ACE

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ESE – 2019 MAINS

OFFLINE TEST SERIES

CIVIL ENGINEERING

TEST – 4

SOLUTIONS

All Queries related to **ESE – 2019 MAINS Test Series** Solutions are to be sent to the following email address

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01(a).

Sol: Q_u (Ultimate load carried by pile) $= C_b N_c A_b + P\sum_{i=1}^{n} \alpha_i C_i L_i$

C_b = cohesion at base

A_b = Area of base of pile

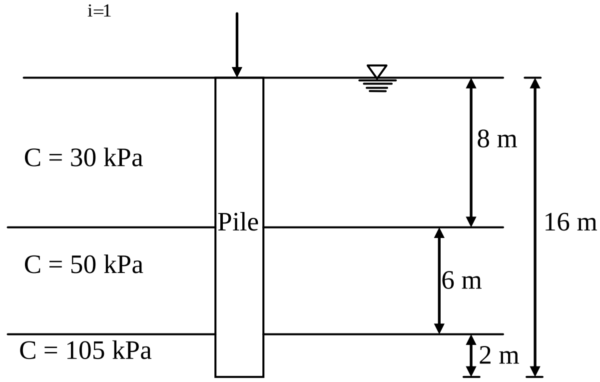
P = Perimeter of pile

α_i = adhesion factor for i^{th} layer

C_i = cohesion of i^{th} layer

L_i = Length of pile in i^{th} layer

n = no. of layers



$$Q_u = 105\times 9\left(\frac{\pi}{4}\times 0.45\right)^2 + \pi\times 0.45[0.9\times 30\times 8 + 0.75\times 50\times 6 + 0.5\times 105\times 2]$$

= 922.185 kN

Allowable load = $Q_c = \frac{Q_u}{FOS} = \frac{922.185}{2.5}$ = 368.87 kN

01(b).

Sol: Given $\phi_u = 20^o$, e = 1.0, C_u = 20 kN/m^2, G = 2.65

$$\gamma_{sat} = \left(\frac{G+e}{1+e}\right)\gamma_w = \left(\frac{2.65+1}{1+1}\right)\times 9.81$$

γ_{sat} = 17.9 kN/m^3

γ' = 17.9 – 9.81 = 8.09 kN/m^3 [Taking γ_w as 9.81 kN/m^3]

(i) canal full condition

$$F_c = \frac{C}{S_n \gamma' H}$$

'S_n' depends on i, ϕ_m

As 'F_ϕ' is not given F_ϕ = 1

$\phi_m = \phi = 20^o$

S_n = 0.062

$$F_c = \frac{20}{0.062\times 8.09\times 5} = 7.97$$

(ii) for sudden drawdown condition

$$F_c = \frac{C}{S_n \gamma_{sat}.H}$$

S_n depends on i, ϕ_w

$$\phi_w = \frac{\gamma'}{\gamma_{sat}}.\phi$$

$$= \frac{8.09}{17.9} \times 20^o = 9.04 \approx 10^o$$

$S_n = 0.108$

$$F_c = \frac{20}{0.108 \times 17.9 \times 5} = 2.07$$

01(c). (i)

Sol: Coarse fraction = 100% – 7% = 93%

$\therefore$ It is a coarse grained soil as the value is >50%

Gravel fraction = 100 –77 = 23%

Sand fraction = 93 – 23 = 70%

Since sand fraction > Gravel fraction, the soil is sand

D_{77} = 4.75 mm

D_7 = 0.075 mm

Considering linear variation

$$\frac{77-7}{4.75-0.075} = \frac{77-60}{4.75-D_{60}}$$

$\Rightarrow D_{60}$ = 3.615 mm

$$\frac{77-7}{4.75-0.075} = \frac{77-30}{4.75-D_{30}}$$

$\Rightarrow D_{30}$ = 1.61 mm

$$\frac{77-7}{4.75-0.075} = \frac{77-10}{4.75-D_{10}}$$

$\Rightarrow D_{10}$ = 0.275 mm

I_P = 0 (Non-plastic) so soil is silty (M)

Finer (size less than 0.075 mm) = 7% (5 – 12%)

$$C_C = \frac{D_{30}^2}{D_{60} \times D_{10}} = 2.61 \qquad 1 < C_C < 3$$

$$C_u = \frac{D_{60}}{D_{10}} = 13.15 > 6 \qquad \text{Soil is SW – SM}$$

$C_u > 6$

Well graded

01(c). (ii)

Sol: Vane: $d = 7$ cm

$H = 10$ cm

$T = 500$ N-m

For soft clay $S = C_u$

For undisturbed condition:

$$T = \pi d^2 . C_u \left[\frac{H}{2} + \frac{d}{6}\right] \text{-- Considering both ends partaking in shear}$$

$$500 = \pi \times \left(7 \times 10^{-2}\right)^2 \times C_u \left[\frac{10}{2} + \frac{7}{6}\right] \times 10^{-2}$$

$500 = 949.3 \times 10^{-6} \times C_u$

$\therefore\ S = C_u = 526.7\ \text{kN/m}^2$

In Remoulded state: $T = 200$ N-m

$$\text{Sensitivity} = \frac{(C_u)_{undisturbde}}{(C_u)_{Remoulded}} = \frac{(T)_{undistrubde}}{(T)_{Remoulded}} = \frac{500}{200} = 2.5$$

01(d). (i)

Sol: $q_{max} = 2000$ veh/hr

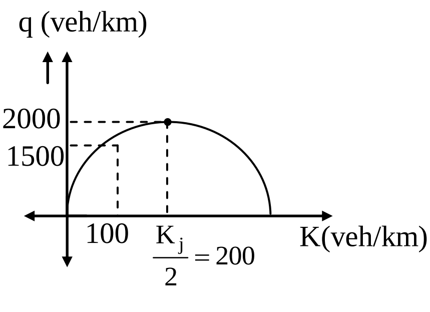
$$K_j = \frac{1000}{S_j} \qquad \text{(Jam density)}$$

$S_j = 0.7 \times 0 + 5$ [Under jam condition $\nu = 0$]

$= 5$ m

$$K_j = \frac{1000}{5} = 200 \text{ veh/km/lane}$$

$= 200 \times 2 = 400$ veh/km



$$q_{max} = \frac{V_{sf} \times K_j}{4} \Rightarrow V_{sf} = \frac{4 \times 2000}{400}$$

$$= 20 \text{ km/hr}$$

For K = 100 veh/km

$$q = V_{sf}\left(K - \frac{K^2}{K_j}\right) = 20\left(100 - \frac{100^2}{400}\right)$$

$$= 1500 \text{ veh/hr}$$

01(d). (ii)

Sol: [Original Pavement Design]

$x = 1$

$r = 10\%$

$n_1 = 15$ years

$V = 2.0$

$L = 0.5$ (2 lane single carriageway)

$P_1 = 600$

$A_1 = 600\ (1.1)^1$

Design Traffic $= 365 A_1 \dfrac{(1+r)^{n_1} - 1}{r} \times V \times L = T_1$ [After delay]

$x = 1 + 4 = 5$ years

$A_2 = 600\ (1.1)^5$

Since pavement design is unchanged. Design traffic remains same, along with V, L, r.

But design life of pavement is changed

$$T_2 = 365 A_2 \left[\frac{(1+r)^{n_2} - 1}{r}\right] \times V \times L$$

$T_1 = T_2$ (Same design traffic)

$$365 \times 600 \times (1.1)^1 \left[\frac{(1.1)^{15} - 1}{0.1}\right] \times 2 \times 0.5 = 365 \times 600 \times (1.1)^5 \times \left[\frac{(1.1)^{n_2} - 1}{0.1}\right] \times 2 \times 0.5$$

$$(1.1)^{15} - 1 = (1.1)^4 [(1.1)^{n_2} - 1]$$

$$(1.1)^{n_2} = 2.17 + 1 = 3.17$$

$$n_2 = 12.1 \simeq 12 \text{ years}$$

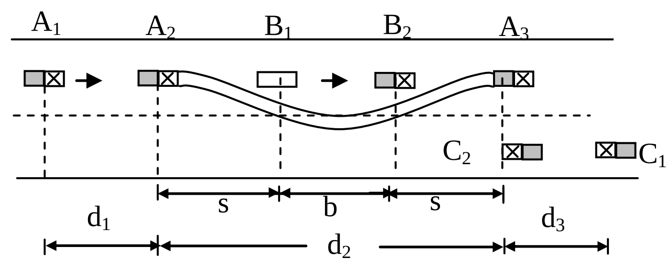
So, although pavement design (layer thickness) remained same.

Design life reduced by 3 years

New design life = 12 years

01(e).

Sol: Given:



Speed of car 'A' = 60 kmph

'B' = 40 kmph

Design speed = 75 kmph

Acceleration of car 'A' = 0.7 m/sec^2

2- lane undivided highway

$\therefore$ Overtaking sight distance = $d_1 + d_2 + d_3$

d_1 = distance travelled by 'A' during reaction time = $V_b t$

Assuming t = 2 sec

$\therefore$ $d_1 = (0.278 \times 40 \times 2) = 22.24$ m

d_2 = distance travelled by 'A' during over taking operation

$d_2 = b + 2\,S$

$= V_b\,T + 2S$

$S = 0.7\,V_b + l = 0..7 \times 0.278 \times 40 + 6 = 13.784$ m

$$T = \sqrt{\frac{4S}{a}} = \sqrt{\frac{4\times 13.784}{0.7}} = 8.87 \text{ sec}$$

$\therefore$ $d_2 = V_2\,T + 2S$

$= (0.278 \times 40 \times 8.87) + (2 \times 13.784)$

$= 126.2$ m

d_3 = Distance travelled by 'c' from opp. Direction

Assuming speed of 'C' as design speed = 75 kmph

$d_3 = V_C\,T$

$= 0.278 \times 75 \times 8.87 = 184.94$ m

$\therefore$ Overtaking sight distance required = 22.24 + 126.2 + 184.94

= 333.38 m

02(a).

Sol: Volume of excavation = V_e,

Void ratio of excavation = e_e

Volume of fill = V_f

Void ratio of fill = e_f

$$\left(\frac{V_e}{V_f}\right) = \left(\frac{1+e_e}{1+e_f}\right) \Rightarrow V_e = V_f\left(\frac{1+e_e}{1+e_f}\right)$$

$V_f = 5000\ m^3$

$e_f = 0.75$

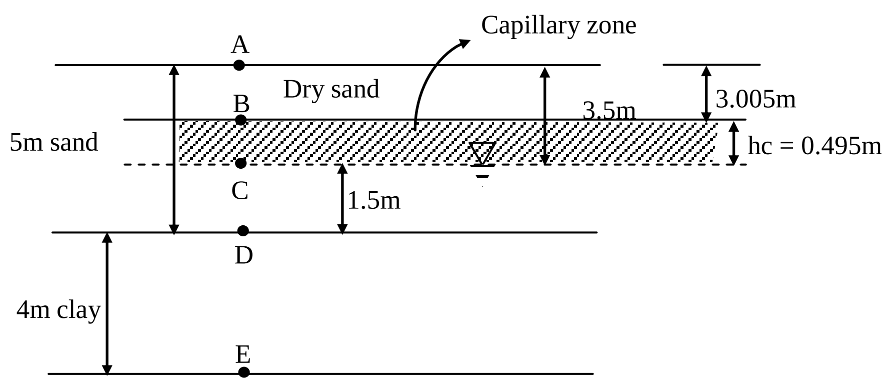
$\Rightarrow V_e = 2857.143\ (1 + e_e)$

Contractor's Name	Void ratio of excavated soil	Rate of soil (per m^3)	Transportation distance (km)	Volume of excavation (V_e) m^3	Contract value V_eR+2 V_eT (in lakhs)
Vinay Pathak	0.77	350	25	5057.14	20.23
Badal Gony	0.67	420	20	4771.43	22.90
Pradeep Reddy	0.83	370	45	5228.57	24.05
Ravi Nair	0.58	455	20	4514.29	22.35

Contract awarded to vinay Pathak (Rs. 20.23 lakhs)

02(b).

Sol:



$$\gamma_d\,(\text{sand}) = \frac{G_S\gamma_w}{1+e} = \frac{2.67\times10}{1+0.7} = 15.71\ \text{kN/m}^3$$

$$\gamma_{sat}\,(\text{sand}) = \left(\frac{G_S+e}{1+e}\right)\gamma_w = \left(\frac{2.67+0.7}{1+0.7}\right)10 = 19.82\ \text{kN/m}^3$$

$$\gamma_{sat}(\text{clay}) = \frac{G_S\gamma_w(1+w)}{1+e} = \frac{2.65\times10(1.4)}{1+1.06} = 18\,\text{kN/m}^3$$

$$e = \frac{wG}{s}$$

$$= \frac{0.4\times2.65}{1}$$

$$= 1.06$$

$$h_C \text{ (height of capillary rise)} = \frac{C}{e\,D_{10}} = \frac{0.45}{0.7\times0.013}\text{cm}$$

$$= 49.5 \text{ cm}$$

$$= 0.495 \text{ m}$$

Point	**Total Stress (σ_T) kN/m^2**	**Pore water Pressure (u) kN/m^2**	**Effective stress ($\bar{\sigma}$) = σ_T – u kN/m^2**
A	0	0	0
B	γ_d(sand) $\times$3.005 = 47.21	$-\gamma_w \times 0.495 = -4.95$	52.16
C	47.21+γ_{sat}(sand) $\times$0.495 = 57.02	0	57.02
D	57.02 + γ_{sat}(sand) $\times$ 1.5 = 86.75	$\gamma_w \times 1.5 = 15$	71.75
E	86.75 + γ_{sat}(clay) $\times$ 4 = 158.75	$\gamma_w \times 5.5 = 55$	103.75

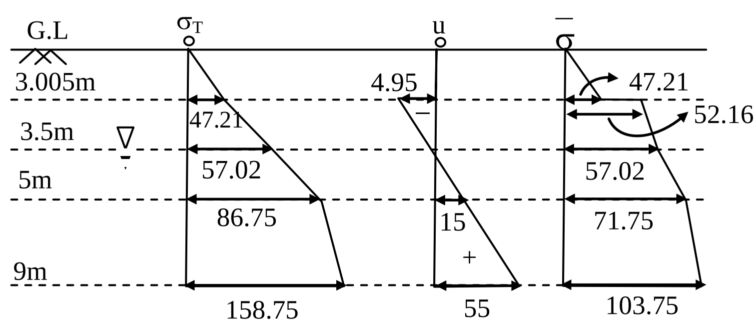


Fig. Variation of σ, u and σ′

02(c).

Sol: **Given:** design speed 'V' = 80 kmph

Terrain is hilly

Radius of curve = Rulling minimum radius

Length of wheel base = 6 m

Geometric features:

(1) Radius of curve = ruling min radius = $\frac{V^2}{127(e+f)}$

For hilly terrain e = 0.1

Assuming lateral friction coefficient = f = 0.15

$$\therefore R = \frac{80^2}{127(0.1+0.15)} = 201.57 \text{ m}$$

(2) Superelevation

$$e = \frac{(0.75V)^2}{127\,R} = \frac{V^2}{225\,R} = \frac{80^2}{225\times 201.57} = 0.14 > e_{max} = 0.1$$

$\therefore$ provide e = e_{max} = 0.1

$$f = \frac{V^2}{127\,R} - e = \frac{80^2}{127\times 201.57} - 0.1 = 0.15$$

(3) Extra widening

$$W_e = \frac{n\ell^2}{2R} + \frac{V}{9.5\sqrt{R}} = \frac{2\times 6^2}{2\times 201.57} + \frac{80}{9.5\sqrt{201.57}} = 0.77 \text{ m}$$

Total width = 7 + 0.77 = 7.77 m

(4) Transition curve

(i) Length of transition curve as per rate of change of centrifugal acceleration = $\frac{V^3}{CR}$(ν in m/sec)

$$e = \frac{80}{75+v} = \frac{80}{75+80} = 0.516 \quad (C < 0.8 \text{ and } C > 0.5)$$

$$L = \frac{(0.278\times 80)^3}{0.516\times 201.57} = 105.76 \text{ m}$$

(ii) Length as per rate of change of superelevation:

Assuming the pavement is rotated about centre

$$L = \frac{eN(W+W_e)}{2} \qquad (N = 150)$$

$$= 0.1\times 150\left(\frac{7+0.77}{2}\right) = 58.275 \text{ m}$$

(iii) As per IRC: for mountainous steep terrain

$$L = \frac{V^2}{R} = \frac{80^2}{201.57} = 31.75 \text{ m}$$

$\therefore$ Provide length of transition curve = 105.76 m

Set back distance for SSD:

$$SSD = (0.278 \times 80 \times 2.5) + \frac{80^2}{254 \times 0.35} = 127.6\,\text{m}$$

Length of horizontal curve = 250 m

$$L_C > SSD$$

$\therefore$ Set back distance from centre of road = R – (R – d) cos $\left(\frac{\alpha}{2}\right)$

$$R = 201.57 \text{ m},\ d = \frac{7+0.77}{4} = 1.94 \text{ m}$$

$$\frac{\alpha}{2} = \frac{180}{2\pi} \times \left(\frac{SSD}{R-d}\right) = \frac{180}{2\pi} \times \frac{127.6}{(201.57-1.94)}$$

$$= 18.31^o$$

Set back distance = 201.57 – (201.57 – 1.94) COS 18.31 = 12.04 m

03(a).

Sol: (i) The given medium is anisotropic.

In this case equation of continuity

$$k_x \frac{\partial^2 H}{\partial x^2} + k_y \frac{\partial^2 H}{\partial y^2} = 0 \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Solution of above equation cannot be given as it is not in Laplace form.

So, we have to transform it by substituting a transformed co-ordinate x_T for x such that

$$x_T = x\sqrt{\frac{k_y}{k_x}} \text{ or } x = x_T\sqrt{\frac{k_x}{k_y}}$$

$$\partial x = \partial x_T\sqrt{\frac{k_x}{k_y}}$$

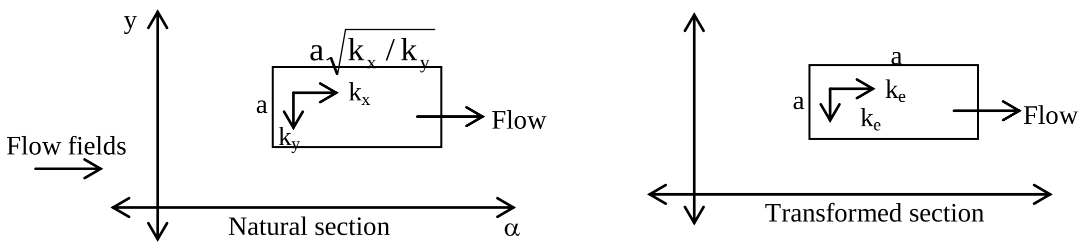
$$\partial x^2 = \partial {x_T}^2 \frac{k_x}{k_y}$$

Replacing ∂x^2 in equation (1)

$$k_x \frac{\partial^2 H}{\partial x_T^{\,2} \times \left(\dfrac{k_x}{k_y}\right)} + k_y \frac{\partial^2 H}{\partial y^2} = 0$$

$$\Rightarrow k_y \left[\frac{\partial^2 H}{\partial x_T^{\,2}} + \frac{\partial^2 H}{\partial y_T^{\,2}}\right] = 0 \qquad \text{or} \qquad \left[\frac{\partial^2 H}{\partial x_T^{\,2}} + \frac{\partial^2 H}{\partial y^2} = 0\right] \ldots\ldots (2)$$

Equation (2) is in standard Laplace form. Flow net for which is drawn with transformed co-ordinates.



Flow for transformed section (through one flow field) $\Delta q_T = k_e \dfrac{\Delta h}{a} \times (a \times 1)$

Flow for actual section $\Delta q_a = k_x \dfrac{\Delta h}{a\sqrt{\dfrac{k_x}{k_y}}} \times (a \times 1)$

$$= \sqrt{k_x k_y}\, \frac{\Delta h}{a} \times a \times 1$$

$$\Delta q_T = \Delta q_a$$

$$\Rightarrow k_e = \sqrt{k_x k_y}$$

Flow through one flow channel = $\Delta q = \sqrt{k_x k_y}\ \Delta h$

$$\Delta q = \sqrt{k_x k_y}\, \frac{H}{N_d}$$

N_d = Number of potential drops

H = Total head available

$$\Delta h = \frac{H}{N_d}$$

Total flow for N_f flow channels $q = \Delta q \times N_f$

$$q = \sqrt{k_x k_y}\ H\left(\frac{N_f}{N_d}\right)$$

Seepage flow per m length.

(ii) In above question:

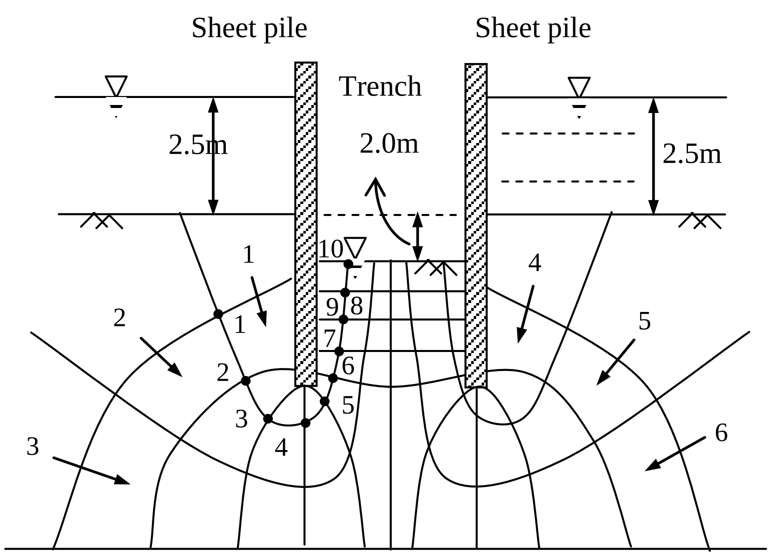
$q = 0.3\ m^3/hr/m$

$k_x = 5 \times 10^{-5}$ m/s

$H = 2.5 + 2 = 4.5$ m

Number channels of flow = 6

Number of potential drops = 10



$$q = \sqrt{k_x k_y}\ H\left(\frac{N_f}{N_d}\right)$$

$$\Rightarrow \frac{0.3}{60\times60}\frac{m^3}{s\,m} = \sqrt{k_y 5\times10^{-5}}\ \frac{m}{s}\times4.5\times\frac{6}{10}$$

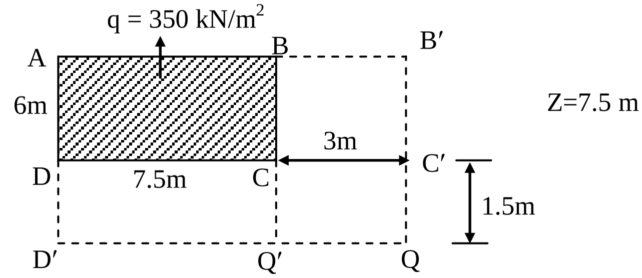
$\Rightarrow k_y = 1.905 \times 10^{-5}$ m/s.

03(b).

Sol: ABCD is the loaded rectangular area.

Two imaginary rectangles BB′ QQ′, DD′QC′ having common corner Q are constructed.

$$\sigma_Z = \begin{bmatrix} I_{QD'AB'} \\ -I_{QQ'BB'} \\ -I_{QD'DC'} \\ +I_{QQ'CC'} \end{bmatrix} q$$



Area	L	B	m = L / Z	n = B / Z	I
QD′AB′	10.5	7.5	1.4	1	0.1914
QQ′BB′	7.5	3	1	0.4	0.1013
QD′DC′	10.5	1.5	1.4	0.2	0.0589
QQ′CC′	3	1.5	0.4	0.2	0.0328

$$I = \frac{1}{4\pi}\left[\frac{2mn(m^2+n^2+1)^{\frac{1}{2}}}{m^2+n^2+m^2n^2+1}\times\frac{(m^2+n^2+2)}{(m^2+n^2+1)} + \tan^{-1}\frac{2mn(m^2+n^2+1)^{\frac{1}{2}}}{m^2+n^2-m^2n^2+1}\right]$$

σ_Z = [0.1914 – 0.1013 – 0.0589 + 0.0328] 350

= 22.4 kN/m²

03(c).

Sol: **Given**

Width of road A = 18 m

B = 12 m

Approach speed of road A = 55 kmph

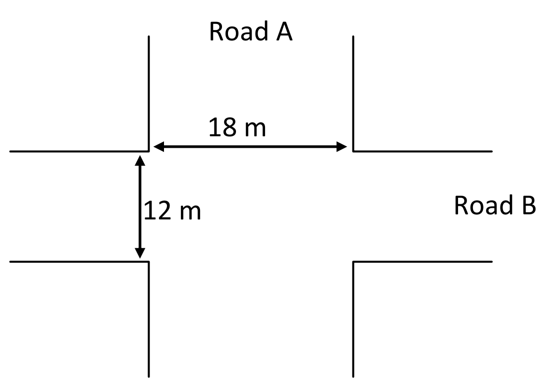
B = 40 kmph

Heaviest traffic volume for road A = 275 veh/hr

B = 225 veh/hr

Amber period for road A = 4 sec

B = 3 sec



Step – 1:

Based on Pedestrian crossing:

Assuming pedestrian walking speed = 1.2 m/sec

And initials walk period = 7 sec

Pedestrian crossing time for road A

$$= 7 + \frac{18}{1.2}$$

= 7 + 15 = 22 sec

For road B = $7 + \frac{12}{1.2}$

= 7 + 10

= 17 sec

$\therefore$ Minimum red time for road A = 22 sec

Minimum red time for road B = 17 sec

Green time:

Minimum green time for road B = 22 – 3

= 19 sec

A = 17 – 4 = 13 sec

Step – 2:

Based on approach volume:

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

Since traffic volume of road 'A' is. more, its green time is increased using minimum green time for road B.

$$\Rightarrow G_A = \frac{275}{225} \times 19 = 23.2 \text{ sec}$$

Step – 3:

Total cycle:

Cycle length = $G_A + A_A + R_A = G_A + A_A + G_B + A_B$

= 23.2 + 4 + 19 + 3 = 49.2 sec

Say 50 sec

$\therefore$ Adjusting balance 0.8 sec to 'A' and 'B' proportionately with respect to traffic volume

$\Rightarrow$ for road A = $0.8\times\dfrac{275}{275+225}=0.44$ sec

B = 0.8 – 0.44 = 0.36 sec

Final green time of road A = 23.2 + 0.44 = 23.64 sec

B = 19 + 0.36 = 19.36 sec

Red time of road A = $G_B + A_B$

= 19.36 + 3 = 22.36 sec

Red time of road B = $G_A + A_A$

= 23.64 + 4 = 27.64 sec

Step 4 : Design of pedestrian signal:

Do not walk period for pedestrians at road A = 27.64 sec

for road B = $G_B + A_B$

= 22.36 sec

Pedestrain clearance interval for road A = 15 sec $\left(=\dfrac{18}{1.2}\right)$

B = 10 sec $\left(=\dfrac{12}{1.2}\right)$

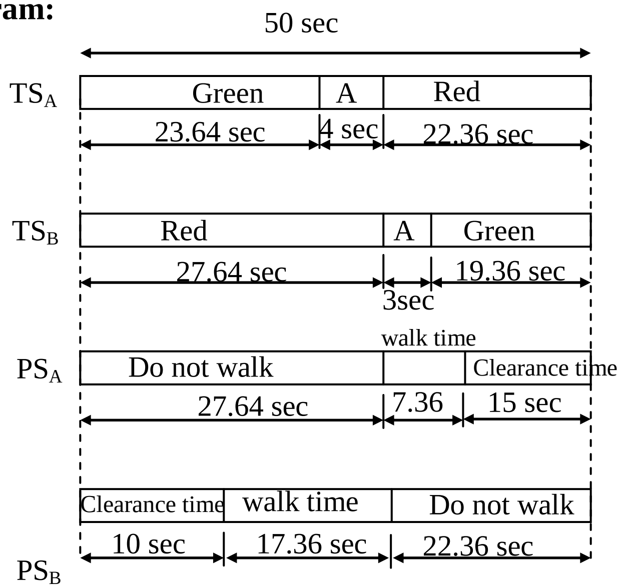
$\therefore$ Walk time for road A = 50 – (27.64 + 15)

= 7.36 sec

Walk time for road B = 50 – (22.36 + 10)

= 17.64 sec

Phase diagram:

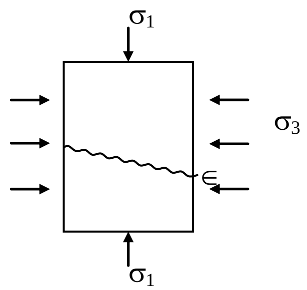


04(a). (i)

Sol: **(A) Types of failures in triaxial test**

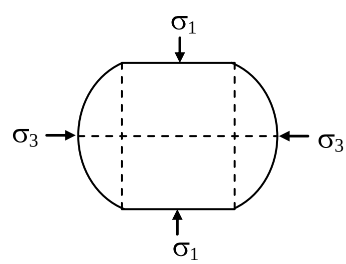
(a) Brittle failure:

- Occurs In dense sands & heavily over consolidated clays (OCC)
- Well defined failure plane, axial strain is small & failure plane is inclined as shown in figure.



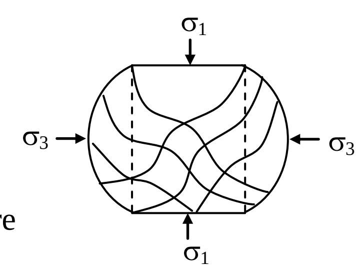
(b) Plastic failure:

- Occurs in normally consolidated clays & loose sands
- Well expressed lateral bulging
- Large axial & lateral strain occurs at failure



(c) Semi-plastic (or) semi brittle failure:

- Occurs in silts & C - ϕ soils
- It has shear cone & some lateral bulging
- Intermediate stage of brittle & plastic failure



(B) Liquefaction of soil:

Due to earthquake forces, positive pore water pressure increases and becomes equal to total stress causing zero effective stress

In cohesionless soils, at this condition, soil losses all its shear strength & behaves like a liquid (viscous material). Such a phenomenon is known as liquefaction

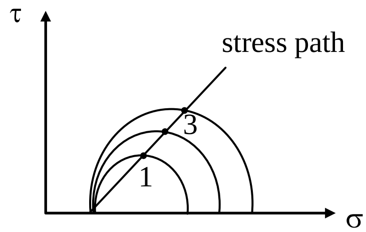
Fine sands, silts are easily susceptible to this condition

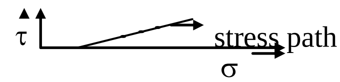
(C) Stress path: A curve which shows the changes in stress as the load acts on soil specimen changes

- It is a line drawn through the points representing maximum shear stress (generally) acting on specimen

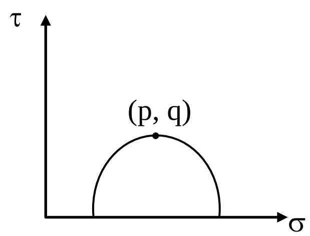
- It is more convenient to draw stress path on p-q plot which represents modified failure envelope

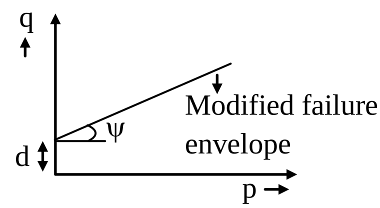
$$p = \frac{\sigma_1 + \sigma_3}{2}, q = \frac{\sigma_1 - \sigma_3}{2}$$





PS_B





04(a). (ii)

Sol: Assume c = 0 for the sand

Direct shear test

$$\sigma = \frac{N}{A} = \frac{0.4}{40 \times 10^{-4}} = 100 \text{ kN/m}^2$$

$$\tau_f = \frac{T}{A} = \frac{0.25}{40 \times 10^{-4}} = 62.5 \text{ kN/m}^2$$

(a) Sandy soil (c = 0)

At failure $\tau_f = s = c + \sigma.\tan\phi$

$$62.5 = 100. \tan \phi$$

$$\phi = \tan^{-1}\left(\frac{62.5}{100}\right) = 32^{\circ}$$

(b) $\sigma = \frac{\sigma_1 + \sigma_3}{2} + \frac{\sigma_1 - \sigma_3}{2}\cos 2\alpha_f \rightarrow \quad (1)$

$$\tau = \frac{\sigma_1 - \sigma_3}{2}\sin 2\alpha_f \quad \rightarrow (2)$$

From (1) & (2) $\qquad \alpha_f = 45 + \phi/2$

$$\sigma = \frac{\sigma_1 + \sigma_3}{2} + \frac{\tau}{\tan 2\alpha_f} \qquad \alpha_f = 45 + \frac{32}{2}$$

$$100 = \frac{\sigma_1 + \sigma_3}{2} + \frac{62.5}{\tan(2 \times 61^o)} \qquad \alpha_f = 61^o$$

$\sigma_1 + \sigma_3 = 278.1$ kPa

$$\tau = \frac{\sigma_1 - \sigma_3}{2} \sin 2\alpha_f$$

$$62.5 = \frac{\sigma_1 - \sigma_3}{2} \sin(2 \times 61^o)$$

$\sigma_1 - \sigma_3 = 147.397$

≈ 147.4 kPa

$\therefore\ \sigma_1 + \sigma_3 = 278.1$

$\sigma_1 - \sigma_3 = 147.4$

$2\sigma_1 = 425.5$

$\sigma_1 = 212.75$ kPa

$\sigma_3 = 65.35$ kPa

(c) Same sand: $\phi = 32^o$, $C = 0$

$\sigma_c = \sigma_3 = 50$ kPa

$\sigma_1 = \sigma_3 \tan^2 \alpha_f + 2\, c \tan \alpha_f$

$\sigma_1 = 50 \tan^2 (61^o)$

$\sigma_1 = 162.73$ kPa

$\therefore\ \sigma_d = \sigma_1 - \sigma_c = 162.73 - 50 = 112.73$ kPa

04(b). (i)

Sol: Given $f = 1.5$

$$b = \frac{7.5}{2} = 3.75$$

$h = 22$ cm

γ_c (unit weight of concrete) = 2400 kg/m^3

σ_{st} (Permissible tensile stress in steel) = 1400 kg/cm^2

τ_{bd} (bond stress) = 24 kg/cm^2

A_{st} (Area of steel tie bars) $= \dfrac{fbh\gamma_c}{\sigma_{st}}$ (per m)

$$= \frac{1.5 \times 3.75 \times 0.22 \times 1 \times 2400}{1400}$$

$= 2.12\ \text{cm}^2$ (per m)

Spacing of tie bars (in mm) $= S_t = \dfrac{1000 \times \frac{\pi}{4}\phi^2}{A_{st}}$

$$= \frac{1000 \times \frac{\pi}{4} \times 1^2}{2.12}$$

$= 370.47$ mm

We choose 350 mm < 370.47 mm

Minimum length of tie bar $= \dfrac{\sigma_{st}\phi}{2\tau_{bd}}$

$$= \frac{1400 \times 1}{2 \times 24} = 29.17\ \text{cm}$$

We can choose (30 cm) > (29.17 cm)

04(b). (ii)

Sol: The Assumptions made in arriving at basic runway length

(a) no wind is blowing on runway

(b) Aircraft is loaded to its full loading capacity

(c) airport is at mean sea level

(d) There is no wind blowing on the way to destination

(e) Standard temperature is maintained along the way

(f) Standard temperature of 15^o C exists at airport

(g) The runway is levelled in longitudinal direction i.e. it has zero effective gradient

Given: Basic runway length = 2000 m

Attitude of airport = 800 m

Airport reference temp. = 18^o C

Correction for elevation:

As per ICAO, basic runway length should be increased at 7% per 300 m rise in elevation above mean sea level.

$\therefore$ correction for elevation = $\frac{7}{100}\times\frac{800}{300}\times 2000$

= 373.33 m

$\therefore$ Corrected length = 2000 + 373.33 = 2373.33 m

Correction for temperature:

Standard atmospheric temperature at given attitude

= 15 – 0.0065 h = 15 – 0.0065 × 800

= 9.8^o C

Airport reference temperature = 18^o C.

As per ICAO, basic runway length corrected for elevation should be increased @ 1% for every 1^o C rise of ART

Rise in temperature = 18 – 9.8 = 8.2^{o}C

Correction for temp = $2373.33\times\frac{8.2}{100} = 194.61$ m

$\therefore$ Corrected length = 2373.33 + 194.61 = 2567.94 m

04(c). (i)

Sol: P = 4100 kg, E = 3.1 × 10^5 kg/cm^2

h = 20 cm, a = 15 cm

μ = 0.15, K = 20 kg/cm^3

Radius of Relative stiffness,

$$\ell = \left[\frac{Eh^3}{12K(1-\mu^2)}\right]^{1/4} = \left[\frac{3.1\times 10^5\times 20^3}{12\times 20(1-0.15^2}\right]^{1/4}$$

= 57.02 cm

Radius of equivalent resisting section,

$$(b) = \sqrt{1.6a^2+h^2} - 0.675h \quad \text{(as a < h) so, (a < 1.724 h)}$$

$$\Rightarrow b = \sqrt{1.6\times 15^2+20^2} - 0.675\times 20$$

= 14.07 cm

As per Westergard

Stress at interior $= \sigma_i = \dfrac{0.316P}{h^2}\left[4\log_{10}\dfrac{\ell}{b} + 1.069\right]$

$$= \frac{0.316 \times 4100}{(20)^2}\left[4\log_{10}\left(\frac{57.02}{14.07}\right) + 1.069\right]$$

$= 11.34$ kg/cm^2

Stress at edge $= \sigma_e = \dfrac{0.572P}{h^2}\left[4\log_{10}\left(\dfrac{\ell}{b}\right) + 0.359\right]$

$$= \frac{0.572 \times 4100}{(20)^2}\left[4\log_{10}\left(\frac{57.02}{14.07}\right) + 0.359\right]$$

$= 16.357$ kg/cm^2

04(c). (ii)

Sol:

Speed (kmph)	Frequency	Cumulative Frequency	Percentile (%)
0 – 20[10]	10	10	(10/200) × 100 = 5
20 – 40[30]	35	45	(45/200) × 100 = 22.5
40 – 60[50]	67	112	56
60 – 80[70]	53	165	82.5
80 – 100[90]	25	190	95
100 – 120[110]	10	200	100
[ ] are mean speed			

(a) Design speed = 98 Percentile

$$= 90 + \left(\frac{110 - 90}{100 - 95}\right)(98 - 95) = 102 \text{ kmph}$$

(b) Safe Speed = 85 percentile

$$= 70 + \frac{(90 - 70)}{(95 - 82.5)}(85 - 82.5) = 74 \text{ kmph}$$

(c) Lower limit speed = 15 percentile

$$= 10 + \left(\frac{30 - 10}{22.5 - 5}\right)(15 - 5) = 21.43 \text{ kmph}$$

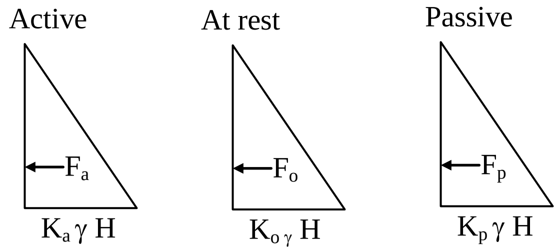
05(a).

Sol: 6 m

$c = 0$

$\phi = 30^o$

$\gamma_d = 15\ kN/m^2$



Co-efficient: $K_o = 1 - \sin\phi = 1 - \sin 30^o = 0.5$

$$K_a = \frac{1-\sin 30^o}{1+\sin 30^o} = \frac{1}{3}$$

$K_p = 1/k_a = 3$

(i) wall restrained against yielding (at rest condition)

$$\text{At rest thrust, } F_o = \frac{K_o\gamma_d H^2}{2} = \frac{0.5\times15\times6^2}{2} = 135\ kN/m$$

(ii) Wall is free to yield (active state)

$$\text{Active thrust, } F_a = \frac{K_a\gamma H^2}{2}$$

$$= \frac{1}{3}\times\frac{15\times6^2}{2}$$

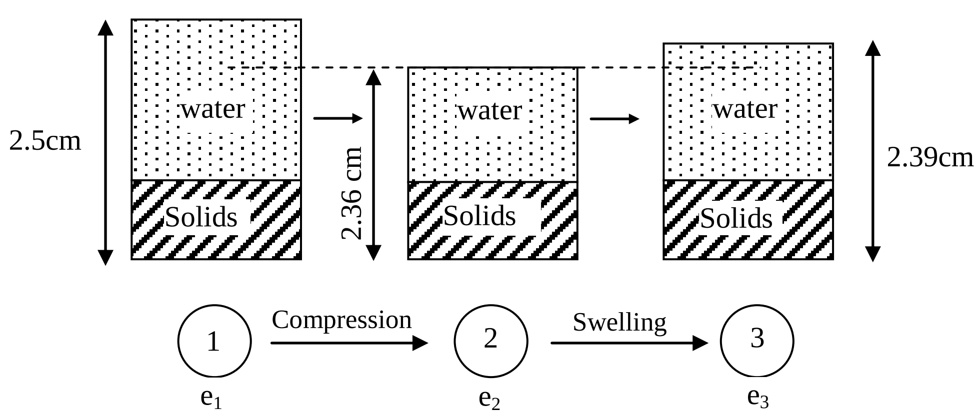
$F_a = 90\ kN/m$

(iii) Wall is pushed against the backfill (passive state)

$$\text{Passive thrust, } F_p = \frac{K_p\gamma H^2}{2} = \frac{3\times15\times6^2}{2} = 810\ kN/m$$

05(b).

Sol:



Void ratio,

$w_3 = 25\%$

$$e_3 = \frac{w_3 G_S}{S}$$

$= 0.25 \times 2.72$ [S = 100%]

$= 0.68$

From stage (2) to (3) volume is increased,

$$\frac{\Delta V}{V} = \frac{\Delta H}{H_f} = \frac{\Delta e}{1+e_f}$$

ΔH = Change in thickness

Δe = Change in void ratio

e_f = Final void ratio

$$\Rightarrow \frac{\Delta H}{H_3} = \frac{\Delta e}{1+e_3}$$

$$\Rightarrow \Delta e = \frac{(2.39-2.36)}{2.39} \times 1.68 = 0.021$$

$e_2 = e_3 - \Delta e = 0.659$

From stage (1) to (2)

$$\frac{\Delta H}{h_f} = \frac{\Delta e}{1+e_f}$$

$$\Rightarrow \frac{\Delta H}{2.36} = \frac{\Delta e}{1+0.659}$$

$$\Rightarrow \Delta e = \frac{(2.36-2.5)}{2.36} \times 1.659 = -0.0984$$

$e_1 = e_2 - \Delta e = 0.659 + 0.0984 = 0.7574$

b) Coefficient of compressibility = $a_v = \dfrac{\Delta e}{\Delta \overline{\sigma}} = \dfrac{0.0984}{200}\, m^2/kN$

$= 4.92 \times 10^{-4}\, m^2/kN$

Coefficient of volume compressibility $m_r = \dfrac{a_v}{1+e_0}$

where e_0 (Void ratio before compression)

$$m_r = \frac{4.92 \times 10^{-4}}{1+0.7574} = 2.8 \times 10^{-4}\ m^2/kN$$

05(c).

Sol: weight of soil + paraffin = 4.76×10^3 kN

weight of paraffin = 1.77×10^{-4} kN

weight of soil = $(4.76 - 1.77) \times 10^{-3}$ kN

$= 4.583 \times 10^{-3}$ kN

Volume of soil + paraffin = 3.2×10^{-4} m^3 [Volume of displaced water]

$$\text{Volume of paraffin} = \frac{\text{Weight of paraffin}}{G_{\text{Paraffin}}\gamma_w}$$

$$= \frac{1.77\times10^{-4}}{0.9\times9.81} = 0.2\times10^{-4}\,\text{m}^3$$

Volume of soil = $(3.2 - 0.2) \times 10^{-4}$ m^3 = 3×10^{-4}m^3

$$\text{Bulk unit weight} = \gamma_t = \frac{W_{soil}}{V_{soil}} = \frac{4.583\times10^{-3}}{3\times10^{-4}} = 15.28\,\text{kN/m}^3$$

$$\text{Dry unit weight} = \frac{\gamma_t}{1+w} = \frac{15.28}{1.1} = 13.89\,\text{kN/m}^3$$

$$\gamma_d = \frac{G\gamma_w}{1+e}$$

$$\text{Void ratio} \quad e = \frac{G\gamma_w}{\gamma_d} - 1 = \frac{2.7\times9.81}{13.89} - 1$$

$$= 0.907$$

$$\text{Porosity} = n = \frac{e}{1+e} = \frac{0.907}{1.907}$$

$= 0.476$

$= 47.6\%$

Degree of saturation (S)

$eS = wG$

$\Rightarrow 0.907 \times S = 0.1 \times 2.7$

$S = 0.298$

$= 29.8\%$

05(d). (i)

Sol: $N_1 = -\frac{1}{20}, \quad N_2 = \frac{1}{30}$

Deviation angle = $N_1 - N_2$ = $-\frac{1}{20} - \frac{1}{30} = -\frac{1}{12}$

Design speed = 80 kmph

Stopping sight distance = (0.278 Vt) + $\frac{V^2}{254(f + 0.01\,n)}$ $(V \text{ in kmph})$

Assuming t = 2.5 sec; f = 0.35 ; n = 0

$$\therefore SSD = (0.278 \times 80 \times 2.5) + \frac{80^2}{254 \times 0.35}$$

$$= 127.6 \text{ m}$$

(i) Length of valley curve from SSD criteria:

Assuming L > SSD

h = 0.75 m; α = 1

$$\therefore L = \frac{NS^2}{1.5 + 0.035\,S} \text{ m}$$

$$= \frac{1}{12} \times \frac{127.6^2}{[1.5 + 0.035 \times 127.6]} = 227.42 \text{ m} > SSD$$

Hence assumption is correct

(ii) Length of valley curve from comfort criteria

$$L = 2\sqrt{\frac{NV^3}{C}} \quad (V \text{ in } m/s)$$

$$= 2\sqrt{\frac{1}{12} \times \frac{(0.278 \times 80)^3}{0.6}} = 78.17 \text{ m}$$

$\therefore$ Length of valley curve, required is maximum of above = 227.42 m

05(d). (ii)

Sol: Design speed = 100 kmph

Capacity = $\frac{1000\,V}{S}$

(a) For basic capacity

$S = S_g + L$

$S_g = vt$ (v in m/sec)

$t = 0.7$ sec

$\therefore S_g = 0.278 \times 100 \times 0.7 = 19.46$ m

$L = 6$ m

$S = 19.46 + 6 = 25.46$ m

$$\therefore \text{ Basic capacity } = 1000 \times \frac{100}{25.46} = 3927.73 \text{ veh/hr}$$

(b) For practical capacity:

$S = SSD + L$

$$SSD = 0.278Vt + \frac{V^2}{254f}$$

For SSD $t = 2.5$ sec; $f = 0.35$

$$= 0.278 \times 100 \times 2.5 + \frac{100^2}{254 \times 0.35}$$

$= 181.98$ m

$S = 181.98 + 6 = 187.98 \sim 188$ m

$$\therefore \text{ Practical capacity } = 1000 \times \frac{100}{188} = 531.91 \text{ veh/hr}$$

05(e).

Sol: Origin and Destination Studies:

The origin and destination (O & D) study is carried out mainly to

(i) plan the road network and other facilities for vehicular traffic and

(ii) plan the schedule of different modes of transportation for the trip demand of commuters.

The O & D studies of vehicular traffic determines their number, their origin and designation in each zone under study. The data may also be supplemented by the number of passengers in each vehicle, purpose of each trip, intermediate stops made and reasons etc. Origin and destination study gives informations like the actual direction of travel, selection of routes and length of the trip. These studies are most essential in planning new highway facilities and in improving some of the existing systems.

As an example there can be a high percentage of through traffic which may be diverted by providing a by-pass and thus considerable saving in distance and time can be made. O & D study provides the basic data for determining the desired directions of flow or the desire lines. This is considered to be one of the important traffic studies needed to solve many traffic problems in a zone and the most important study to plan the highway system in a region.

Scientific planning of transportation system and mass transit facilities in cities should be based on O & D data of passenger trips. Also further traffic needs may be estimated by extrapolating the data from O & D study, together with socio-economic studies.

The various applications of O & D studies may be summed up as follows:
To judge the adequacy of existing routes and to use in planning new networks of roads.
(i) To plan transportation system and mass transit facilities in cities including routes and schedules of operation.
(ii) To locate expressway or major routes along the desire lines.
(iii) To establish preferential routes for various categories of vehicle including by-pass.
(iv) To locate terminals and to plan terminal facilities.
(v) To locate new bridges as per traffic demands.
(vi) To locate intermediate stops of public transport.
(vii) To establish design standards for the roads, bridges and culverts along he route.

There are a number of methods for collecting the O & D data. Some of the methods commonly adopted are:
Road-side interview method, License plate method.

Return post card method. Tag-on-car method and Home interview method.
The choice of the method is made judiciously depending on the objective and location.

Road side interview method:
The vehicles are stopped at previously decided interview stations, by a group of persons and the answers to prescribed questionnaire are collected on the spot. The information collected include the place and time of origin and destination, route locations of stoppages, the purpose of the trip, type of vehicle and numbers of passengers in each vehicle. The traffic may be filtered through a

prescribed lane by previous warning signs and with the help of police so that each driver of the selected sample of vehicles is interviewed. The percentage of sample interviewed out of the total traffic in each selected period should also be noted from appropriate traffic volume study taken simultaneously.

In this method the data is collected quickly in short duration and the field organization is simple and the team can be trained quickly. The main drawback of the method is that the vehicles are stopped for interview, and there is delay to the vehicular movement. Also resentment is likely from the road users. Further, unless there is enough space, undue congestion may result due to stopped vehicles.

License plate method:

The entire area under study is cordoned out and the observers are simultaneously stationed at all points of entry and exit on all the routes leading to and out of the area. Each party at the observation station is given synchronized time pieces and they note the license plate numbers (registration numbers) of the vehicles entering and leaving the cordoned area and the time. Separate recording sheets are maintained for each direction of movement for a specified time interval. After collecting the field data major work remains of the office computations and analysis, by tracking each vehicle number and its time of entering and leaving the cordoned area.

This method is quite easy and quick as far as the field work is concerned. The field organization can also be trained quickly. The method however involves a lot of office computations in tracing the trips through a network of stations. Unless there is a large network of stations to take observation along the route of the vehicle, it is not easy to get the information of the routes followed by the vehicles.

Hence a large number of teams are required to take simultaneous observations when a large area is to be surveyed. However, this method is quite advantageous when the area under consideration is small, like a large intersection or a small business centre.

Return post card Method:

Pre-paid business reply post cards with return address are distributed to the road users at some selected points along the route or the cards are mailed to the owners of vehicles. The questionnaire to be filled in by the road user is printed on the card, along with a request for co-operation and purpose of the study. The distributing stations for the cards may be selected where vehicles have to stop as in case of a toll booth.

The method is suitable where the traffic is heavy. The personnel need not be skilled or trained just for distributing the cards. Only a part of the road users may return the cards promptly after filling in the desired details properly and correctly. If conclusions are drawn in such cases, it is likely that these may not give a true picture.

Tag on car method:

In this method a pre-coded card is stuck on the vehicle as it enters the area under study. When the car leaves the cordon area the other observations are recorded on the tag. This method is useful where the traffic is heavy and moves continuously. But the method gives only information regarding the points of entry and exit and the time taken to traverse the area.

Home interview method:

A random sample of 0.5 to 10 percent of the population is selected and the residences are visited by the trained personal who collect the travel data from each member of the house hold. Detailed information regarding the trips made by the members is obtained on the spot. The data collected may be useful either for planning the road network and other roadway facilities for the vehicular traffic or for planning the mass transportation requirements of the passengers. The problem of stopping vehicle and consequent difficulties are avoided altogether. The present travel needs are clearly known and the analysis is also simple. Additional data including socio-economic and other details may be collected so as to be useful for forecasting traffic and transportation growth. But to have complete coverage of the entire cross section of the population is very tedious.

While planning for O and D studies at a place, it is necessary to decided the method of study. The selection of the method is dependent on the objective and the location. The influence of year and dates of study on the type and amount of traffic demand should be known. Care is needed in selecting the method of sampling and mode of data collection. The sample size should be decided keeping in view the desired accuracy and cost.

Work spot interview method:

The transportation needs of work trips can be planned by collecting the O & D data at work spots like the offices, factories, educational institutions, etc. by personal interviews.

06(a).

Sol: From plastic equilibrium equation

Total stress $\sigma_1 = \sigma_3 \tan^2 \alpha_f + 2C_u \tan \alpha_f$

Given $C_u = 0$

$\sigma_c = \sigma_3 = 150 \text{ kN/m}^2$

$\phi = 20^o$

$\sigma_1 = \sigma_3 \tan^2 \alpha_f$

$\sigma_1 = 150 \times \tan^2 (45 + \frac{20}{2})$

$\sigma_1 = 305.94 \text{ kN/m}^2$

(i) Deviatric stress at failure

$$\sigma_d = \sigma_1 - \sigma_3$$
$$= 305.94 - 150$$
$$= 155.94$$
$$\approx 156 \text{ kN/m}^2$$

(ii) Effective stress analysis

$$\sigma_1' = \sigma'_3 \tan^2 \alpha_f + 2C' \tan \alpha_f$$

$C' = 0$

$\phi' = 30^o$

$$(\sigma_1 - u) = (\sigma_3 - u) \tan^2\left(45 + \frac{30}{2}\right)$$

$$(305.94 - u) = (150 - u). \tan^2 60$$

$$305.94 - u = 450 - 3u$$

$$2u = 450 - 305.94$$

$$u = 72.03 \text{ kN/m}^2$$

(iii) & (iv)

$$\sigma'_1 = \sigma_1 - u$$
$$= 305.94 - 72.03 = 233.91 \text{ kN/m}^2$$

$$\sigma'_3 = \sigma_3 - u$$
$$= 150 - 72.03 = 77.97 \text{ kN/m}^2$$

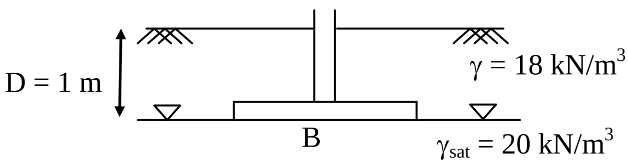
(v) As It is consolidated undrained test, pore pressure develops in shearing stage

$$\Delta u_d = u = A.\ B.\ \Delta \sigma_{df}$$
$$u = \bar{A}.\sigma_d$$
$$\bar{A} = \frac{u}{\sigma_d} = \frac{72.03}{156} = 0.462$$

06(b).

(i)

Sol:



Given: strip footing, $q_u = CN_c + \gamma DN_q + 0.5\gamma' BN_\gamma$

Design condition

$$q = q_s$$
$$q = \frac{q_{nu}}{F} + \gamma D$$
$$\frac{Q}{(B \times 1)} = \frac{\gamma D(N_q - 1) + 0.5\gamma' B N_\gamma}{F} + \gamma D$$
$$\frac{1000}{(B \times 1)} = \frac{18 \times 1(20.4) + 0.5 \times (20 - 9.8) \times B \times 22.4}{3}$$
$$\frac{3000}{B} = 367.2 + 114.13\ B$$
$$114.13\ B^2 + 367.2\ B - 3000 = 0$$

By solving $B = 3.76$ m

06(b). (ii)

Sol:

Compaction	**Consolidation**
1. Expulsion of pore air	1. Expulsion of pore water
2. Soil involved is partially saturated	2. Fully saturated soil
3. Applies to cohesive as well as cohesionless soil	3. Applies to cohesive soils only
4. Brought about by artificial agency (human)	4. By application of load (or) by natural agency (structural load)
5. Dynamic loading	5. Static loading
6. Improves Bearing capacity	6. Improves Bearing capacity & settlement characteristics
7. Relatively Quick process	7. Relatively slow process
8. Used primarily in embankment & earth dams	8. Primarily means of improving the properties of foundation soil

06(c). (i)

Sol: (a) Theoretical and actual density

Volume of specimen = $\frac{\pi}{4}D^2H$

$$= \frac{\pi}{4}\times 10^2 \times 5.5 = 431.97\ \text{cm}^3$$

Weight of compacted specimen in air = 1000 gm

$\therefore$ Actual density $= \frac{W}{V} = \frac{1000}{431.97} = 2.315\ \text{gm/cc}$

$\therefore G_{ac} = 2.315$

Theoretical density:

$$G_{th} = \frac{W_1 + W_2 + W_3 + W_4}{\frac{W_1}{G_1}+\frac{W_2}{G_2}+\frac{W_3}{G_3}+\frac{W_4}{G_4}} = \frac{100}{\frac{5}{1.05}+\frac{5}{2.7}+\frac{50}{2.65}+\frac{40}{2.55}}$$

$= 2.43$

$\therefore$ Theoretical density = 2.43 gm/cc

(b) % volume occupied by bitumen

$$= \frac{\text{Vol. of bitumen}}{\text{total volume}} \times 100$$

$$= \frac{\dfrac{W_{bit}}{G_{bit}}}{\dfrac{W}{G_{act}}} \times 100 = \left(\frac{W_{bit}}{W}\right)\frac{G_{act}}{G_{bit}} \times 100$$

$$= (W_{bit}\,\%)\frac{G_{act}}{G_{bit}}$$

$$V_b = 5 \times \frac{2.315}{1.05} = 11.02\%$$

Similarly

% volume occupied by filler = $(W_{fill}\,\%) \times \dfrac{G_{act}}{G_{fill}}$

$$V_{fill} = 5 \times \frac{2.315}{2.7}$$

$$= 4.287\%$$

% Volume occupied by fine aggregate = $50 \times \dfrac{2.315}{2.65}$

$$= 43.68\%$$

% volume occupied by coarse aggregate = $40 \times \dfrac{2.315}{2.55}$

$$= 36.31\%$$

(c) Percentage of air voids

V_V = 100 – (% volume of bitumen, filler, CA, FA)

V_V = 100 – (11.02 + 4.287 + 43.68 + 36.31)

= 4.7%

(d) Voids is mineral aggregate

= $V_v\% + V_b\%$

= 4.7% + 11.02%

= 15.72%

(e) Voids filled with bitumen

$$= \frac{V_b}{VMA} \times 100 = \frac{11.02}{15.72} \times 100$$

$$= 70.1\%$$

06(c). (ii)

Sol: Tunnelling in rock:

Full face method: This method is conveniently adopted for tunnels of small cross sections through stable and self supporting rocks. The full face is opened out once for all the driven. As the full section has to be tackled, extra units of tunnelling equipment will become necessary. This method has become popular because of Tunnel Boring Machines (TBM).

Advantages:

- The amount of equipment required is minimum and it leads to simplicity in operation.
- It minimizes the total magnitude of ground disturbance and settlement.
- The work is easily and speedily completed.
- It provides a definite advantage in sensitive ground conditions where multiple phase excavation could generate unacceptable ground pressure and settlement effects
- The mucking trucks could be laid once for all on the tunnel floor and progressively extended.
- This method is suitable for face diameters less than 6m and face areas less than 19 m^2.

Mucking: mucking is the removal of the blasted debris or spoil from the tunnel interior to sites outside the tunnel entrance. In all big tunnels this is a major item of expenditure and efficient and quick removal of muck minimizes the costs.

This can be done by labour. In modern tunneling practice, various types of machines like the **Conway** loader and **Elmco** are employed to quicken the work and save labor.

In normal sized tunnels light railway equipment is employed for muck disposal.

Drainage of Tunnels:

In tunnel water comes from the following two sources:

(i) Wash water, which is used for washing drill holes and the cuttings inside the tunnel, at the time of construction.

(ii) Ground or sub – soil water, from the ground through which the tunnel is driven.

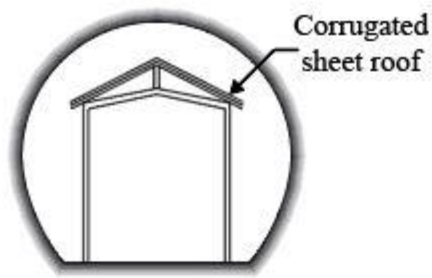


Fig: Corrugated sheet to drain roof seepage

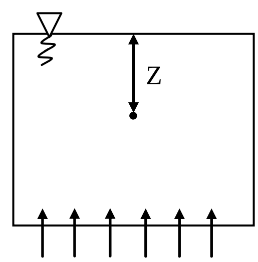
07(a).

Sol: **(i)** For upward seepage condition effective stress in soil mass or net effective stress

$\bar{\sigma}$ = Effective stress – seepage pressure

$= \gamma_{sub} Z - p_s$

When seepage pressure equals submerged unit weight of soil, net effective stress reduces to zero. Under such condition, cohesionless soil lose all shear strength and start flowing or lifted in upward direction. This is known as quick sand or boiling condition as surface of sand looks like boiling.



$\bar{\sigma}$ (Net effective stress) $= \gamma_{sub}\, z - p_s = 0$

$\Rightarrow \gamma_{sub}\, Z = p_s = i\, Z\, \gamma_w$

$\Rightarrow i = \dfrac{\gamma_{sub}}{\gamma_w} = \left(\dfrac{G-1}{1+e}\right)$

This 'i' is known as critical hydraulic gradient (i_C)

For safety against boiling ($i < i_C$) in sands.

$$\text{Factor of safety, } FOS = \frac{i_C}{i}$$

(ii) Upward seepage pressure $= h\,\gamma_w = 10 \times 10 = 100$ kN/m^2 (upward)

Weight of soil = Total stress below excavation $= 5 \times \gamma = 5 \times 20 = 100$ kN/m^2 (Downward)

$$\text{FOS (boiling)} = \frac{\text{Downward Pressure}}{\text{Upward Pressure}}$$

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

(iii) Water level h = 7m

Upward pressure = 7 × 10 = 70 kN/m^2

Let excavation depth = d

Downward pressure = (15 – d) γ = (15 – d)20

$$FOS = \frac{\text{Downward Pressure}}{\text{Upward Pressure}} = 1.7$$

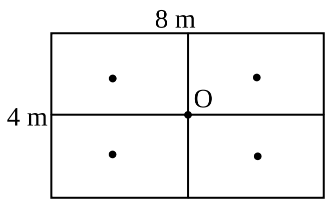
$$\Rightarrow \frac{(15-d)20}{70} = 1.7$$

$\Rightarrow$ d = 9.05 m

07(b).

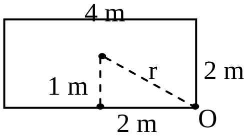
(i)

Sol:



4 m × 8 m area carries a distributed load of 300 kN/m^2

For equivalent point load method, the total load is converted into 4 equivalent point loads as given in diagram



Radial distance of each load from centre O

$r = \sqrt{2^2 + 1^2}$ = 2.24 m

Each point load, Q = 300 × (4 × 2)

= 2400 kN

Using Boussinesq equation, stress at 3 m depth from O due to point load Q

$$\sigma_z = \frac{3Q}{2\pi z^2}\left[\frac{1}{1+\left(\frac{r}{z}\right)^2}\right]^{5/2} = \frac{3\times 2400}{2\times\pi\times 3^2}\left[\frac{1}{1+\left(\frac{2.24}{3}\right)^2}\right]^{5/2}$$

= 42.06 kN/m^2

Total stress due to 4 point loads = 4× 42.06 = 168.23 kN/m^2

07(b). (ii)

Sol: Active force, $F_a = \frac{1}{2} k_a \gamma H^2$

From coulomb's theory

$$k_a = \frac{\sin^2(\beta+\phi)}{\sin^2\beta.\sin(\beta-\delta)\left[1+\sqrt{\frac{\sin(\phi+\delta).\sin(\phi-i)}{\sin(\beta-\delta).\sin(\beta+i)}}\right]^2}$$

$$k_a = \frac{\sin^2(80+30^o)}{\sin^2 80.\sin(80-20)\left[1+\sqrt{\frac{\sin(30+20).\sin(30-15)}{\sin(80-20).\sin(80+15)}}\right]}$$

$$k_a = \frac{0.883}{1.839} = 0.48$$

$$F_a = \frac{1}{2} \times 0.48 \times 19 \times 4^2 = 72.96 \approx 73 \text{ kN/m}$$

Passive fore, $F_p = \frac{1}{2} k_p \gamma H^2$

$$k_p = \frac{\sin^2(\beta-\phi)}{\sin^2\beta\sin(\beta+\delta).\left[1-\sqrt{\frac{\sin(\phi+\delta).\sin(\phi+i)}{\sin(\beta+\delta).\sin(\beta+i)}}\right]^2}$$

$$k_p = \frac{\sin^2(80-30^o)}{\sin^2 80.\sin(80+20)\left[1-\sqrt{\frac{\sin(30+20).\sin(30+15)}{\sin(80+20).\sin(80+15)}}\right]^2}$$

$$k_p = \frac{0.586}{0.97 \times 0.984 \times 0.066} = 9.299 = 9.3$$

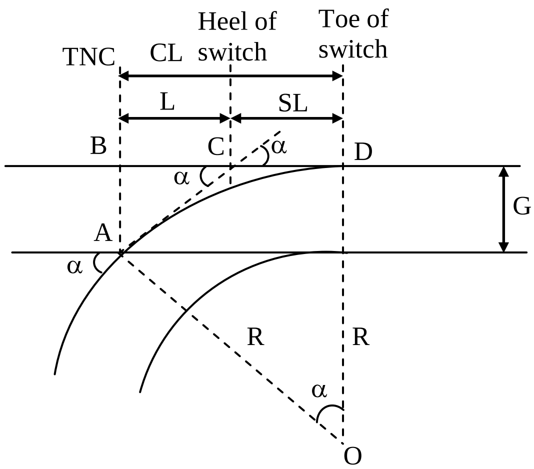
$$F_p = \frac{1}{2} \times 9.3 \times 19 \times 4^2$$

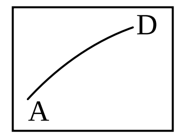
= 1413.5 kN/m

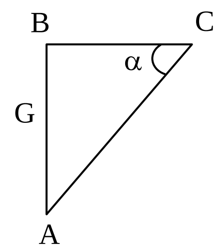
07(c). (i)

Sol: **Turnout:** It is a combination of point and crossing to enable one track to take off another track.

Given crossing curve is starting from toe of switch and ends at TNC.







Let AD be the curve of radius ‘R’ with centre at ‘o’

Tangents at ‘A’ and ‘D’ meet at ‘C’

$$\therefore AC = CD; \quad AO = OD$$

Curve lead $CL = BC + CD$

$$= BC + AC$$

From Δ^{le} ABC:-

$$\tan\alpha = \frac{G}{BC}; \quad \sin\alpha = \frac{G}{AC}$$

Also, Crossing number $N = \frac{1}{\tan\alpha}$

$$\Rightarrow \tan\alpha = \frac{1}{N}; \quad \sin\alpha = \frac{1}{\sqrt{1+N^2}}$$

$$\therefore BC = \frac{G}{\tan\alpha} = G\cot\alpha = GN$$

$$AC = \frac{G}{\sin\alpha} = G\,\mathrm{cosec}\,\alpha = G\sqrt{1+N^2}$$

$$CL = BC + AC$$

$$= G(\cot\alpha + \mathrm{cosec}\,\alpha)$$

$$= G(N + \sqrt{1+N^2})$$

$N >> 1$

$G (N + N)$

$\therefore$ CL = 2 GN

Problem:

Given N = 16

Heel divergence = 11.5 cm

(i) Curve lead = 2 GN = 2 × 1.676 × 16 = 53.632 m

(ii) Switch lead = $\sqrt{2R_o d}$

As per Railway board $R_o = 2\ GN^2 + 1.5\ G$

$= (2 \times 1.676 \times 16^2) + (1.5 \times 1.676)$

$= 860.626$ m

$$\therefore \text{SL} = \sqrt{2 \times 860.626 \times \frac{11.5}{100}} = 14.07 \text{ m}$$

(iii) $\therefore$ L = CL – SL = 53.632 – 14.07

= 39.56 m

(iv) Mean radius $R = R_o - \frac{G}{2}$

$$= 860.626 - \frac{1.676}{2}$$

= 859.79 m

07(c). (ii)

Sol: Requirements of a good port:

(i) It should be centrally situated for the hinterland. For a port, the hinterland is that part of the country behind which it can be served with economy and efficiency by the port

(ii) It should get good tonnage i.e., charge per kN of cargo handled by it.

(iii) It should have good communication with the rest of the country through rail and highways so that the commodities can be transported to and from the port easily and quickly.

(iv) The hinterland should be fertile with a good density of population.

(v) It should be advanced in culture, trade and industry.

(vi) It should be a place of defence and for resisting the sea – borne invasion

(vii) It should command valuable and extensive trade.

(viii) It should be capable of easy, smooth and economic development

(ix) It should afford shelter to all ships and at all seasons of the year

(x) It should provide the maximum facilities to all the visiting ships including the servicing of Ships

(xi) The passage to open sea must have sufficient depth and width and it should be suitably marked to aid navigation.

(xii) The land surfaces of the coastline should be fully hard so that frequent repairs are not required. If the coast is sandy, intermittent repairs to docks and port buildings will have to be carried out frequently making their maintenance very expensive.

08(a). (i)

Sol: Degree of consolidation = 40% = U

Time of consolidation = t = 8 months = 0.67 year

Increment in stress = $\Delta\overline{\sigma}$ = 60 kN/m^2

Thickness of clay layer = 5 m = H

Drainage path, $d = \frac{H}{2} = 2.5\text{ m}$ (double drainage)

Time factor $= T_v = \frac{C_v t}{d^2}$

$$\Rightarrow C_v = \frac{T_v d^2}{t}$$

$$T_v = \frac{\pi}{4}\left(\frac{U}{100}\right)^2$$

$$= \frac{\pi}{4}\times\left(\frac{40}{100}\right)^2 = 0.126$$

$$\Rightarrow C_v = \frac{0.126\times 2.5^2}{0.67}$$

$$= 1.175\text{ m}^2\text{/year}$$

$$C_v = \frac{K}{\gamma_w m_v} \Rightarrow m_v = \frac{K}{\gamma_w C_v}$$

$$= \frac{0.02}{9.81\times 1.175} = 1.74\times 10^{-3}\text{ m}^2\text{/kN}$$

$$m_v = \frac{\Delta e}{\Delta \bar{\sigma}(1+e_o)}$$

$$\Rightarrow 1.74\times10^{-3} = \frac{\Delta e}{60(1+0.6)}$$

$\Rightarrow \Delta e = 0.167$

$\Rightarrow e_o - e_f = 0.167$

$e_f = 0.6 - 0.167$

$= 0.433$

or

$$\Delta H = m_v \Delta\bar{\sigma} H$$

$$= 1.74\times10^{-3}\times60\times5$$

$= 0.522$ m

$$\frac{\Delta e}{1+e_o} = \frac{\Delta H}{H}$$

$$\Rightarrow \Delta e = \frac{0.522}{5}\times(1+0.6)$$

$= 0.167$

$e_o - e_f = 0.167$

$e_f = 0.6 - 0.167 = 0.433$

08(a). (ii)

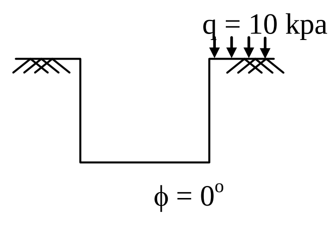
Sol: Soft clay $= \phi = 0^o$

Critical height, $H_c = 2\,Z_c$

$$H_c = 2\left(\frac{2c}{\gamma\sqrt{k_a}} - \frac{q}{\gamma}\right)$$

$$5 = 2\left(\frac{2\times c}{20\times1} - \frac{10}{20}\right)$$

c = 30 kPa

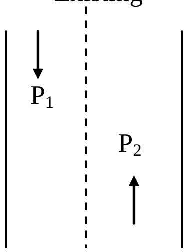


08(b).

Sol:

Initial Traffic

Existing



$P_1 + P_2 = 8000$

$P_1 = P_2 = \dfrac{8000}{2}$

$= 4000$

$x = 2.5$ yr

$r = 6\%$

$A = P(1 + r)^x$

$= 2400\,(1.06)^{2.5}$

$= 2776.36$

$L = 0.75$

$n = 15$

Calculation of V

$P_1 + P_2 = 0.6 \times 8000 = 4800$

(60% diverted)

$P_1 = P_2 = 2400$

[Traffic is considered in one direction]

(dual carriageway)

Standard Axle load $W_s = 8.2$ t

W(Axle load) (tonnes)	**Frequency (N)**	$\text{EALF} = \left(\dfrac{W}{W_s}\right)^4$	**N(EALF)**
18	10	23.2	232
14	20	8.5	170
10	35	2.2	77
8	15	0.91	13.65
6	20	0.29	5.8
	$\Sigma N = 100$		$\Sigma N(\text{EALF}) = 4985$

$$V = \frac{\Sigma N(EALF)}{\Sigma N} = \frac{4985}{100} = 4.985$$

Design traffic

$$= 365A\left[\frac{(1+r)^n - 1}{r}\right] \times V \times L$$

$$= 365 \times 2776.36\left[\frac{(1.06)^{15} - 1}{0.06}\right] \times \frac{4.985 \times 0.75}{10^6}$$

$$= 88.2 \text{ msa}$$

$$\simeq 88 \text{ msa}$$

08(c). (i)

Sol: Prime coat:

- It is an application of low viscosity bituminous material to an existing porous surface (untreated granular base) on which an bituminous layer will be placed.
- It acts as an initial sealer by blocking other layers from moisture , debris etc.
- It also acts as binder between secondary and tertiary layers.
- It penetrates into the underlying layer, plugs the voids, and forms a watertight surface.

Tack coat:

- It is an light application of bituminous material (emulsion) diluted with water over a relatively impervious material.
- It ensure the bond between the surface being paved and the overlying course
- It prevents slippage and protects from moisture.
- It does not require the penetration of asphalt into the underlying layer.

Seal coat:

- It is a thin asphalt surface treatment used to waterproof the existing surface.
- It seals the surface against ingress of water
- It develops skid resistance where the aggregates in the surface course could be polished by traffic and become slippery
- It is used to exalt an existing dry or worn out bituminous pavement.

08(c). (ii)

Sol: A pavement should have adequate stability to withstand design traffic under prevailing conditions. Due to economic developments, wheel loads increase and strengthening of pavement is required if there is no alternate route available. Also, if the pavement may get distresses due to the prevailing conditions which provides the need for strengthening.

Strengthening of the pavement can be done by providing additional adequate thickness of the pavement in one or more layers over an existing pavement. This is called overlay.

Overlay can be various combinations. The possible combinations are

- Flexible overlay over flexible pavement
- Flexible overlay over rigid pavement
- Rigid overlay over rigid pavement
- Rigid overlay over flexible pavement

If the existing pavement is completely deteriorated both structurally, functionally, then overlay would not serve the purpose and the existing pavement has to be removed and reconstructed.

In partially deteriorated pavement sections patch repairs are carried out before constructing overlay.

08(c). (iii)

Sol: Given:

No. of wagons = 20

Axle load = W_d = 26 tn

Ruling gradient = 1 in 200

Curvature = 2

Speed = 50 kmph

Weight of locomotive = 100 tn

Friction coefficient = 1/6

2-8-2 locomotive means ‘8’ driving wheels i.e. 4 driving axles

Step 1: $\therefore$ Hauling capacity = μ n W_d $= \frac{1}{6} \times 4 \times 26 = 17.33$ tn

Step 2:

Total resistance = resistance due to friction + speed + wind + gradient + curve

For BG track:-

$$RT = 0.0016\ W + 0.00008\ W\ V + 0.0000006\ WV^2 + \frac{W}{n} + \frac{0.04}{100} \times WD$$

$$RT = 0.0016\ W + (0.00008 \times W \times 50) + (0.0000006\ W \times 50^2) + \frac{W}{200} + \left(\frac{0.04}{100} \times W \times 2\right)$$

$$RT = 0.0489\ W$$

Step 3: Hauling capacity = Total resistance

$\Rightarrow 0.0489\ W = 17.33$

$\Rightarrow W = 1343.41$ tn

$\therefore$ Maximum permissible weight = 1343.41 tn

Assume maximum permissible weight on each wagon = W_w

$\Rightarrow 20\ W_w + W_{locomotive} = 1343.41$

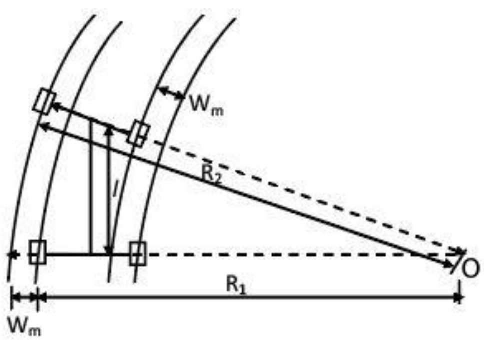
$\Rightarrow 20\ W_w + 100 = 1343.41$

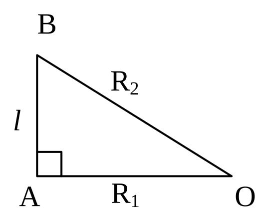
$\Rightarrow W_w = 62.17$ tn

08.(c) (iv)

Sol: **Mechanical widening:** It is provided due to rigidity of wheel base.

Consider a vehicle of wheel base 'l' m traversing a horizontal curve of radius 'R_1' m





R_1 = radius of path traversed by outer rear wheel

R_2 = radius of path traversed by outer front = $R_1 + W_m$

W_m = mechanical widening

From Δ^{le} OAB:

$$OA^2 + AB^2 = OB^2$$

$$\Rightarrow R_1^2 + \ell^2 = R_2^2$$

$$\Rightarrow (R_2 - W_m)^2 + \ell^2 = R_2^2$$

$$\Rightarrow \ell^2 + W_m^2 = 2R_2W_m$$

Neglecting higher order terms

$$2\ R_2\ W_m = l^2$$

$$\Rightarrow W_m = \frac{\ell^2}{2R}$$

R : mean radius of curve

For single lane road (or) single vehicle, extra widening is required for each lane road; $W_m = \frac{\ell^2}{2R}$

For 'n' lane road, $W_m = \frac{n\ell^2}{2R}$