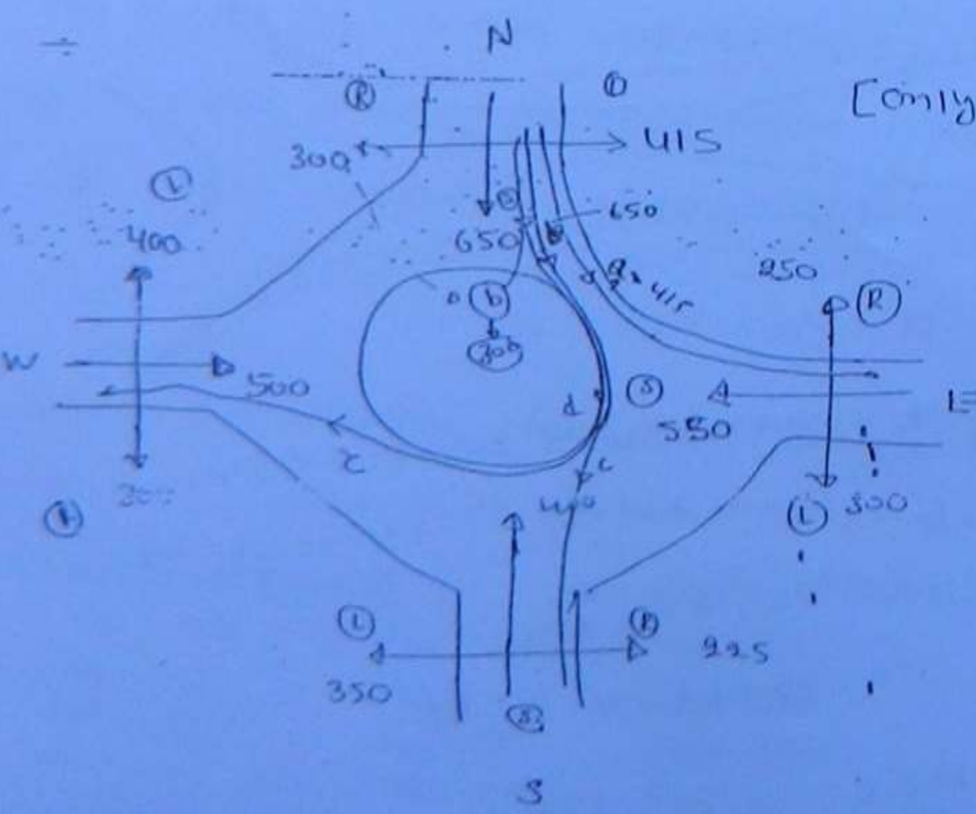
Both road = 15M wide

Traffic volume

Approach Road	Left turning	Straight turning	Right turning.
North	415	650	300
East	300	550	250
South	350	400	225
West	400	500	300

Design & draw a rotary intersection and check for it's practical capacity making suitable assumptions.

Ans.



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

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

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

$= 0.70$

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

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

value of $P = 0.745$

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

take $= e_1 = 7.50m$

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

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

weaving portion width

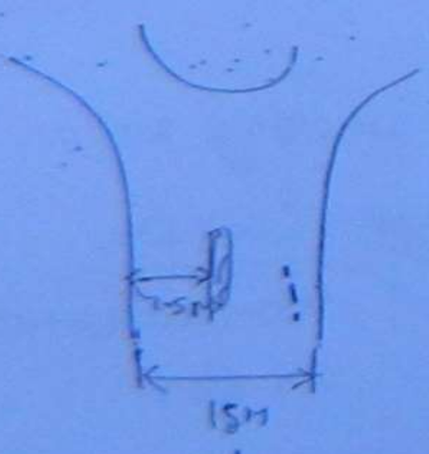
$$w = \frac{e_1 + e_2}{2} + 3.5 = 7.50 + 3.50 = 11.0m$$

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

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

$$Q_p = 3114.9 = 3115\ veh/hr$$

Road width = 15m



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

Pavement design

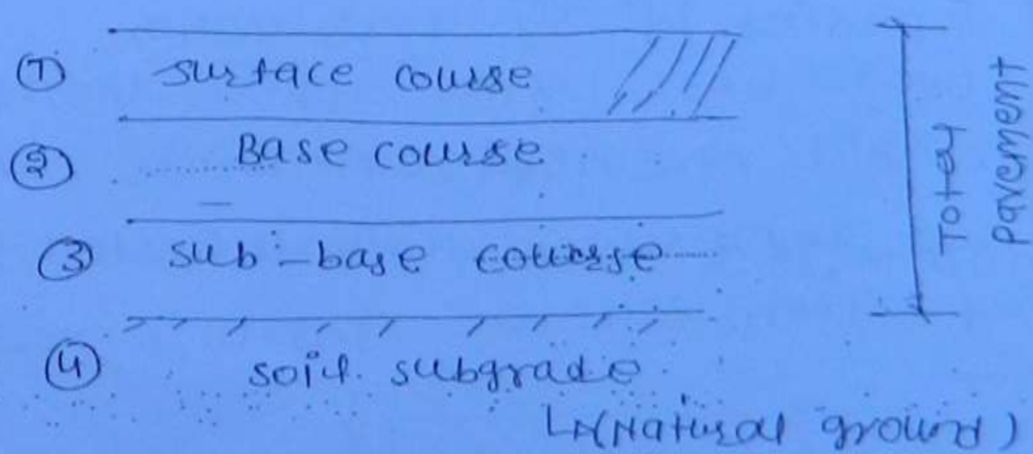
Type of pavement :-

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.

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

Rigid pavement :-

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

▷ consists of generally three layers.

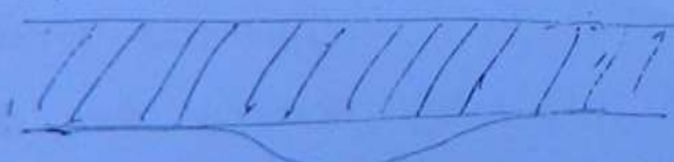
① pavement (cement concrete)

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.

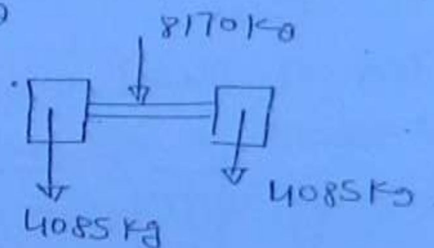
(115)

* Design of Flexible pavement :-

Some important points :-

① Max^m Legal axle load as per IRC

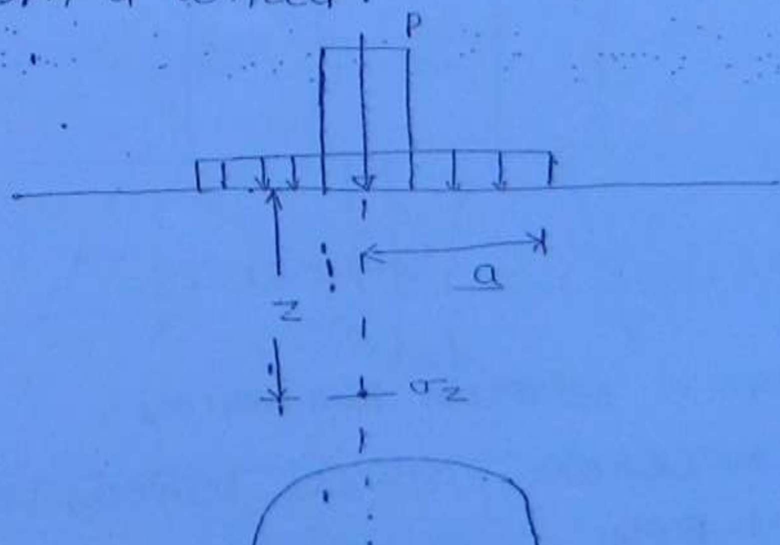
= 8170 kg



② Equivalent single wheel load [ESWL]

= 4085 kg.

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



if P = Total wheel load

a = radius of contact area

Tyre pressure

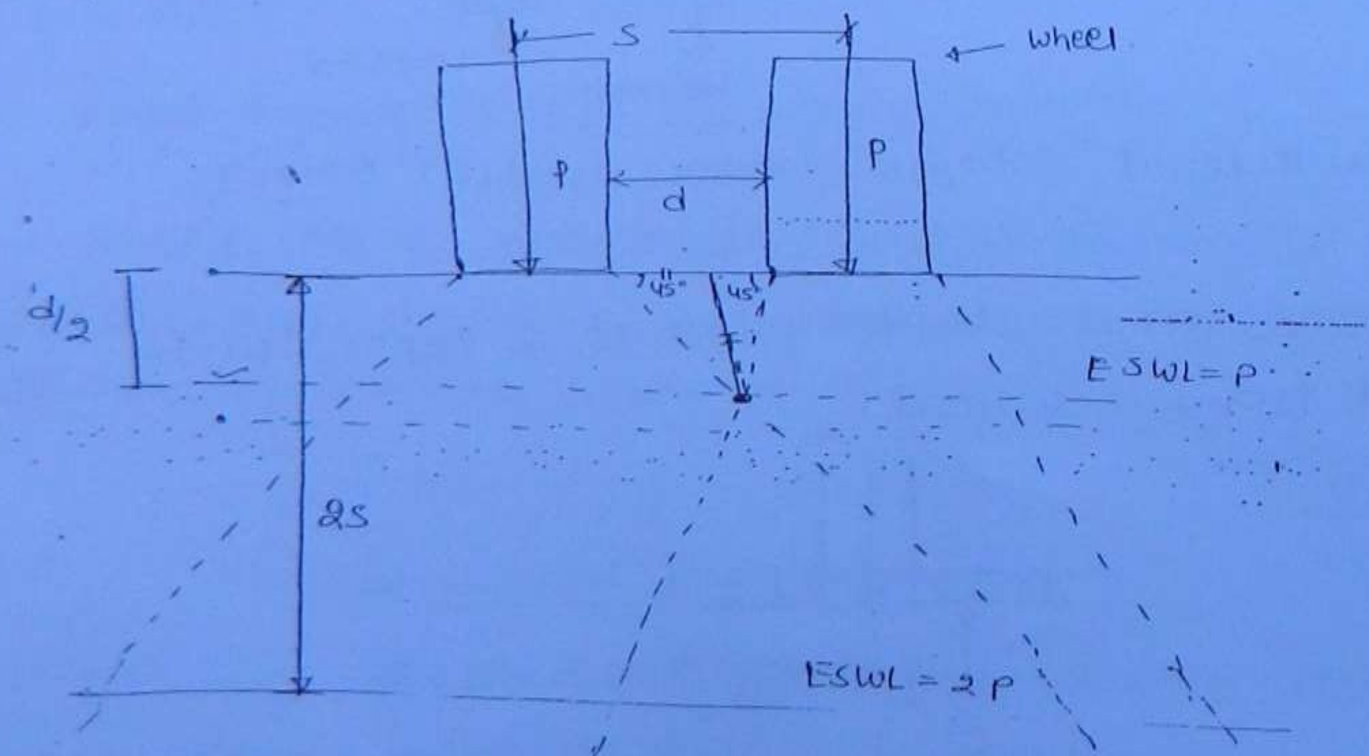
$$p = \frac{P}{A} = \frac{P}{\pi a^2}$$

stress at z depth below the load

Boussineques Equation

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

1) ESWL for a Dual wheel assembley



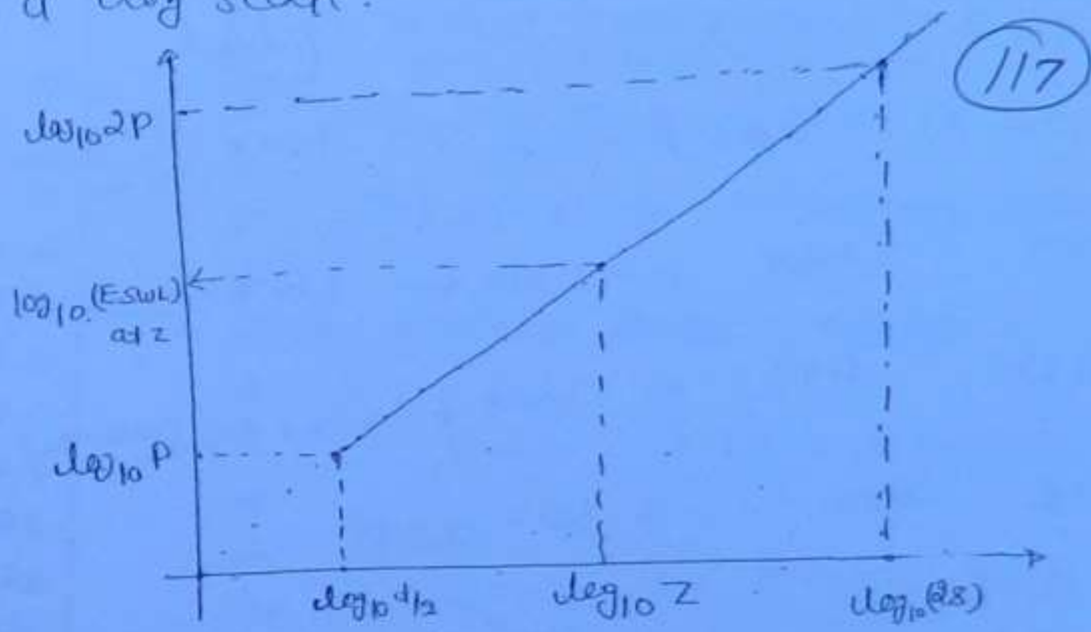
if d = clear distance between two wheels

S = Centre to Centre distance between wheels

upto d/2 depth → ESWL = P

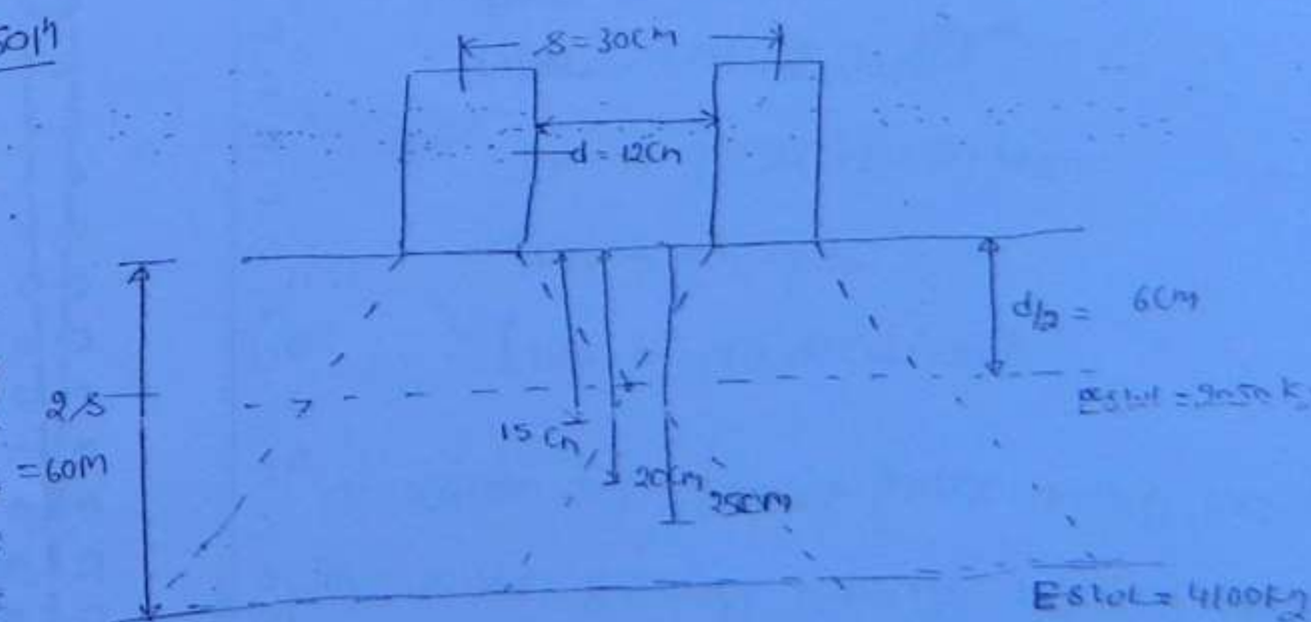
beyond 2S depth → ESWL = 2P

-between $\frac{d}{2}$ and 2S ⇒ ESWL values can be interpolated on a log scale.



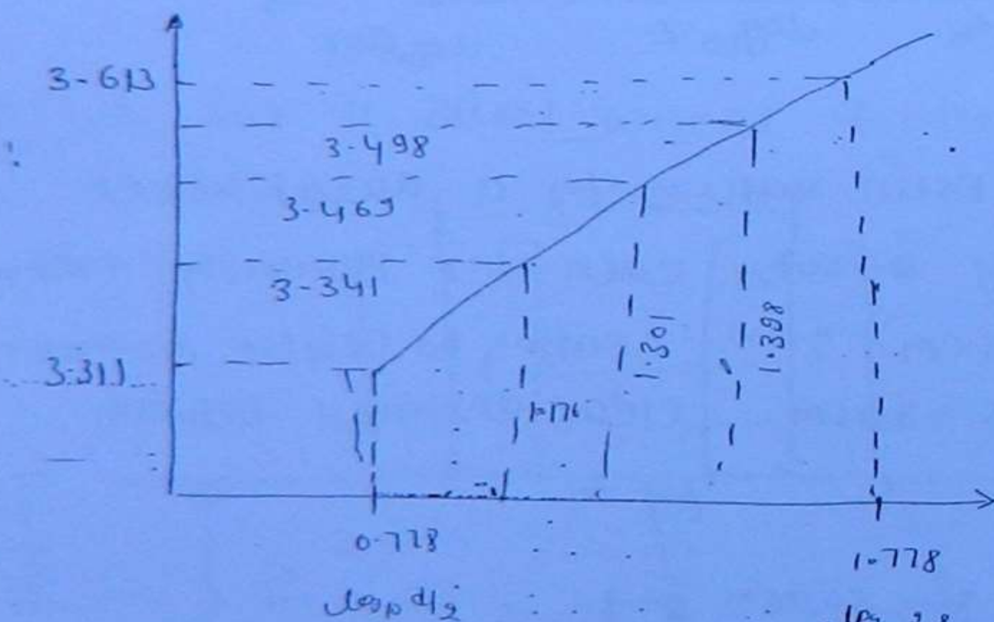
Que: Calculate ESWL value for a dual wheel Assembley carry 2050kg each for pavement thickness of 15, 20 and 25 cm. If centre to centre distance between tyre is = 30cm. Clear distance between wall is = 12cm.

Soln



(118)

pth	$\log_{10}$(depth)	ESWL	$\log_{10}$ ESWL	Remarks
cm	0.778	2050	3.311	
5 cm	1.176	2699 ←	3.431 ←	$= 3.311 + \frac{3.613 - 3.311}{1.778 - 0.778}[1.176 - 0.$
0 cm	1.301	2944 ←	3.469 ←	$= 3.311 + \frac{0.302}{1}(1.301 - 0.778)$
5 cm	1.398	3149 ←	3.498 ←	$3.311 + \frac{0.302}{1}[1.398 - 0.778]$
0 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

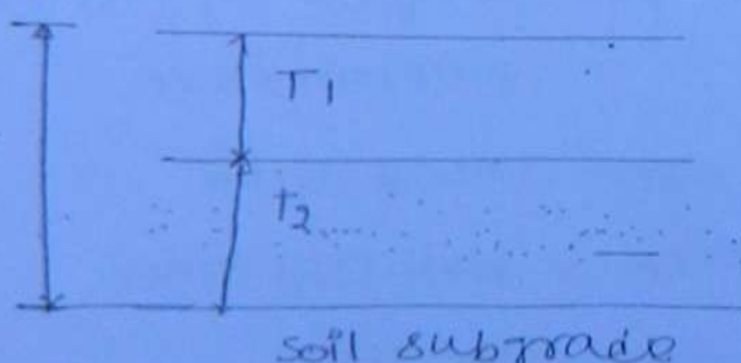
→ soil getting having higher group index is a poor soil.

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

→ Table :-

Total thickness of pavement required over a soil having GI value →

GI value	Base+surface (T_1)	subbase (T_2)
0 - 4	15cm	10 cm
5 - 9	20.5cm	20cm
10-20	30cm	30cm



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

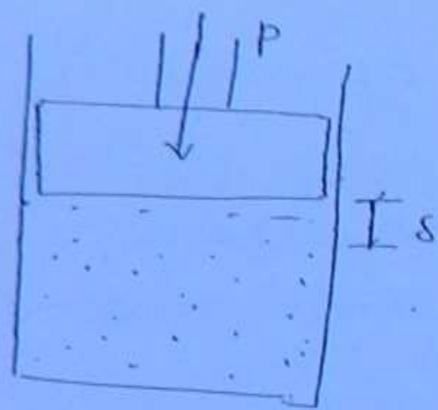
(2) Sub base = 30 cm

Total = T = 30+30 = 60 cm

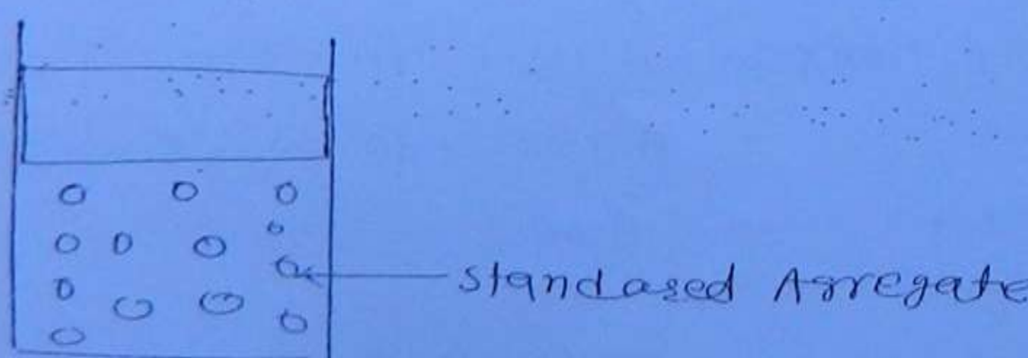
CBR Method :-

(California bearing Ratio Method)

> CBR value :-



- 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 2.5 mm penetration (P_1) and 5.0 mm penetration (P_2) are compared with standard load values



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

- Standard load values are

2.5mm penetration = 1370 kg

5.0mm penetration = 2055 kg = 2055 kg.

4) CBR values

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

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

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

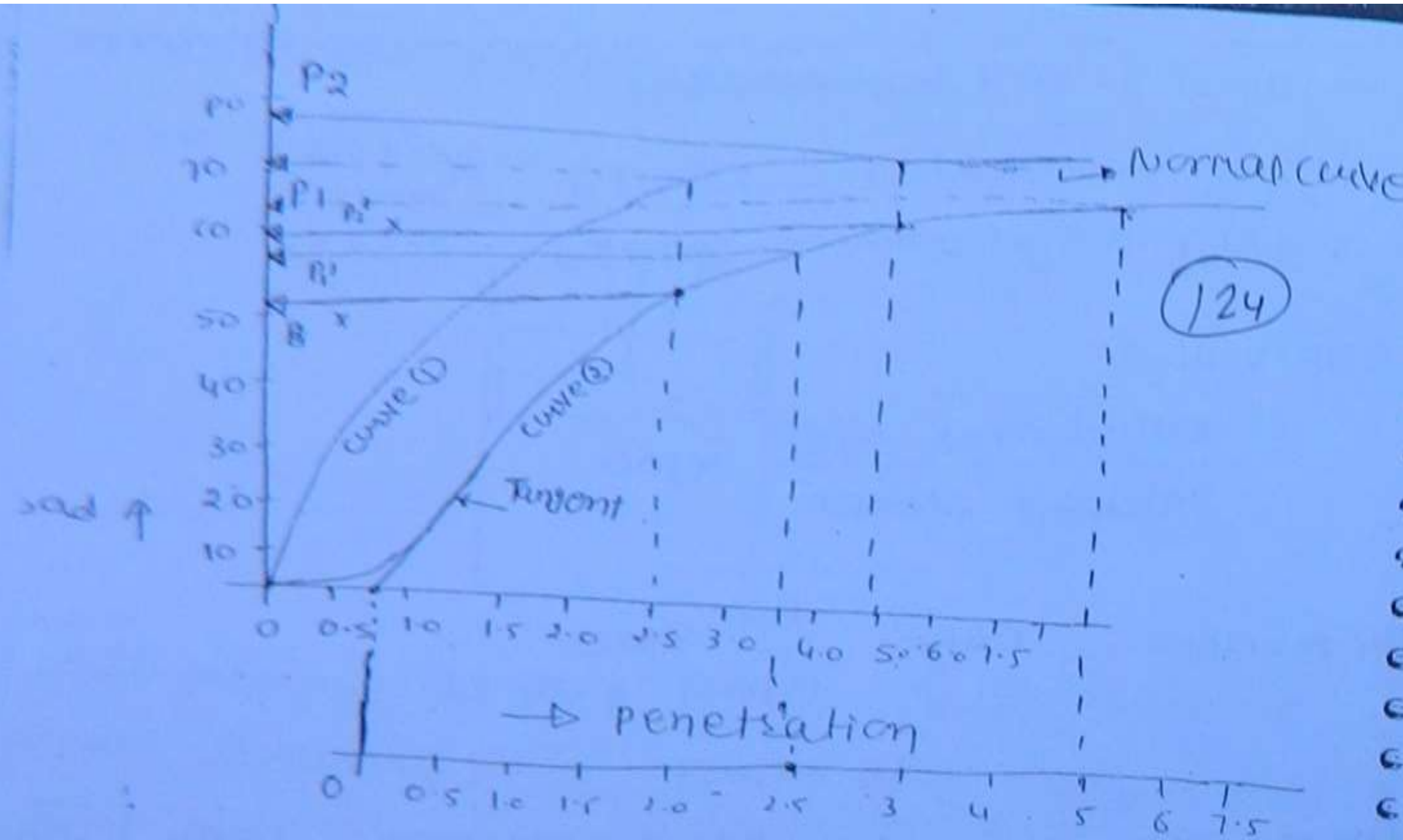
5) Generally 2.5mm penetration CBR values is higher, it is accepted as CBR values.

6) if 5.0mm CBR value is higher,
In this case test is reapeated and it same results is obtained again this 5.0mm 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 5.0mm penetration.

② False reading or initial concavity due to the soil compacted by hand not properly may occurs (the correction)



- If there is a initial concanity 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

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

Imp.

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

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

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

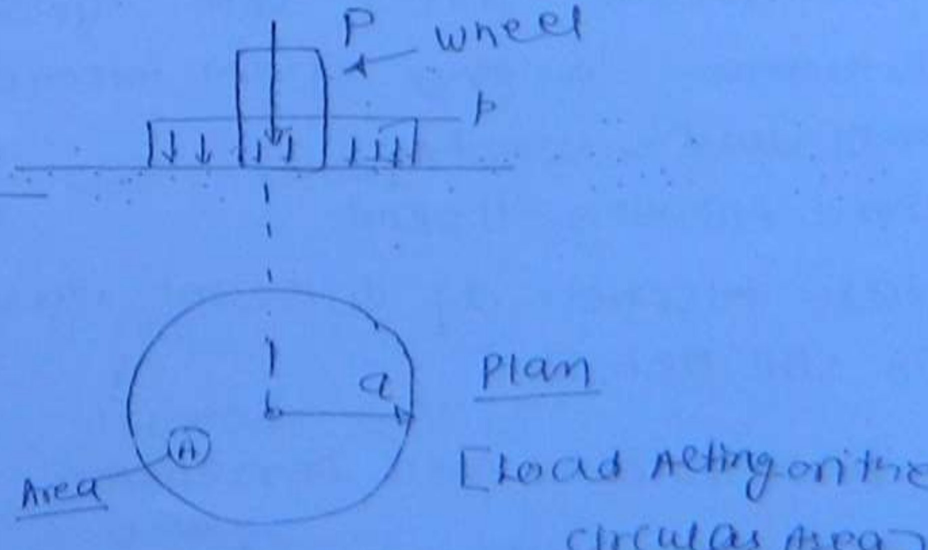
where

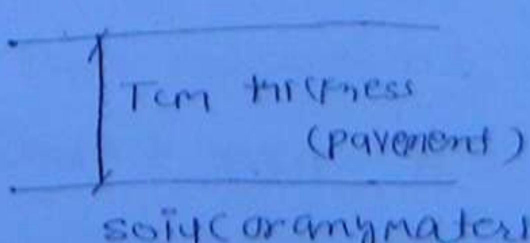
P = wheel load (kg)

p = tyre pressure (kg/cm²)

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

CBR = CBR value in %.





mitations:-

Quality of material used in pavement is not considered. (126)

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

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

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

Above this soil subgrade following materials were used →

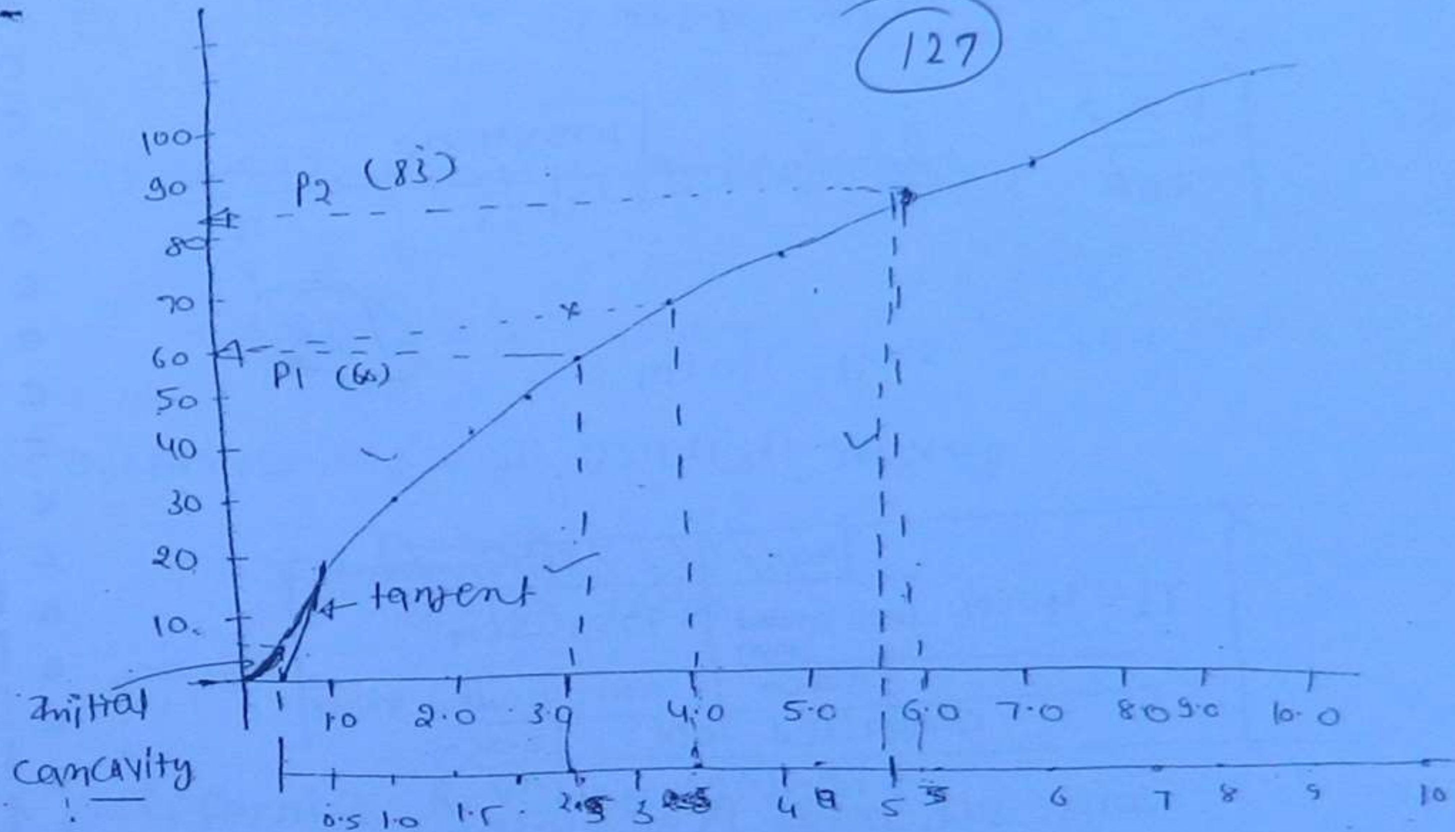
) Compacted soil having CBR = 6.0%.
Poorly graded gravel CBR = 13.0%.
) Well graded gravel CBR = 48.0%.
) Bituminous surfacing of 4cm thickness
Wheel load = 4500 kg
tyre pressure = 7 kg/cm²

alculate thickness of different layers of pavement using CBR method.

n

- 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/cm2

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

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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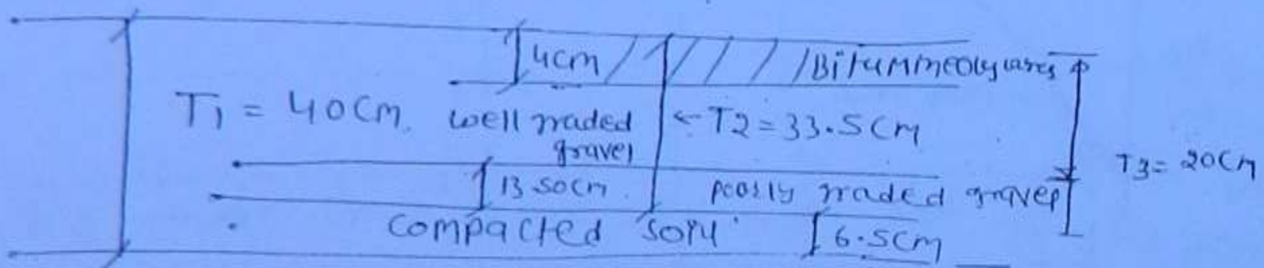
$= 39.91 \simeq$ say 40 cm



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.

Nos of 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
EWL value	$330V_1$	$1070V_2$	$2460V_3$	$4620V_4$	$3040V_5$	

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

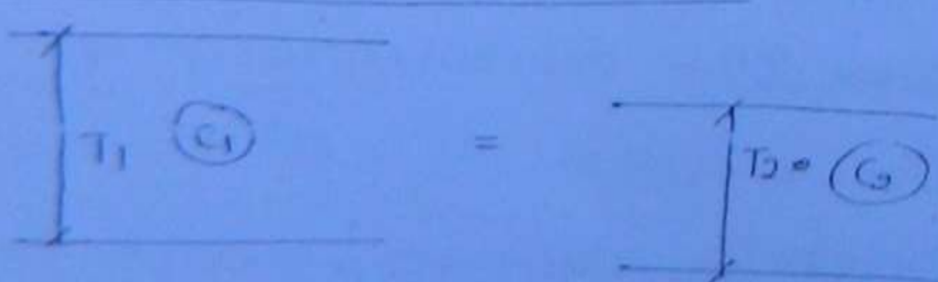
Thickness of Pavement

[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

(131)

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

Sol^n

Yearly value of EWL [Present year]

Nos of Axle	AADT (volume)	EWL constant	Yearly annual EWL
2	3750	330	1237500
3	470	1070	502900
4	320	2460	787200
5	120	4620	554400

Sum = 3082000

After 10 years = 1.60 × 3082000 [60% increase]

= 4931200

Average value (yearly value)

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

= 4006600

EWL for 10 years period = 10x4006600

= 40066000

Traffic index

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

$$TI = 9.26$$

thickness

(132)

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

~~= 0.22 x 9.260 x (~~

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

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

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

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

Sol^n

C	Layer	Thickness (cm)
C = 62	bituminous	12.5
C = 180	Cement	25.0
C = 25	well graded	20

T = 57.5 cm

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

(1) Bituminous

$T_B = 12.5$, $C_B = 62$

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

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

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

(2) Cement

$T_c = 25.0$, $C_c = 180$

$T_w = ?$, $C_w = 25$

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

(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 = 92.09 cm

Equivalent C-value = 25

$T_w = 72.09\,cm$, $C_w = 25$ for total pavement

$T_p = 57.50\,cm$, $C_p = ?$

↓

Actual thickness

(134)

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

$$C_p = C_w \times \left(\frac{T_w}{T_p}\right)^5 = 25\left(\frac{72.09}{57.50}\right)^5$$

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

$$T_R = \frac{K \cdot (TI) \cdot (90-R)}{C^{1/5}} = \frac{0.166 \times 1.35 (EWL)^{0.11} \times (90-R)}{C^{1/5}}$$

(35)

Step(2) Thickness based on Expansion pressure

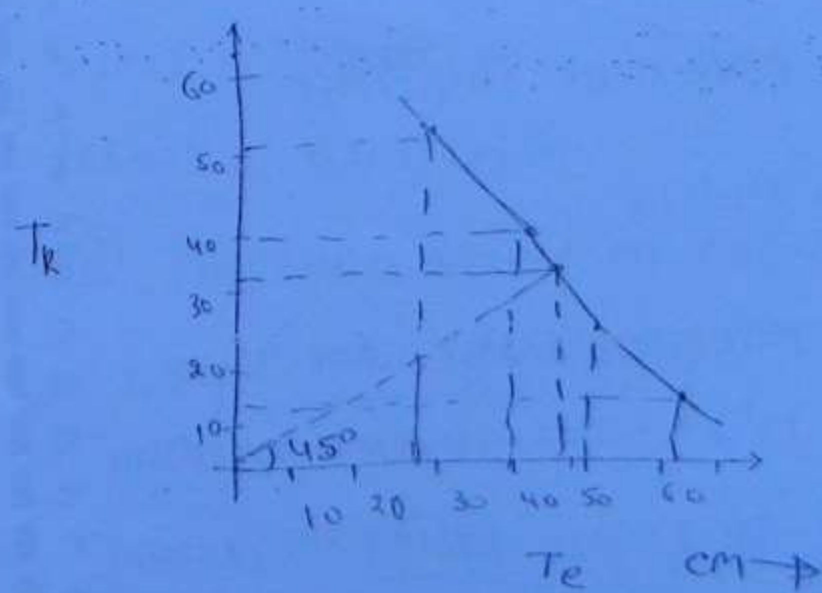
Thickness of pavement is

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

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

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

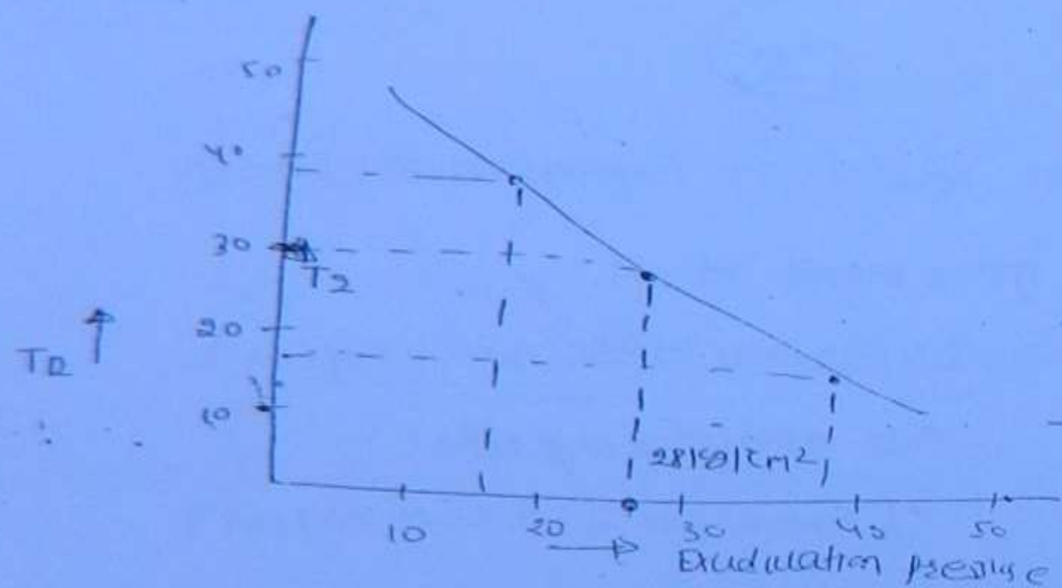
Step(3) Plot T_R v/s T_e



Thickness 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



→ 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)

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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

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

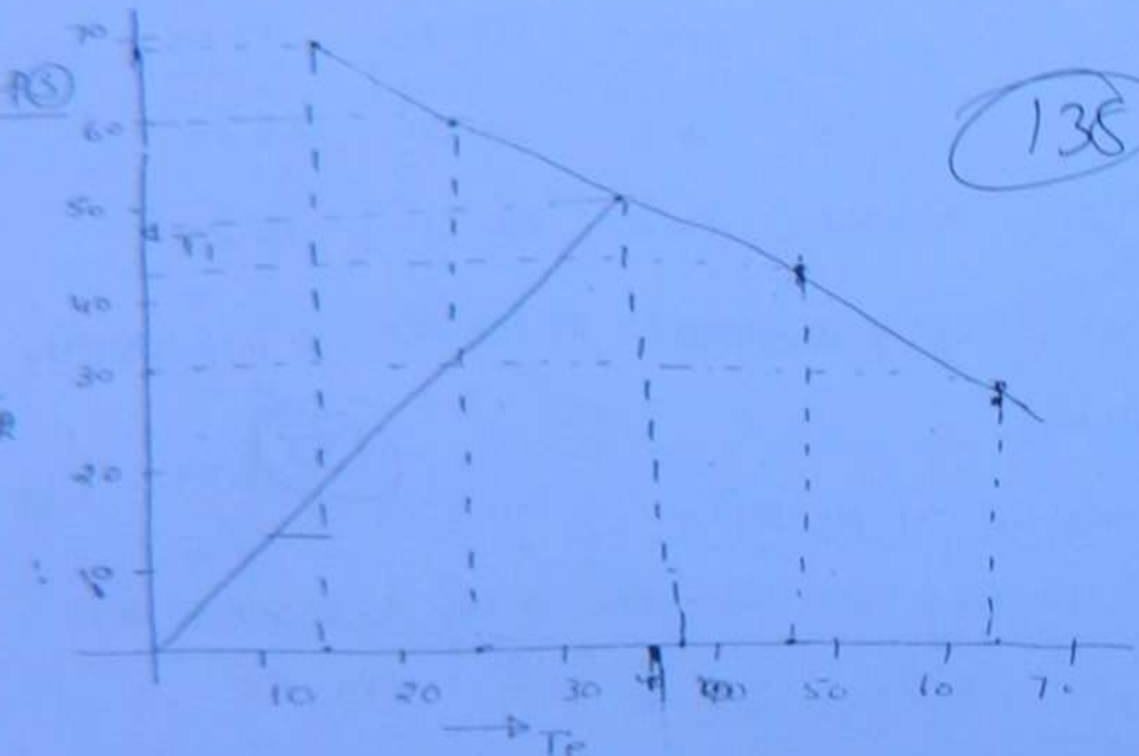
$$T_{e(15\%)} = \frac{0.135}{0.0021} = 64.30\text{ cm}$$

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

$T_e (2\%) = \frac{0.055}{0.0021} = 26.20$

$T_e (3\%) = \frac{0.034}{0.0021} = 16.20$

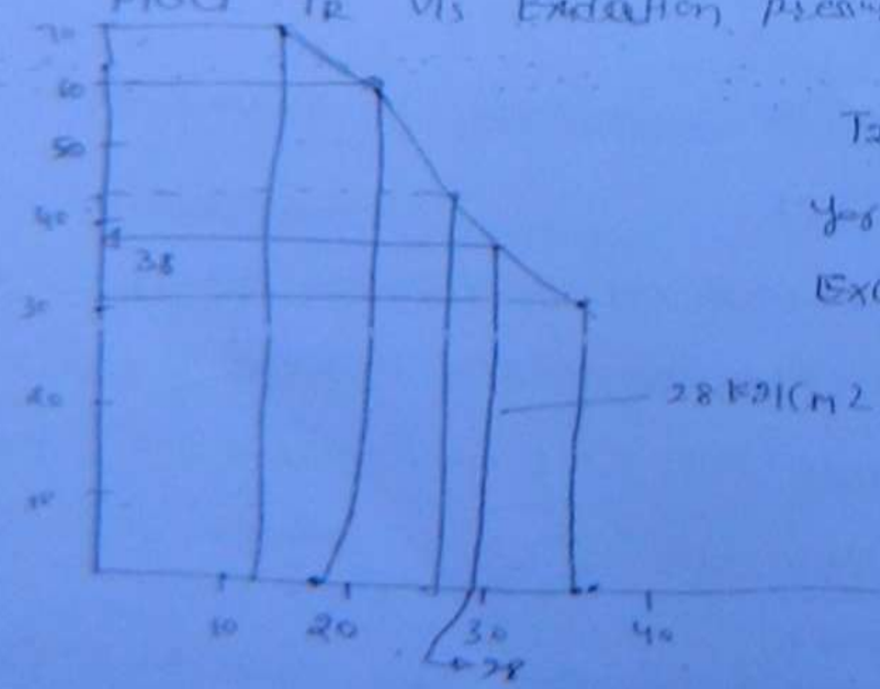
Step (3)



Thickness

say $T_1 = 44$ cm

Step (4) Plot T_R v/s Exudation pressure



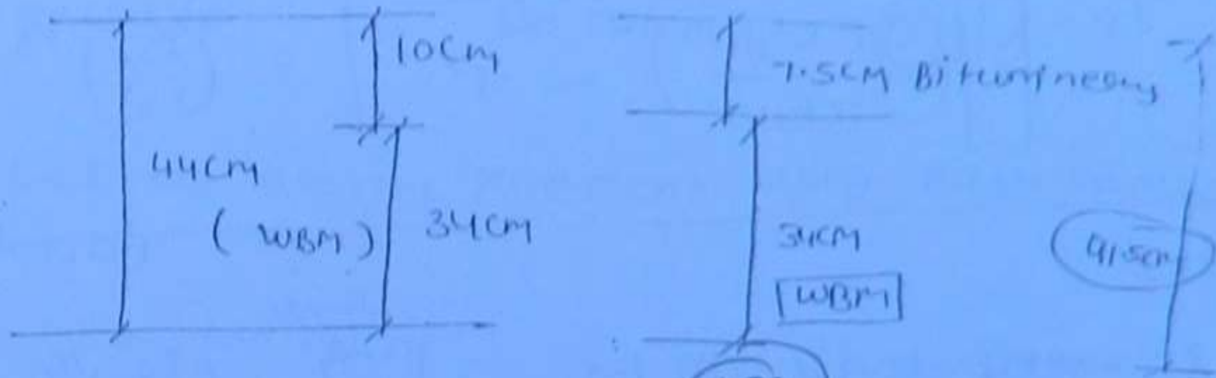
$T_2 = 38$ cm

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 :-

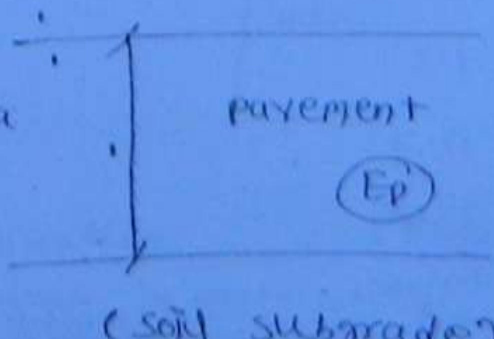
→ This Method Based on E-value

Thickness of

↳ Young Modulus of Elasticity of different layers

$E_P > E_S$

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 :→

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

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 [illegible]

(1) Base course, E_B = 360 kg/cm2

(2) Bituminous surfacing of 6cm of, E_{Bit} = 1200 kg/cm2

E soil subgrade = E_{ss} = 120 kg/cm2 (141)

Solⁿ

Let us design pavement using Base course material.

E_P = 360 kg/cm2

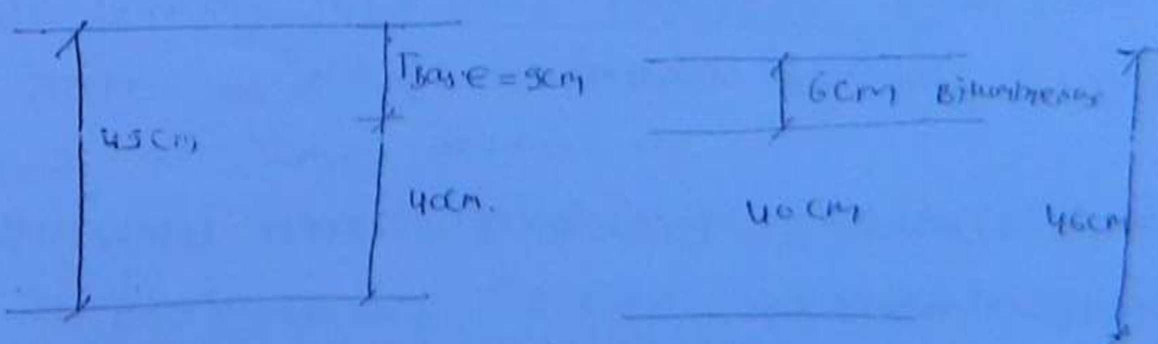
E_s = 120 kg/cm2

Thickness

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

$$T = \sqrt{\left(\frac{3\times4000\times1.6\times0.7}{2\times\pi\times120\times0.25}\right)^2} \cdot \times \left(\frac{120}{360}\right)^{1/3}$$

$\therefore T = 48.33 \approx 49$ cm (say)



T_{Bit} = 6cm, E_{Bit} = 1200 kg/cm2

T_{Base} = ? E_{Base} = 360 kg/cm2

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

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

say 9cm

Remaining thickness of Base course material

= 49cm - 9cm = 40 cm.

Total thickness of pavement is provided as ≈ 46cm

= 40+6 = 46 cm

Imp

5) **Burmister's Method :-**

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

→

Layer	
Surface	E_1
Base	E_2
Sub-Base	E_3
Soil subgrade	E_4

→ Better quality materials are used in upper 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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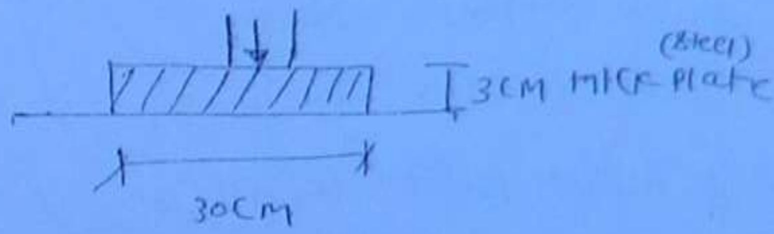


$$\Delta = 1.18 \frac{p \cdot a}{E_s} \cdot F_2$$

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)

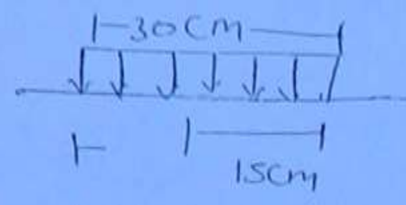
Que. plate bearing test was conducted with 30cm diameter plate on a soil subgrade yielded a pressure of $1 kg/cm^2$ at 5mm deflection.

The test carried out over 18cm base course yielded a pressure of $5 kg/cm^2$ at 5mm deflection

Design the pavement section for wheel load of 4100 kg with a tyre pressure of $6 kg/cm^2$ and allowable deflection of 5mm using Burmister method.

sol^n

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)

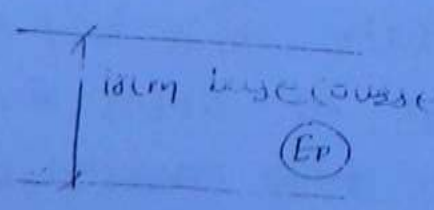
$$0.5 = 1.18 \times \frac{1 \times 15}{E_s} \times 1$$

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

② plate bearing test over 18cm thick base course

⇒ This is two layer system

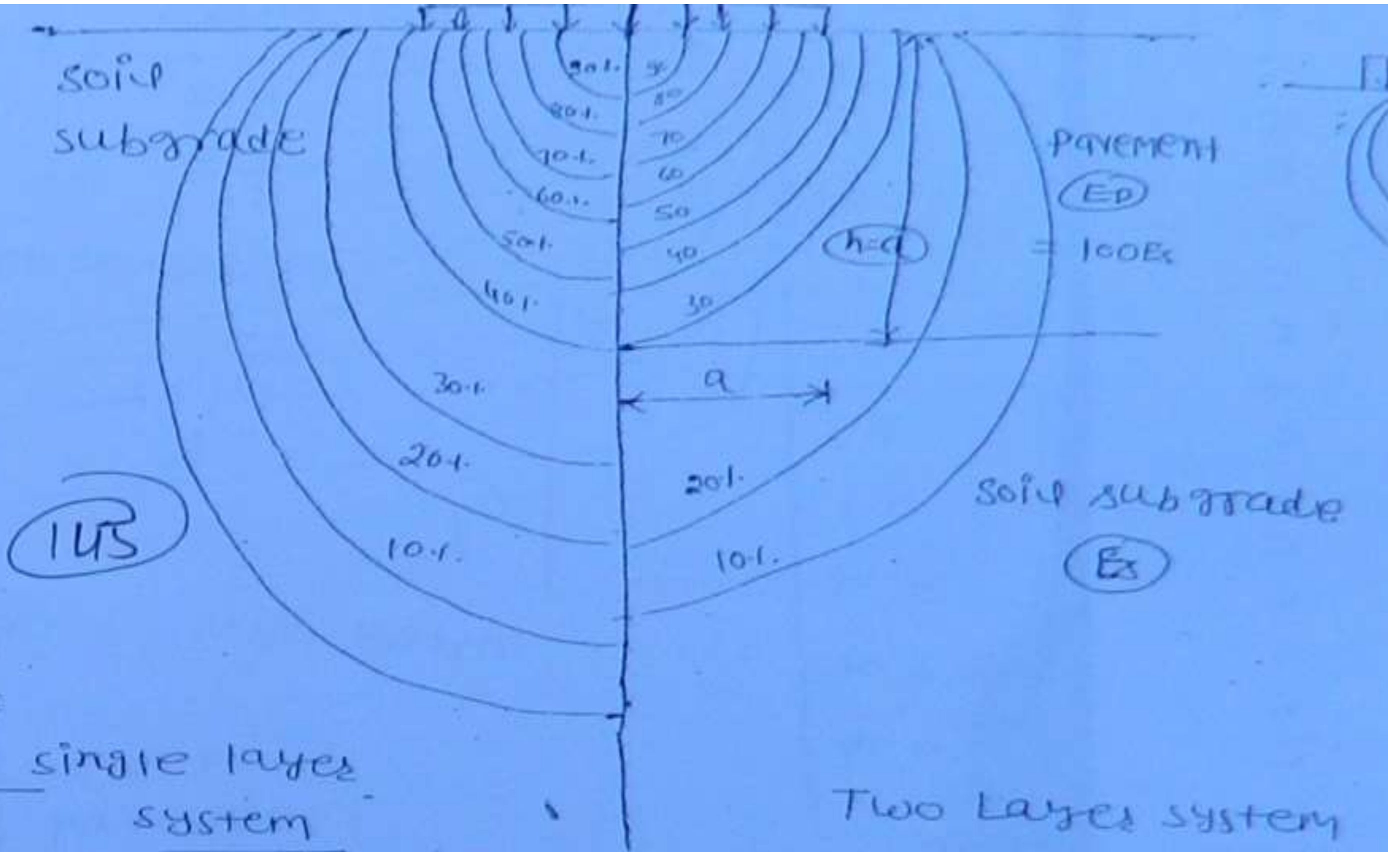
⇒ using rigid plate formula



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

0.5 = Δ Es = 34.4 kg/cm²

p = 5 kg/cm² h = 18cm, a = 15cm



single layer system
$F_2 = 1.0$

Two Layer system
(F_2 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

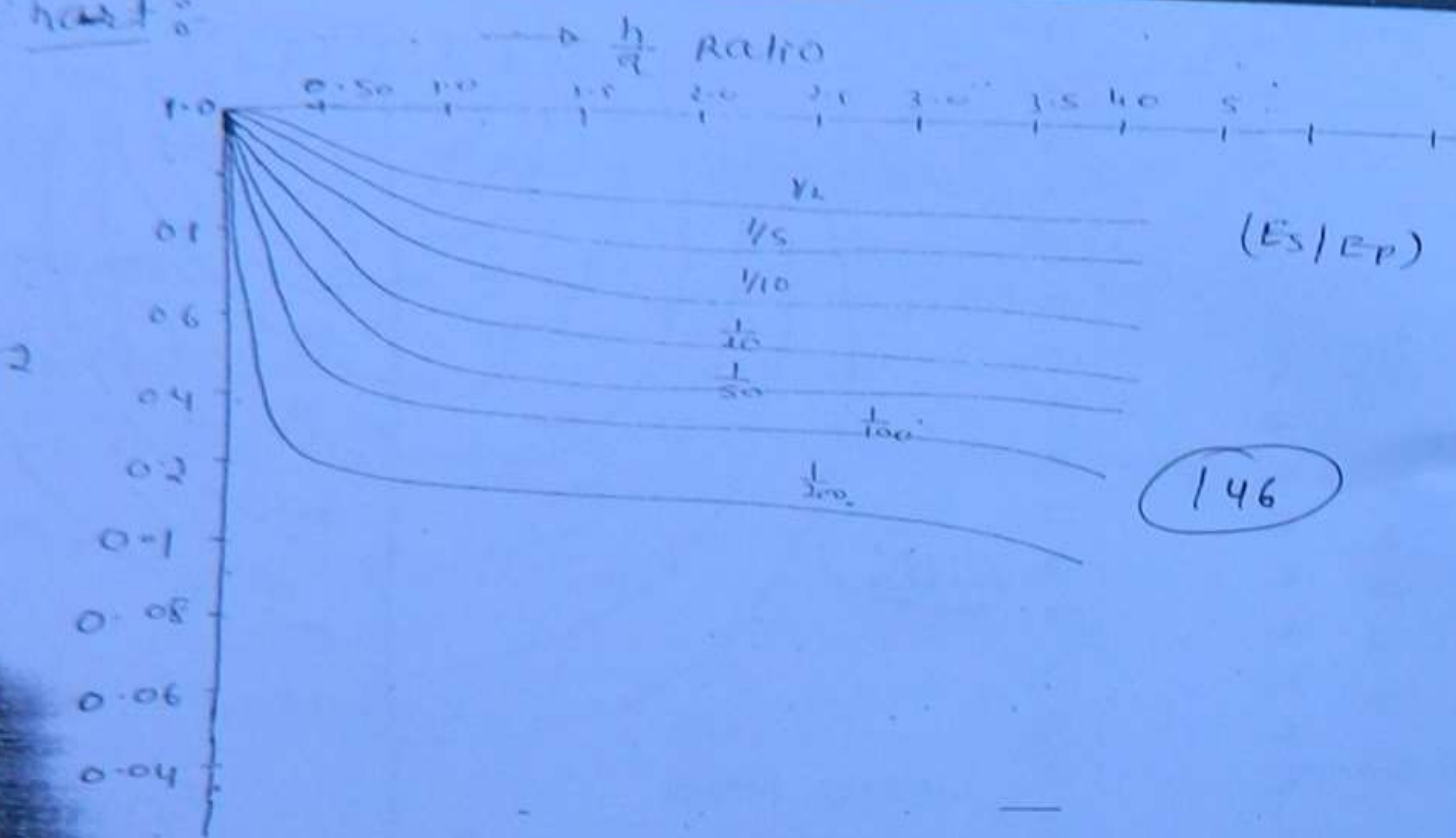
① Ratio $\left(\frac{h}{a}\right) = 1.0$

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

[All line pavement
All load pavement

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

hart :-



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...r a single layer system (when there is no ...vement)

h = 0

...value of F_2 = 1.0

...placement relationship :-

... Flexible plate :-

[... wheel load is acting over a road surface, ...ble plate is to be considered]

...placement

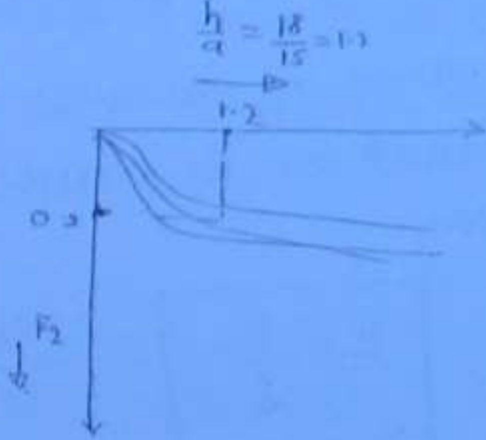
$$\Delta = 1.5 \cdot \frac{p \cdot a}{E_s} \cdot F_2$$

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

$$F_2 = 0.2$$

From graph [given question]

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



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

③ wheel over pavement
(Design of pavement)

so that consider Flexible pavement

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

$P = 4100 \text{ kg}$

$p = 6 \text{ kg/cm}^2$

$\Delta = 5 \text{ mm} = 0.5 \text{ cm}$

$E_s = 34.5 \text{ kg/cm}^2$

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

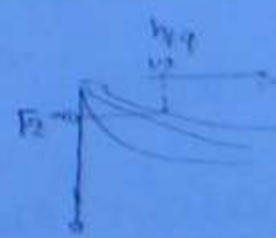
$$= \frac{4100}{6} = 683.33 \text{ cm}^2$$

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

$$a = 14.75 \text{ cm}$$

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

$$\boxed{F_2 = 0.1333}$$



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

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

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

* Design of Rigid pavement :-

Importents terms :-

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1) Modulus of subgrade reaction :- (K)

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

$$K = \frac{P}{\delta}$$

$\frac{kg/cm^2}{cm}$ $\frac{kg}{cm^3}$

[Apply pressure than δ deflection]

2) Radius of Relative stiffness (l) :-

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

where

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

h = thickness of slab

K = Modulus of subgrade reaction for soil

μ = poissions Ratio = 0.15

Equivalent Radius of Resisting section :- (b)

→ The area effective for taking B.M.

(1) $a < 1.724h$

$$b = \sqrt{1.6a^2 + h^2} - 0.675h$$

(2) $a > 1.724h$

$$b = a$$

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.
(I) Load stresses: [Westergaurds Method] :-

→ Westergaurds stress Equations

(1) Interior stress

$$S_i = \frac{0.316P}{h^2}\left[4\log_{10}\left(\frac{l}{b}\right) + 1.069\right]$$

Edge stresses

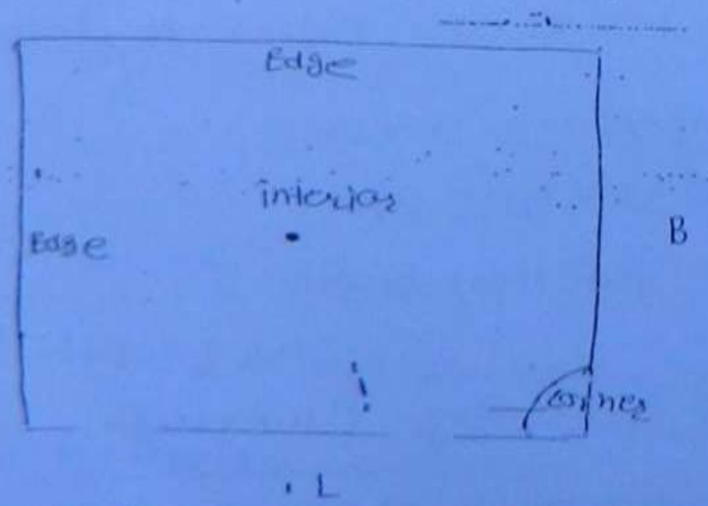
$$S_e = \frac{0.572P}{h^2}\left[4\log_{10}\left(\frac{l}{b}\right) + 0.359\right]$$

Corner stresses

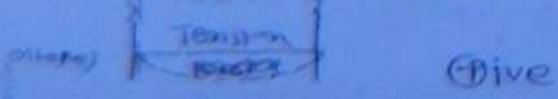
$$S_c = \frac{3P}{h^2}\left[1 - \left(\frac{a\sqrt{2}}{l}\right)^{0.6}\right]$$

where

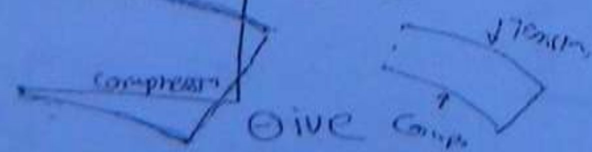
- P = wheel load in (kg)
- h = slab thickness in (cm)
- l = Radius of relative stiffness (cm)
- b = Radius of resisting section (cm)
- a = Radius of contact Area.



1) Interior case/Edge



2) At corner



ES 1997 Que. Calculate the stresses at interior, edge and corner region of a cement concrete pavement using westergaurds stress Equations, using following data

wheel load value P = 4100 kg (15)

$E_c = 3.3 \times 10^5$ kg/cm²

h = 18 cm, μ = 0.15, K = 25 kg/cm², a = 12 cm

Soln

① Radius of Relative stiffness

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

$$l = \left[\frac{3.3 \times 10^5 \times 18^3}{12 \times 25 (1-0.15^2)}\right]^{1/4}$$

l = 50.61 cm

② Equivalent Radius of Resisting section

a = 12 cm, h = 18 cm

a < 1.724 h

$$b = \sqrt{1.6a^2 + h^2} - 0.675h$$

$$b = \sqrt{1.6 \times 12^2 + 18^2} - 0.675 \times 18 = 11.4 \text{ cm}$$

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/cm2

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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/cm2

) Corner stresses

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

$$S_c = \frac{3 \times 4100}{18^2}\left[1 - \left(\frac{12 \times \sqrt{2}}{50.61}\right)^{0.6}\right]$$

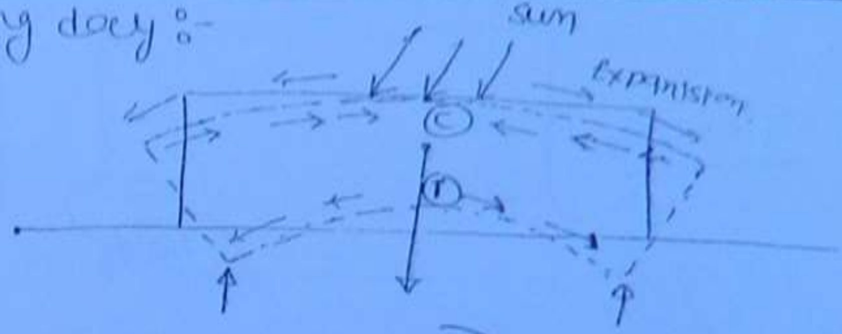
$S_c = 18.25$ kg/cm2

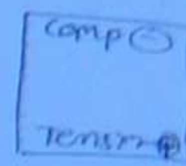
) Temperature stress :-

I) warping stress :-

Due to variation of temperature during day/ night.

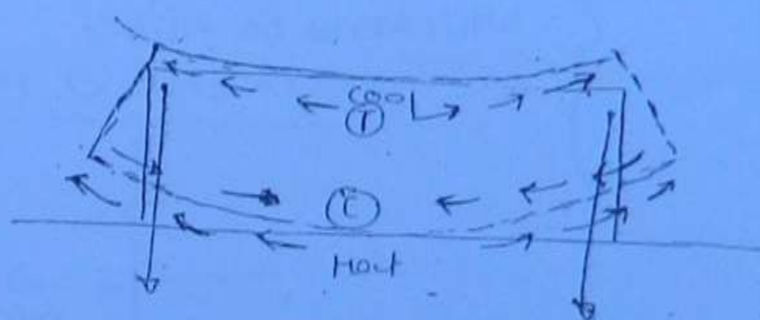
(a) During day:-

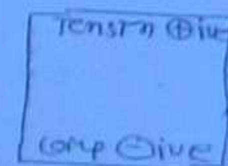




C → Comp. ⊝
T → Tension ⊕

(b) During Night:-



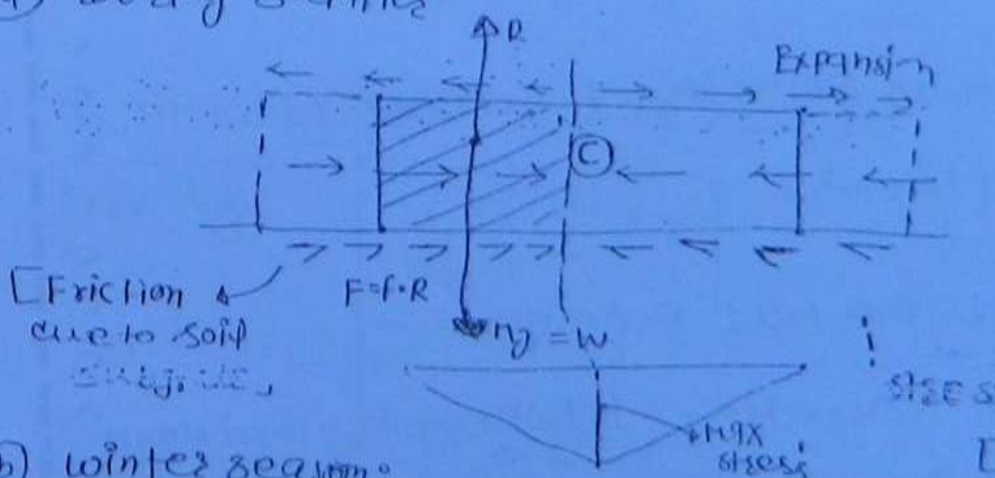


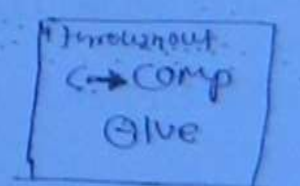
→ Max stresses occurs due to warping.

(2) Frictional stresses:-

[Due to seasonal temperature variation]

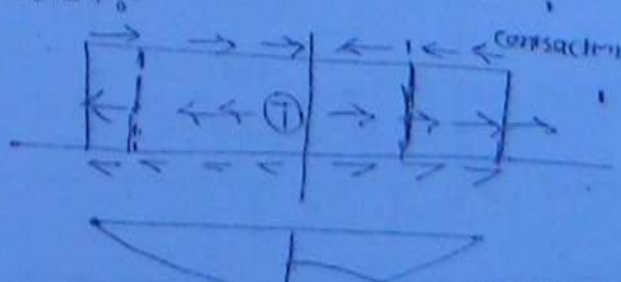
(a) During summer

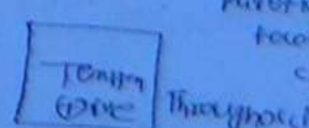




[Stress Increase towards centre because weight of pavement increase towards the centre]

(b) Winter season:





Warping stresses

Interior stress

$$S_{ti} = \frac{E\alpha T}{2}\left(\frac{C_x + \mu C_y}{1-\mu^2}\right)$$

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

$$S_{tc} = \frac{E\alpha T}{3(1-\mu)}\sqrt{\frac{a}{l}}$$

ere

E = Young modulus of Elasticity of cement concrete pavement (kg/cm²)

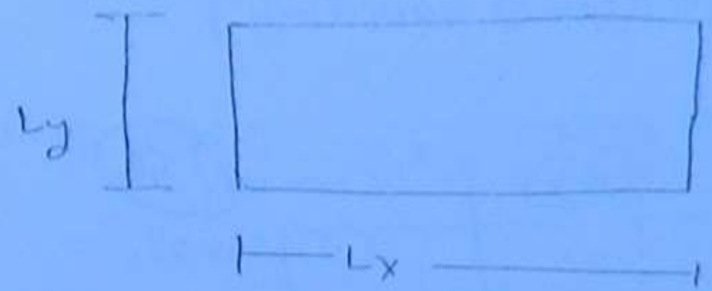
= coefficient of thermal Expansion

= temperature variation between day and Night

= Poissons Ratio

= coefficient based on $\left(\frac{L_x}{l}\right)$

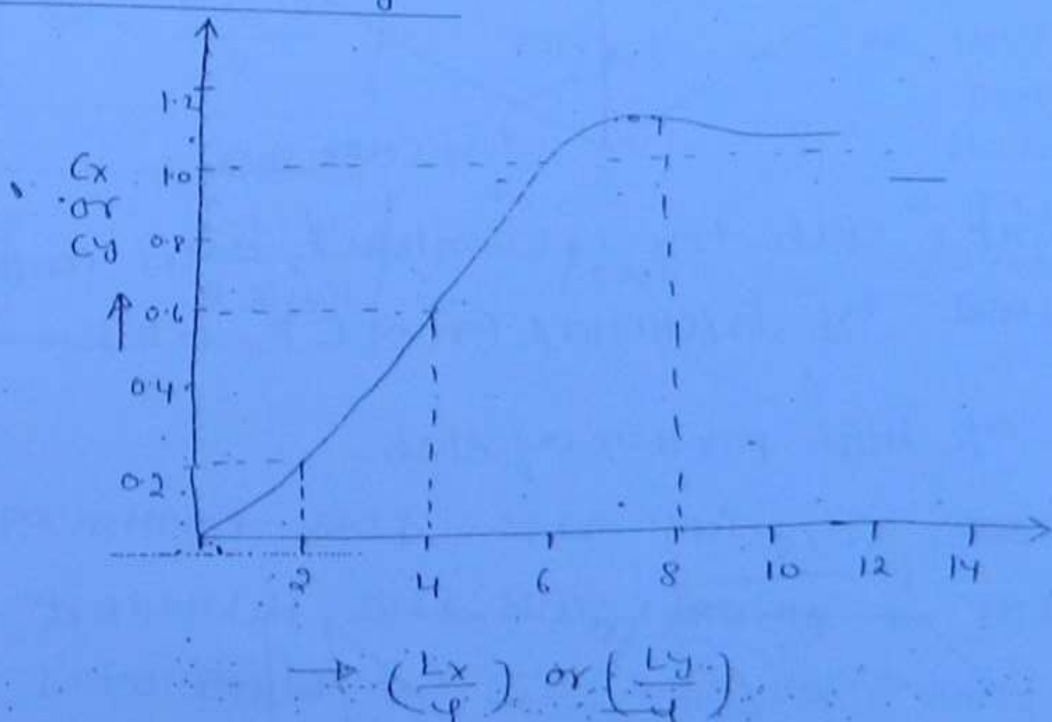
= coefficient based on $\left(\frac{L_y}{}\right)$



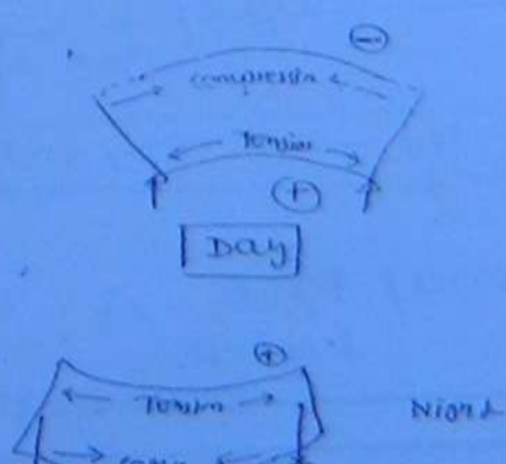
l = Radius of Relative stiffness

a = Radius of contact Area

Value of Cx and Cy



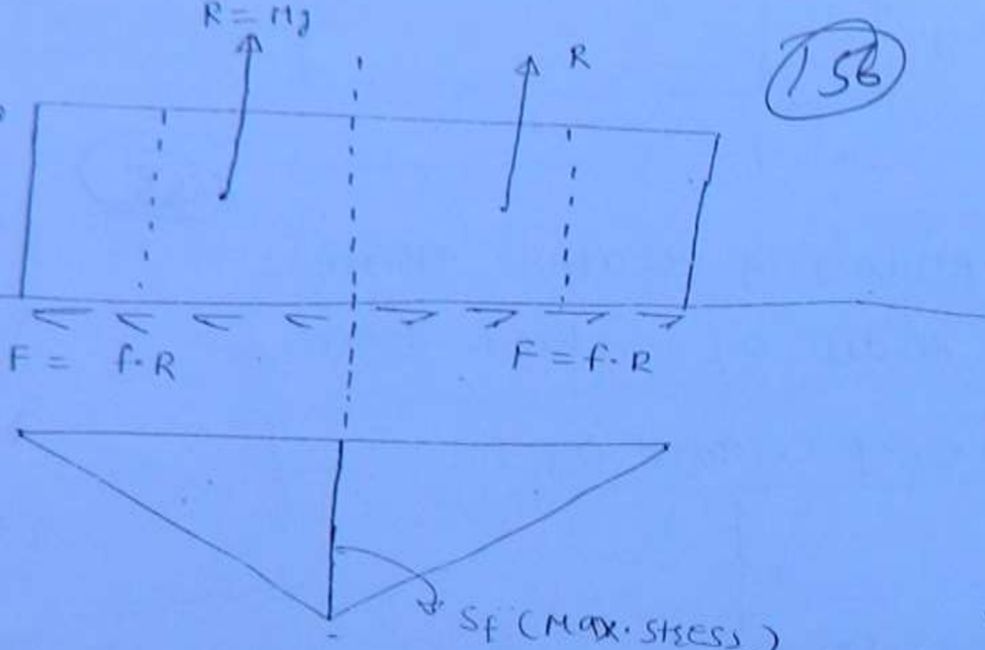
$\frac{L_x}{l}$ or $\frac{L_y}{l}$	C_x or C_y
2	0.2
4	0.6
8	1.1
12	1.02



3) Frictional stresses :-

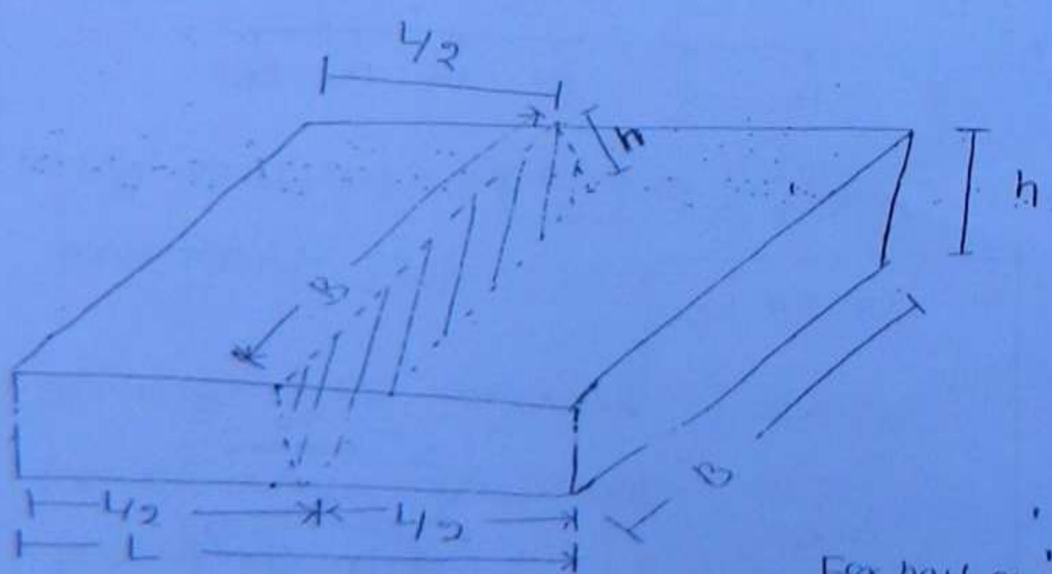
[Due to seasonal temperature variation]

…ring winter]
Tensile Stress
…veloped, This stresses
…re dangerous to the
…mp. stress developed
…ring summer than
…nside 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 $\gamma = W/V$

$\boxed{R = Mg} = (\frac{L}{2} \times B) \times h \times \gamma$

Frictional force

$F = f \cdot R$.

[Resisting force Sf is acts at centre on shaded area, Sf max tensile stress then $F = S_f \times Area = S_f \times B \times h$

$$F = f \cdot \left(\frac{L}{2} \times B\right) \times h \times W \quad \text{——— (1)}$$

(157)

Resisting Force

$$= S_f \times (B \times h) \quad \text{——— (2)}$$

(S_f → stress; $(B \times h)$ → Area)

$W = kg/m^3 = \gamma$

$\boxed{W = \gamma}$

$\omega = mg = (B \times h) \times (\rho g)$ (wt (V))

$= (B \times h) \times W$

$\omega = (B \times h) \times \gamma$ (ω → (weight))

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 material

⇒ 24, 25 kN/m³

⇒ 2400 kg/m³ or 2500 kg/m³

$$\therefore \boxed{S_f = \frac{f \cdot L \cdot W}{2 \times 10^4}} \quad kg/cm^2$$

Que. A pavement slab 22 cm thick is constructed over a granular 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

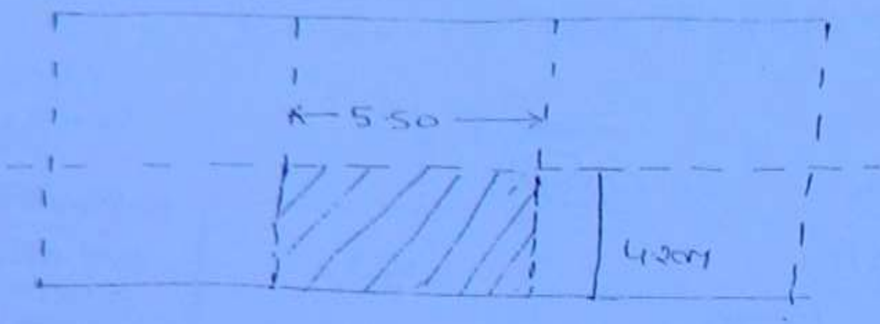
Max. difference of temperature = 20°C

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.



$L_y = B = 4.20m$, $L = L_x = 5.50 M$

$H = 22 cm$, $P = 4500 kg$, $T = 20°c$, $a = 15 cm$.

) 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

$$S_e = \frac{0.572\,P}{h^3}\left[4\log_{10}\left(\frac{l}{b}\right) + 0.359\right]$$

(154)

$$= \frac{0.572 \times 4500}{22^2}\left[4\log_{10}\frac{62.37}{14.20} + 0.359\right]$$

$$= 15.58\ \text{kg/cm}^2$$

(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 $\frac{L_y}{l}$	C_x or C_y
8	1.10
12	1.02

→ Value of C_x and C_y

$$\frac{L_x}{l} = \frac{550}{62.37} = 8.82\ , \quad C_x = 1.10 - \frac{1.10 - 1.02}{4} \times 0.82$$

$$= 1.08$$

$\frac{l_y}{l} = \frac{420}{62.37} = 6.73$

$\frac{l_x}{l}$ or $\frac{l_y}{l}$	C_x or C_y
4	0.6
8	1.1

$C_y = 0.6 + \frac{1.1 - 0.6}{4} \times 2.73 = 0.94$

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$$\sigma_i = \frac{3\times10^5 \times 12\times10^{-6} \times 20}{2}\left[\frac{1.08 + 0.15\times0.94}{1 - 0.15^2}\right].$$

$\sigma_i = 44.97\ kg/cm^2$

Edge stresses

$$S_{te} = \frac{C_x \cdot E\alpha T}{2} \quad \text{or} \quad \frac{C_y \cdot E\alpha T}{2}$$

$C_x > C_y$

$$S_{te} = \frac{C_x \cdot E\alpha T}{2} = \frac{1.08 \times 3\times10^5 \times 12\times10^{-6} \times 20}{2}$$

$= 38.88\ kg/cm^2$

Corner stresses

$$S_{tc} = \frac{E\alpha T}{3(1-\mu)}\sqrt{\frac{a}{l}}$$

$$= \frac{3\times10^5 \times 12\times10^{-6} \times 20}{3\times(1-0.15)}\sqrt{\frac{15}{62.37}}$$

$S_{tc} = 13.88\ kg/cm^2$

(3) Frictional stress

W = unit wt. of pavement material, 2400, 2500 kg/m or 24 or 25 kN/m²

$$S_f = \frac{f \cdot L \cdot W}{2 \times 10^4}$$

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$$S_f = \frac{1.5 \times 5.50 \times 2500}{2 \times 10^4} = 1.03 \ kg/cm^2$$

Worst combination

At interior = $S_i + S_{ti} + S_f$ = 10.69 + 44.97 + 1.03 = 56.69 kg/cm²

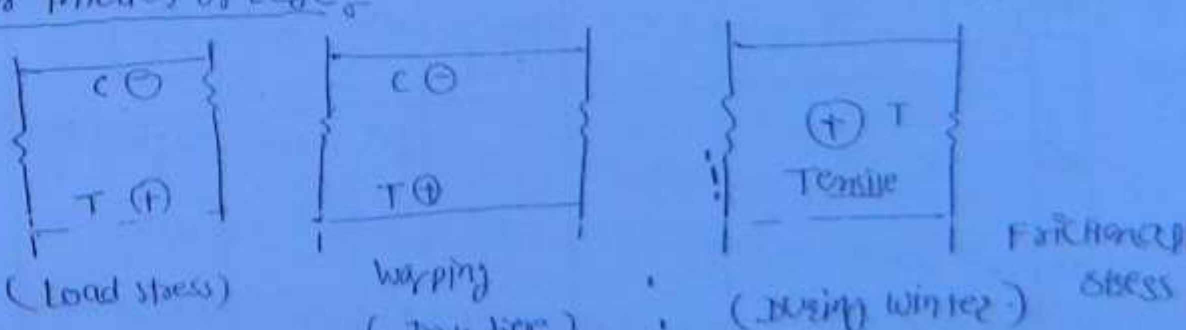
At Edge = $S_e + S_{te} + S_f$ = 15.58 + 38.38 + 1.03 = 55.43 kg/cm²

Worst case at corner, At top = $S_c + S_{tc} + S_f$

= 13.28 + 13.84 + 1.03 = 28.15

* Worst combination :-

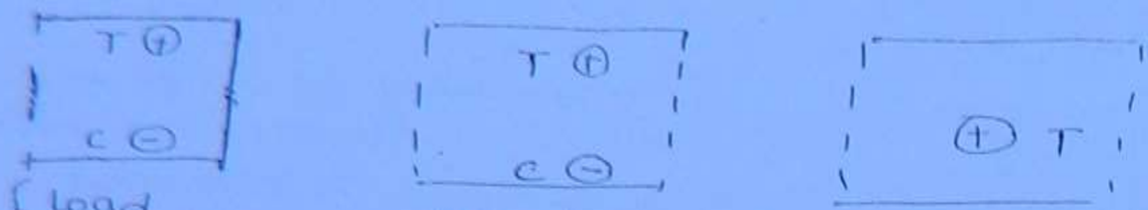
For interior or Edge :-



At interior = $S_i + S_{ti} + S_f$ (At bottom)

At Edge = $S_e + S_{te} + S_f$ (At bottom)

Worst case at corner.



(Load stresses) — Warping stresses (Night) — Frictional stresses (winter)

At top = $S_c + S_{tc} + S_f$

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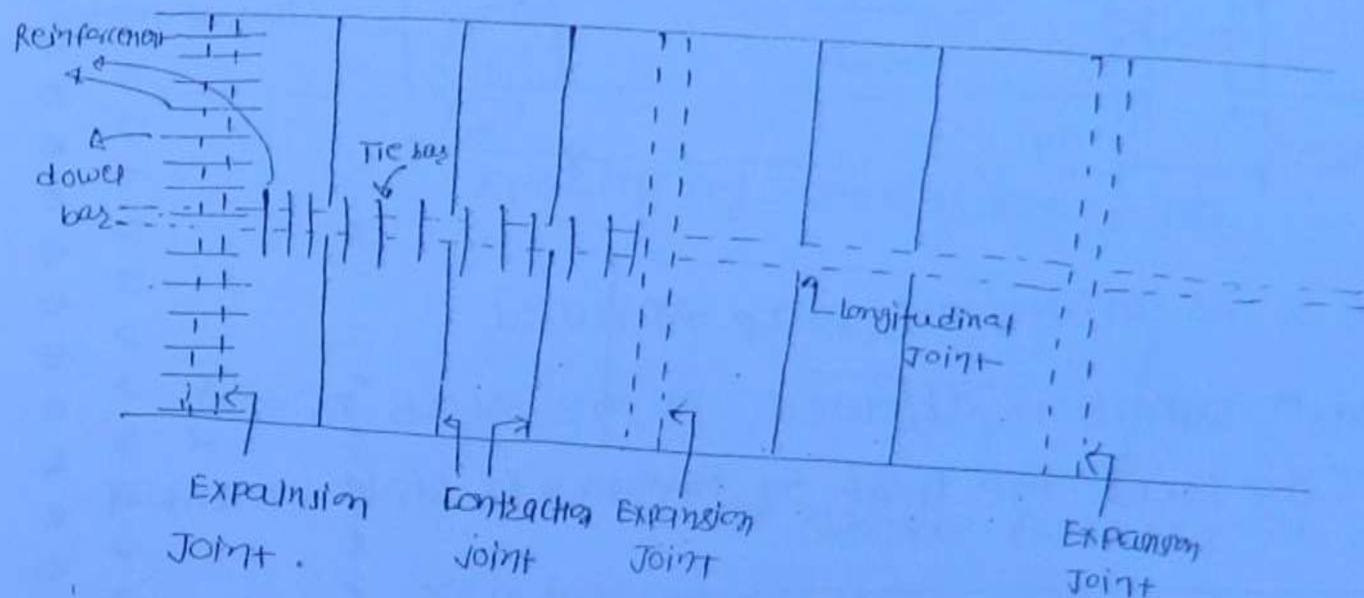
→ Worst combination of stresses (Table) :-

		Load stresses	Warping stress		Frictional stresses	
			Day	Night	Summer	Winter
Interior stresses	Top	C (−)	C	T	C	T
	Bottom	T (+)	T	C	C	T
Edge stresses	Top	C (−)	C	T	C	T
	bottom	T (+)	T	C	C	T
Corner stresses	Top	T (+)	C	T	C	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.

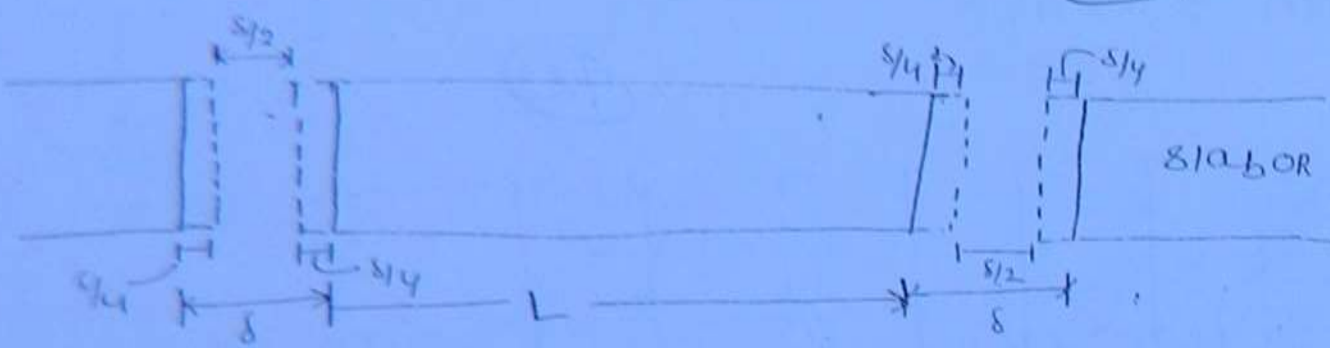
(2) Contraction joint :-

→ 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.]

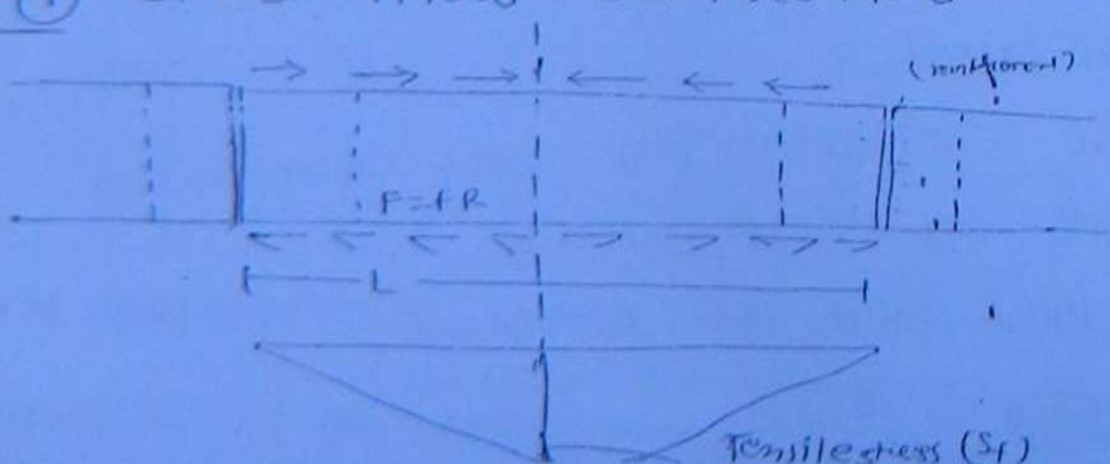
$$\frac{\delta}{2} = L \cdot \alpha \cdot (T_2 - T_1)$$

Spacing of Expansion joints

$$L = \frac{\delta}{2 \cdot \alpha \cdot (T_2 - T_1)}$$

Design of contraction joint :-

Case (1) slab without reinforcement.



- Tensile stress developed at contrac

$$S_f = \frac{WLf}{2\times10^4} \quad kg/cm^2$$ W =

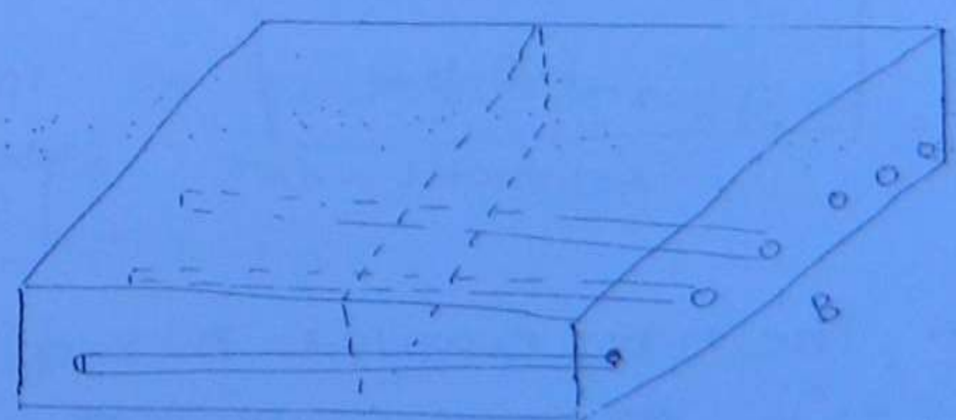
(165)

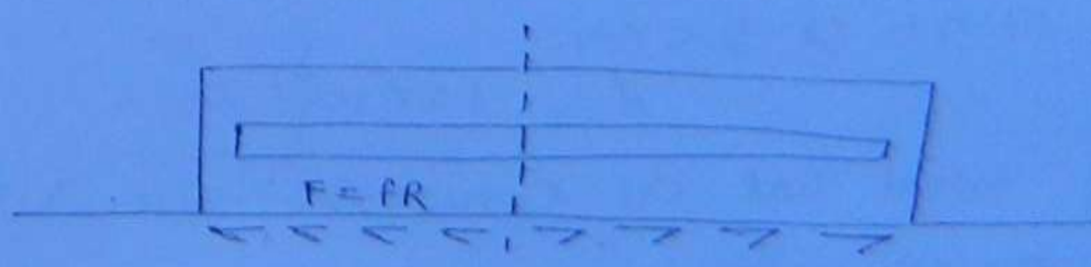
spacing of contraction joint

$$L = \frac{2\times10^4 \cdot S_f}{W \cdot f}$$

↑ All above formula is used ... 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.

> 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 $= F = f \cdot R$

$$F = f \cdot \left(\frac{L}{2} \times B \times h \times W\right) \quad \text{—— (2)}$$

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 = $\delta/2$

$$= \frac{2.50}{2} = 1.25\ cm$$

$$L \cdot \alpha \cdot T = \frac{\delta}{2}$$

$$L = \frac{1.25}{15 \times 10^{-6} \times 26^\circ \times 100}$$

$$\boxed{L = 32.05\ m}$$

Que. A cement concrete pavement has 4.5m width and thickness of 25cm. Design contraction joints spacing for

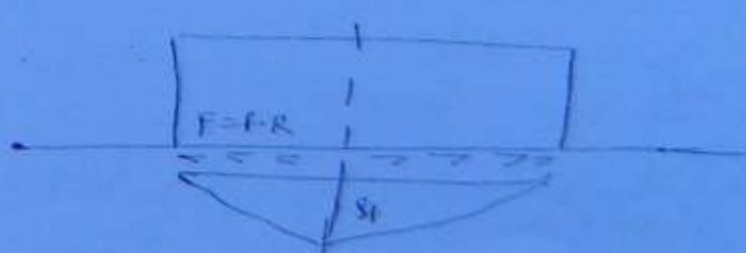
(i) if No reinforcement is given

(PCC) Max^M permissible stress of concrete in tension $= 0.8\ kg/cm^2$

(ii) if reinforcement of 12mm ϕ @ 300 mm c/c are used. Mild steel used. $\sigma_{st} = 1400\ kg/cm^2$

(RCC) Coefficient of friction $f = 1.5$

Sol^n:- (i) PCC (No steel used)



$- \quad F = S_f \cdot (B \cdot h)$

$f \cdot \frac{1}{2} \cdot B \cdot h \cdot W = S_f \cdot B \cdot h$

$S_f = \frac{f\ L\ W}{2}$ kg/m2

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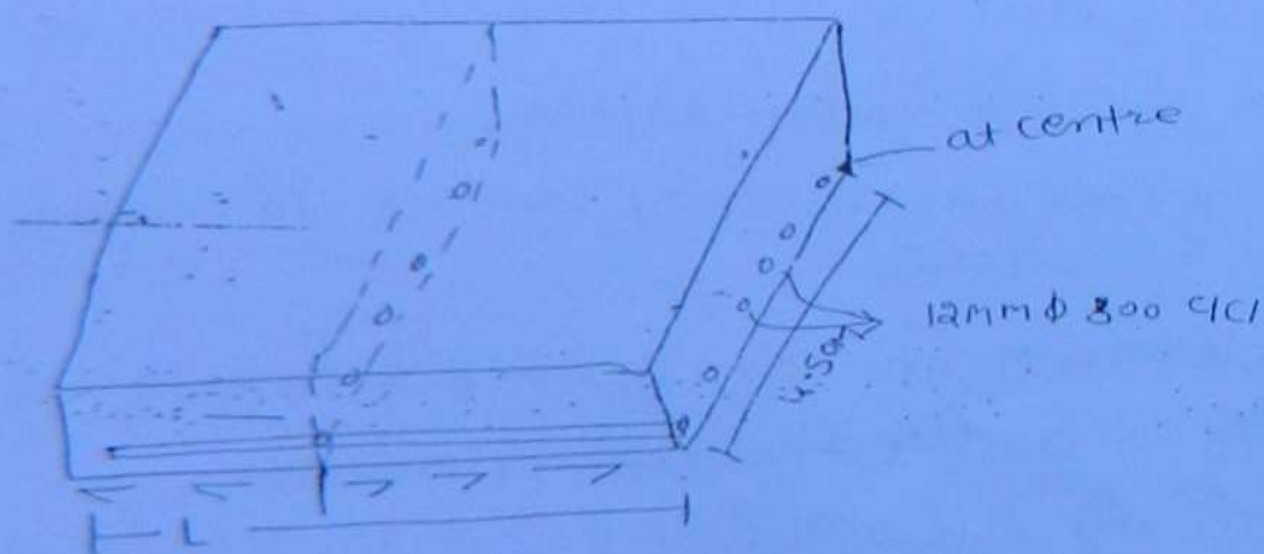
$S_f = \frac{f\ L\ W}{2 \times 10^4}$ kg/cm2

~~Sf~~

$L = \frac{2 \times 10^4\ S_f}{f \cdot W} = \frac{2 \times 10^4 \times 0.8}{1.5 \times 2400} = 4.44M.$

) steel is used [RCC]



$F = f \cdot R = A_{sd} \cdot \sigma_{sd}$

$f \cdot \frac{1}{2} \times B h \cdot W = A_{sd} \cdot \sigma_{sd}$

$L = \frac{2 A_{sd} \cdot \sigma_{sd}}{f \cdot B \cdot h \cdot W} =$

$$A_{st} = \left(\frac{B}{h}\right) \frac{\pi}{4} \times \phi^2$$

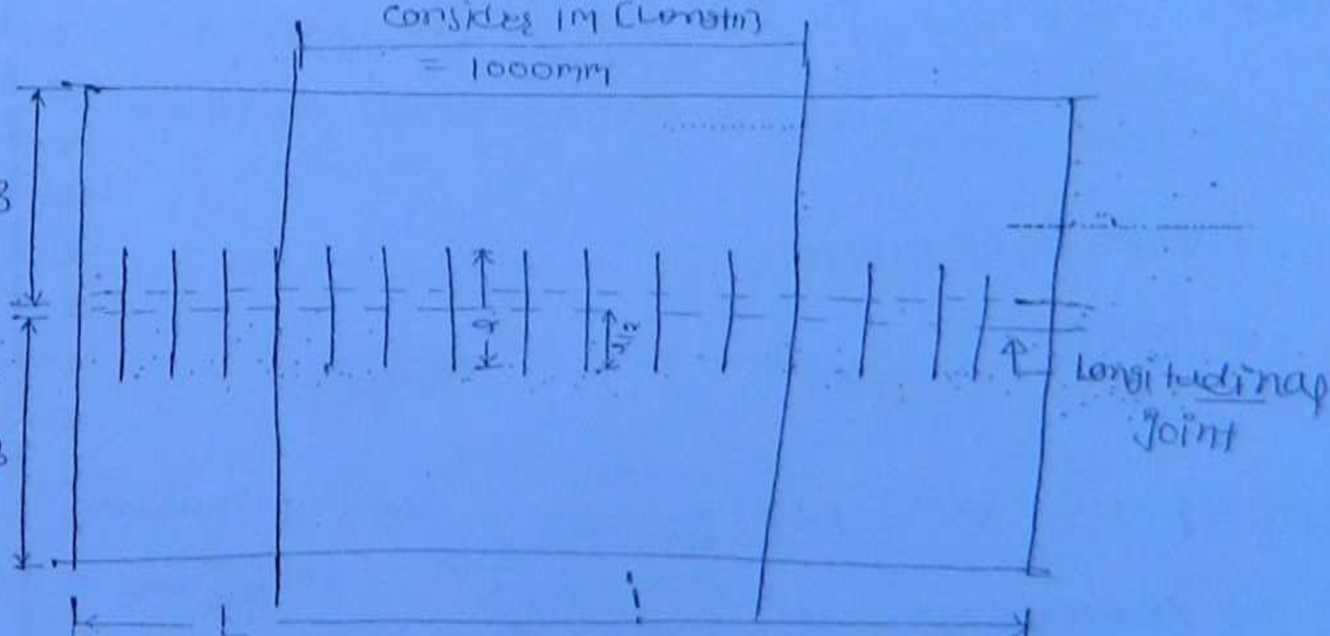
$$= \left(\frac{4500}{300}\right) \times \frac{\pi}{4} \times 12^2 \times \frac{1}{100}$$ ← For change in cm

$$A_{st} = 16.9646\ cm^2$$

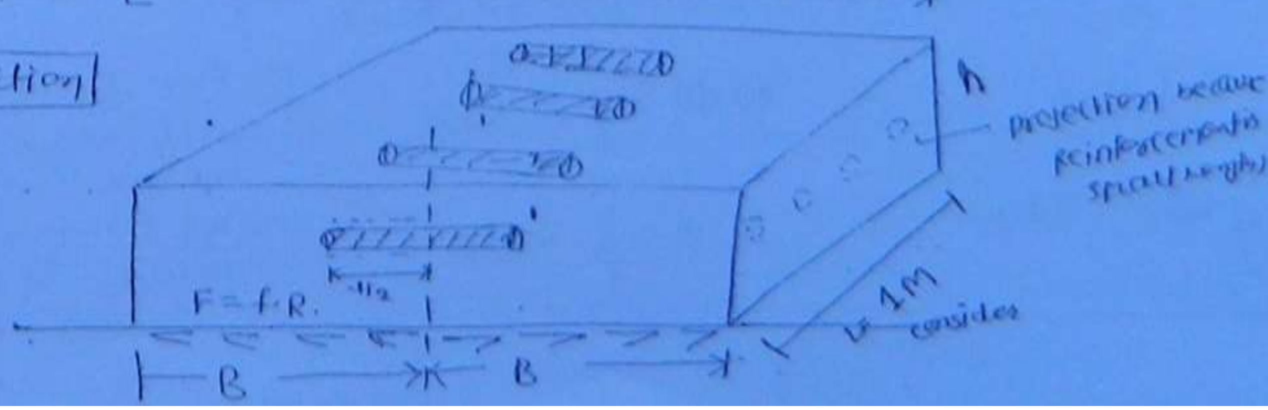
$$L = \frac{2 \times 16.9646 \times 1400}{1.5 \times 4.50 \times 0.25 \times 2500} = 11.25m$$

L = 11.25m

* Design of tie bar :-



Cross section



Force of friction

$F = f \cdot R = f \cdot$ [weight of half portion of slab]

$F = f \cdot [(B \times 1) \times h \times W]$ —— (1)   [W → unit wt. of pavement] $\boxed{W = \rho g} = \gamma$

(Area, volume)

Force of Resistance by steel

$= A_{st} \cdot \sigma_{st}$ —— (2)

Equating (1) and (2)

$f \cdot B \cdot h \cdot W = A_{st} \cdot \sigma_{st}$

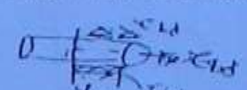
Area of steel required (for 1m width)

$$\boxed{A_{st} = \frac{f \cdot B \cdot h \cdot W}{\sigma_{st}}} \longrightarrow (A)$$

Spacing of reinforcement

$$= \frac{1000}{A_{st}} \cdot \frac{\pi}{4} \times \phi^2$$

Length of tie bars (d) :- $\pi\phi = \pi D =$ Circumference



Force of Resistance = strength in Bond

$A_{st} \cdot \sigma_{st} = (\pi\phi) \times \frac{d}{2} \times \tau_{bd}$

$\frac{\pi}{4}(\phi)^2 \cdot \sigma_{st} = \pi \phi \cdot \frac{d}{2} \cdot \tau_{bd}$

[Take $\frac{d}{2}$, bcoz tie has one side fail than so the that both side of pavement]

$$l = \frac{2 \cdot \phi \cdot \sigma_{st}}{4 \cdot \tau_{bd}}$$

→ Length of ties bar is Equal to twice of development length (Ld)

$$l = 2L_d$$

$\because L_d = \frac{\phi \cdot \sigma_{st}}{4 \cdot \tau_{bd}}$

(171)

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.

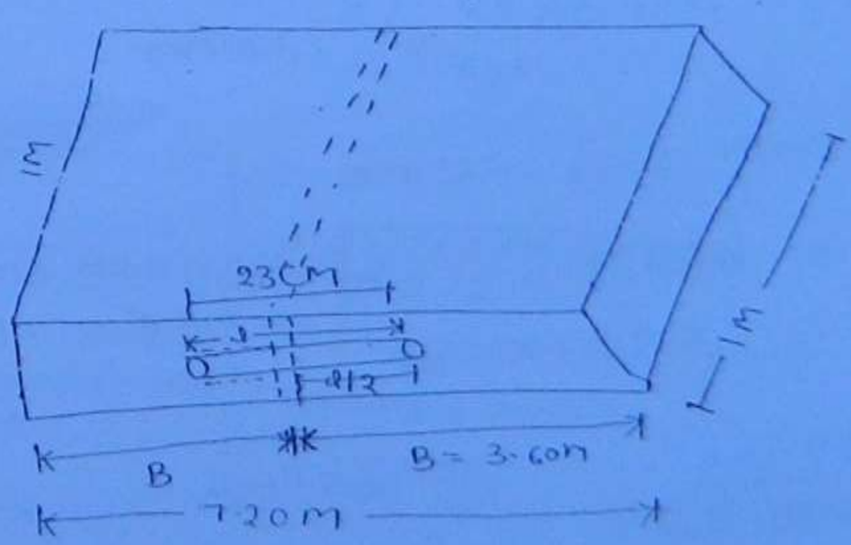
Allowable stress in steel in tension = 1400 kg/cm²

Unit weight of concrete = 2400 kg/m³

Coefficient of friction = f = 1.5

Allowable bond stress in concrete = 24.6 kg/cm²

Sol



Total width of slab = 7.20m

Half width = B = 3.60m

consider 1m length of slab

h = 24cm = 0.24m

<u>Area of steel</u>

$$A_{st} \cdot \sigma_{st} = f \cdot B \cdot h \cdot 1 \cdot W$$

$$A_{st} = \frac{f \cdot B \cdot h \cdot W}{\sigma_{st}} = \frac{1.5 \times 3.60 \times 0.24 \times 2400}{1400 \text{ kg/cm}^2}$$

$$A_{st} = 2.2217 \text{ cm}^2$$

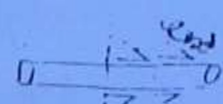
$$= 222.17 \text{ mm}^2$$

using 10mm ϕ bars

$$\text{Spacing} = \frac{1000}{222.17} \times \frac{\pi}{4} \times 10^2 = 353.5 \text{mm}$$

$$\text{using 8mm} = 353.3 \times \frac{8^2}{10^2} = 226 \text{mm}$$

Provide 8mm ϕ @ 220mm c/c



Length of tie bars:- [when the bar in fail in one side slab then Assume will be fail on both side]

$$A_{st} \cdot \sigma_{st} = \frac{l}{2} \pi \phi \times \tau_{bd}$$

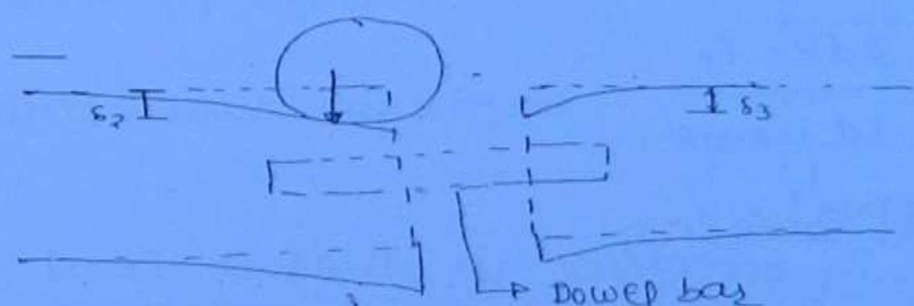
$$l = \frac{2\phi \, \sigma_{st}}{4 \times \tau_{bd}} = \frac{2 \times 0.8 \times 1400}{4 \times 24.6} = 22.76 \text{cm}$$

$$\boxed{l = 23 \text{ cm}}$$

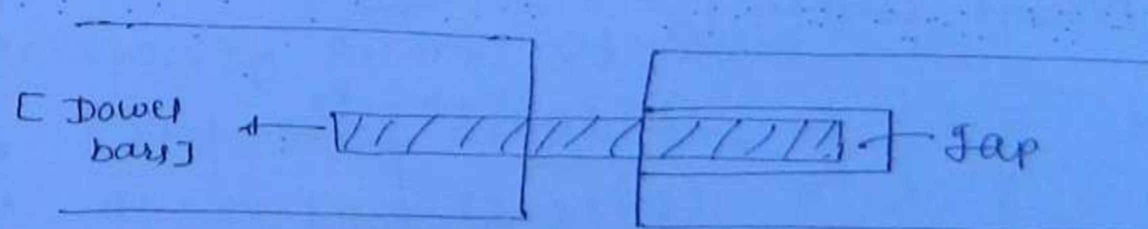
* Dowel bars :-

→ 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)

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

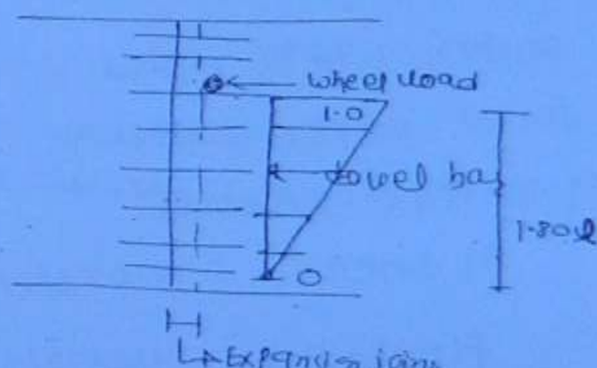
Design steps:-

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 = 1400 kg/cm² = f_f

Bearing = 120 kg/cm² = f_b

use Diameter of dowel bar = 20mm

soln Development length required

$$L_d = 5d\left[\frac{f_f}{f_b} \times \frac{L_d + 1.5\delta}{L_d + 8.8\delta}\right]^{1/2}$$

$$= 5\times2.0\left[\frac{1400}{120} \times \frac{L_d + 1.5\times2.4}{L_d + 8.8\times2.4}\right]^{1/2}$$

$$L_d^2\left[\frac{L_d + 21.12}{L_d + 3.6}\right] = 1166.67$$

by trial and error

$l_d = 27.27 \, cm$.

Total length of bar = $L_d + \delta = 27.27 + 2.4 = 29.6$

say = 30 cm

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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

$$= \frac{f_b \cdot L_d^2 \cdot d}{12.5 \, [L_d + 1.5\delta]}$$

$$F_b = \frac{120 \times 27.27^2 \times 2.0}{12.5 \, [27.27 + 1.5 \times 2.4)}$$

$= 462.50 \, kg$

③ Strength in flexure or bending

$$F_f = \frac{f_f \times 2d^3}{L_d + 8.8\delta} = \frac{1400 \times 2 \times 2^3}{[27.27 + 8.8 \times 2.4]}$$

$= 462.90 \, kg$

strength of single dowel bars.

$P' = 462.50$ kg

) Load capacity of dowel groups systems

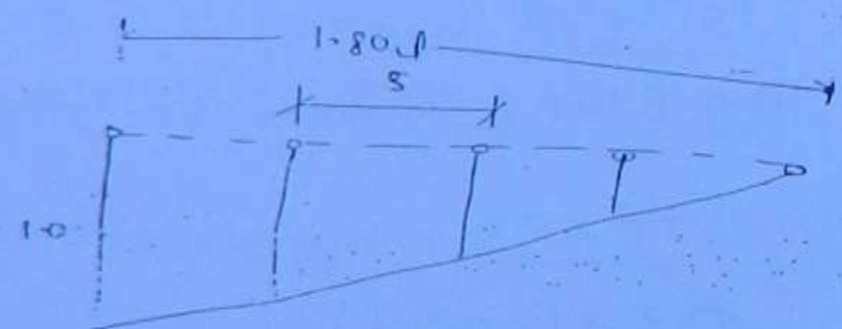
$= 40\%$ of wheel load

$= 0.40 \times 5100 = 2040$ 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

$$1 + \frac{144-30}{144} \times 1 + \frac{144-2\times30}{144} \times 1 + \frac{144-3\times30}{144} + \frac{144-120}{144}$$

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

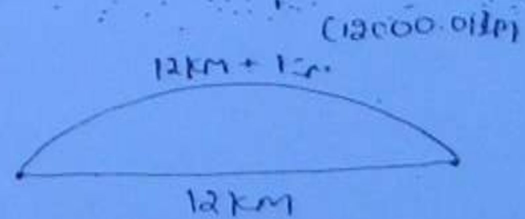
→ Plain surveying :-

→ Earth curvature is not considered.

* Geodetic survey:- Earth curvature is considered for large Area.

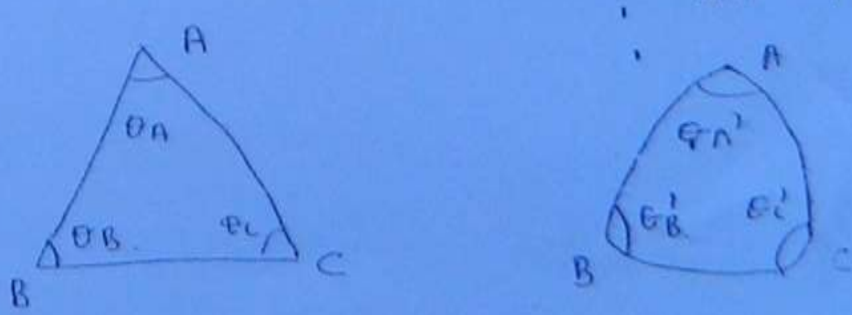
Example :-

(1)



→ For a 12 KM long line
diff = 1.0cm only

(2)



for an area
= 195 km²

$= 2.9$

[Pivoting method ?? calculating max spacing] ... are more than these value

$\rightarrow \dfrac{144 \times 5 - [30 + 60 + 90 + 120]}{144}$

→ Assume spacing = 20 cm

capacity factor

$= \dfrac{144 \times 8 - [20 + 40 + 60 + 80 + 100 + 120 + 140]}{144}$

$= 4.11$

→ Spacing = 18 cm

$\dfrac{144 \times 8 - (18 + 36 + 54 + 72 + 90 + 108 + 126]}{144} = 4.50 > 4.44$ (ok)

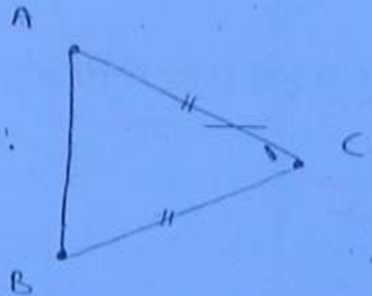
$(\theta_A' + \theta_B' + \theta_C') - (\theta_A + \theta_B + \theta_C) = 1$ second.

$= 0° 0' 1''$ or $0° 0' 1''$

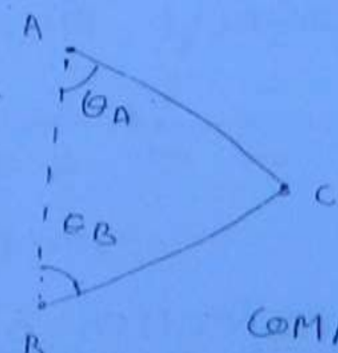
Principle of surveying :-

① Location of a point by measurement from two reference point.

A, B → Reference point

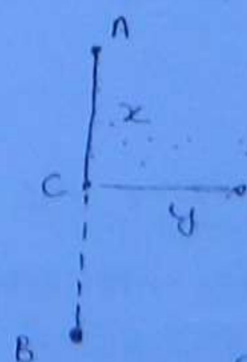


chain survey



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 measurment.

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* Accuracy And Error :-

① Precision :-

- Degree of perfection used in Measurment is called precision.

[using correct instruments, correct manner of reading]

② Accuracy :-

Degree of perfection obtained in measurment is called accuracy.

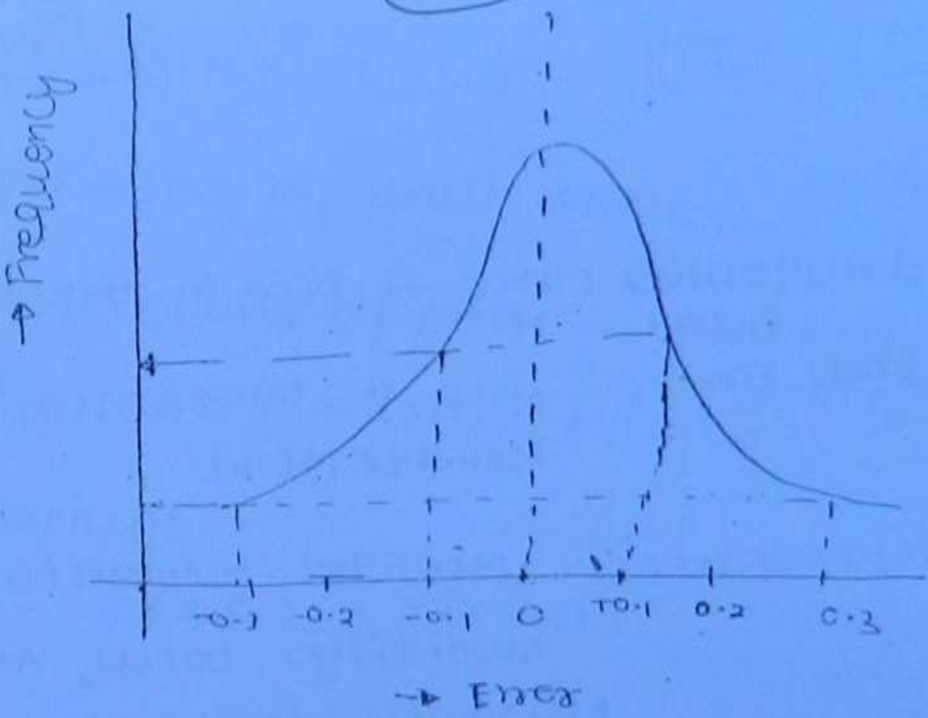
③ True Error :-

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 chance of being the correct value of a quantity is called most probable value.

Errors :-

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. Compensating 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	$(x-x_2)$	$(x-x_2)^2 \times w_2$
$x_3 = w_3$		$(x-x_3)$	$(x-x_3)^2 \times w_3$
$\vdots$		$\vdots$	$\vdots$

As per principle of least square

$$y = \omega_1 (x-x_1)^2 + \omega_2 (x-x_2)^2 + \cdots$$

$$\frac{dy}{dx} = 2\omega_1 (x-x_1) + \omega_2 (x-x_2) + \cdots = 0$$

$$x(\omega_1 + \omega_2 + \omega_3 \cdots) = \omega_1 x_1 + \omega_2 x_2 + \cdots \omega_n x_n$$

$$x = \frac{\omega_1 x_1 + \omega_2 x_2 + \cdots \omega_n x_n}{\omega_1 + \omega_2 + \cdots \omega_n}$$

→ 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

$V = (x - x_1)$, $(x - x_2)$, $(x - x_3)$ [difference b/w any single measurement and mean of 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 :-

$$E_m = \pm 0.6745 \sqrt{\frac{\Sigma v^2}{n(n-1)}}$$

$$E_m = \frac{E_s}{\sqrt{n}}$$

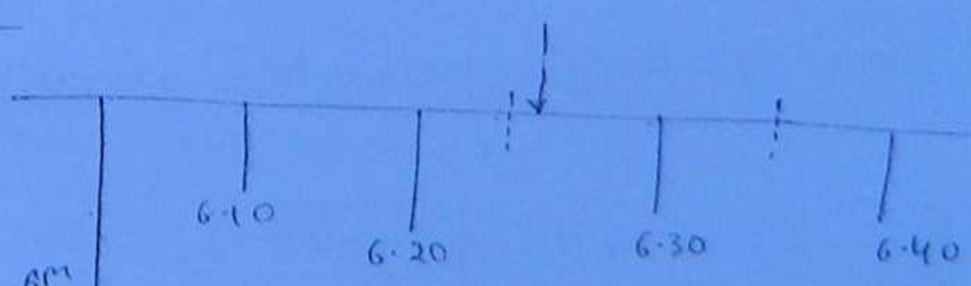
* Significant Figure in a Measurement :-

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.

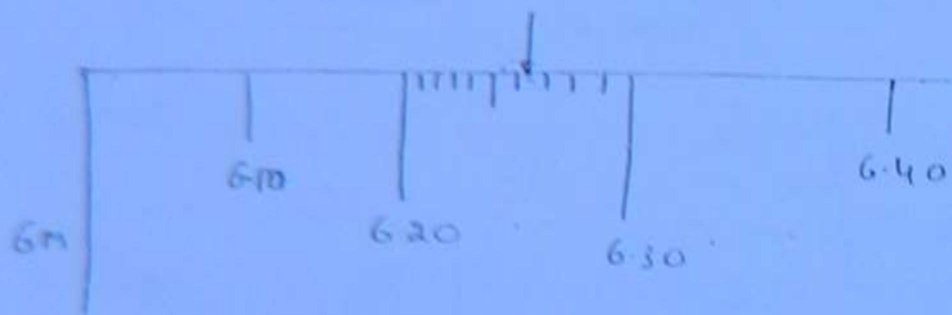
→ chances of Errors are in uncertain figure..

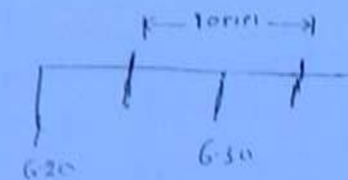


→ read 6.3

Max^m Error = 0.05m

Probable Error = 0.025 m $\left(\frac{\text{max}^m \text{ Error}}{2} \right)$





Reading = 6.26

Max^m Error = 0.005m

Probable Error = 0.0025 m

3. The probable Error of weighted arithmetic mean :-

$$E_s = \pm 0.6745 \sqrt{\frac{\Sigma(wv^2)}{(\Sigma w)(n-1)}}$$

4. Probable Error of any observation of weighted w

$$= \frac{E_s}{\sqrt{w}} = \pm 0.6745 \sqrt{\frac{\Sigma wv^2}{w(n-1)}}$$

* Errors in computed results:-

→ Significant figure

If a measurement has n digits.

initial (n-1) figures = certain figure

Last figures → uncertain figure

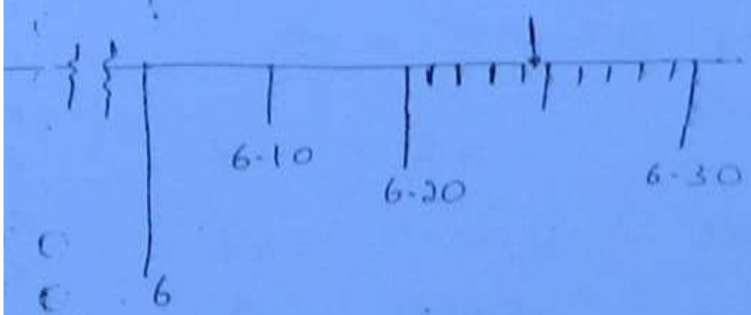
6.94 m

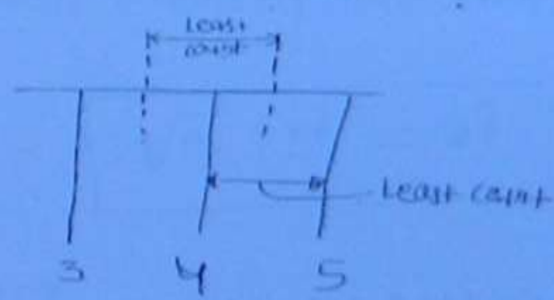
certain ← 9, 4 → uncertain

For this measurement

(1) Max^n Error = 0.005 m

[Half of least count]





(2) Probable Error = Half of Max^n Error

= 0.0025 m

Summation of Errors:-

Max^n Error:- sum is simple algebric.

$$e_t = e_1 + e_2 + e_3 + \cdots$$

Probable Error:- In this case accumulation is root mean square

$$e_t = \sqrt{e_1^2 + e_2^2 + e_3^2 + \cdots}$$

(190)

① Sum:- (S)

$$S = x + y$$

$$ds = 1 \cdot dx + 1 \cdot dy$$

① For Max^M Error

Max^M Error in ⓧ = δx — For S: $1 \cdot dx$

Max^M Error in ⓨ = δy — $1 \cdot dy$

Max^M Error in Ⓢ = δs

$$\boxed{\delta s = \delta x + \delta y} \quad \text{——— ①}$$

② Probable Error

Probable error in x = e_x — For S: $1 \cdot e_x$

Probable Error in y = e_y — $1 \cdot e_y$

Probable Error in S = e_s

$$\boxed{e_s = \sqrt{e_x^2 + e_y^2}} \quad \text{——— ②}$$

② Deduction:-

$$S = x - y$$

$$\frac{e_s}{s} = \sqrt{\left(\frac{e_x}{x}\right)^2 + \left(\frac{e_y}{y}\right)^2}$$

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 Maxm Error

in $x = \delta x$ for (s) $= \frac{1}{y} \cdot \delta x$

in $y = \delta y$ for (s) $= \left(-\frac{x}{y^2}\right)(\delta y) = \frac{x}{y^2}\delta y$

Maxm Error $s = \delta s$

$$\delta s = \frac{1}{y} \cdot \delta x + \frac{x}{y^2}\delta y$$

(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]

$(+\delta y) \quad (-\delta y)$

$\delta s = (\delta x) - (-\delta y)$

$\boxed{\delta s = \delta x + \delta y}$

Max^m Error in S = $\boxed{\delta s = \delta x + \delta y}$

$$\boxed{\delta s = \delta x + \delta y}$$

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 Ⓢ

$y \cdot \delta x$

$x \cdot \delta y$

Max^m Error in S :

$$\boxed{\delta s = y \cdot \delta x + x \cdot \delta y}$$

(3) Probable Error

Probable Error in $x = e_x$

Probable Error in $y = e_y$

Probable Error in $s = e_s$

For (S)

$y \cdot e_x$

$x \cdot e_y$

$$e_s = \sqrt{(y \cdot e_x)^2 + (x \cdot e_y)^2}$$

$$= \sqrt{[(y \cdot e_x)^2 + (x \cdot e_y)^2] \frac{x^2 y^2}{x^2 y^2}}$$

$$e_s = xy \sqrt{\left(\frac{y \cdot e_x}{x \cdot y}\right)^2 + \left(\frac{x \cdot e_y}{xy}\right)^2}$$

$xy = s$

$$e_s = s \sqrt{\left(\frac{e_x}{x}\right)^2 + \left(\frac{e_y}{y}\right)^2}$$

$$\frac{e_s}{s} = \sqrt{\left(\frac{e_x}{x}\right)^2 + \left(\frac{e_y}{y}\right)^2}$$

(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 $S - e_s = 9.66 - 0.025124 = 9.635$

Q. 2 if $S = \frac{96.83}{4.9} = \frac{x}{y}$

$x = 96.83$ $y = 4.9$

$\delta x = 0.005$ $\delta y = 0.05$

$e_x = 0.0025$ $e_y = 0.025$

Max^M Error

For (S)

$ds = \frac{y\,dx - x\,dy}{y^2}$

$= \left(\frac{1}{y}\right)dx - \left(\frac{x}{y^2}\right)dy$

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

$$\text{Ratio} = \frac{1\text{CM}}{500 \times 100\ \text{CM}} = \frac{1}{50{,}000}$$

Scale = (1 : 50000) ← R.F.

↓

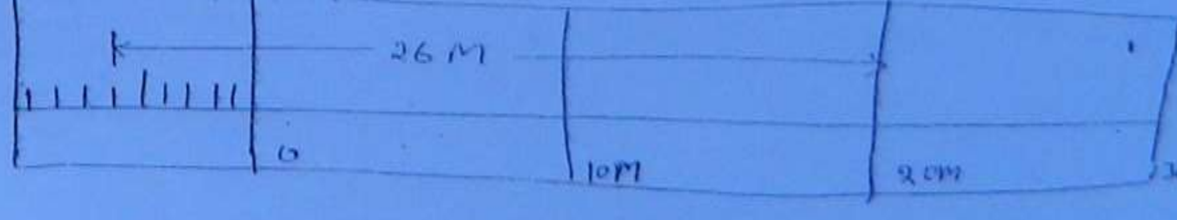
Representative fraction

Types :-

1) Plain scale :-

Measure upto two Dimensions only.

→ Let us make scale 1CM = 4M



Scale 1cm = 4m

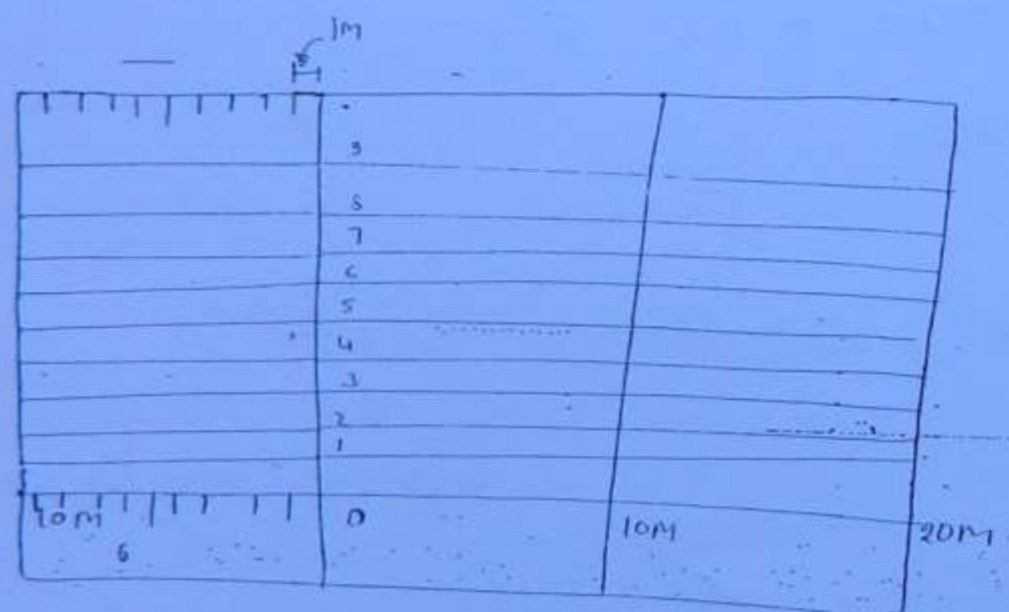
Take 10cm long line

In this case, Read two Dimension

① Decameter (= 10m)
② meter.

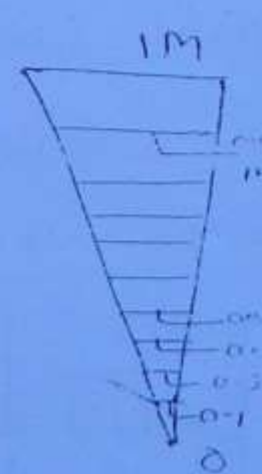
② Diagonal scale :-

→ Measure upto three dimensions.



In this case, Measure three dimensions

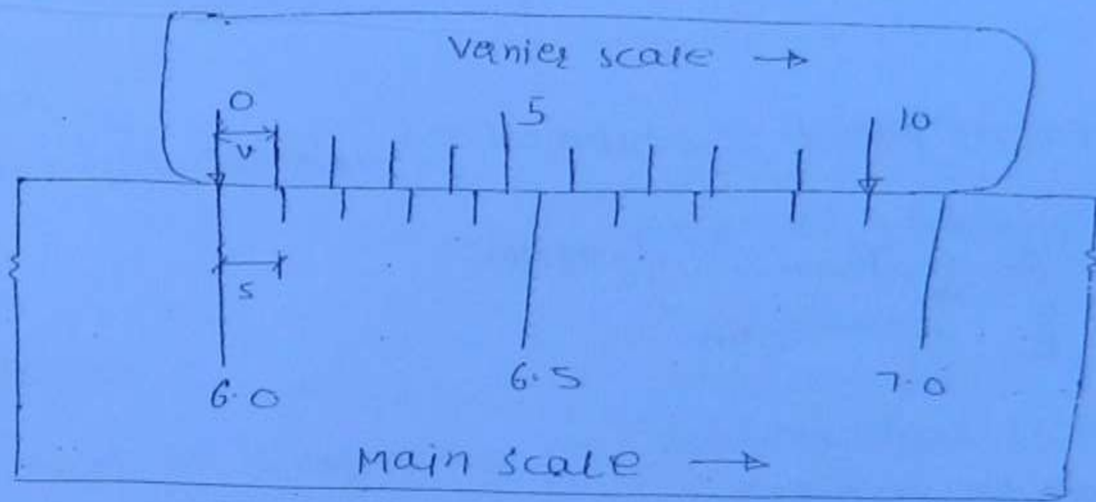
① 10m → Decameter
② meter → meter
③ 0.1 meter (10cm) → decimeter



(3) Vernier scale:-

→ Also Read three Dimensions

(I) Direct Vernier



(i) Vernier scale is in same direction as that of main scale.

(ii) (n-1) divisions of main scale is divided into n division of vernier scale

$$(n-1)s = n \cdot v$$

$$v = \left(\frac{n-1}{n}\right) \cdot s$$

Least count:-

Smallest measurement that can be read by the scale

$$= s - v \qquad (s > v)$$

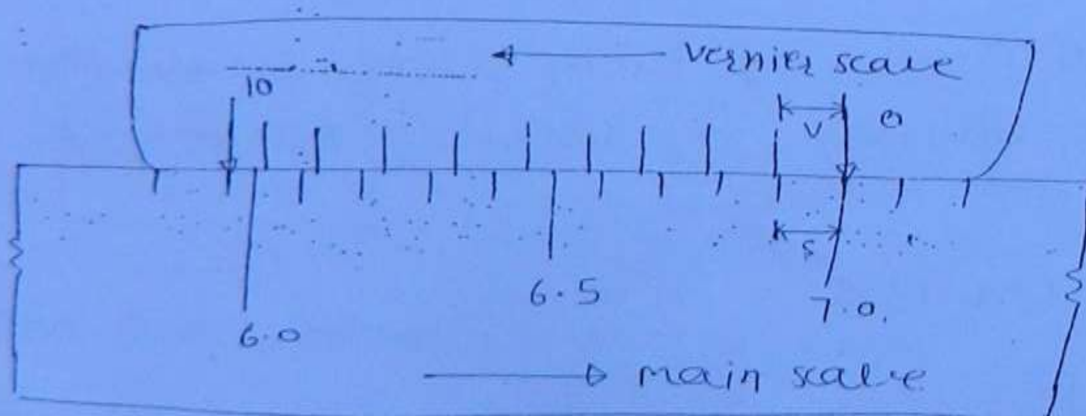
$$= s - \left(\frac{n-1}{n}\right)s = \frac{ns - ns + s}{n}$$

$$\boxed{\text{Least count} = \frac{s}{n}}$$

In this case Read, 3 Dimensions, say = 6.67.

6. 6 7 ← $\frac{1}{10}$ of mm.
↑ cm ↑ 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

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.

$$\text{shrinkage factor} = S.F. = \frac{\text{shrunk length}}{\text{original length}}$$

$$= \frac{9.5}{10}$$

$$S.F. = 0.95$$

Shrunk scale = original scale × 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

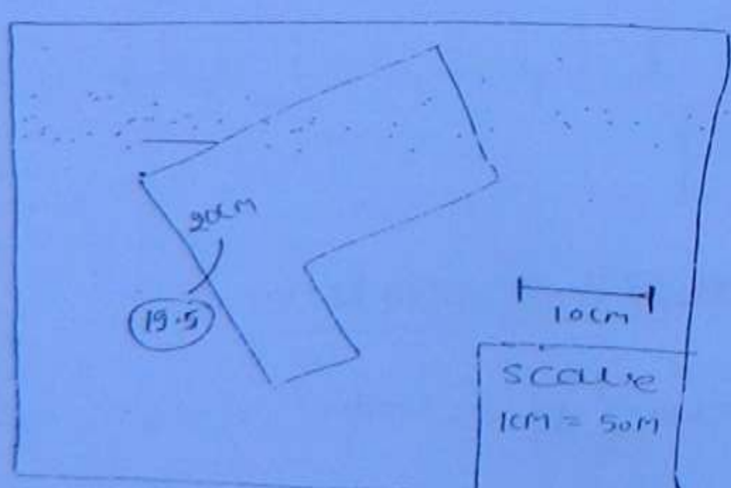
Least count $= v - s \quad (v > s)$

$$= \left(\frac{n+1}{n}\right) \cdot s - s$$

$$= \frac{s}{n}$$

$$\boxed{\text{Least count} = \frac{s}{n}}$$

* Shrunk scale :-



Now scale

$9.5\,cm = 50 \times 10 = 500\,m$

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)

T:

L' = wrong length of tape (Actual) (30.10m)

If l' = length of line measured (600m)

l = True length of ~~wire~~ line.

| True × True = wrong × wrong |

$$L \times l = L' \times l'$$

True length of line

$$l = \frac{L' \times l'}{L} = \frac{L'}{L} \times l'$$

Ex:- $L = \frac{30.10}{30} \times 600 = 602M$

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 :-

(207)

Correction Due to slope

$$C_s = AB - AC$$

$$= l - \sqrt{l^2 - h^2}$$

$$= l - l\left[1 - \left(\frac{h}{l}\right)^2\right]^{1/2}$$

$$= \frac{h^2}{2l} + \cdots\cdots = \frac{h^2}{2L}$$

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 :-

(i) 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

$$= l' + \text{correction}$$

$$= 600 + 2.0$$

$$= 602\,m$$

(4) Correction due to temperature :-

$$C_t = l' \alpha (T_m - T_0)$$

l' = length of line Measured

α = Correction of thermal Expansion

T_m = Temperature at the time of Measurement

T_0 = Temperature at the time of Standardization of Tape

(5) correction Due to pull :-

$$C_p = \frac{(P_m - P_0) l}{AE}$$

P_m = Pull at the time of Measurement

P_0 = pull at the time of standardization

l = length of line

A = cross section area of tape

E = young modulus of tape/chain

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⑥ Sag Correction :-

$$\text{sag correction} = S_g = \frac{(w \cdot l)^2 \cdot l}{24 \cdot P_m^2}$$

$$S_g = \frac{w^2 \cdot l}{24 \cdot P_m^2}$$

w = weight of tape

l = length of line

Pm = pull at the time of measurement

Laboratory Determination of California Bearing Ratio

13

AIM :

To determine the California bearing ratio of sub grade soil in the laboratory.

SCOPE & APPLICATION OF THE TEST :

This test is used for evaluating subgrade strength for the design of flexible pavements .The ratio is used in conjunction with curves evolved through a study of the performance of the flexible pavements.

THEORY :

California bearing ratio (CBR) test was originally developed by the California State High way Department in U.S.A and is one of the most commonly used methods to evaluate the strength of sub- grade soil & base course materials for the design of pavement thickness. This method provides a good substitute for heavy field tests which would have been other wisely required to determine the strength properties. This test is empirical and the results of this test cannot be related accurately with the fundamental properties of the material but are useful in the design of flexible pavements.

The CBR is a measure of resistance of a material to penetration of standard plunger under controlled density and moisture conditions . The test procedure is to be strictly adhered if reliable results are desired. The CBR test may be conducted on re- moulded or undisturbed specimen in the laboratory as well as in situ condition in the field .There are many methods that exist today which utilize mainly CBR test values for design of pavement structure. The test is simple and has been extensively investigated for field correlations of flexible pavement thickness requirement.

The California bearing ratio (CBR) is defined as the ratio expressed in percentage of force per unit area required to penetrate a soil mass with a circular plunger of 50mm diameter at the rate of 1.25 mm/min to that required for corresponding penetration in a standard material i.e. the standard load .The standard load is that load which has been obtained from the average of a large number of tests on different crushed stones whose CBR value is taken to be 100 percent as given in the table below.

<u>Standard load for different penetration values</u>

Penetration, mm	Standard load, Kg	Unit standard load Kg/cm^2
2.5	1370	70
5.0	2055	105
7.5	2630	134
10.0	3180	162
12.5	3600	183

The ratio is usually determined for penetration of 2.5 and 5 mm and the greater of the ratios is taken as the CBR value. In most cases , the CBR value corresponding to 2.5 mm penetration comes to be higher .However, for the cases, where the ratio at 5mm is constantly higher than that at 2.5 mm, the ratio at 5mm is used.

APPARATUS REQUIRED :

(1) C.B.R mould – A metallic cylinder of 150 mm internal diameter and 175 mm high, provided with a detachable metal extension collar 50 mm in height. It also has a detachable perforated base plate of 10mm thickness , the perforations being not more than 1.5 mm in diameter. It has threaded stay rods and wing nuts for assembling.

(2) Steel cutting edge (collar) which can fit flush with the mould.

(3) Spacer disc – A metal disc of 148 mm diameter and 47.7 mm in height used to obtain specimen of exactly 127.3 mm height.

(4) Surcharge weights –Annular metal weights and slotted weights each of 2.5 k g (and 5 kg as spares) and 147 mm in diameter with a central hole of 53 mm in diameter.

(5) Dial gauges – Two dial gauges with accuracy of 0.01 mm.

(6) I.S sieves of size – 4.75 mm and 19 mm.

(7) Penetration plunger – A metallic plunger having a diameter of 50 mm and at least 100 mm long.

(8) Loading machine with a capacity of at least 5000kg equipped with a movable base which can move vertically at a rate of 1.25 mm /min and having a load measuring device like a load cell or a proving ring.

(9) Metal rammer – of weight 2.6 kg (for light compaction) or 4.89 kg (for heavy compaction) for dynamic compaction.

(10) Expansion measuring apparatus – perforated plate with adjustable stem, tripod etc.

(11) Miscellaneous apparatus – Mixing bowl, straight edge, scales, soaking tank, drying oven, filter paper, dishes and calibrated measuring jar.

(12) Compression testing machine for static compaction.

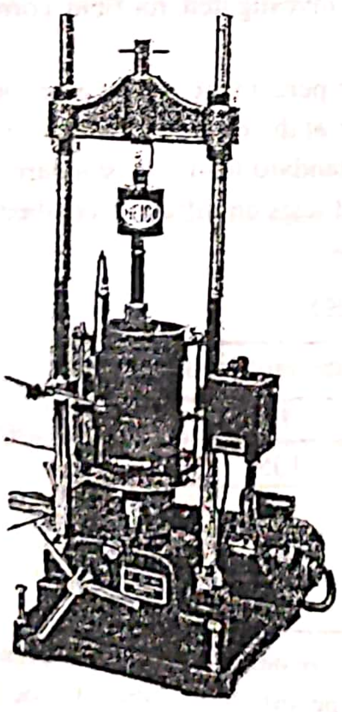


Fig. 13.1 CBR test apparalus

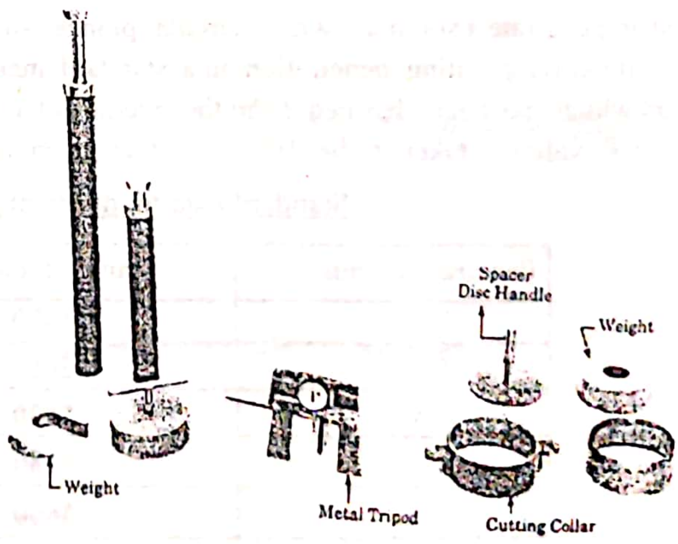


Fig. 13.2. Laboratory CBR test apparatus

Laboratory Determination of California Bearing Ratio

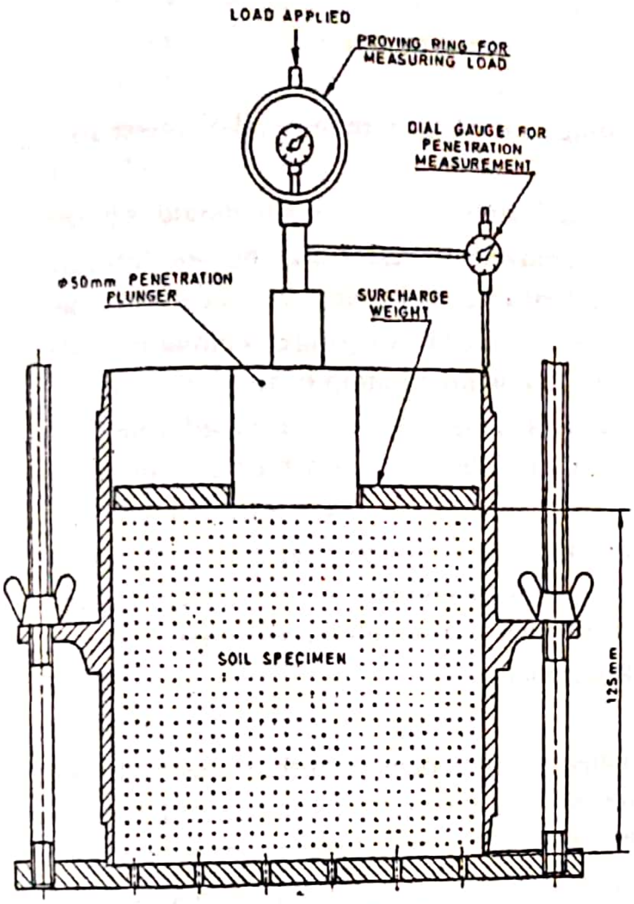
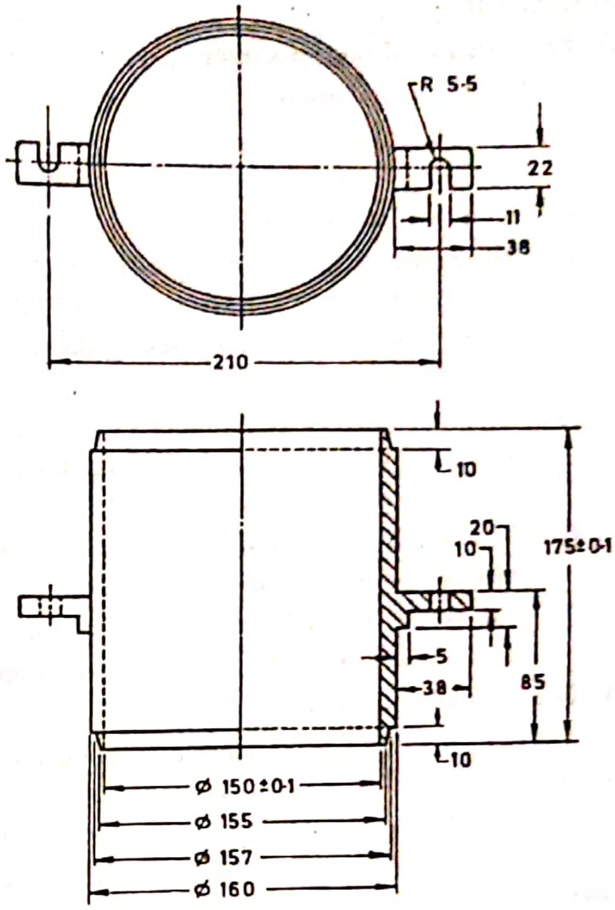


Fig.13.3 SET-UP FOR CBR TEST



All dimentions is mm

Fig. 13.4 MOULD

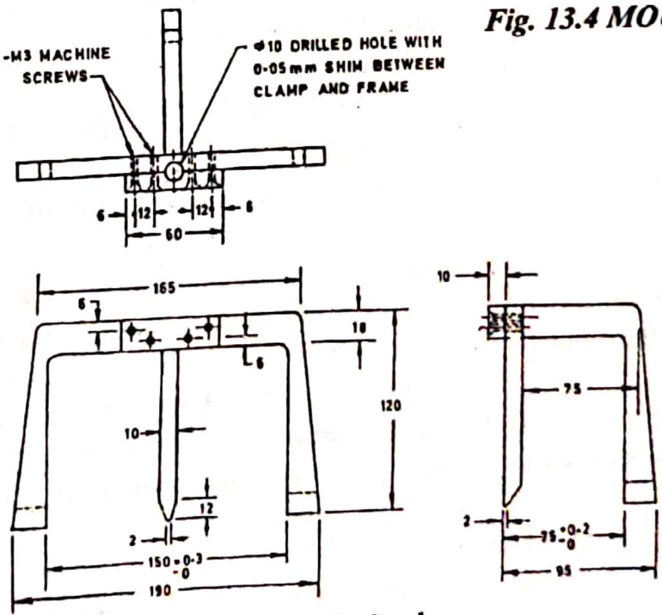


Fig. 13.5 Metal tripod

MATERIALS REQUIRED

(1) Sample of soil.

(2) Grease.

(3) Water.

PROCEDURE :

[A] Preparation of test specimen:

(i) Undisturbed specimen

(1) It is obtained by fitting to the mould, the steel cutting edge of 150mm internal diameter and pushing the mould as gently as possible into the ground.

(2) This process may be facilitated by digging away soil from the outside as the mould is pushed in.

(3) When the mould is sufficiently full of soil, it is removed by under digging, the top and bottom surfaces are then trimmed flat so as to give the required length of specimen ready for testing.

(4) If the mould cannot be pressed in, the sample may be collected by digging at a circumference greater than that of the mould and thus bringing out a whole undisturbed lump of soil.

(5) The required size of the sample to fit into the test mould is then carefully trimmed from this lump. If the specimen is loose in the mould, the annular cavity is filled with paraffin wax thus ensuring that the soil receives proper support from the sides of the mould during the penetration test.

(6) The density of the soil is determined either by weighting the soil with mould when the mould is full with soil or by measuring the dimensions of the soil sample accurately and weighing or by measuring the density in the field in the vicinity of the spot at which the sample is collected.

(7) In all cases, the water content of the sample is determined.

(ii) Remoulded specimen:

The dry density for remoulded soil specimen is to be either the field density or the value of the maximum dry density estimated by the compaction tests and/or any other density at which the bearing ratio is desired. The water content used for compaction is to be the optimum water content or the field moisture as the case may be.

The material used in the remoulded specimen is to pass a 19mm IS sieve .But if there is noteworthy proportion of materials retained on 19mm IS sieve, allowance for larger size material is made by replacing it by an equal amount of material which passes a 19mm IS sieve but is retained on 4.75 mm IS sieve. The remoulded samples are compacted either statically or dynamically.

(a) Statically compacted specimen :

(1) The mass of the wet soil at the required moisture content to give the desired density when it occupies the standard specimen volume in the mould is calculated.

(2) A batch of soil is thoroughly mixed with calculated quantity of water to give the required water content.

(3) The extension collar is fixed to the mould and clamped to the base plate.

(4) A circular filter paper of diameter same as the inside diameter of the mould is placed on the perforated base plate and the mould is filled with correct mass of moist soil by gently pressing it with hands so that it does not spill out of the mould ,after which the extension collar is removed.

(5) A coarse filter paper is placed on the leveled soil surface, the spacer disc is inserted and the compaction is obtained by pressing the displacer disc in a compression testing machine till it is flush with the top of the mould.

(b) Dynamically compacted specimen :

(1) A representative sample of soil weighing approximately 4.5kg or more for fine grained soils and 5.5 kg or more for granular soils is taken.

(2) Water is added to the soil in the quantity such that the moisture content of the specimen is either equal to the field moisture content or optimum moisture content as desired and mixed uniformly.

(3) The mould with the extension collar attached is clamped to the base plate, the spacer disc is inserted over the base plate and a disc of coarse filter paper is placed on the top of the spacer disc.

(4) The soil water mixture is compacted into the mould in accordance with the methods applicable to the 150 mm diameter mould as per light or heavy compaction test as desired. [5 layers -56 blows -2.6 kg rammer /310 mm or 4.89 kg rammer /450 mm]

(5) If the other densities and water contents are desired, they may be used and indicated in the report.

(6) Then the extension collar is removed and the compacted soil is carefully trimmed evenly with the top of the mould by means of a straight edge.

(7) Any hole that may then develop on the surface of the compacted soil by the removal of the coarse material is to be patched with smaller size material.

(8) The perforated base plate and the spacer disc is removed and the mass of the mould and compacted soil specimen recorded.

(9) A disc of coarse filter paper is placed on the perforated base plate, the mould and the compacted soil is inverted and the perforated base plate clamped to the mould with the compacted soil in contact with the filter paper.

Water content of soaked sample:

In both cases of compaction, if the sample is to be soaked, representative sample of material at the beginning of the compaction and another sample of the remaining material after compaction is to be taken for determination of water content. Each water content sample should weigh not less than about 50g.

Water content of un-soaked sample:

If the sample is not to be soaked, a representative sample of material from one of the cut pieces of the material after penetration of the plunger is to be taken to determine the water content.

[B] Test for swelling (if required)

(1) A filter is placed over the specimen and the perforated plate with adjustable stem is placed on the compacted soil specimen in the mould.

(2) Weights to produce a surcharge equal to the weight of the base material and pavement (2.5kg or its multiple) is placed on the compacted soil specimen.

(3) The whole mould along with weights is immersed in a tank of water allowing free access of water to the top and bottom of the specimen.

(4) The tripod for the expansion measuring device is mounted on the edge of the mould and the initial dial gauge reading recorded.

(5) The set-up is kept undisturbed for 96 hours noting down the readings everyday against the time of reading. A constant water level is maintained in the tank throughout the period.

(6) At the end of the soaking period, the change in dial gauge is noted, the tripod removed and the mould taken out of the water tank.

(7) The free water collected in the mould is removed and the specimen allowed to drain downwards for 15 minutes. Care is taken not to disturb the surface of the specimen during removal of the water.

(8) The weights, the perforated plate and the top filter paper is removed and the mould filter with the soaked soil sample is weighed and the mass recorded.

[C] Penetration test :

(1) The mould containing the specimen, with the base plate in position but the top face exposed is placed on the lower plate of the testing machine.

(2) Surcharge weights, sufficient to produce an intensity of loading equal to the weight of the base material and pavement (generally 5 kg or multiple of 2.5kg) is placed on the specimen.

(3) If the specimen has been soaked previously, the surcharge is to be equal to that used during the soaking period.

(4) To prevent upheaval of soil into the hole of the surcharge weights, 2.5 kg annular weight is placed on the soil surface prior to seating the penetration plunger after which the remainder of the surcharge weight is placed.

(5) The plunger is seated under a load of 4kg so that full contact is established between the surface of the specimen and the plunger.

(6) The load and deformation gauges is then set to zero.(otherwise ,the initial load applied to the plunger is considered as zero when determining the load penetration relation)

(7) The load is applied through the plunger into the soil at the rate of 1.25 mm per minute and reading of the load is taken at penetrations of 0.5, 1.0, 1.5, 2.0, 2.5, 4.0, 5.0, 7.5, 10.0 and 12.5mm.(The maximum load and penetration is recorded if it occurs for a penetration of less than 12.5mm).

(8) The plunger is raised and the mould detached from the loading equipment.

(9) About 20 to 50 g of soil is collected from the top 30mm layer of the specimen and the water content determined.

(10) If the average water content of the whole specimen is desired, water content sample is to be taken from the entire depth of the specimen.

(11) The undisturbed specimen for the test is carefully examined after the test is completed for the presence of any oversize soil particles which are likely to affect the result, if they happen to be located directly below the penetration plunger.

(12) The penetration test may be repeated as a check test for the rear end of the sample.

PRECAUTIONS :

(i) The holes of the base plate of the mould should not be blocked.

(ii) The surcharge weight should not touch the plunger so that the plunger penetrates freely into the soil.

(iii) The top plate or bar of the machine should be properly leveled so that the bottom of the plunger remains perfectly horizontal to have proper contact on the top of the soil sample.

CALCULATION AND OBSERVATIONS :

(i) Expansion ratio: Which qualitatively identify the potential expansiveness of soil is calculated based on the tests conducted on the soaked sample and is given by $= \frac{d_f - d_s}{h} \times 100$

where, d_f = final dial gauge reading in mm.

d_s = initial dial gauge reading in mm.

h = initial height of the specimen in mm.

(ii) Load penetration curve :

This curve is usually convex upwards although the initial portion of the curve may be convex down wards due to surface irregularities .This may be due to (i) piston surface not being fully in contact with top of the specimen or (ii) the top layer of the soaked soil being too soft. A correction is then applied by drawing a tangent to the point of greatest slope and then transporting the axis of the load so that zero penetration is taken as the point where the tangent cuts the axis of penetration. The corrected load penetration curve would then consist of the tangent from the new origin to the point of tangency on the re-sited curve and then the curve itself.

(iii) California Bearing Ratio :

The CBR values are usually calculated for penetrations of 2.5 mm and 5mm .The corrected load value corresponding to the penetration value at which the CBR value is desired is taken from the load penetration curve and the CBR calculated as follows.

$$\text{California Bearing Ratio} = \frac{P_T}{P_S} \times 100$$

where P_T= corrected unit (or total) test loads corresponding to the chosen penetration from the load penetration curve.

and P_S= unit (or total) standard load for the same depth of penetration as for P_T taken from the table.

Generally, the CBR value at 2.5 mm penetration is greater than that at 5mm penetration and in such acase, the former shall be taken as the CBR value for design purposes. If the CBR value corresponding to a penetration of 5mm exceeds that for 2.5 mm, the test is repeated. If identical results follow, the CBR corresponding to 5mm penetration is taken for design.

The average value of three specimens is reported to the first decimal place.

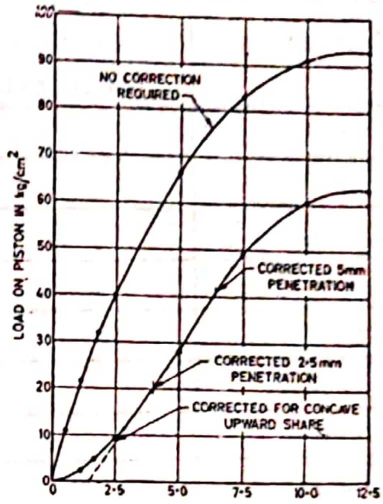


Fig. 13.6

Observation sheet for specimen data :

(i) Soil identification: ___________.

(ii) Condition of the specimen at test :

(a) Undisturbed /Remoulded.

(b) Soaked /Un soaked.

(iii) Type of compaction :

(a) Static/ Dynamic compaction.

(b) Light /heavy compaction.

(iv) Soil fraction above 20 mm replaced _________kg.

Water content	Before soaking	After test		
		Top	Centre	Bottom
Can No.				
Wt. of can + wet soil(g)				
Wt. can + dry soil(g)				
Wt. of water(g)				
Wt. of can(g)				
Wt. of dry soil(g)				
Water content (%)				

Condition of specimen	Before soaking	After soaking
Wt. of mould + soil(kg)		
Wt. of mould(kg)		
Wt. of soil(kg)		
Volume of specimen(cc)		
Bulk density(g/cc)		
Average water content (%)		
Dry density(g/cc)		

Observation sheet for penetration data

Surcharge weight used = ____________ Kg

Penetration	Test – 1		Test – 2	
	Load measuring device reading	Load(Kg)	Load measuring device reading	Load (Kg)
0				
0.5				
1.0				
1.5				
2.0				
2.5				
3.0				
4.0				
5.0				
7.5				
10.0				
12.5				

RESULT :

CBR of specimen at 2.5mm penetration =

CBR of specimen at 5.0mm penetration =

CBR of specimen = ____________%

Surcharge weight used (Kg) =

Period of soaking (days) =

Initial height of the specimen, h (mm) =

Initial dial gauge reading, d_s (mm) =

Final dial gauge reading, d_f(mm) =

Expansion ratio $= \frac{d_f - d_s}{h} \times 100 =$

CONCLUSION /REMARKS :

(Comment on the result by comparing with standard values).

DISCUSSION :

Initially the CBR tests were carried out in U.S.A on materials comprising the sub grade and sub-base of a number of roads with known performance. While some of these roads remained stable, others failed. From this data, it was concluded that a material with a certain CBR value required a certain minimum thickness of stronger material above it. Design curves were developed to get the required thickness for wheel loads corresponding to light, medium and heavy traffic respectively. Thus for a given CBR and wheel load, the total thickness of the pavement required on the top of that material can be directly obtained from these curves.

The CBR value of a soil can thus be considered to be an index which in some fashion is related to its strength. The value is highly dependent on the condition of the material at the time of testing.CBR values has been correlated to parameters like modulus of sub grade reaction, modulus of resilience and plasticity index etc. The CBR value of embankment /sub -grade soil should in no case be less than 2 and for granular sub base it should be more than 25.

REFFERNCE :

IS: 2720 (Part-16) Methods of test for soil, Laboratory determination of CBR.

SHORT TYPE QUESTIONS :

1. What is CBR value ? Under which circumstances soaked CBR test is conducted ?

Ans. It is the ratio of force per unit area required to pentrate a soil mass with place the mould assembly with the surcharge weight on the pentration test.

2. What is the necessity of surcharge weight ?

Ans. The califarnia bearing ratio test is penetration test meant for the evaluation of sub grade strength of road and pavements. The results obtained by these test are used with the empirical curve to determine.

3. What are the field applications of CBR test results ?

Ans. Load pentration curve of compacted soil. This values of water content. is called the equlibrium moisture content of the curve is concave upward and over this section, a correction

4. When is the correction of load-penetration Curve called for ?

Ans. When - Piston surface not being fully in contact with top of the specimen on the top layer of the soaked soil being too soft, then the correction of load-penetration curve called.

5. What are the causes for the initial concavity of the load-penetration curve ?

Ans. Load pentration curve of compacted soil - The reason Load pentration curve of compacted soil for the diamtr for the odd dimension of 49.6 mm for the diamtr of the plunger, but sometimes the initial part of the curve is concave.

Jyotirmayee Sahu

Signature of the Student

Roll No:...F16110001017...

Date : ...03-09-18...

Soundness Test of Road Aggregates 15

AIM :

To determine the soundness of road aggregates.

SCOPE OF THE TEST:

This test furnishes information helpful in judging the soundness of aggregates subjected to weathering action, particularly when adequate information is not available from service records of the material exposed to actual weathering conditions.

THEORY :

Soundness may be defined as the resistance of aggregates to the weathering action of natural agents. In the absence of adequate information from performance studies, a laboratory test simulating accelerated weathering condition is carried out to judge the durability or the soundness of aggregates.

In order to quicken the effect of weathering due to alternate wet –dry and or freeze-thaw cycles in the laboratory, the resistance to disintegration of aggregates is determined by socking the aggregate specimens in saturated solution of sodium sulphate or magnesium sulphate.

INSTRUMENTS /EQUIPMENTS REQUIRED :

(1) Containers for the aggregates – made with suitable perforations or with wire mesh to permit free access or drainage of the solution from the sample.

(2) Balance of capacity -500 gm, sensitive to 0.1 gm.for fine aggregate &5000g, sensitive to 1gm for coarse aggregate.

(3) Device for temperature regulation of samples during immersion.

(4) Drying oven for maintaining a temperature of 105°C to 110°C and of rate of evaporation of 25g/hr.

(5) IS sieves – 4.75mm, 8mm,10mm,12.5mm,16mm,20mm,25mm,31.5mm,40mm,50mm,63mm,80mm..

PROCEDURE:

A. **Preparation of reagents**

METHOD –I

(1) Saturated solution of sodium sulphate (the anhydrous Na_2SO_4 or the crystalline Na_2SO_4, $10H_2O$) is prepared in water at a temperature of 25°C to 30°C such that the solution is saturated and excess salt is present. It may be necessary to use not less than 420g of anhydrous s salt or 1300g of the crystalline dehydrate salt per liter of water.

(2) The solution is maintained at a temperature of 27°C ± 2°C and stirred at frequent intervals, until it is used.

(3) At the time of using, the solution should have a specific gravity of not less than 1.151 and not greater than 1.171 and discolored solution should not be used.

METHOD- II

(1) Alternatively ,saturated solution of Magnesium Sulphate may be prepared by dissolving either anhydrous ($MgSO_4$) or crystalline ($MgSO_4$,$7H_2O$) Magnesium Sulphate .Not less than 400 g of the anhydrous salt or 1600 g of the crystalline heptahydrate may be used per litre of water .

(2) Same as method –I.

(3) At the time of using, the solution should have a specific gravity of not less than 1.295 and not more than 1.308.

B. Preparation of sample:

(4) The specimen of coarse aggregate for the test may be prepared after removing the fraction finer than 4.75 mm IS sieve.

(5) The sample should be of such size that it will yield not less than the following amounts of the different sizes, which should be available in amounts of 5 percent or more.

Sieve size	*Yield*
10mm to 4.75mm	300g
20mm to 10mm{12.5 to 10mm-33%} {20 to 12.5mm-67%}	1000g
40mm to 20mm {25 to 20mm-33%} {40 to 25mm-67%}	1500g
63mm to 40mm{50mm to 40mm-50%} {63mm to 50mm-50%}	3000g
80mm and larger sizes by 20mm spread in sieve size, each fraction	3000g

(6) The sample of course aggregate should be thoroughly washed and dried to a constant weight at 105°C to 110°C and is separated to different size ranges by sieving as per preceding table.

(7) The proper weight of the sample for each fraction is weighed and placed in separate containers for the test. In the case of fraction coarser than 20mm, the particle are also counted.

C. Test Cycles:

(8) The samples are immersed in the prepared solution of sodium sulphate or magnesium sulphate for 16 to 18 hours in such a manner that the solutions cover them to a depth of at least 15mm.

(9) The containers are kept covered to reduce evaporation and during the period of immersion, the temperature of the solution is maintained at 27°C ±1°C.

(10) After the immersion period , the aggregates are removed from the solution , drained for about 15 minutes and placed in the drying oven maintained at a temperature of 105°C to 110°C.

(11) The samples are dried to a constant weight at this temperature by checking the weights after 4 hours up to 18 hours. When the successive weights differ by less than 1g, it may be considered that constant weight has been attained and then it may be allowed to cool to room temperature.

(12) Then the aggregates are again immersed in the prepared solution for the next cycle of immersion and drying. In this manner, alternate immersion and drying is done for a pre-decided number of cycles.

D. Assessment of weathering effects:

(13) After completion of the final cycle , the sample is cooled , washed free from the sulphate , which is determined when there is no more reaction of the wash water with barium chloride resulting in white precipitation .

(14) Each fraction of the sample is then dried to constant weight at a temperature of 105°C to 110°C and weighed. Course aggregate fractions are sieved by IS sieves of sizes as indicated below.

Size of aggregate	*Sieve size used to determine loss*
63 to 40mm	31.5mm
40 to 20mm	16.0mm
20 to 10mm	8.0mm
10 to 4.75mm	4.0mm

(15) Each fraction of the aggregate is also examined visually to see if there is any evidence of excessive splitting, crumbling or disintegration of the grains.

(16) A combined sieve analysis of all the materials subjected to the above test cycles, may also be carried out to note the variation from the original grain size distribution of the sample

PRECAUTIONS :

(1) Arrangements are made to ensure that the volume of the solution in which samples are immersed is at least five times the volumes of the sample immersed at any onetime.

(2) Grading of the samples and weights of the test fractions should be taken accurately.

(3) Test results by the use of the two salts may differ considerably and care is taken in fixing proper limits in any specification.

OBSERVATION AND CALCULATION

Type of reagent used: ______________

Type of coarse aggregate sample: ____________ Number of cycles ____________________

Sieve size, mm		Grading of original sample %	Weight of test fraction before the test, g	Percentage passing finer sieve after test(actual % loss)	Weighted average (corrected % loss)
Passing (1)	Retained (2)				
60	40				
40	20				
20	10				
10 4.	75				

No of particles coarser than 20mm before the test			Number of particles affected, classified as the number disintegrating, splitting, crumbling, cracking or flaking.		
Passing	Retained	Number before test			
40mm	20mm				
60mm	40mm				

RESULT :

Percentage of loss of weight = ____________

CONCLUSION :

(Comment on the result by comparing with standard values)

DISCUSSION :

If the sample contains less than 5 percent of any of the sizes specified under procedure, that size should not be tested; but for the purpose of calculating the test result; it shall be considered to have the same loss in sodium sulphate or magnesium sulphate treatment as the average of the next smaller or next larger size.

If one of these sizes is absent, it may be considered to have the same loss as the next larger or next smaller sizes whichever is present. When the 20mm to 10mm, 40mm to 20mm or 63 to 40 mm test samples specified cannot be prepared due to the absence of one or two sizes of aggregates shown for each the size available may be used to prepare the sample.

As a general guide, it may be taken that the average loss of weight after 10 cycles should not exceed 12 % when tested with sodium sulphate and 18% when tested with magnesium sulphate.

IRC has specified 12% as the maximum permissible loss in soundness test after 5 cycles with sodium sulphate, for the aggregate to be used in bituminous surface dressing, penetration macadam and bituminous macadam constructions.

REFERENCE:

IS: 2386 (Part – V) – Method of test for aggregates of concrete: Soundness.

SHORT TYPE QUESTIONS :

1. ***What do you mean by soundness of aggregate ?***

Ans.

2. ***How the test of durability is simulated in the laboratory ?***

Ans.

3. ***What are the salts usually used in soundness test of aggregates and which one gives a higher loss in weight ?*** .

Ans.

4. ***What is the necessity of testing durability of aggregate ?***

Ans.

5. ***What is the maximum permissible loss of weight in soundness test after 5 cycles as per IRC ?***

Ans.

Signature of the Student

Date : ....

Roll No:.........................

Crushing Value Test of Aggregates 16

AIM :

To determine the strength of aggregate against crushing.

SCOPE OF THE TEST :

To assess the suitability of an aggregate for road or gravity dam construction where excessive compressive stress may cause failure.

THEORY :

One of the principal mechanical properties required to be satisfied by road aggregates is the resistance to crushing under the roller during construction and high surface stresses under rigid tyres of heavily loaded vehicles. Crushing strength of road stones may be determined either on aggregates or on cylindrical specimens cut out of parent rocks.

As the aggregates used in road construction are to be strong enough to resist crushing under traffic wheel loads or enormous compressive stress under high gravity dams , the stability of the pavement or dam structure is likely to be adversely affected in case of weak aggregates . The strength of the aggregates is assessed by aggregate crushing value test, which provides a relative measure of resistance of the aggregate to crushing under a gradually applied compressive load. It is the percentage by weight of the initially untested standard size aggregate that gets crushed smaller than a specified size when subjected to specified load under standard conditions.

The standard aggregate crushing test is made on aggregate passing through 12.5mm I.S. sieves and retained on 10mm I.S sieve. The aggregate placed in a cylindrical mould and a load of 40 tons is applied through the plunger. The material crushed to finer than 2.36mm is separated and expressed as a percentage of original weight taken on the mould. This percentage is referred to as aggregate crushing value. It is, therefore, a numerical index and higher the value, more prone the aggregate to get crushed under the load and hence to achieve a high quality pavement, aggregates possessing low aggregate crushing value should be preferred.

INSTRUMENTS / EQUIPMENTS/ APPARATUS REQUIRED :

The apparatus for the standard aggregate crushing value test consist of the following;

(1) An open – ended 150 mm or 75mm dia cylindrical cell with appropriate base plate and plunger , metal measure and tamping rod conforming to IS:9376

(a) For 150mm cylindrical cell- Height B=130 to 140mm, plunger of piston dia 148mm,square base plate 6mm thick and 200 to 230 mm size,16 mm dia tamping rod 450 to 600mm long,and cylindrical metal measure 115 mm dia and 180 mm high.

(b) For 75mm cylindrical cell-Height B=70 to 80mm, plunger of position dia73mm,square base plate 6mm thick and 110 to 115 mm size,16 mm dia tamping rod 300 to 350mm long and cylindrical metal measure 60 mm dia and 90 mm high.

(2) A balance of capacity 3 kg readable and accurate to one gram.

(3) I.S sieves of sizes 12.5 mm,10 mm,2.36 mm

(4) A compressive testing machine capable of applying a load of 40- tons in not more than 10 minutes at a uniform rate of loading. The machine may be used with or without a spherical seating.

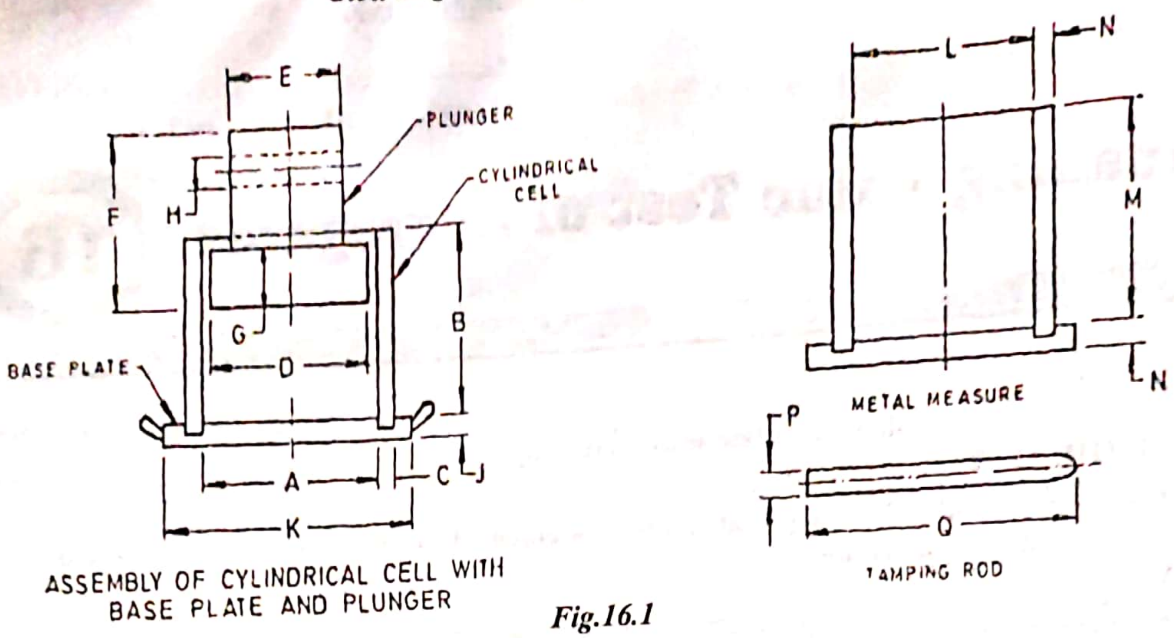


Fig.16.1

SPECIMEN /MATERIALS REQUIRED :

The material for the standard test consists of aggregates passing a 12.5mm I.S sieve and retained on a 10 mm I.S sieve and is to be thoroughly separated on these sieves before testing.

Tests with non- standard size aggregates – If required or if the standard size is not available, the test may be carried out with different gradings. However the specification is to be different for such cases and is to confirm to the following table;

Normal size (IS sieve)		Diameter of the cylinder to be used (cm)	Size of IS sieve for separating fines
Passing through (mm)	Retained on (mm)		
25	20	15	4.75 mm
20	12.5	15	3.35 mm
10	6.3	15.0 is 7.5	1.70 mm
6.3	4.75	15.0 is 7.5	1.18 mm
4.75	3.35	15.0 is 7.5	850μ
3.35	2.36	15.0 is 7.5	600μ

Note: About 6.5 kg of natural aggregate is required to provide the two test samples for 15 cm dia. cylinder or about 1 kg. for the 7.5 cm cylinder. For light weight aggregates, the quantity will vary depending on the density of the aggregate.

PROCEDURE :

(1) The aggregate is made surface dry in air or may be dried by heating at a temperature of 100 to 110°C for a period of 4 hours and tested after being cooled to room temperature.

(2) For standard test, the material is sieved through 12.5mm and 10mm I.S sieve and those retained on 10mm sieve is collected.

(3) About 3.25 kg of material is taken for the standard test or the quantity of aggregate is to be such that the depth of material in the cylinder after tamping will be about 10cm.

(4) The cylindrical measure is filled in three layers of approximately equal depth, each layer being tamped 25 times with the rounded end of the tamping rod and finally leveled off using the tamping rod as a straight edge. This is to be used as test sample.

(5) The weight of the material comprising the test sample is determined accurate up to 1g (weight A) and the same weight of the sample is taken for the repeat test.

(6) The cylinder of the test apparatus is placed in position on the base plate. Then one third of the test sample is placed inside the cylinder and tamped 25times by the tamping rod. Similarly, the other two parts of the test specimen are added, each layer being subjected to 25 blows.

(7) The surface of the aggregate is carefully leveled and the plunger inserted so that it rests horizontally on this surface.

(8) The apparatus with the test sample and plunger in position is then placed between the platens of the compression testing machine and loaded at a uniform rate of 4 tons per minute through the plunger until the total load is 40 tons .

(9) Then the load is released and the whole of the material removed from the cylinder and sieved on a 2.36mm I.S sieve for the standard test or the appropriate sieve given in the table.

(10) The fraction passing through the sieve is weighed to an accuracy of 0.1g (weight B), which is a measured of loss of material due to crushing.

PRECAUTIONS :

(1) The plunger should be placed centrally and rest directly on the aggregates, care being taken to see that it does not touch the walls of the cylinder.

(2) Tamping should be done properly by gently dropping the tamping rod and not by hammering action .It should be done uniformly over the surface of the aggregate so that the tamping rod does not frequently strike against the walls of the mould.

(3) While placing the plunger on the sample, care is taken to ensure that the plunger does not jam in the cylinder.

(4) While sieving, weighting or removing the material from the cylinder care is taken to avoid loss of fines so that the sum of the weights of fraction retained and passing the 2.36 mm sieve should not differ from the original weight of the specimen by more than 1 g.

OBSERVATION AND CALCULATION :

Two tests are made and the ratio of weight of fines formed to the total sample weight in each test is expressed as a percentage, the result being recorded to the first decimal place. The mean of the two results is repoted to the nearest whole number as the aggregate crushing value of the size of the material tested, which is to be stated.

Size of the material/test specimen: ______________

Sl. No.	*Particulars*	*Sample-I*	*Sample-II*
1.	Weight of surface dry sample(A)		
2.	Weight of fraction passing 2.36mm or appropriate sieve(B)		
3.	Aggregate crushing value = $\frac{B}{A} \times 100$		

RESULT :

Aggregate crushing value (mean) = ______________

CONCLUSION :

(Comment on the result by comparing with standard values)

DISCUSSION :

As per IS:383 , the crushing value should not exceed 45% for the aggregates used for concrete other than for wearing surface and 30% for the concrete for wearing surfaces such as runways , roads and pavements . However, with aggregate of crushing value 30 or higher, the result may be anomalous and in such cases, the ten percent fines value is determined instead.

However, the suitability of the aggregate is adjudged, depending upon its proposed use in pavement layers. The following table lays down specified limits of percent aggregate crushing value, for different types road construction.

Sl. No.	Type of road construction	Aggregate crushing value not more than
I.	Flexible pavements	
	(a) Soaling	50
	(b) Water bound macadam	40
	(c) Bituminous macadam	40
	(d) Bituminous surface dressing or thin premix carpet	30
	(e) Dense-bituminous mix carpet	30
II.	Rigid pavements	
	(a) Other than wearing coarse	45
	(b) Surface or wearing coarse	30

(a) For aggregates larger than 12.5 mm – In general, the larger size aggregates gives a higher aggregate crushing value but the relationship between the values obtained with different sizes varies from one aggregate to another. Particular care is to be taken with larger size of aggregates to ensure that the plunger does not jam in the cylinder.

(b) Aggregates smaller than 10mm – In general,the smaller sizes of aggregates gives a lower aggregate crushing value, but the relationship between the values obtained with different sizes varies from one aggregate to another. The tests on smaller aggregates may be made either using the standard apparatus or a smaller apparatus consisting of a75 mm cylindrical cell with appropriate accessories .I n case a smaller apparatus is used, the errors for the smaller sizes of aggregate tested in the smaller apparatus are compensated as the result obtained with smaller apparatus have been found to be slightly higher than those with standard apparatus.

The accessories for the smaller apparatus shall be a balance of capacity 500g, readable and accurate to 0.2g, I.S sieves of appropriate sizes as given in the table and a compression testing machine capable of applying a load of 10 tons is not more than 10mins at a uniform rate of loading. Further, in the test using the smaller apparatus, the depth of material in the 75mm cylinder shall be about 50mm and the total load applied in 10 mins. shall be 10 tons.

REFERENCE :

(1) IS: 2386 (Part-IV) – Method of test for aggregate of concrete – Mechanical Properties.

(2) IRC: 15 -Standard specification and code of practice for construction of concrete roads.

(3) IS: 383 -Indian standard specification for course and fine aggregate from natural sources for concrete.

SHORT TYPE QUESTIONS:

1. ***Define the term aggregate crushing value.***

Ans.

2. *What is the significance of crushing value test ?*

Ans.

3. *What are the precautions to be observed in the test ?*

Ans.

4. *What are the limits of crushing value of aggregates to be used in concrete for pavements ?*

Ans.

5. *How does the test result of aggregates larger or smaller than the standard sizes are affected ?*

Ans.

Signature of the Student

Roll No:.........................

Date : ....

Los Angeles Abrasion Value of Aggregate

17

AIM :

To test the abrasive resistance of aggregate

SCOPE OF THE TEST:

To find out the suitability of aggregates for its use in pavement construction as the test values have been correlated with performance studies.

THEORY :

The aggregates used in surface course of the high way pavements are subjected to wearing due to movement of traffic. Resistance to wear or hardness is hence an essential property for rood aggregate especially when used in wearing course. Movement of the fast moving vehicles fitted with pneumatic tyres on the road causes abrasion of stone aggregates used as constituent of pavement surface. The steel tyred wheels of animal driven vehicles also cause considerable abrasion of road surface. Therefore road aggregate should be hard enough to resist abrasion due to various types of traffic. Thus determination of resistance of aggregates to the abrading action of traffic is very important. Of the various tests available for determining the abrasion value, the Los Angeles abrasion test is more commonly adopted.

The principle of Los Angeles abrasion test is to produce the abrasive action by the use of standard steel balls called abrasive charge which when along with the aggregates are rotated in a drum for specific number of revolutions also cause pounding action in addition to rubbing. The percentage wear of the aggregates by the action thus caused is determined which is known as Los Angeles abrasion value.

INSTRUMENTS / EQUIPMENTS /APPARATUS REQUIRED

(i) Los Angeles machine which consists of a hollow steel cylinder closed at both the ends with an internal diameter of 700mm and length 500mm and capable of rotating about its horizontal axis. It has a opening with removable cover for introducing the sample which is dust tight when properly clamped. A steel shelf projecting radially 88mm into the cylinder and extending for full length is mounted firmly on the interior of the cylinder. The shelf is placed at a minimum distance of 1250 mm from the opening in the direction of rotation.

(ii) Abrasive charge: Spherical cast iron or steel balls of approximately 48mm in diameter and each weighing between 390 to 455g- 12nos.

(iii) Sieve – I.S sieve size 1.70mm.

(iv) Balance of capacity 10 kg and accuracy ±1g.

(v) Thermostatically controlled oven

(vi) Metal tray, brush etc.

SPECIMEN / MATERIALS REQUIRED

The material for the standard test consists of clean aggregates dried in an oven at 105°Cto 110°C to substantially constant weight. The sample should conform to any of the gradings shown in the following table.

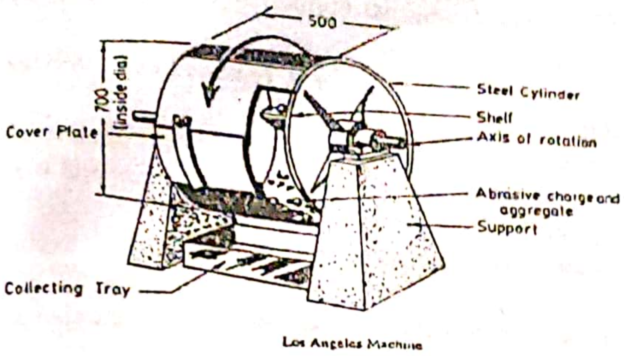


Fig. 17.1 (a)

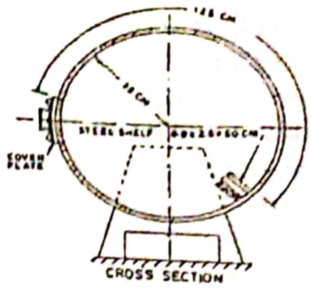


Fig. 17.1 (b)

Grading of test samples

Sieve Size(mm)		Mass in grams of test sample for grade						
Passing through	Retained on	A	B	C	D	E	F	G
80	63					2500*		
63	50					2500*		
50	40					5000*	5000*	
40	25	1250					5000*	5000*
25	20	1250						5000*
20	12.5	1250	2500					
12.5	10	1250	2500					
10	6.3			2500				
6.3	4.75			2500				
4.75	2.36				5000			

Tolerance of ± 2% permitted

PROCEDURE :

1. The grading to be used in the test is selected such that it is nearest to the grading to be used in the construction.
2. 5 kg sample for gradings A, B, C, D and 10 kg of sample (with ± 2% tolerance) for gradings E, F, G is taken.
3. The abrasive charge is selected as per the table below.

Selection of abrasive change

Grading	No of steel balls	Weight of charge in gram
A	12	5000 ± 25
B	11	4584 ± 25
C	8	3330 ± 20
D	6	2500 ± 15
E	12	5000 ± 25
F	12	5000 ± 25
G	12	5000 ± 25

4. The cover is opened, the aggregate and steel balls are fed into the cylinder and the cover is fixed dust tight.

5. The machine is rotated at a uniform speed of 30 to 33 revolutions per minute. 500 revolutions are given for grading A, B, C, D or 1000 revolutions for grading E, F, and G.
6. The machine is stopped after desired number of revolutions, dust cover is removed and materials are taken out with the entire stone dust and steel balls.
7. The steel balls are separated and the material is sieved on a 1.7mm I.S sieve (However, for convenience the material may be separated into two parts by using a sieve of size larger than 1.70mm and the finer portion may be further sieved on a1.7mm, I.S. sieve).
8. The material coarser than 1.7mm I.S sieve is washed and dried in an oven at 105°C to 110° C to constant weight and weighed to an accuracy of 1 g.
9. The result is expressed as percentage wear and the average value of two tests may be adopted as Los Angeles abrasion value.

PRECAUTIONS :

1. The machine should be balanced and driven in such a way as to maintain uniform peripheral speed.
2. The cover should be fixed dust tight before rotating the machine.
3. Care should be taken to avoid loss of any part of the sample and the entire stone dust in taken out from the machine along with abraded stone and abrasive charges (steel balls).

OBSERVATION & CALCULATION

Grading selected ______	Sample - I	Sample - II
(1) Original mass of the aggregate (M_1), g	5kg	
(2) Mass of the aggregate retained on 1.70 mm I.S. sieve after the test (M_2), g	3·380 kg	
(3) Loss in mass due to wear(M_2-M_1), g	1062	
(4) Percentage wear $\frac{M_2 - M_1}{M_1} \times 100$ $\frac{M_2 - M_1}{M_1} \times 100$		

RESULT :

Los Angeles abrasion value ≐ Mean of sample I & II = __________

CONCLUSION:

(Comment on the result by comparison with standard values.)

The aggregate is suitable / unsuitable for pavement construction as ____________________ layer.

DISCUSSION:

The test is more widely accepted because it simulates field conditions more closely by determining resistance to abrasion and impact simultaneously. Many agencies have specified the desirable limits of the test for different methods of pavement construction.

The maximum allowable Los Angeles abrasion values of aggregates as specified by Indian Road Congress for different cases are given in the following table.

Sl. No	*Types of pavement layer*	*Maximum permissible Los Angeles Abrasion value*
1.	Water Board Macadam(WBM) sub-base course	60
2.	(i) WBM base course with bituminous surfacing	50
	(ii) Bituminous Macadam base course	
	(iii) Built up spray grout base course	
3.	(i) WBM surfacing course	40
	(ii) Bituminous Macadam binder course	
	(iii) Bituminous Penetration Macadam	
	(iv) Built up spray grout binder course	

4.	(i) Bituminous carpet surface course (ii) Bituminous surface dressing(single and two coats) (iii) Bituminous surface dressing(precoated aggregates) (iv) Cement concrete surface course(IRC)	35
5.	(i) Bituminous/Asphaltic concrete surface course (ii) Cement concrete pavement surface course(ISI)	30

REFERENCE :

IS : 2386 (Part– IV) Method of test for aggregates for concrete, Mechanical properties.

SHORT TYPE QUESTIONS :

1. ***What is the significance of Los Angeles test ?***

Ans. To find out the suitability aggregate for use in pigment conc function. as the test values have been concalated with performance studies

2. ***Which mechanical properties of aggregate are determined by this test ?***

Ans. The shelf is place at a maximum distance of 1250mm from the opening in the direction of rotation

3. ***What is the propose of providing a shelf inside the cylinder ?***

Ans. The shelf is place a maximum distance of 450 from the opening in the direction of rotation

4. ***How do you select the grading for 20mm size nominal aggregate? How many numbers of abrasive charges will you use for this grading ?***

Ans.

5. ***If two sample have LA abrasion values of 25 and33 respectively, then which sample is better and why ?***

Ans.

Signature of the Student

Roll No:.......................

Date : ....

Impact Test of Aggregate

18

AIM :

To determine aggregate impact value of coarse aggregate.

SCOPE OF THE TEST :

This test is used to assess the suitability of an aggregate for pavement construction with respect to its toughness or resistance to impact simulating the field conditions. The test can be performed in a short time even at construction site or at the stone quarry as the apparatus is simple and portable.

THEORY :

Toughness may be defined as the property of a material to resist impact. Owing to the movement if the traffic on the roads, the road aggregates are subjected to the pounding action or impact of wheel loads which may result in the breaking down of the aggregate to smaller pieces. Therefore, the road aggregates are required to be tough enough so as to resist the fracture tendency under impact. The test designed to evaluate the toughness of stones i.e. the resistance of stones to with stand disintegration under repeated impact is called impact test for road aggregates.

Impact test may be either carried out on cylindrical stone specimen as in Page impact test or on stone aggregate as in the Aggregate impact test. The former has become obsolete now-a –days where as the later has been standardized by Bereau of Indian Standards.

The aggregate impact value gives a relative measure of the resistance of an aggregate to sudden shock or impact, which in some aggregates differs from its resistance to a slow compressive load.

The standard aggregate impact test is made on aggregate passing through 12.5mm and retained on 10mm IS sieve .The aggregate is placed in a cylindrical cup mould and subjected to specified number of blows by free fall of a standardized hammer from a specified height .The material crushed to 2.36mm is separated and expressed as a percentage of original weight taken in the mould, which is referred to as aggregate impact value. So, it is a numerical index and higher value of it indicates that the aggregate is more prone to get crushed under impact load .Therefore to achieve a high quality pavement; aggregate possessing a low impact value is to be preferred.

Thus the aggregate impact value is used to classify stones in respect of their toughness property as follows.

Aggregate impact value	*Classification*
<10%	Exceptionally strong
10-20%	Strong
20-30%	Satisfactory for road surfacing
>35%	Weak for road surfacing

INSTRUMENTS / APPARATUS /EQUIPMENTS REQUIRED :

The apparatus consists of an impact testing machine, a cylindrical measure, tamping rod, IS sieves, balance and oven.

(a) Impact testing machine: - The machine consists of a metal base with a plane lower surface supported well on a firm floor without rocking .A detachable cylindrical steel cup of internal diameter 10.2cm and depth 5cm is rigidly fastened centrally to the base plate. A metal hammer of weight between 13.5 and

14.0 kg having the lower end cylindrical in shape, 10cm in diameter and 5cm long, with a 2 mm chamfer at the lower edge is capable of sliding freely between vertical guides and fall concentric over the cup. There is an arrangement for raising the hammer and allowing it to fall freely between vertical guides from a height of 38cm on the test sample in the cup, the height of fall being adjustable up to 0.5cm. A key is also provided for supporting the hammer while fastening or removing the cup.

(c) Metal measure – A cylindrical metal measure having internal diameter 7.5cm and depth 5cm for measuring aggregates.

(d) Tamping rod – A straight metal tamping rod of circular cross section, 10mm in diameter and 230 mm long rounded at one end.

(e) Sieve – The IS sieves of sizes 12.5, 10 and 2.36 mm.

(f) Balance – A balance of capacity not less than 500g, readable and accurate to 0.1g.

(g) Oven – A well ventilated and thermostatically controlled oven to maintain a temperature of 100 to 110°C.

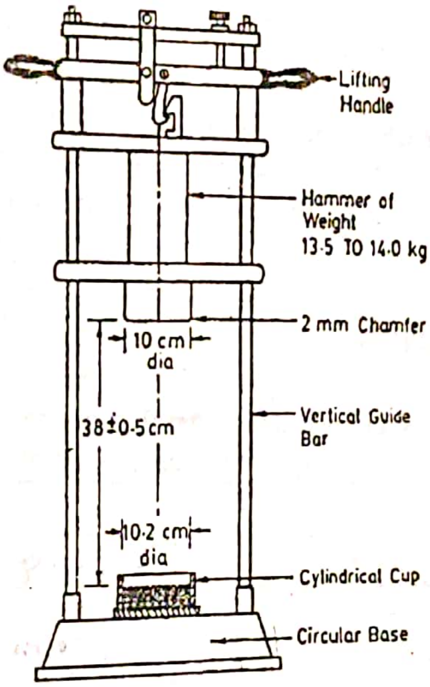


Fig. 18.1 Aggregate impact test set up

SPECIMEN/MATERIALS REQUIRED :

The material for the test sample consists of aggregates sized between 10mm to 12.5mm, dried by heating at 100-110 °C in an oven for a period of 4hours and cooled to room temperature.

PROCEDURE :

(1) Oven dried test sample that passes through 12.5 mm and retained on 10mm IS sieve, of sufficient quantity to fill the metal measure is collected.

(2) The cylindrical metal measure is filled about one –third full with the aggregate and tamped with 25 stokes of the rounded end of the tamping rod.

(3) Again similar quantity of aggregate is added and a further tamping of 25strokes is given. Finally, the measure is filled to over flowing, the tamped 25 times and the surplus aggregate struck off, using the tamping rod as a straight edge.

(4) The net weight of the aggregate in the measure is determined to the nearest gram (Weight A) and this weight of the aggregate is used for carrying out the repeat test on the same material.

(5) The impact testing machine is placed with its bottom plate flat on the floor or pedestal so that the hammer guide columns are vertical.

(6) The cup is firmly fixed in position on the base of the machine and the whole of the test sample from the cylindrical measure is transferred to the cup and compacted by a single tamping of 25 strokes of the tamping rod.

(7) The hammer is raised until its lower face is 38cm above the upper surface of the aggregate in the cup and allowed to fall freely on the aggregate. The test sample is subjected to a total of 15 such blows, each being delivered at an interval of not less than one second.

(8) The crushed aggregate is then removed from the cup and the whole of it is sieved on the 2.36mm sieve until no further significant amount passes.

(9) The fraction passing the sieve is weighted to an accuracy of 0.1g (Weight B) .The fraction retained on the sieve is also weighted (Weight C).

(10) If the total weight of the fraction passing and retained on the sieve (B+C) is less than the initial weight (A) by more than one gram, the result is discarded and a fresh test is to be made.

PRECAUTIONS :

(1) The plunger is to be placed centrally so that it falls directly on the aggregate sample and does not touch the walls of the cylinder in order to ensure that the entire load is transmitted on to the aggregate.

(2) The tamping is to be done properly by gently dropping the tamping rod from a height of approximately 5cm and not by hammering action. Also the tamping should be uniform over the surface on the aggregates so that the tamping rod does not frequently strike against the walls of the mould.

(3) While sieving the crushed aggregates through 2.36mm sieve, the sum of the weights of fractions retained and passing the sieve should not differ from the original weight of the specimen by more than 1 gram.

OBSERVATION AND CALCULATION:

Two tests are made and the ratio of the weight of fines formed to the total sample weight in each test is expressed as a percentage, the result being recorded to the first decimal place .The mean of the two results is reported to the nearest whole number as the aggregate impact value of the tested material.

Sl. No.	*Particulars*	*Sample - I*	*Sample - II*
1.	Weight of dry sample(A)	355.8gm	366.6gm
2.	Weight of fraction passing 2.36mm I.S sieve(B)	9gm	54.6gm
3.	Aggregate impact value = $\frac{B}{A} \times 100$	$\frac{9}{355.8} \times 100$ 2.52	$\frac{54.6}{366.6} \times 100$ = 14.89

RESULT :

Aggregate impact value (mean) = $\frac{2.52 + 14.89}{2}$ = 8.70%.

CONCLUSION :

(Comment on the result by comparing with standard values.)

DISCUSSION :

Impact value is observed to depend up on the shape of the aggregates in addition to quality of the parent rock. Well shaped cubical aggregates provide higher resistance to impact compared to flaky or elongated aggregates.

It has been found that for majority of aggregates, the aggregate crushing and impact values are numerically similar within close limits .But in the case of fine grained highly siliceous aggregates which are less resistant to impact than to crushing , the aggregate impact values are reported to be higher (on the average by about 5)than the aggregate crushing values . The maximum permissible aggregate impact values for different types of pavements as recommended by Indian Road Congress (IRC) & BIS is given in the following table.

Sl. No.	*Type of pavement/layer*	*Aggregate Impact value, maximum,%*
1.	Water bound macadam (WBM)sub-base	50
2.	Cement concrete, base coarse (as pr BIS)	45
3.	(i) WBM base course with bituminous surfacing	40
	(ii) Built up spray grout, base course	
4.	Bituminous macadam, base course	35
5.	(i) WBM,surface coarse	30
	(ii) Built up sray gront,surfacing coarse	
	(ii) Bituminous penetration macadam	
	(iv) Bituminous macadam, binder coarse	
	(v) Bituminous surface dressing	
	(vi) Bituminous carpet	
	(vii) Bituminous or asphaltic concrete	
	(viii)Cement concrete, wearing coarse	

However, this test is commonly used for deciding the suitability of soft aggregate in base course construction. A modified impact test may be carried out to find the wet impact value after soaking the test sample. The following table gives the recommendation of different agencies in this regard.

Condition of the sample	Maximum aggregate impact value, percent	
	Sub-base and base	Surface course
Dry	50	32
Wet	60	39

REFERENCE :

(1) IS: 2386(Part –IV) – Methods of test for aggregates of concrete; mechanical properties.

(2) Tentative specification [for various types of construction methods] IRC.

(3) Standard specification and code of practice for construction of concrete roads ,IRC:15

SHORT QUESTIONS :

1. *What do you mean by toughness of the aggregate ?*

Ans. Taughness may be defined as the property of a material to resist impact

2. *What is the significance of impact value test ?*

Ans. wing the movement is the traffic on the road the road aggregates are subjected to the pounding action on impact which may result in the breaking of which load down of the aggregate & smaller piece

3. *If aggregate impact value of a sample is 23 and that of another sample of aggregate is 38 , which one is better suited for use as a surface coarse and why ?*

Ans. The impact value of sample is 23 is often suited for use as a surface because of it classificated satisfactory for road construction

4. *How does the toughness differ from the compressive strength?*

Ans. The aggregate impact value gives a relative measure of the resistance of a aggregate of sudden shock on impact which is same aggregate differs from its resistance to a slow compressive strength.

5. *What should be the desirable limits of aggregate impact value for the WBM surfacing course and WBM base course with bituminous surfacing?*

Ans. The desirable limit aggregate impact value for the WBM surface course is 30% & wbm base course with bituminous surfacing is 40%.

Signature of the Student

Date : ....

Roll No:........................

Chaptere-4

ROAD PAVEMENTS.

There are two types of pavements based on design considerations i.e flexible pavement & rigid pavements.

Flexible Pavements.

(i) This can be defined as the one consisting of a mixture of asphaltic or bituminous material and aggregates placed on a bed of compacted granular material of appropriate quality in layers over the subgrade.

(ii) Water bound macadam roads and stabilized soil roads with or without asphaltic toppings are exemples of flexible pavements.

(iii) The design of flexible pavement is based on the principle that for a load of any magnitude, the intensity of a load diminishes as the load is transmitted downwards from the surface by virtue of spreading over an increasingly larger area, by carrying it deep enough into the ground through successive layers of granular material.

(iv) flexible pavements are those, which on the whole have low or negligible flexural strength and are rather flexible in their structural action under the loads.

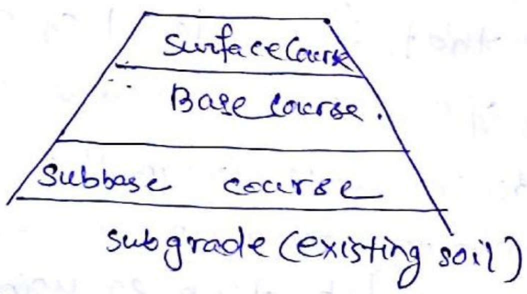
(v) The flexible pavement layers may reflect the non recoverable as well as recoverable deformation of the lower layers including the subgrade on to the upper layers and also to the pavement surface.

(vi) Thus if the lower layer of the pavement or soil subgrade gets deformed or undulated to somewhat similar pattern.

(vii) The vertical compressive stress is maximum on the pavement surface directly under the wheel load and is equal to the contact pressure under the wheel.

(viii) It consists of four layer/course.

(a) Wearing course / surface course.
(b) Base course
(c) Sub base course.
(d) Subgrade course.



(flexible pavement cross section)

merits

The following are the advantages of flexible pavement.

1. Adjust to limited differential settlement
2. Easily repaired.
3. Additional thickness added any time.
4. Non skid properties do not deteriorate.

(5) Tolerates a greater range of temperature.

Demerits

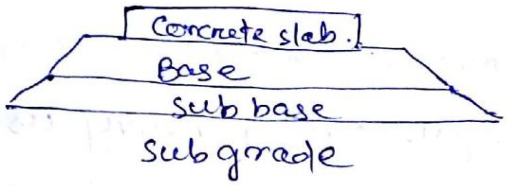
(1) Loses some flexibility and cohesion with time.
(2) Needs resurfacing sooner than PC concrete.
(3) Not normally chosen where water is expected.
(4) Higher maintenance costs.
(5) Shorter life span under heavy use.
(6) Damage by oils & certain chemicals.

Riged pavements.

(i) Riged pavements are those which possess noteworthy flextural strength or flexural rigidity.
(ii) The rigid pavements are generally made of portland cement concrete and are therefore called 'cc pavements'.
(iii) plain cement Concrete pavement slabs made of specified strength characteristics are laid, with or without steel reinforcement at the joints.
(iv) most common material used for the design and construction of rigid pavements is high quality plain cement concrete meant for the pavement, generally called "Pavement Quality Concrete' (PQC).
(v) The CC pavement slabs made of PQC are generally expected to sustain upto 45 kg/cm^2 of flexural stresses.

(vi) In rigid pavements the stresses are not transferred from grain to grain to the lower layers as in the case of flexible pavement layers.

(vii) It consists of four layers including concrete slab.



(Rigid pavement cross-section.)

Merits / Advantages.

1. Durability is good rigid.
2. pavement is good.
3. Life cycle of rigid pavement is long.
4. withstand repeated flooding & surface water.
5. Good subgrade is not required.

Demerits

1. May lose skid surface with time.
2. May fault at transverse joints.
3. Large layer thickness.
4. The setting is so slow.
5.

Subgrade preparation.

(1) setting out is the process of extracting information from the construction drawings, and pegs, Profiles or other marks are then set to control the construction works and to ensure that each features in drawings are constructed.

Setting out alignment of road.

The alignment of road should be according to map or drawing such that every point regarding the necessity of should be fulfilled.

So after identifying the area on which road is constructed should align the road way path property for the next method of road construction.

→ The site should be Cleared Properly.

Setting out bench marks, control pegs for embankment & cutting.

(i) After completion of site clearance/embankment the limits of sub-grade shall be marked by fixing pegs on both sides at regular intervals.

(ii) The chainage boards and working bench mark shall be set outside the limits of construction areas.

Selection of Material & Borrow areas / Borrow pits

Material :-

The material used in subgrade shall be soil, moorum, gravel, a mixture of these or any other material approved by the engineer.

→ It shall be free from logs, stumps, roots, rubbish & any other material detrimental to the stability of structure.

→ The roadway material shall be obtained from source nearby roadway excavation area.

Borrow pits

Borrow pits Borrow pits are dug along the alignment of a road for using its material in the construction of embankment for road. Borrow pits should not be dug within 0.8 km of towns & villages.

Dewatering

If the foundation of the embankment is in area with stagnant water, it is feasible to remove it by bailing out or pumping.

stripping & storing top soil :-

In localities where most of the available embankment materials are not conductive to plant growth, the top soil from all areas of cutting shall be stripped to specified depths not exceeding 150 mm & stored in a stock piles of height not exceeding 2m for covering embankment slopes.

compacting ground supporting embankment/subgrade.

Where necessary, the original ground shall be levelled to facilitate placement of first layer of embankment, scarified, mixed with water & then compacted by rolling so as to achieve minimum dry density.

→ In case difference in subgrade level and ground level is less than 0.5m & the ground does not have 97% relative compaction, the ground shall be loosened upto a level 0.5m below the subgrade level, watered & compacted in layers to not less than 97% of dry density.

spreading materials in layers & bringing to appropriate moisture content.

(1) The embankment & subgrade material shall be spread in layers of uniform thickness.

(2) not exceeding 200mm.

(3) Checking of subgrade.

Trueness of the subgrade is checked after its preparation.
surface level of the subgrade along the road alignment is checked by using a levelling instrument.
As per IRC, the actual level of subgrade should not differ from the drawing by more than 25mm.
The transverse profile like camber is checked by using a template.

Equipment used for subgrade preparation :-

The following equipments are used for subgrade Preparation.

1. Tractor
2. Bulldozer-
3. Grader
4- Shovel - most powerful & giant excavating machine
5- Roller
6- Dumper
7. Dragline.

Sub-base Course.

Necessity of sub-base:-

(1) Sub-base course is a layer of pavement material provided between sub-grade and base course.

(2) It is provided as an additional layer when the sub-grade is of poor quality.

(3) It consists of broken stones, slag, broken burnt bricks etc.

(4) At the sub base course it is desirable to use small size aggregates for proper interlocking.

The sub base course has the following function:

(i) It improves the bearing capacity of sub-grade.

(ii) It checks the capillary rise of sub soil water.

(iii) It prevents subgrade material from working up into the base course.

(iv) It eliminates frost heave in frost affected area.

Component parts of a road pavement structure

The sub base course should be stabilized with the required stabilization.

Soil stabilization.

Definition.

- Soil stabilization is a process of treating a soil to improve its stability and bearing capacity for using construction material.
- This is a method of changing the soil properties by the use of controlled compaction, proportioning or the addition of suitable admixtures.

Purpose of soil stabilization.

Stabilization of soil is practised in road construction for one or more of the following objectives.

(i) To bring economy in road construction.
(ii) To increase the strength of pavement layers like sub-bases, base course etc.
(iii) To alter permeability characteristics.
(iv) To reduce the tendency of swelling or shrinkage due to change in moisture content.
(v) To reduce compressibility and settlement.
(vi) To reduce frost susceptibility.
(vii) To increase the stability of earthwork in embankment as a whole.
(viii) To make use of locally available inferior quality materials.

Methods of soil stabilization/Types of soil stabilization.

Following are the commonly used types of soil stabilization

(1) Mechanical stabilization.
(2) Cement stabilization
(3) Lime stabilization
(4) ~~[illegible]~~ Flyash stabilization.

(1) Mechanical stabilization.

(1) Mechanical stabilization of soil involves two operations:
  (i) Changing the composition of soil by addition or removal of certain constituents.
  (ii) Densification or Compaction.

(2) The stability of a granular soil having negligible amount of fines can be increased by mixing with certain proportion of binder soil.

(3) Similarly the stability of fine grained could be improved by mixing a suitable proportion of granular materials.

(4) For mechanical stabilization, where the primary purpose is to have a soil resistant to deformation and displacement under loads, soil material can be divided into two fractions, the granular fraction and fine soil fraction.

(5) The granular fraction provides strength & hardness

(6) The fine fraction provides cohesion, water retention capacity & also acts as a filler.

(7) If the soil collected from one source does not meet the gradation and plasticity requirements of a job, it becomes necessary to mix materials from more sources for obtaining the desired mixture. ~~The~~

(8) The blending of materials is done by making trial combinations.

Scanned by CamScanner

(2) cement stabilization.

(i) The soil stabilized with cement is known as soil cement.

(ii) The cementing action is the result of chemical reactions of cement with silica content of soil during hydration.

(iii) In coarse grained soils, the mechanism of stabilization is due to the development of bond at the point of contact of hydrated cement and compacted soil particles.

(iv) In fine grained cohesive soils, the stabilization is due to the reduction of plasticity and formation of matrix enclosing clay lumps.

(v) Soil cement can be used as a sub-base or base course of all types of pavements.

(vi) The various factors which influence the properties of soil cement are:

(a) Nature of soil.
(b) Cement content
(c) Conditions of mixing
(d) Compaction & curing
(e) Admixtures.

(3) Lime stabilization.

(1) Hydrated lime is very effective in treating high plastic clayey soil.

(2) When clayey soil with high plasticity are treated with lime, the plasticity index of soil is decreased and the soil becomes friable and easy to be pulverized.

(3) Sandy soil can also be stabilized with lime.

(4) Lime imparts some binding action in granular soils.

(5) Soil-lime is quite suitable as sub base course for high types of pavements and base course for pavements with low traffic.

(6) Soil-lime cannot be used as surface course due to poor resistance to abrasion & impact.

(4) Fly Ash stabilization :-

(i) Fly ash materials have binding properties, so this also are used for the stabilization of soil.

(ii) Fly ash is the waste material generated from the thermal power plants.

(iii) So the use of fly ash makes the soil stabilization cheaper.

(iv) Fly ash is a biproduct from burning coal which makes steam to generate electricity.

(v) When burning coal, combustion particles rise out of the combustion chamber with flue gasses. They are captured in filters to prevent them from reaching the atmosphere & collected for disposal or beneficial reuse. These particles are called fly ash.

(vi) There are two types of fly ash, class C & class F.

(vii) Class C has self cementing properties & is used in the production of concrete as a substitute for portland cement, & as a chemical stabilizing & modifying agent to dry &/or strengthen poor soils.

Base Course.

- Base course is a layer of pavement material between surface course and sub-base course.
- Generally large size particles like boulders, bricks are used as base course.
- This course is considered as the most important component of pavement structure because it has to bear the impact of traffic transferred through wearing course.

Preparation of Base Course.

(i) If there is a sub-base course, the base course is constructed directly above this layer. otherwise, it is built directly on the top of the subgrade.

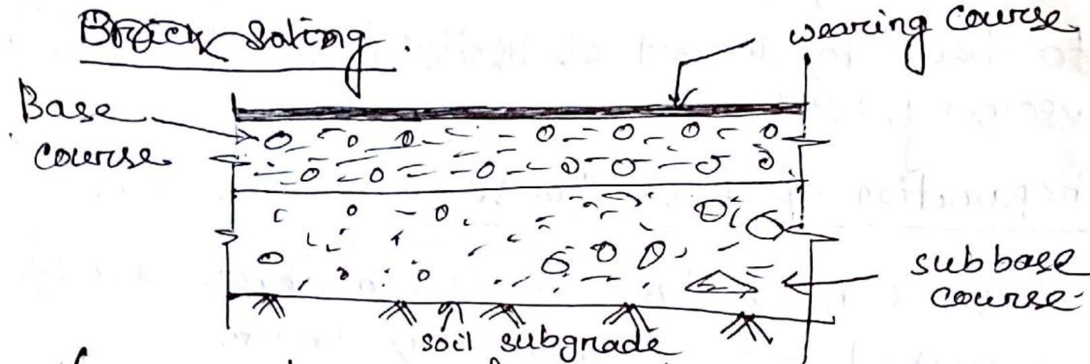
(ii) Typical base course thickness ranges from 100 to 150 mm (4 to 6 inch) and is governed by underlying layer properties.

(iii) Generally consisting of a specific type of construction aggregate, it is placed by means of attentive spreading & compacting to a minimum of 95% relative compaction, thus providing the stable foundation needed to support either additional layers of aggregates or the placement of an asphalt concrete wearing course which is applied directly on the top of the base course.

(iv) Aggregate base (AB) is typically made of a recipe of mixing different sizes of crushed rock together forming the aggregate which has certain desirable properties.

(v) 20mm or 3/4 in aggregate Base, class 2, is used in roadways & is an aggregate made of a specific recipe of different sizes & quality of rock inclusive of 20mm (3/4 inch) to fine dust.

(vi) An aggregate is normally made from newly quarried rock, or it is sometimes allowed to be made from recycled asphalt concrete &/or portland cement concrete.



(Component parts of a road pavement structure).

Brick soling:-

(i) The word "soling" is derived from "sole".

(ii) "Sole" means a base on which something rests.

(iii) In road construction works,
"Brick soling" means the lowest layer of road, which is built with bricks and sand.

(iv) Brick soling is the layers of brick laid directly on the subgrade.

(v) Bricks are laid either on edge or flat in one or more layers.

(vi) The thickness of soling depends upon the traffic conditions.

stone soling

(i) In stone soling, stones are proper shape and size are taken and arranged on the prepared subgrade by hand.

(ii) stones are laid on their wider faces in such a way that their tops conform to the profile of pavement.

(iii) Voids of larger of stones are filled with smaller stones.

(iv) Stone soling is extended at least 15cm beyond the proposed pavement width on either side.

(v) Stones are then compacted by using heavy roller.

(vi) A layer of sandy soil of 25mm thickness is spread over the stones, watered & compacted by using 6 to 8 tonnes roller.

Metalling

(i) Applying gravel or metalling has had two distinct usages in road construction

(ii) The term road metal refers to the broken stone or cinders used in the construction or repair of roads or railways, ~~and~~

(iii) This word metalling derived from the latin word metallum which means both "mine" & quarry.

(iv) It is compacted with a certain thickness in base course so to achieve desirable strength.

Water bound macadam.

(i) water bound macadam construction should consist of clean, crushed or broken aggregates mechanically interlocked by rolling & bounded together with screening binding material & water.

(ii) The most common & durable material for use as aggregates in WBM is broken stone aggregates, crushed slag, overburnt brick aggregates & naturally occuring aggregates such as kankar or laterite are also used.

(iii) The coarse aggregates used in W.B.M construction are of following sizes : 90mm to 40mm size, 63mm to 40mm & 50mm to 25mm sizes are used for surface course.

(iv) The screening also known as "Choke" materials, fill in the voids left in coarse aggregates after they are compacted and help to cement the stone aggregates together.

(v) Generally screenings are of same materials as the coarse aggregates.

Wet mix Macadam.

(i) wet mix macadam consist of laying, spreading and compacting of clean, crushed, well graded granular materials on a prepared & approved granular Sub-base.

(ii) The material is well-~~graded~~ mixed with water and rolled to a dense mass.

(iii) It shall be laid on one or more layers as per line & level, grade & cross section

(iv) The thickness of single compacted wet mixed macadam (WMM) Base shall not be less than 75 mm.

(v) maximum thickness of single compacted layer base can be upto 200 mm upon approval of engineer.

Bituminous Construction:

(i) In bituminous constructions, bituminous materials are used in preparation of base course.

(ii) materials that are bound together with bitumen are called bituminous materials.

(iii) The use of bituminous materials were initially limited to road construction, now have spread over the area of roof construction, for industrial purposes, carpet tiles, paints & as a special coating for water proofing.

The following are the different construction techniques are used.

1. Surface dressing & seal coat
2. Interface treatments like prime coat & tack coat.
3. Grouted or penetration type construction
   - (a) Penetration macadam
   - (b) Built up spray macadam
4. Premix which may be any of the following
   - (a) Bituminous bound macadam
   - (b) Carpet
   - (c) Bituminous Concrete
   - (d) Sheet asphalt or rolled asphalt
   - (e) mastic asphalt.

Surfacing:

Surface dressing: The surface dressing work is done only in dry & clear weather when the atmospheric temperature is above 16°C.

(I) Premixed Carpet:

(i) It is used for surface course.

(ii) Open graded, should be covered by suitable seal coat.

(iii) The premixed carpet consists of all aggregates passing 20mm & retained on 6.3 mm sieve

(iv) Premix Carpet (PC) is the oldest hot mix in India.

(v) It is good, economical, bituminous wearing course mixed to be placed in road construction. ation.

(II) Semi dense Carpet.

(i) The semi-dense bituminous concrete (SDBC) mixes have neither dense nor open graded characteristics.

(ii) It consists of the so called pessimum voids when they are fully constructed.

(iii) When the semi dense bituminous concrete is employed with bitumen macadam (BM) layer, there is chances for the penetration of rain water through the SDBC & reach the bitumen macadam.

(iv) This will create the separation of aggregates and the bitumen in the BM layer.

(v) This will cause stripping & the scaling of SDBC, etc

(vi) The scaling later with time will result in the potholes on the road.

Bituminous Concrete / Asphalt concrete (AC)

(i) It is a dense graded premixed bituminous mix which is well compacted to form a high quality pavement surface course.

(ii) The AC consists of a carefully proportioned mixture of course aggregates, fine aggregates, mineral fillers & bitumen & mix is designed by an appropriate method (Marshal method)

(iii) The IRC has provided specification for 40mm thick AC surface course for highway pavements.

Mastic Asphalt

(i) Mastic Asphalt is a mixture of bitumen, fine aggregates & filler in suitable proportions which yields a voidless & impermeable mass.

(ii) It can absorb vibrations & has a property of self healing of cracks without bleeding.

(iii) It is a suitable surfacing material for bridge deck slabs.

(iv) It should be spread at a temp of about 200°C to a thickness betn 2.5 to 5.0cm.

(v) No rolling is required in this.

Grouting

(i) Grouting is the process through which the dense fluid which is used to fill the gaps or used as reinforcement in the cracks on the roads pavement.

(iv) Grouted is generally a mixture of water, cement & sand & is employed in pressure grouting, embedding rebar in masonry walls, filling voids & sealing joints on the roads.

(iii) It is often color tinted when it has to be kept visible & sometimes includes fine gravel when being used to fill large spaces.

Prime coat

(i) Bituminous prime coat is the first application of low viscosity liquid bituminous material over an existing porous or absorbent pavement surface like WBM base course.

(ii) The main object of priming is to plug in the capillary voids of the porous surface and to bond the loose minerals particles on the existing surface using a binder of low viscosity which can penetrate into the voids.

(iii) Usually MC or SC cutbacks are used.

(iv) The primed surface is allowed to cure for at least 24 hours, during which period no traffic is allowed.

Rigid pavements.

(i) Rigid pavements posses noteworthy flexible strength or flexural rigidity.

(ii) These transfer the load through slab action but not grain to grain as in case of flexible pavements.

(iii) These Consists of 3 layers
  (a) Cement Concrete slab
  (b) Base course
  (c) Soil subgrade.

(iv) The rigid pavements are made of portland cement concrete either plain, reinforced or prestressed.

(v) The plain cement concrete are expected to take up about 40kg/cm² flexural stress.

(vi) These are designed using elastic theory, assuming pavement as an elastic plate resting over an elastic or a viscous foundation.

Concept of Concrete roads as per IRC specification

Sub base for rural roads as per IRC : SP : 62-2004

(1) It provides a uniform and reasonably firm support.

(2) It ~~prevent~~ prevents mud-pumping on subgrad of clays & silts.

(3) It acts as a levelling course on distorted, non-uniform and undulating subgrade.

(4) It acts as a capillary cut-off.

Thickness of sub base.

① For a designed wheel load of 51 kN, 150 mm thick WBM or GSB may be provided.

② For a designed wheel load of 30 kN, 75 mm thick WBM or GSB may be provided.

Note: When the above type of sub-base is provided, effective k value may be taken as 20% more than k value of the Subgrade.

③ A plastic sheet of 125 micron thick shall be provided over the sub-base to act as a separation layer between the sub-base & concrete slab.

Chapter No-05

HILL ROADS.

Introduction-

→ A terrain can be classified into following four groups based on the cross slope:

Terrain.	Cross slope (%)
plain or level	0 - 10
Rolling	10 - 25
Mountaneous	25 - 60
steep	Above 60

→ The terrain having cross-slope of more than 25% comes under hilly terrain.

→ The road laid in the area having cross-slope of 25% or more is a called a hill

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Chapter No-05

HILL ROADS.

Introduction-

→ A terrain can be classified into following four groups based on the cross slope:

Terrain.	Cross slope (%)
plain or level	0 - 10
Rolling	10 - 25
Mountaneous	25 - 60
Steep	Above 60

→ The terrain having cross-slope of more than 25% comes under hilly terrain.

→ The road laid in the area having cross-slope of 25% or more is a called a hill or Ghat road.

→ Selection of a suitable alignment of a hill road is a complex job.

→ To decide the road alignment thorough knowledge of the geological formations of the area is essential.

→ Geometric standards of plain roads cannot be adopted in hill roads.

→ In the hill alignment massive and costly protective works are required at many places resulting in heavy expenditure.

→ In the maintenance of hill roads prevention of soil erosion and landslides of hill ~~slo~~ slopes is a major problem.

classification of hill roads.

Generally hill roads are classified as :

(i) National highways.
(ii) state highways
(iii) Major district roads.
(iv) Other district roads
(v) Village roads.

Hill roads can also be classified as.

(i) Motor roads → Main
(ii) Bridle paths → Paths used ~~for~~ by pedestrians & mule traffic
(iii) Village paths → communication between villages and other working areas in hill regions.

Component of hill road.

(i) Retaining wall
(ii) Breast wall

(iii) Parapet wall
(iv) Catch water drain
(v) Cross drain
(vi) Side drain - It is provided on the road side, usually at the foot of hill slope to collect drain off ...
(vii) Road bed → It is pavement portion of the hill road.

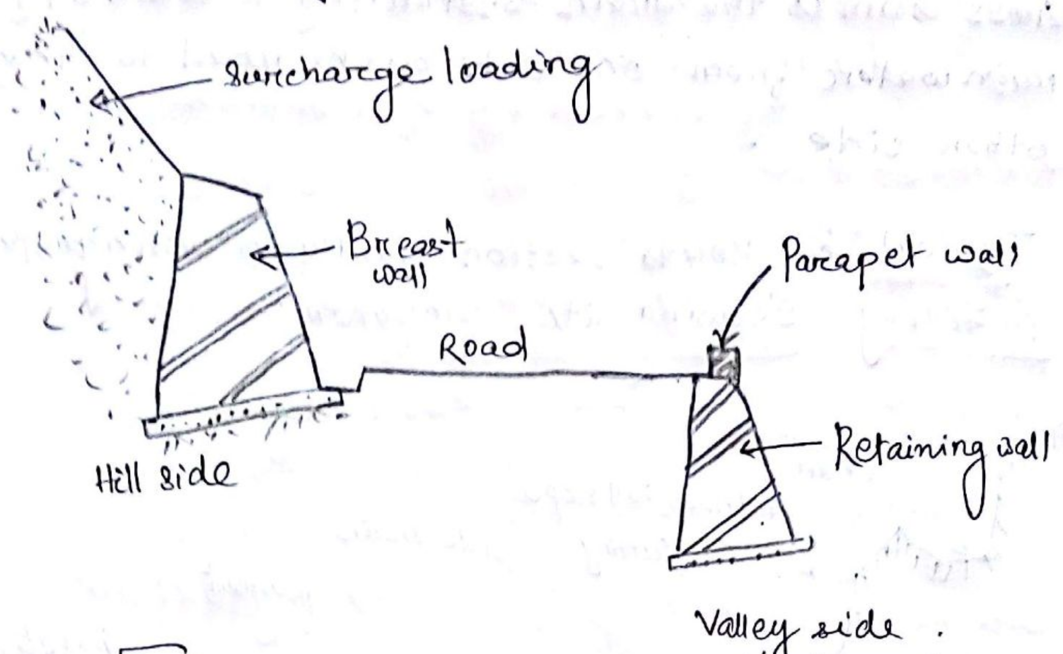
Retaining wall

- The wall constructed down slope side of the hill road to resist the pressure of earth fill and traffic load coming on the road is known as retaining wall.
- This type of wall is constructed in case the cross-section of the road is partly in cutting and partly in filling.
- In order to permit easy drainage the retaining wall should be built in dry stone masonary.
- The high retaining walls can be built of brick masonary or cement Concrete.
- The top width of retaining wall should not be less than 600mm, while the bottom width should not be less than 0.4 times the height of the retaining wall.
- Top width should be at least 750m.

Breast wall.

- The wall construction on the uphill side of roadway in order to retain earth from slippage is called breast wall.
- This wall has back face vertical and front face batter.
- The top width of breast wall should be 600mm thick.

→ This type of wall is constructed of stone masonary brick masonary or cement concrete.



[Cross section of a hill road].

Parapet wall :-

→ The wall constructed above the formation level of a hill road usually towards the down hill side is known as parapet wall

→ Parapet walls are provided to give protection, physical and psychological, to the motorists while travelling on roads with steep valley slopes.

→ This type of wall should not be made continuous but suitable gap is provided in between.

→ Generally the walls are 3.6 m long with gaps of 1.5m.

Catch water drain.

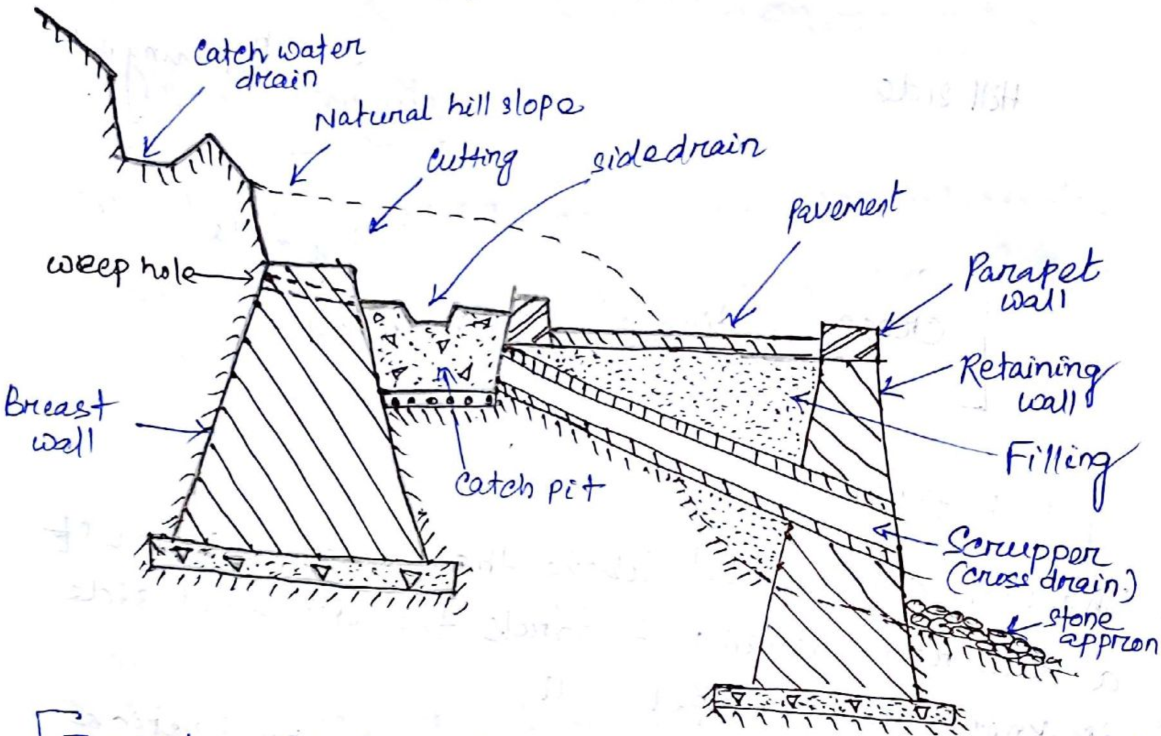
* The drain provided high up on the hill slope side in order to intercept and divert the water from hill

slope is called catch water drain

Cross drain

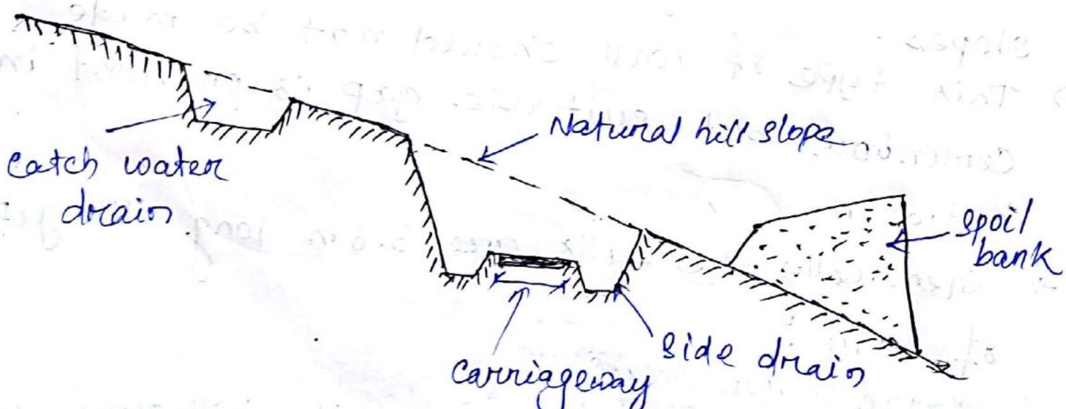
Cross drain is the drain constructed to drain off rainwater from one side of the road to the other side.

Typical hill roads section partly in cutting & partly in filling showing its components.



[Typical cross sections showing all details of a typical hill road partly in cutting and partly in filling]

Hill road Completely in cutting



[Section of hill road completely in cutting]

Different types of bend / curve on hill roads.

The curves which are commonly used in hill roads are as follows:

(i) Hair pin curves.
(ii) Re entrant curves
(iii) Salient curves

(i) Hair pin curves.

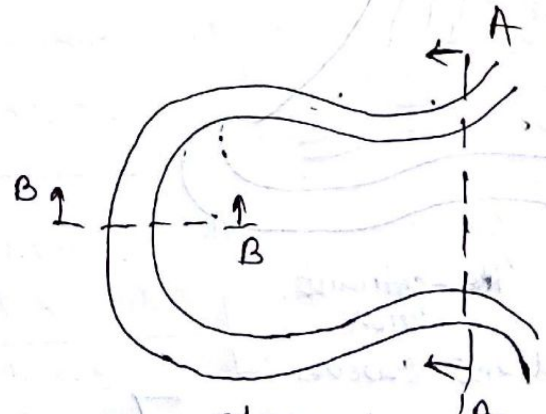
→ This is a compound curve in a hill road which changes its direction through an angle of 180° or so, on the same side down the hill.

→ The curve confirms the shape of a hair pin so it is called a hair pin curve

→ The bend is just like hair pin is located on a hill side having the minimum slope and maximum stability.

→ It must be safe from view point of landslides and ground water.

→ IRC recommended that where a number of hair pin bends have to be introduced a minimum intervening length of 60m should be provided between successive bends.



Plan.

Re-entrant curves.

→ Re-entrant curve at the valley of a hill having its concavity outwards.

→ The centre of curvature of a re-entrant curve lies away from the hill side.

→ it is provided to negotiate a deep but narrow valley, forming an open bend. re-entrant curves provide adequate visibility and are less dangerous.

Salient curves

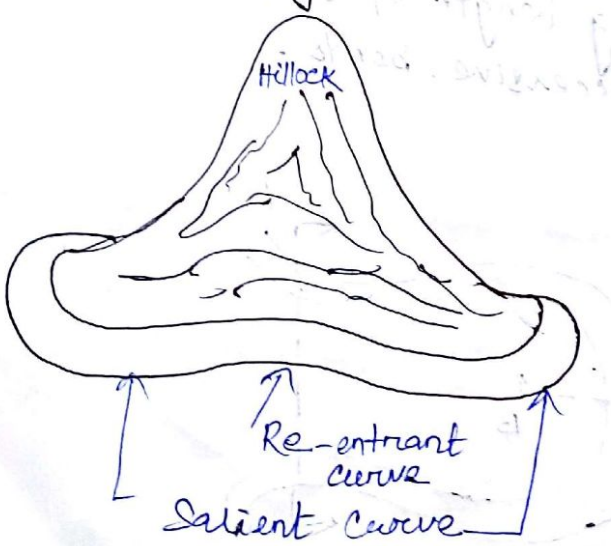
→ Salient curves having their convexity outwards.

→ The centre of curvature of this type of curve lies towards the hill side.

→ The bend formed by the salient curve in a hill road is known as corner bends.

→ These curves are very dangerous as they donot provide adequate visibility.

→ A parapet wall is provided at the outer edge of this type of curve to prevent the vehicles from falling down hill slopes.



[Re-entrant & salient curves]

Chapter-06

ROAD DRAINAGE

Introduction:-

→ Road drainage is the process of interception & removal of water from over, under and vicinity of the road surface.

→ For safe and efficient design of road, road drainage is very important.

→ The stability of road pavements can be maintained only if their surface and foundation bed remain in dry condition.

→ During rains, part of the rain-water flows on surface and part of it percolates in the subgrade or any other layer of ~~water flows~~ the pavement.

→ If this water is not removed it may cause the road pavement failure.

Necessity of road drainage work

Road drainage work is necessary because of the following reasons.

(i) Variation in moisture content in expensive soils causes variation in the volume of sub-grade and contributes to the failure of pavement.

(ii) Excess moisture content in soil subgrade causes considerable lowering of its stability.

(iii) The entrance of water causes reduction in bearing capacity of soil subgrades like WBM & stabilized soil.

(iv) Due to poor drainage, waves and corrugations are formed in flexible pavements which causes failure of pavement.

(v) Due to poor drainage of road, water remains in contact with the bituminous material for longer time causing stripping of bitumen from aggregates and formation of pot holes.

(vi) In rigid pavements failure occurs by mud pumping due to the presence of water in fine subgrade soil.

(vii) Poor drainage work causes erosion of soil from the top of unsurfaced road, slopes etc.

(viii) The shoulder and pavement edges get damaged due to excess water.

(ix) Increase in moisture content causes increase in weight and thus increase in stress & simultaneous reduction in strength of the soil.

Cross drainage works.

→ The function of the cross drainage works is to discharge water, collected in side drains or that of natural streams, across the road from one side to the other as quickly as possible.

→ The adequate functioning of a road depends to a large extent on the effectiveness of cross drainage work.

Scanned with CamScanner

→ Quick drainage prevents water from penetrating into the soil sub-grade & thus prevents failure.

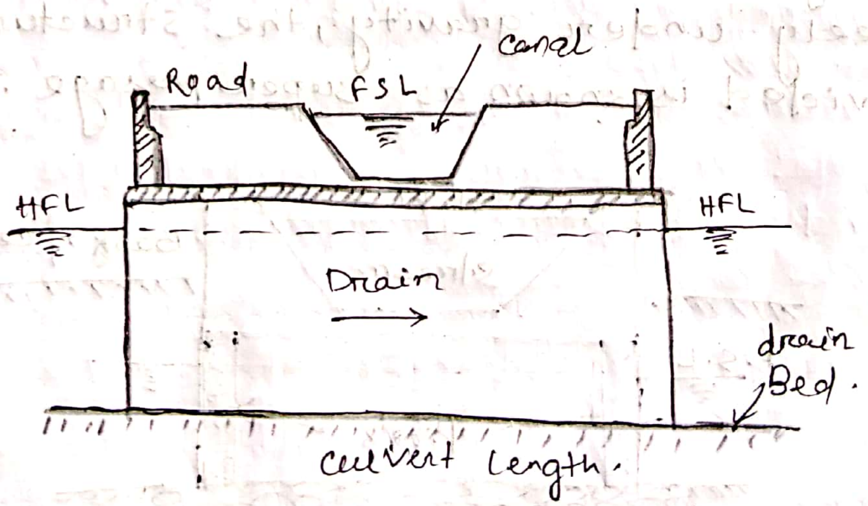
→ The structures constructed at the crossing point for the easy flow of water of the canal and drainage in the respective directions, are known as cross drainage works.

Thus the cross drainage works are classified depending upon the bed levels of the canal & drainage as follows.

1. Aqueduct and syphon aqueduct.
2. Super passage & canal syphon
3. Level crossing.

① Aqueduct

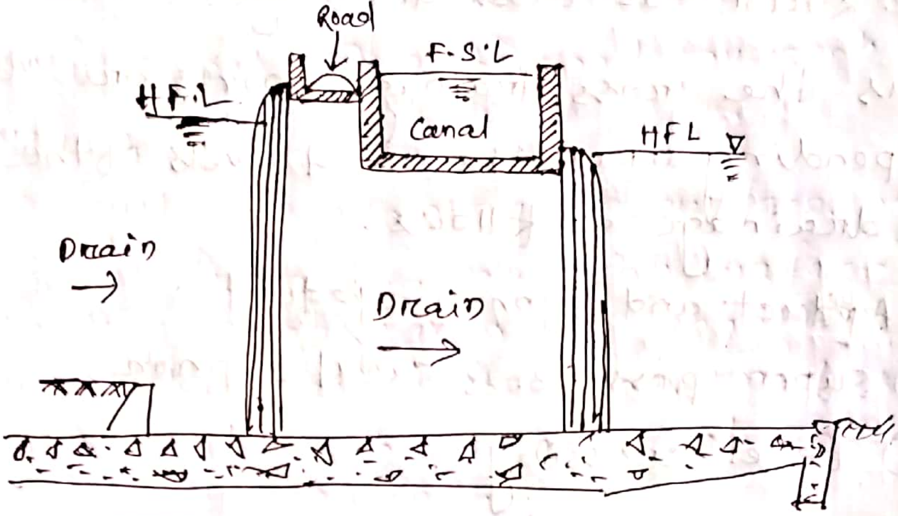
when the bed level of the canal is higher than the higher flood level (H.F.L) of the drainage, then the cross drainage work (or structure) is said to be aqueduct.



[Aqueduct]

Syphon aqueduct

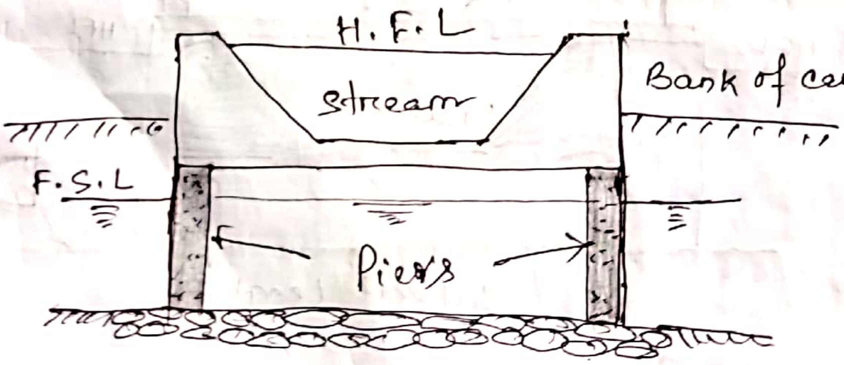
In case the bed level of the canal is below the highest flood level (H.F.L) of the drainage so that the drainage water passes through the aqueduct barrels under syphonic Action, then the structure provided is known as syphon aqueduct.



[Syphon aqueduct]

Super passage

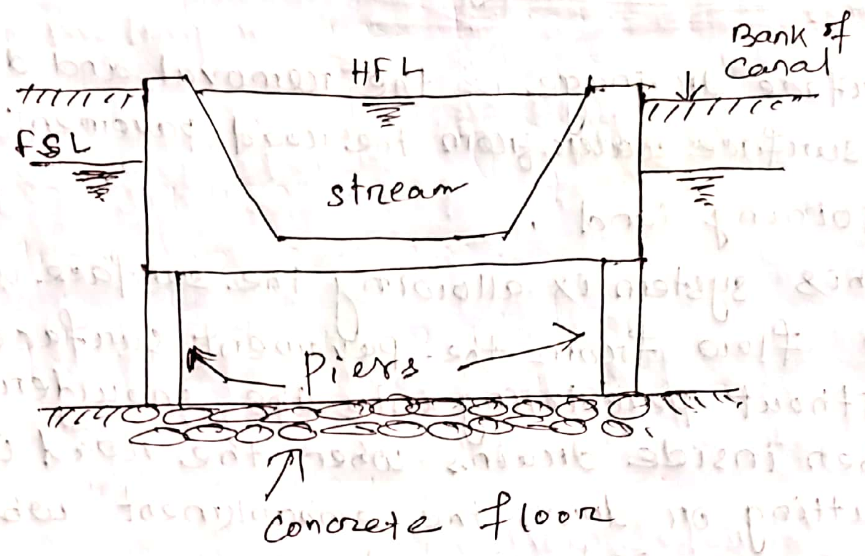
When FSL of the ~~drainage~~ canal is much below the bed level of the drainage trough, so that the ~~cho~~ canal water flows freely under gravity, the structure provided is known as super passage.



[Super passage]

Canal syphon.

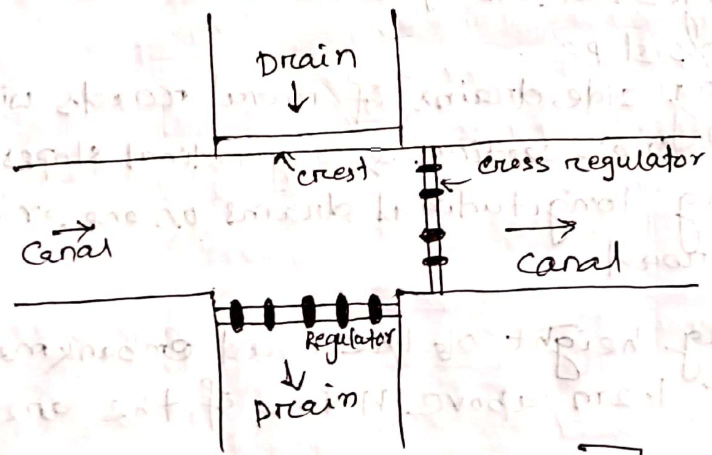
When the FSL of the canal is much above the bed level of the drainage trough, so that the canal water flows under syphonic action under trough (drain), the structure provided is known as canal syphon.



[Canal syphon]

Level crossing

When the bed level of the canal and that of the drainage are at the same level, the structure provided is called level crossing. This is a type of cross drainage works in which the canal water and drain water get intermixed.



[Level crossing]

Road drainage works are classified as follows.

① Surface drainage
② Sub surface drainage
③ Cross drainage.

① Surface drainage.

→ Surface drainage is the removal and diversion of surface water from the road pavement and adjoining land.

→ This system is allowing the surface water to flow from the pavement surface without percolating into the shoulders & then inside drains when the road is in cutting or down the embankment when it is in embankment.

→ The water is first collected in side drains and it is disposed off at the nearest stream, valley of water course.

Methods of providing surface drainage:

steps generally taken to provide effective surface drainage are as follows.

(i) Providing a impervious pavement surface.
(ii) Providing a sufficient cross slope or camber to the pavement.
(iii) Providing shoulders of rural roads with sufficient cross slope.
(iv) Providing side drains of rural roads with suitable cross section & longitudinal slopes.
(v) Providing longitudinal drains on one or both sides of road.
(vi) Keeping height of the road embankment atleast 1.2m above H.F.L of the area.

Sub surface drainage.

→ Sub-~~base~~ surface drainage is the system of diversion or removal of excess soil water to the ground water.

→ The main function of sub surface drainage is to keep the variation of moisture in subgrade soil to a minimum.

Methods of providing sub-surface drainage.

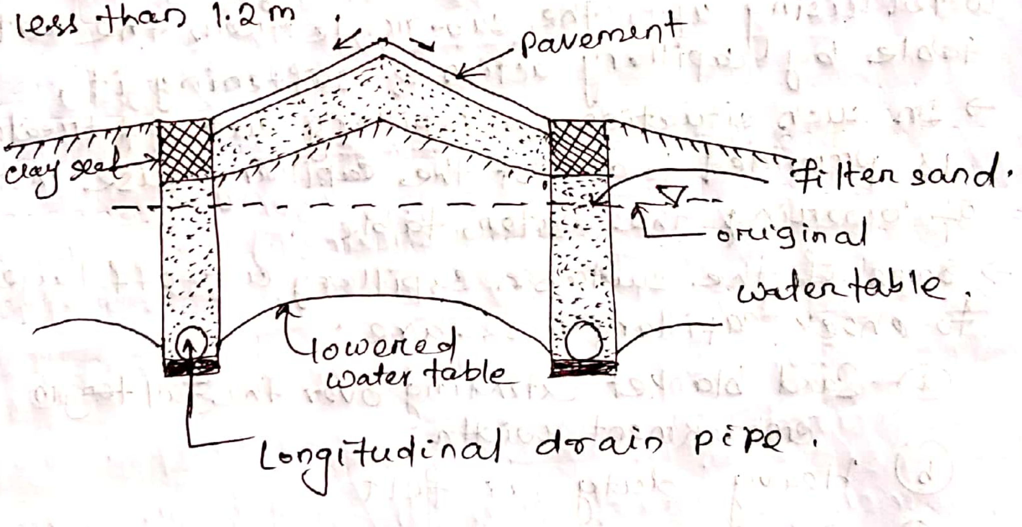
The following methods are adopted for sub-surface drainage:

(i) Lowering the water table.
(ii) Control of seepage flow
(iii) Control of capillary rise.

(i) Lowering the water table.

→ In order that the sub-grade and pavement layers are not subjected to excessive moisture, the highest level of the water table should be atleast 1.0 to 1.2 m below the level of sub-grade.

→ At places where water table is high, the best remedy is to make the road formation in embankment of height not less than 1.2 m



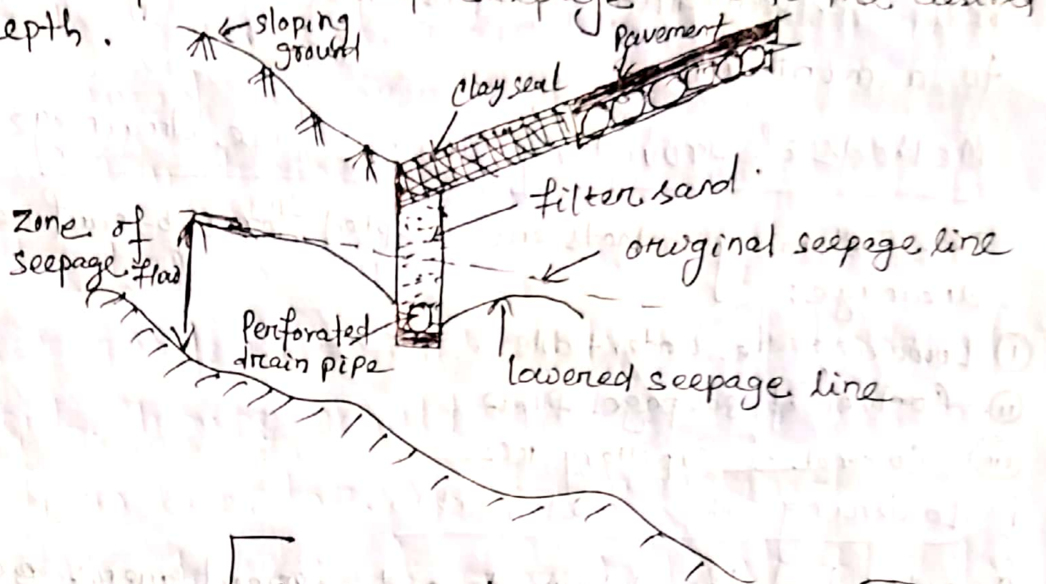
[Lowering of water table by using Longitudinal drain & filter sand]

(ii) Control of seepage flow.

→ where surface of ground and impervious strata below it are sloping towards the road, seepage flow is likely to reach the road sub-grade and affects its strength.

By Gayatri Jena

→ If the seepage zone is at a depth less than 60 to 90cm from the road subgrade, it should be intercepted to keep seepage line to the desired depth.



[Control of seepage flow]

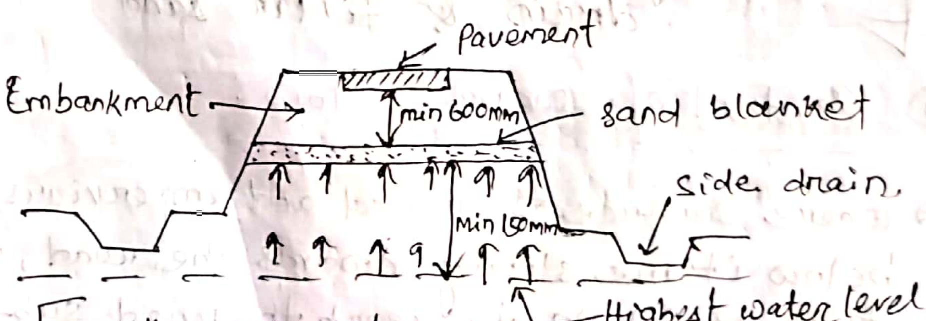
(iii) Control of capillary Rise.

In water logged areas, there is a possibility of water rising upto the sub-grade from the water table by capillary action & softening it.

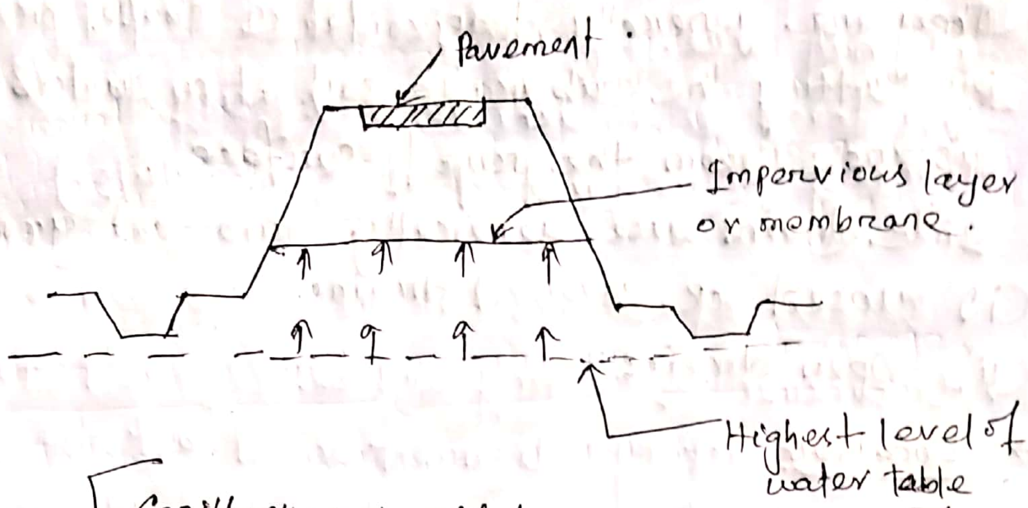
→ In such situations, a capillary cut off treatment is provided to arrest the capillary rise instead of lowering the water table.

→ Some of the suitable capillary cut-off layers to check capillary rise are:

- (a) Sand blanket extending over the full ~~length~~ embankment width.
- (b) Heavy duty tar felt
- (c) polythene envelope
- (d) Bituminous stabilized soil.



[capillary cut-off by sand blanket]



[Capillary cut-off by Impervious layer]

Storm water drains.

A storm ~~drain~~ water drain is infrastructure designed to drain excess rain and ground water from impervious surfaces such as paved streets, car parks, parking lots, foot paths, sidewalks & roofs.

→ storm drains vary in design from small residential dry wells to large municipal systems

→ storm drains often cannot manage the quantity of rain that fall in heavy rains or storms.

→ There are two main types of storm water drain inlets.

(i) side inlets
(ii) Grated inlets.

→ Many inlets having gratings or grids to prevent people, vehicles, large objects or debris from falling into the storm drains.

Side drains.

Side drains are more commonly known as ditches from which the water is ~~laid~~ led away in mitre drains.

→ These are longitudinal drains provided parallel to the road for collecting & disposing the surface water.

→ They are generally trapizoidal in shape provided by cutting the subgrade soil at a suitable distance from the road surface.

Side drains are generally two ~~cat~~ groups

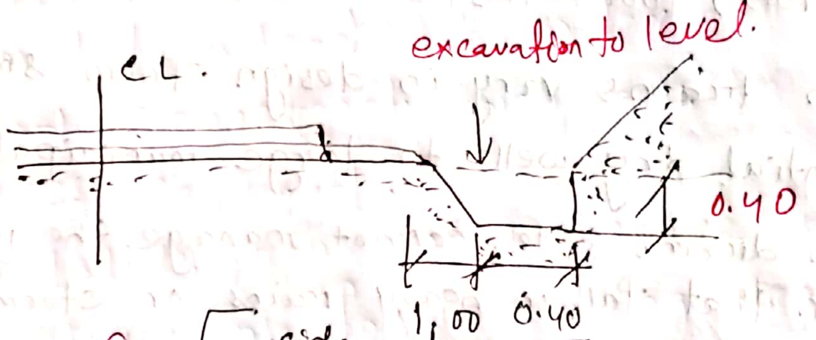
(i) closed or covered drains

(ii) Open drains

→ Location

For roads in embankment the distance of side drains should not less than 1.85 m from the toe of the embankment.

→ Side drains are provided just after the edges of shoulder for road in cutting.



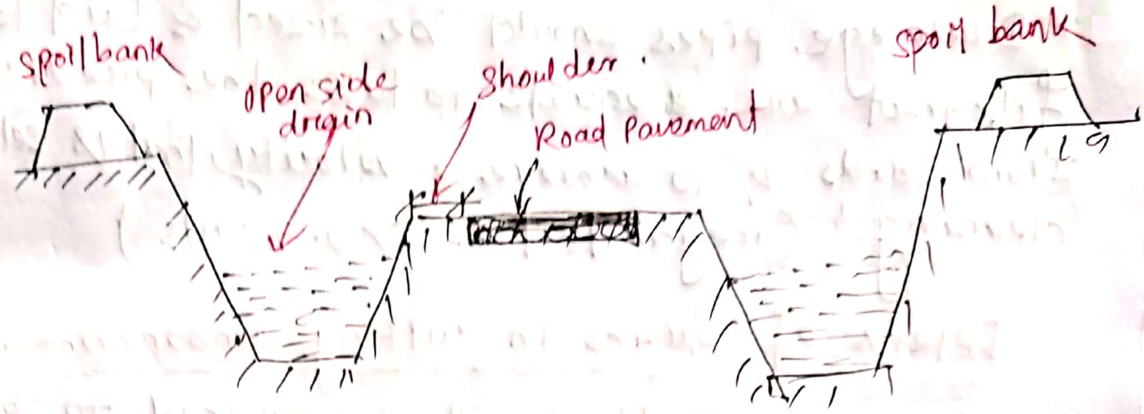
[side drains]

side ditches (~~Side drain (one ditch only)~~)

The side of side ditches must therefore be sufficient to cope with the run off water.

→ When a road with ~~4½~~ 4 ½ m formation width is to be provided with a 5% compacted camber (7% loose) the size of ditch should be.

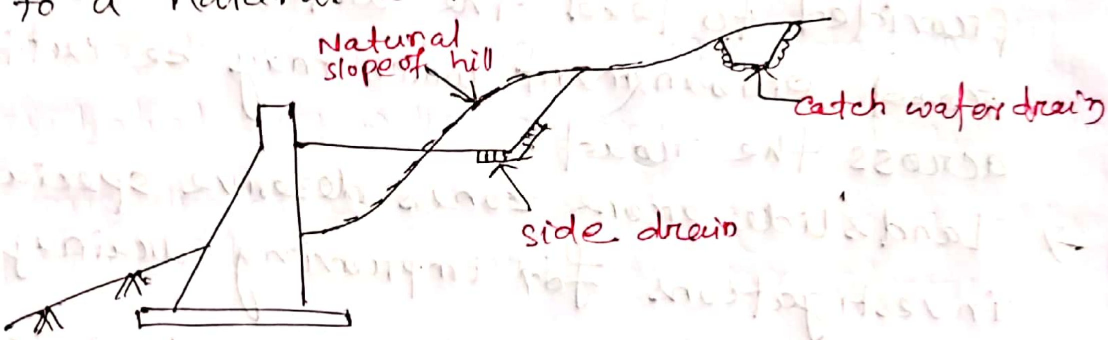
When there are ditches on both sides of the road the of each side ditch can be reduced to 0.3 m.



(Open side drain)

Intercepting drain.

→ A drain located between the water source and Protected area.
→ Intercepting drain also known as catch-water drains.
→ These are provided in the uphill slope of hill roads to intercept the water and lead it to a natural water stream.



Intercepting Drain

Pipe drains in hill roads

water drained from the pavement surface can be carried forward in the longitudinal direction between the kerb & the pavement for short distances which may be collected in catch pits at suitable intervals & lead through under-ground pipes.

→ Drainage of surface water is all the more important in hill roads.

→ Drainage pipes should be sized & laid to falls that are adequate to take the predicted flow loads & to achieve a velocity that is self-'cleaning' (regarded as > 0.75 m/s)

Details of drains in cutting embankment.

→ Embankment & cutting will be required to obtain a satisfactory alignment on all but the lowest standard of road embankment will be needed.

(i) To rise the road above flood water level.

(ii) In sidelong ground.

(iii) Across gullies.

(iv) At the approaches.

→ suitable cross drainage channels should be provided to lead the water across the road embankment which may be cutting across the road.

→ Landslide prone zones deserve special investigations for improving drainage.

→ Relatively poor embankment soils can perform satisfactorily if drainage is considered in the design.

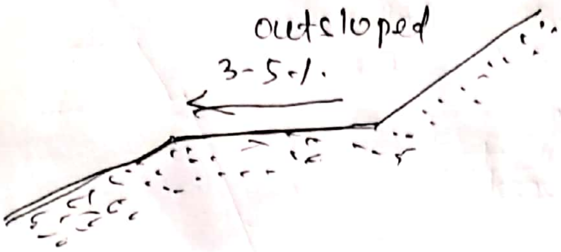
→ Consideration should be given to deal with the precipitation on the embankment and cut slopes so that erosion is not caused.

→ Longitudinal drainage should also be ensured, despite the provision of adequate cross-slopes, for better internal drainage of pavement layers, especially granular materials

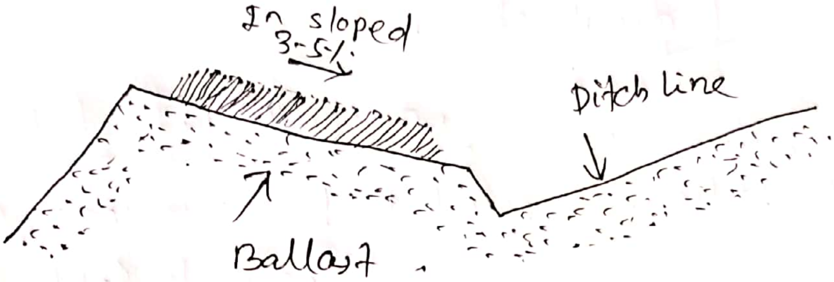
Scanned with CamScanner

and in cut sections.

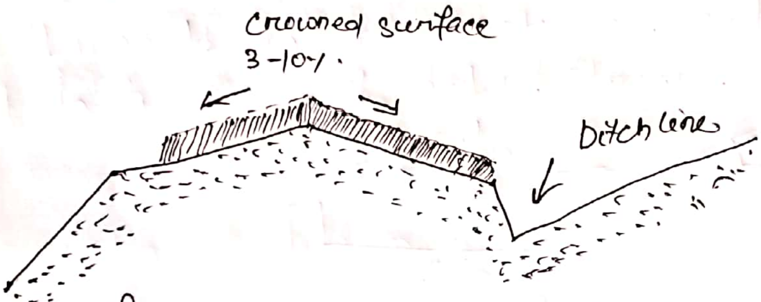
Typical cross sections



typical for temporary roads with dirt surface (no ballast).



Typical cross-section for permanent roads with or without ballast or ditch line.



fastest water removal.
Requires water control on both sides.

(Typical cross section of different roads for drainage)

—X—

Road Maintenance.

By Gayatri jena

Common types of road failures :- Causes :- Introduction

→ Pavement failure is caused by a number of variables including ~~including~~, water intrusion, stress from heavy vehicles, expansion & contraction from seasonal temperature changes & sun exposure.

→ It is important to keep up with proper maintenance like crack & asphalt sealing to prevent cracks from spreading or forming.

~~Types~~ Causes

⇒ The following are the causes of failure of any pavement.

(i) Bad quality of construction material.
(ii) faulty design & improper quality control of construction.
(iii) Inadequate road drainage system.
(iv) Increase in wheel load.
(v) Settlement of fill material of embankment.

failure of flexible pavement.

The failure in flexible pavement may be due to
(i) Sub-grade failure
(ii) Base course failure.
(iii) Wearing course failure
These includes :-

(1) Map cracking
This is the most common type of failure of the bituminous surfacing and occurs due to local weak spot.

(2) Longitudinal cracks
These cracks are developed along the length of the pavement.

③ ~~Atkso~~ Edge cracking

It forms along the edge of a road & is ~~basically~~ typically caused by water damage, insufficient base materials & heavy road usage.

④ Block cracking

→ It is formed by seasonal temperature differences that cause the asphalt to expand and contract.

→ It forms when the asphalt surface is too ~~hor~~ rigid.

5 Joint cracking

Joint cracking forms along asphalt overlay projects where a flexible concrete base is paved over.

→ over time the concrete sub-base will expand & contract causing cracks to form along the joints of the concrete

6. Potholes

→ These are formed through prolonged water intrusion from existing cracks in the surface.

Remedy

→ once a pothole is formed a patch can be applied to the ~~surface~~ road surface.

7. Rutting

Rutting is channeled depressions in an asphalt surface that form over time from exceeded weight limits & improper base construction

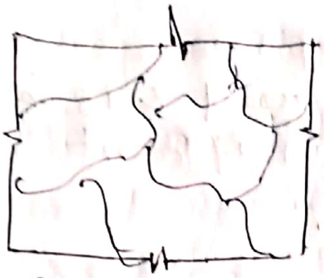
→ It is due to repeated movement of iron wheeled load & heavy traffic wheel load.

Remedies

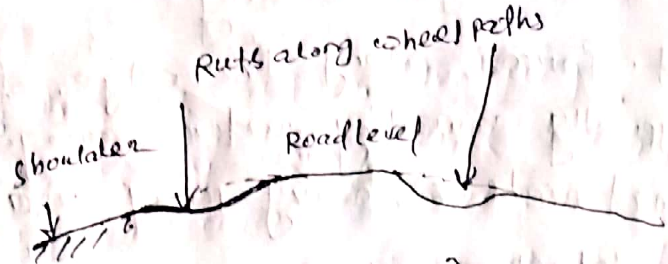
→ Proper strengthening of subgrade layer by compaction.

→ Providing proper drainage system.

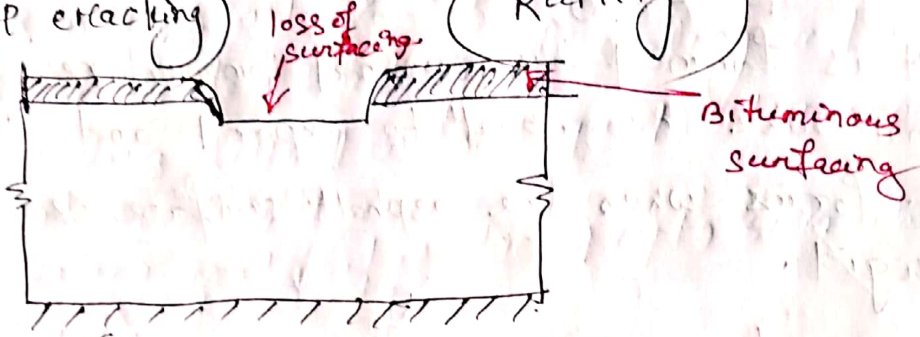
→ Proper designing of different layer of road.



(map cracking)



(Rutting)



(formation of pot holes)

Maintenance of bituminous Roads

It consists of

(i) Patch repairing work.

(ii) Surface treatment.

(iii) Resurfacing

Maintenance of cement concrete roads:

(i) Treatment of cracks / filling cracks

(ii) Maintenance of joints.

(iii) maintenance of shoulders.

(iv) maintenance of traffic control devices.

(i) Patch repairing works.

patch work is carried out when localized pot holes are developed on the road surface.

These consist of following stages.

(i) cutting of pot holes → cutting of marked areas

(ii) is done in rectangular shape & all the affected materials are then removed from it.

(ii) cleaning of pot holes :- The cut pot holes are cleaned of all loose materials & dust.
* prime coat is then applied in the pot holes.

(iii) Preparing Premix :-
coarse aggregate & bitumen are mixed in desired proportion to get a premix.
→ while preparing premix it should be ensured that prepared premix is similar to original construction.

(iv) filling the premix.
The premix is filled in the pot holes and compacted by using rammer.
→ when pot holes is more than 75 mm deep, filling should done in two to three layers.

(2) Surface treatment

If the road surface becomes slippery & patchy due to bleeding of excess bitumen.
That can be rectified by spreading aggregates chips ~~on the~~ or sand on the road surface & Rolling should be done to develop permanent bond.

(3) Resurfacing

when the pavement surface is totally worn out and develops a poor riding surface, laying of an additional surface coarse on the existing surface may be more economical.
→ Resurfacing operation consists of cleaning the road surface, applying seal coat, applying aggregate chips & rolling.

Maintenance of cement Concrete roads.

(i) Treatment of cracks/ filling cracks.
(ii) Maintenance of joints / Repairing joints.
(iii) Maintenance of shoulders.
(iv) Maintenance of traffic control devices.

(i) Filling cracks

→ First cleaned the cracks after identying.

→ Cleaned by the cracks by using stiff brush, a sharp tool or by pressure blower.

→ Then kerosine oil is applied on the cleaned cracks for proper bonding of sealing materials.

→ Then cracks filled with liquid bituminous material.

→ The sealing material is placed upto 3mm above road level.

(ii) Repairing joints

→ The weakest parts of cement concrete pavement are the joints.

→ During summer, the sealer material is squized out due to expansion of CC slab.

→ During winter, the joint gap opens up due to contraction of CC slab.

→ The open up joints are cleaned properly & refill with joint sealer material.

(iii) Maintenance of shoulders.

→ If shoulders are not properly maintained, damage may occur to the pavement as well as to vehicles.

→ Shoulders are properly maintained to keep them stable & smoth.

→ During rainy season, shoulders are generally damaged & large pits are developed.

→ These pits are immediately filled with soil & compacted.

(iv) Maintenance of traffic control devices.

The main object of providing traffic control devices is to provide safe, convenient & economical movement of vehicles & persons on the road.

→ The periodic maintenance of these ~~vehich~~ devices is very essential to avoid any road accident.

→ for maintenance of traffic signals, the traffic signals lights are cleaned time to time to remove dust and any defect in the light system is rectified.

→ painting & repairing of traffic ~~si~~ islands are carried out.

Traffic study

Basic Concepts

Traffic engineering:- Traffic engineering is that phase of transportation engg which deals with planning, geometric design & traffic operations of roads, streets & highways, their networks, terminals etc.

Scope of traffic engg.

It consists

(i) Traffic Surveys.

(ii) Transportation planning

(iii) Geometric design.

(iv) Traffic control.

(v) Administration & management.

(vi) Research.

Traffic Survey

It is conducted to assess traffic characteristics & to collect other data necessary to meet the future traffic needs.

It includes:

1. (i) Origin & destination study
2. (ii) Speed & travel time counts.
3. (iii) Traffic volume measurements.
4. (iv) Parking study
5. (v) Accident study
6. (vi) Highway capacity study.

Traffic Safety

→ Road traffic safety refers to the methods & measures used to prevent road users from being killed or seriously injured.

→ Typical road users include pedestrians, cyclists, motorists, vehicle passengers, horse riders, & passengers of an road public transport. (mainly buses & trains).

→ Regulation of road users.

~~motor vehicle users~~

→ Dependent on jurisdiction, drivers age, road type & vehicle type, may be required to pass a driving test, conform to restrictions on driving after consuming alcohol or drugs, uses of mobile phones & speed limits.

→ These all should be in mind of a driver ~~when driv~~ during driving a vehicles.

→ While government has primary responsibility for providing safe roads, the challenges of development & equity requires that all segments of society engage & contribute including private sectors.

Traffic Control signals

~~The signals are classi~~

→ Traffic signals are the signalling devices positioned at road intersections, pedestrian crossings & other locations to control flows of traffic.

→ The signals are classified into the following types:

(i) Traffic control signals.
- (a) fixed time signal
- (b) Manually operated signal
- (c) Traffic actuated (automatic) signal.

(ii) Pedestrian signal

(iii) Special traffic signal.

Types of traffic signal system.

Simultaneous system.

→ All the signals show the same indication at the same time.

→ As the division of cycle is also the same at all intersections, this system doesnot work satisfactorily

Alternate system.

→ Alternate signals or group of signals show opposite indications in a route at the same time.

→ More satisfactory than simultaneous system.

~~Flexible~~ Simple Progressive system:

→ A time schedule is made to permit as nearly as possible a continuous operation of groups of vehicles along the main road at a reasonable speed.

Flexible Progressive System:-

→ In this system it is possible to automatically vary the length of cycle, cycle division & the time schedule at each signalised intersection with the help of a computer.

→ This is the most efficient system of all the four types.

→ Traffic control signals have three coloured light (Red, green, yellow) glows facing each direction of traffic flow:

Red light means - for "stop".
Green light means - for "Go".
(Amber) Yellow light means - for "Clearance time".

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