ACE
Engineering Academy
(Leading institute for ESE/GATE/PSUs)

ESE – 2019 MAINS
OFFLINE TEST SERIES

CIVIL ENGINEERING

TEST – 10
SOLUTIONS

All Queries related to **ESE – 2019 MAINS Test Series** Solutions are to be sent to the following email address
testseries@aceenggacademy.com | Contact Us : 040 – 48539866 / 040 – 40136222

01(a).

Sol: Ultimate settlement = ΔH = 374 mm

At t_1= 3 years Δh_1 = 182 mm

Degree of consolidation

$$U_1 = \frac{\Delta h_1}{\Delta H} = \frac{182}{374} = 0.486 \text{ or } 48.6\%$$

For $\Delta h_2 = 262$ mm

$$U_2 = \frac{\Delta h_2}{\Delta H} = \frac{262}{374} = 0.7005 = 70.05\%$$

Since $U_1 < 60\%$

$$T_{v_1} = \frac{\pi}{4}\left(\frac{U_1}{100}\right)^2 = 0.186$$

Since $U_2 > 60\%$

$$T_{v_2} = 1.781 - 0.933 \log_{10}(100 - U_2)$$

$$= 1.781 - 0.933 \log_{10}(100 - 70.05)$$

$$= 0.403$$

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

Since we are estimating time for same layer of soil C_v and d will be same

$$\frac{T_{v_1}}{T_{v_2}} = \frac{t_1}{t_2}$$

$$\Rightarrow t_2 = \frac{T_{v_2}}{T_{v_2}} \times t_1$$

$$= 3 \times \frac{0.403}{0.186} = 6.5 \text{ years}$$

Additional time required = 6.5 – 3 = 3.5 years

01(b).

Sol: Population = 250

Percapita sewage flow = 200 *l*pcd

D_t = 24 hrs

= 1 Day

D_{s1} = 2 years

Septic tank is divide into 2 zones (A) Setting zone, (B) Sludge zone

(A) Design of settling zone:

1. Q = Population × Percapita sewage Flow

= 250 × 200

= 50000 L/Day

= 50 m^3/Day

2. D_t = 1 Day

3. Volume = Q × D_t = 50 × 1 = 50 m^3

4. Assume depth of settling zone as 1 m

$\therefore$ H = 1 m

5. Surface area 'A' = $\frac{V}{H} = \frac{50}{1} = 50\ m^2$

6. $\frac{L}{B} = \frac{Z}{1}$ $\therefore$ $B = \sqrt{\frac{5A}{2}}$

$= \sqrt{\frac{50}{2}} = 5m$

So, L = 2B

= 2 × 5

= 10 m

B. Design of sludge zone:

1. Q_{sludge} = Population × Sludge Accumulation rate

Assume, sludge accumulation rate as 30 L/person/year

$\therefore$ Q_{sludge} = 250 × 30

= 7500 L/year = 7.5 m^3/year

2. Desludging period = 2 years

3. Volume of sludge = $Q_{s1} \times D_{s1}$

$= 7.5 \times 2$

$= 15 \text{ m}^3$

4. Depth of sludge zone = $\frac{V_s 1}{SA}$

$= \frac{15}{50}$

$= 0.3 \text{ m}$

5. Total Depth = 1 + 0.3

$= 1.3 \text{ m}$

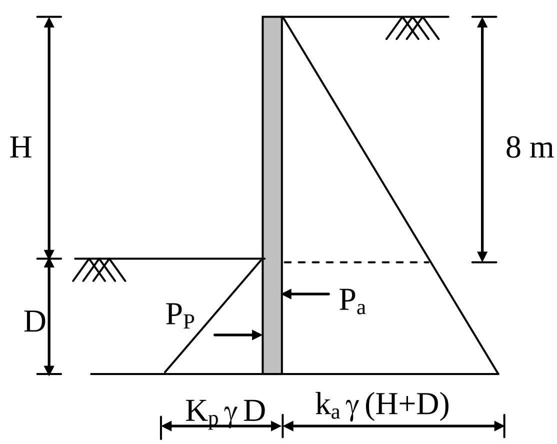
Dimensions of septic tank → 10 m length

5 m width

1.3 m depth

01(c).

Sol:



Given $\gamma = 19 \text{ kN/m}^3$, $\phi = 30^o$, C = 0, FOS = 2

For $\phi = 30^o$ $K_a = \frac{1}{3}$ and $K_p = 3$

Coefficient of passive pressure with respect to FOS

$$K_p' = \frac{3}{2} = 1.5$$

$$P_a = \frac{1}{2}K_a\gamma(H+D)^2 = \frac{1}{2}\times\frac{1}{3}\times 19\times(8+D)^2$$

$P_a = 3.17\ (8+D)^2$

$$\therefore P_p = \frac{1}{2}K'_p\gamma D^2 = \frac{1}{2}\times 1.5\times 19\times D^2$$

$P_p = 14.25\ D^2$

For no overturning

$M_R = M_O$ (Taking moments about bottom end)

$$P_P \times \frac{D}{3} = P_a \times \left(\frac{H+D}{3}\right)$$

$$14.25\times\frac{D^3}{3} = 3.17\times(8+D)^2\times\left(\frac{8+D}{3}\right)$$

$4.75\ D^3 = 1.057\ (8 + D)^3$

$4.75\ D^3 = 1.057\ [512 + D^3 + 192D + 24D^2]$

$4.493\ D^3 = 512 + D^3 + 192\ D + 24\ D^2$

$3.493\ D^3 - 24D^2 - 1920 - 512 = 0$

On solving D = 12.30 m

01(d).

Sol: Parameters:

Thickness, h = 20 cm

Wheel load, P = 5100 kg

Radius of relative stiffness, $\ell = \left[\frac{Eh^3}{12K(1-\mu^2)}\right]^{1/4}$

$$= \left[\frac{3\times10^5\times 20^3}{12\times6\times(1-0.15^2)}\right]^{1/4}$$

= 76.417 cm

Equivalent radius of resisting section (b) = $\sqrt{1.6^2 + h^2} - 0.675h$ if a < 1.724

= a a > 1.724 h

a = 15 cm; 1.724h = 34.48 cm i.e a < 1.724h

$$\therefore b = \sqrt{1.6\times15^2 + 20^2} - 0.675(20) = 14.07 \text{ cm}$$

Step 1: stress due to wheel load at edge region:

From Westergaard's equation

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

$$= \frac{0.572\times5100}{20^2}\left[4\log_{10}\left(\frac{76.417}{14.07}\right) + 0.359\right]$$

$$= 24.056 \text{ kg/cm}^2$$

Step 2: Warping Stress:

$$\sigma_{warp} = \frac{E\alpha t}{2}.C_x \text{ (or) } \frac{E\alpha t}{2}.C_y \qquad \text{(Whichever is higher)}$$

$C_x = 1.05$, $C_y = 0.55$

$t = 0.6 \times 20 = 12^oC$

$$\therefore \text{Maximum warping stress} = \frac{3\times10^5\times10\times10^{-6}\times12}{2} = 18 \text{ kg/cm}^2$$

Step 3: Frictional Stress:

$$\sigma_f = \frac{WLf}{2} = \frac{2400\times10^{-6}\times4.5\times10^2\times1.5}{2}$$

$$= 0.81 \text{ kg/cm}^2$$

Step 4: Critical Combination:

For edge region, critical combination occurs on winter mid-day

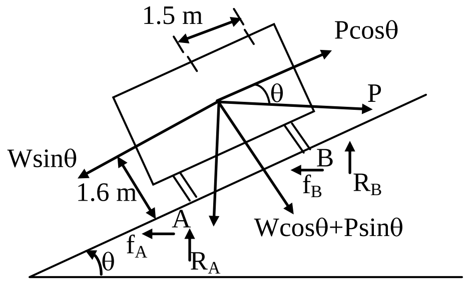
$$= \sigma_e + \sigma_{warp} + \sigma_f$$

$$= 24.056 + 18 + 0.81$$

$$= 42.866 \text{ kg/cm}^2$$

01(e).

Sol:



Given: e = tanθ = 0.05, f = 0.15

Impact factor $= \dfrac{f}{W} = \dfrac{mV^2}{R \times mg} = \dfrac{V^2}{gR}$

The vehicle is subjected to self weight (W), centrifugal force (P) and frictional force, (f_A, f_B)

Step 1: To avoid skidding:

For no skid: Component of centrifugal force along the plane should be less than or equal to combined effects of gravity and frictional force along the plane.

$P\cos\theta \le W\sin\theta + F_A + F_B$

$F_A = fR_A$; $F_B = f\,R_B$

$\therefore\ F_A + F_B = f(R_A + R_B) = f(W\cos\theta + P\sin\theta)$

$P\cos \le W\sin\theta + f(W\cos\theta + P\sin\theta)$

$\Rightarrow P(\cos\theta - f\sin\theta) \le W(\sin\theta + f\cos\theta)$

$$\Rightarrow \frac{P}{W} \le \frac{\sin\theta + f\cos\theta}{\cos\theta - f\sin\theta}$$

Dividing by cosθ

$$\Rightarrow \frac{P}{W} \le \frac{\tan\theta + f}{1 - f\tan\theta}$$

$$\le \frac{0.05 + 0.15}{1 - 0.15 \times 0.05}$$

≤ 0.201 ………….(1)

Step 2: To avoid Overturning:

In order to avoid overturning, net resultant moment about B > 0

$\Rightarrow$ (P sinθ + Wcosθ) × 1.5 + W sinθ (1.6) – P cosθ (1.6) ≥ 0

$\Rightarrow$ P (1.5sinθ – 1.6cosθ) + W (1.5 cosθ + 1.6 sinθ) ≥ 0

$\Rightarrow$ W(1.5cosθ + 1.6 sinθ) ≥ P (1.6cosθ – 1.5 sinθ)

$$\Rightarrow \frac{P}{W} \le \frac{1.5\cos\theta + 1.6\sin\theta}{1.6\cos\theta - 1.5\sin\theta}$$

Dividing by cosθ

$$\Rightarrow \frac{P}{W} \le \frac{1.5 + 1.6\tan\theta}{1.6 - 1.5\tan\theta}$$

$$\le \frac{1.5 + 1.6\times 0.05}{1.6 - 1.5\times 0.05}$$

≤ 1.036 ……………..(2)

From (1) and (2), impact factor ≤ 0.201 to avoid both skidding and over turning

02(a). (i)

Sol: Depth of tank = 3.5 m (given)

Out of this depth, 0.5 m can be assumed as free board

Thus, effective depth of tank or water depth is given by

H = 3.5 – 0.5 = 3 m

Length of tank, L = 65 m

Flow velocity, V = 1.22 cm/s

Specific gravity of particles = 2.65

Temperature, T = 25^{o}C

Kinematic viscosity, ν = 0.01 cm^2/s

Let the particle size be 'd' and the settling velocity be V_s

We know that for a particle to be removed in the settling tank it must satisfy the relation,

$$\frac{V}{V_s} = \frac{L}{H}$$

$$\Rightarrow V_s = \frac{VH}{L} = 1.22\times\frac{3}{65} = 0.0563 \text{ cm/s}$$

But settling velocity V_s as per Stoke's equation is given as

$$V_s = \frac{g}{18}(S_s - 1)\frac{d^2}{\nu} \quad \text{for } d < 0.1 \text{ mm}$$

and $V_s = 418(S_s - 1)d^2\left(\frac{3T+70}{100}\right)$........ for $d < 0.1$ mm

$$\therefore V_s = \frac{981}{18}(2.65-1)\frac{d^2}{0.01}$$

$\Rightarrow 0.0563 \times 18 \times 0.01 = 1.65 \times 981 \times d^2$

$\Rightarrow$ d = 0.002502 cm

$\Rightarrow$ d = 0.025 mm (< 0.1 mm) Hence OK

also, $V_s = 418(2.65-1)\times d^2 \times \left(\frac{3\times 25+70}{100}\right)V$

$$\Rightarrow 0.0563 \times 10 = 418 \times 1.65 \times d^2 \times \frac{145}{100}$$

$\Rightarrow$ d = 0.024 mm (< 0.1 mm) Hence OK

Thus, the particles of size 0.024 mm and above shall be effectively removed.

Checked against the scour of deposited particles:

Scour velocity, $V_d = \sqrt{\frac{8\beta \times g(S_s - 1)d}{f'}}$

Where, β = 0.04 for unigranular sand and f' = 0.03 for settling tanks

$$\therefore V_d = \sqrt{\frac{8\times 0.04}{0.03}\times 9.81 \times (2.65-1)\times 0.0024}$$

= 6.44 cm/sec > 1.22 cm/sec (Hence OK)

02(a). (ii)

Sol: Air flow rate Q = 7 m^3/s

Diameter of cyclone D = 2 m

N_e = 5 turn

Based on lapple equation the diameter of particle that is collected with 50% efficiency is

$$d_s = \left[\frac{9\mu b}{2\pi NeV_i\rho_P}\right]^{V_2}$$

For cyclone of standard properties:

$$b = \frac{D}{4} = \frac{2}{4} = 0.5\,m$$

$$h = \frac{D}{2} = \frac{2}{2} = 1m$$

$\therefore$ Area of inlet = 0.5 × 1 = 0.5 m^2

V_i = Inlet Gas velocity = $\frac{Q}{A} = \frac{7}{0.5} = 14$ m/s

$$\therefore\ d_{50} = \left[\frac{9\times 2.1\times 10^{-5}\times 0.5}{2\pi\times 5\times 14\times 1500}\right]$$

$= 1.2 \times 10^{-5}$ μm

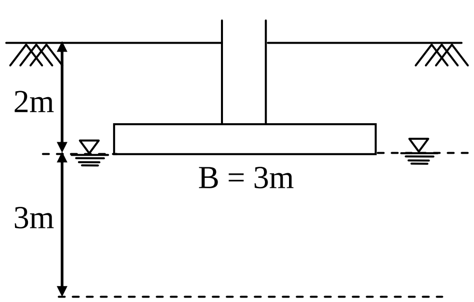
= 12 μ ms

Standard dimensions of cyclonic separator:

1. Length of cylinder L_1 = 2D = 2 × 2 = 4 m
2. Length of cone L_2 = 20 = 2 × 2 = 4 m
3. Length of exit duct $L_3 = \frac{D}{8} = \frac{2}{8} = 0.25\,m$
4. Diameter of exit $D_e = \frac{D}{2} = \frac{2}{2}$ = 1 m
5. Inlet width $b = \frac{D}{4} = \frac{2}{4}$ = 0.5 m
6. Inlet height $h = \frac{D}{2} = \frac{2}{2} = 1m$
7. Diameter of Dust exit $D_d = \frac{D}{4} = \frac{3}{4}$ = 0.5 m

02(b).

Sol:



B =3 m

D = 2 m

$\gamma = 20\ kN/m^3$

$c' = 50$ kPa

$\phi' = 0^o$

(i) $q_u = C'N_c + \gamma' DN_q + 0.5\,\gamma' BN_\gamma$

$q_{nu} = C'N_c$

$= 50 \times 5.7$

$q_{nu} = 285 \text{kPa}$

$$q_{ns} = \frac{q_{nu}}{F} = \frac{255}{2.5} = 114 \text{ kPa}$$

$$q_s = \frac{q_{nu}}{F} + \gamma' D$$

$$q_s = \frac{285}{2.5} + (20 - 9.81) \times 2$$

$\therefore q_s = 134.38$ kPa

$$S_i = \frac{q_n}{E} \times B \times (1 - \mu^2)\, I$$ For design $q_n \le q_{ns}$

$$S_i = \frac{114}{8.5 \times 10^3} \times 3 \times (1 - 0.45^2)\, 0.7$$

$\therefore S_i = 0.02246$ m

$= 22.46$ mm

$= 2.25$ cm

(ii) When water lowered to Base of foundation

$q_{nu} = C'N_c$

$$q_s = \frac{C'N_c}{F} + \gamma D$$ (Assume $\gamma = \gamma_{sat}$)

$$= \frac{50 \times 57}{2.5} + 20 \times 2$$

$= 154$ kPa

$$\% \text{ change} = \frac{154 - 134.38}{134.38} \times 100$$

$= 14.6$ % (increase)

02(c)

Sol:

(i) Bulk density of compacted mix (without paraffin coating):

$$G_{bulk-comp} = \frac{1195.4}{1195.4 - 684.4} = 2.339$$

$\therefore$ Unit weight of compacted bituminous mix= 2.339 ×1 g/cc = 2.339 g/cc

(ii) Bulk density of compacted mix specimen coated with paraffin:

The bulk density of paraffin or wax coated specimen $= \dfrac{W_{spec}}{W_{wax-air} - W_{wax-water} - \left(\dfrac{W_{wax}}{G_{wax}}\right)}$

$$= \frac{1195.4}{1240.9 - 678.3 - \left(\dfrac{45.5}{0.91}\right)} = 2.33$$

($\because W_{wax}$ = 1240.9 – 1195.4 = 45.5 g)

(iii) Combined specific gravity of aggregates:

bulk specific gravity of combined aggregates

$$(G_{bulk\text{-}agg}) = \frac{p_1 + p_2 + p_3}{\dfrac{p_1}{G_1} + \dfrac{p_2}{G_2} + \dfrac{p_3}{G_3}}$$

On substitution, $G_{bulk\text{-}agg} = \dfrac{54.5 + 38.0 + 7.5}{\dfrac{54.5}{2.61} + \dfrac{38.0}{2.71} + \dfrac{7.5}{2.69}}$

$$= \frac{100}{20.88 + 14.02 + 2.78}$$

$= 2.653$

(iv) Maximum Theoretical Density,

$$G_t = \frac{100}{\dfrac{51.5}{2.61} + \dfrac{35.9}{2.71} + \dfrac{7.1}{2.69} + \dfrac{5.5}{1.02}} = 2.438$$

(v) Percentage of voids present in the compacted mix:

$$V_v\% = \frac{G_t - G_m}{G_t} \times 100$$

$$= \frac{2.438 - 2.339}{2.438} \times 100 = 4.07\%$$

(vi) Voids in mineral aggregates:

$$V_b\% = (\text{percent of bitumen}) \times \frac{G_{bulk-comp}}{G_b}$$

$$= 5.5 \times \frac{2.339}{1.02} = 12.61\%$$

VMA (%) = $V_v + V_b$ = 4.07 +12.61= 16.68%

(vii) Voids filled with bitumen:

$$VFB(\%) = 100 \times \frac{V_b\%}{VMA}$$

$$VFB\ (\%) = 100 \times \frac{12.61}{16.68} = 75.56\%$$

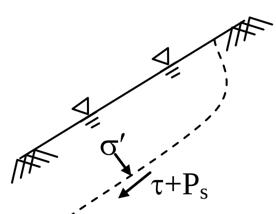
03(a). (i)

Sol: For Infinite slope

Given : γ_{sat} = 19 kN/m^3

γ' = 19 – 9.81 = 9.19 kN/m^3

$C' = 0$, $\phi' = 28^o$



$$F = \frac{C' + \gamma' z(\cos^2 i)\tan\phi'}{\gamma_{sat} z \cos i \sin i}$$

$$F = \frac{\gamma'}{\gamma_{sat}} \frac{\tan\phi'}{\tan i} (C' = 0)$$

$$\tan i = \frac{9.19}{19} \times \frac{\tan 28^o}{1.5}$$

$i = 9.73^o$

For no seepage: C′ = 0

$$F = \frac{\tan\phi}{\tan i}$$

$$F = \frac{\tan 28^o}{\tan 9.73^o}$$

F = 3.1

03(a). (ii)

Sol: (a) Equivalent Noise level

$$L_{eq} = 10\log\sum_{i=1}^{i=4}\left(10^{4/10}\times t_i\right)$$

$$= 10\log\left[10^{\frac{60}{10}}\times\frac{5}{30}+10^{\frac{80}{10}}\times\frac{10}{30}+10^{\frac{65}{10}}\times\frac{10}{30}+10^{\frac{70}{10}}\times\frac{5}{30}\right]$$

= 75.589 dB

(b) Average sound pressure

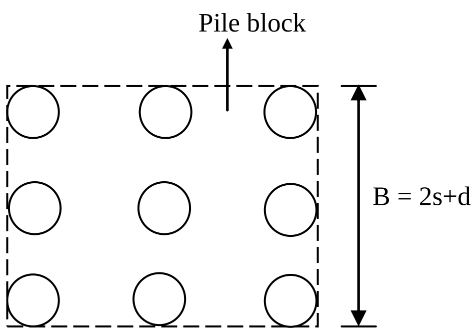
$$\tau = 20\log_{10}\left(\frac{1}{N}\sum_{i=1}^{4}10^{2i/20}\right)$$

$$= 20\log_{10}\left(\frac{5}{30}10^{\frac{60}{20}}+10^{\frac{80}{20}}\times\frac{10}{30}+10^{\frac{65}{20}}\times\frac{10}{30}+10^{\frac{70}{20}}\times\frac{5}{30}\right)$$

= 73.29 dB

03(b).

Sol:



S = spacing of piles = 1 m

d = diameter of pile = 60 cm = 0.6 m

B = 2 × 1 + 0.6 = 2.6 m

Negative skin friction occurs due to the fill as well as soft clay.

Pile capacity based on stiff clay.

Group pile capacity considering individual pile failure.

$Q_{gi} = n[A_b\, CN_C + A_f\, \alpha\, C]$

n = number of piles

A_b = Area of base

C = Cohesion at base

A_f = Side friction area

α = Adhesion factor

$$Q_{gi} = 9\left[\frac{\pi}{4}\times 0.6^2 \times 65\times 9+\pi\times(0.6)\times 6\times 0.4\times 65\right]$$

$= 9[165.4 + 294.05]$

$= 4135.1$ kN

Group capacity based on block failure

$Q_{gb} = A_B\, C\, N_C + A_f\, B\, C$

A_B = Area of base of block = B^2

A_{fB} = side friction area of block = 4 B L

$Q_{gb} = 2.6^2 \times 65 \times 9 + 4 \times 2.6 \times 6 \times 65$

$= 3954.6 + 4056 = 8010.6$ kN

Group capacity is smaller of above values

$Q_g = 4135.1$ kN

We have to subtract negative skin friction to get final group capacity

Negative skin friction acting on group:

i) Based on individual pile failure.

$Q_{ni} = n[A_{nf}\, L_n\, \alpha\, C]$

A_{nf} = Area of pile where negative side friction acts

L_n = length of pile where negative skin friction acts

$= 9[(\pi \times 0.6) \times 4 \times 0.7 \times 30 + (\pi \times 0.6) \times 6 \times 0.35 \times 20]$

$= 2137.54$ kN

ii) Based on Block Failure

$Q_{nb} = P_g\, L_n\, C + A_B\, L_n\, \gamma$

$= [(4 \times 2.6) \times 4 \times 30 + (4 \times 2.6)\ 6 \times 20] + [2.6^2 \times 4 \times 15 + 2.6^2 \times 6 \times 17]$

$= 2496 + 1095.12$

$= 3591.12$ kN

Negative skin friction is taken the higher of above two

$Q_n = 3591.12$ kN

Net load carrying of pile group $= Q_g - Q_n = 4135.1 - 3591.12$ kN

$= 544$ kN

03(c). (i)

Sol: $q_1 = 200$ PCU/hr; $q_2 = 250$ PCU/hr, $q_s = 180$ PCU/h

$S_1 = S_3 = 1600$ PCU/hr, $S_2 = S_4 = 2000$ PCU/hr

Lost time = 2n + R (R is all red time, n is no. of phases)

L = 2 (4) + 12

= 20 sec

Cycle length $= \dfrac{1.5L + 5}{1 - y}$

$\Rightarrow 80 = \dfrac{1.5(20) + 5}{1 - y}$

$\Rightarrow y = 0.5625$

$\Rightarrow y_1 + y_2 + y_3 + y_4 = 0.5625$

$y_1 = \dfrac{q_1}{S_1} = \dfrac{200}{1600} = 0.125$

$y_2 = \dfrac{q_2}{S_2} = \dfrac{250}{2000} = 0.125$

$y_3 = \dfrac{q_3}{S_3} = \dfrac{180}{1600} = 0.1125$

$\Rightarrow 0.125 + 0.1125 + 0.125 + \dfrac{q_u}{S_4} = 0.5625$

$\Rightarrow \dfrac{q_4}{S_4} = 0.2$

$\Rightarrow q_4 = 0.2 \times 2000 = 400$ PCU/hr

Effective Green Time:

For phase 1 = $G_1 = \frac{y_1}{y}(C_o - L) = \frac{0.125}{0.5625}(80-20)$ =13.33 sec

For phase 2 = $G_2 = \frac{y_2}{y}(C_o - L) = \frac{0.125}{0.5625}(80-20)$ = 13.33 sec

For phase 3 = $G_3 = \frac{y_3}{y}(C_o - L) = \frac{0.1125}{0.5625}(80-20)$ = 12 sec

For phase 4 = $G_4 = \frac{y_4}{y}(C_o - L) = \frac{0.2}{0.5625}(80-20)$

= 21.33 sec

03(c). (ii)

Sol: Requirements of good ballast:

Ballast material should possess the following properties.

(a) It should be tough and wear resistant.

(b) It should be hard so that it does not get crushed under the moving loads.

(c) It should be generally cubical with sharp edges.

(d) It should be non-porous and should not absorb water.

(e) It should resist both attrition and abrasion.

(f) It should be durable and should not get pulverized or disintegrated under adverse weather conditions.

(g) It should allow for good drainage of water.

(h) It should be cheap and economical.

Creep is defined as the longitudinal movement of the rail with respect to the sleepers as rails have a tendency to gradually move in the direction of dominant traffic

Effects of Creep

The following are the common effects of creep.

- **Buckling of track:**_ If the creep is excessive and there is no maintenance of the track, then there is a possibility of buckling of the track causing derailment.

- **Sleepers out of square:** The sleepers move out of their position as a result of creep and become out of square. This in turn affects the gauge and alignment of the track, which finally results in uncomfortable rides
- **Distortion of points and crossings** Due to excessive creep, it becomes difficult to maintain the correct gauge and alignment of the rails at points and crossings.
- **Difficulty in changing rails :** Changing of rail becomes difficult as the new rail is found to be either too short or too long because of creep.
- **Disturbance in gaps get disturbed :**Due to creep, the expansion gaps widen at some places and reduces at others. This results in the joints getting jammed. Undue stresses are created in the fish plates and bolts, which affects the smooth working of the switch expansion joints in the case of long welded rails.
- The interlocking mechanism of the points and crossings gets disturbed by creep.
  Breaking of bolts and kinks in the alignment

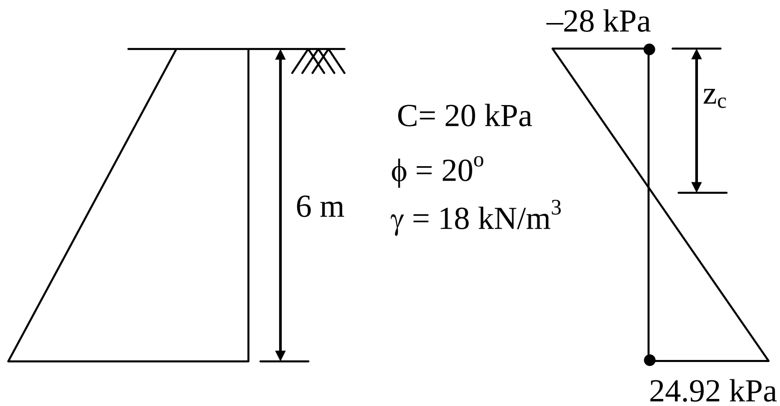
04(a).

Sol: Given: C = 20 kPa

$\phi = 20^o$

$\gamma = 18$ kN/m^3

$$K_a = \frac{1-\sin 20^o}{1+\sin 20^o} = 0.49$$



(i) At top z = 0 m

$\sigma_v = 0$

$p_a = K_a \sigma_v - 2C\sqrt{K_a}$

$= -2 \times 20 \times \sqrt{0.49}$

$p_a = -28$ kPa

At bottom z = 6 m

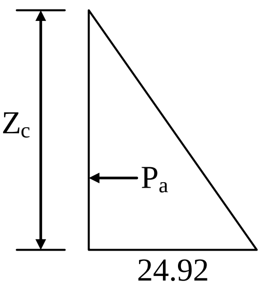
$\sigma_v = 6 \times 18 = 108$ kPa

$p_a = 0.49 \times 108 - 28$

$p_a = 24.92$ kPa

(ii) Depth of tension zone

$$Z_c = \frac{2c}{\gamma\sqrt{K_a}} = \frac{2\times 20}{18\times\sqrt{0.49}} = 3.175\ \text{m}$$



(iii) By ignoring tension zone

$\therefore$ $H - Z_c = 6 - 3.175$

$= 2.825$ m

$$F_a = \frac{1}{2}\times 24.92\times 2.825 = 35.2\ \text{kN/m}$$

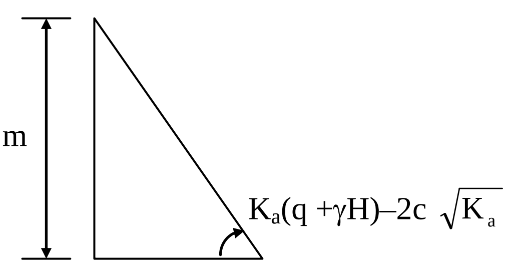
Line of action = $\frac{2.825}{3} = 0.942\text{m}$ from base

(iv) Fictious surcharge for no tension crack

$$Z_c = 0 \Rightarrow \frac{2C}{\gamma\sqrt{K_a}} = \frac{q}{\gamma}$$

$$\therefore\ q = \frac{2C}{\sqrt{K_a}} = \frac{2\times 20}{\sqrt{0.49}} = 57.14\,\text{kPa}$$

(v) By placing surcharge



At Base:

$P_a = K_a (q + \gamma H) - 2C\sqrt{K_a}$

$= 0.49 (57.14 + 18 \times 6) - 2 \times 20 \times \sqrt{0.49}$

$= 52.92$ kPa

$\therefore F_a = \frac{1}{2}\times 52.92\times 6$

$= 158.75$ kN/m

04(b). (i)

Sol: Requirements of a good port: These can be enlisted as follows:

(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.

04(b). (ii)

Sol: In this aggregates and bituminous binder are mixed thoroughly before spreading and compacting. The advantage is it is possible to coat each particle of aggregate with binder and the quantity of binder required is less than other types like penetration macadam.

Depending on the graduation of aggregates used, the premixed construction can be open graded, semidense and dense mixes.

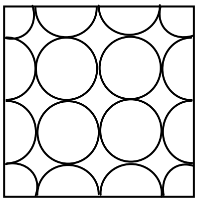
Bituminous Macadam:

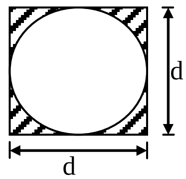
Bituminous macadam is a type of premix bituminous construction in which one or more courses of compacted crushed aggregates is premined with bituminous binder and is laid immediately after mixing.

It is used as a base course or binder course and should be covered by suitable surface course. It is superior than other types of base course materials like WBM. w.r.to durability and load dispersion.

04(b). (iii)

Sol: Loosest State: Each sphere is fitted in a cube of side 'd'





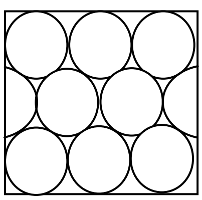
Total volume = V = d^3

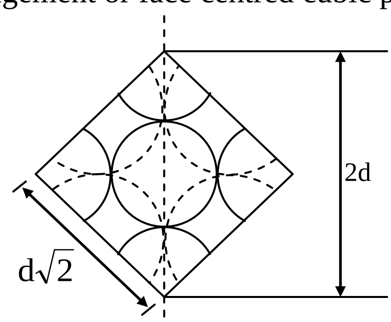
Volume of voids = total volume – volume of sphere

$$= d^3 - \frac{\pi}{6}d^3$$

$$e = \frac{V_v}{V_s} = \frac{d^3 - \frac{\pi}{6}d^3}{\frac{\pi}{6}d^3} = \frac{1-\frac{\pi}{6}}{\frac{\pi}{6}} = 0.91$$

Densest state: Diagonal array arrangement or face centred cubic packing





Total volume $= (\sqrt{2}d)^3$

Volume of solids $= 4\times\frac{\pi d^3}{6}$

$$V_v = (\sqrt{2}d)^3 - 4\times\frac{\pi d^3}{6}$$

$$e = \frac{V_v}{V_s} = \frac{2\sqrt{2}d^3 - \frac{2}{3}\pi d^3}{\frac{2}{3}\pi d^3} = 0.35$$

Difference = 0.91 – 0.35 = 0.56

04(c).

Sol: Since the stream flow is to be fully utilized for delivering water to the city to meet its fixed monthly demand

$\therefore$ Average fixed monthly demand = Average monthly inflow

$$= \frac{821.9232}{12} = 68.4936$$

S.No	Month	Monthly Inflow (cumec)	Monthly Inflow (Mm^3)	Monthly outflow (Mm^3)	Monthly Deficit	Monthly Surplus	Cum. Deficit	Cum. Surplus
1.	Jan	15	40.176	68.4936	28.3176	-	-	-
2.	Feb	10	24.192	68.4936	44.3016	-	-	-
3.	March	8	21.4272	68.4936	47.0664	-	-	-
4.	April	6	15.552	68.4936	52.9416	-	-	
5.	May	5	13.392	68.4936	50.1016	-	-	
6.	June	12	31.104	68.4936	37.3896	-	-	
7.	July	25	66.960	68.4936	1.5336	-	261.652	-
8.	Aug.	40	107.136	68.4936	-	38.6424	-	
9.	Sep.	71	184.032	68.4936	-	115.5384	-	
10.	Oct.	60	160.704	68.4936	-	92.2104	-	
11.	Nov.	40	103.680	68.4936	-	35.1868	-	281.578
12.	Dec.	20	53.568	68.4936	14.9256	-	14.9256	
Total:		**312**	**821.9232**					

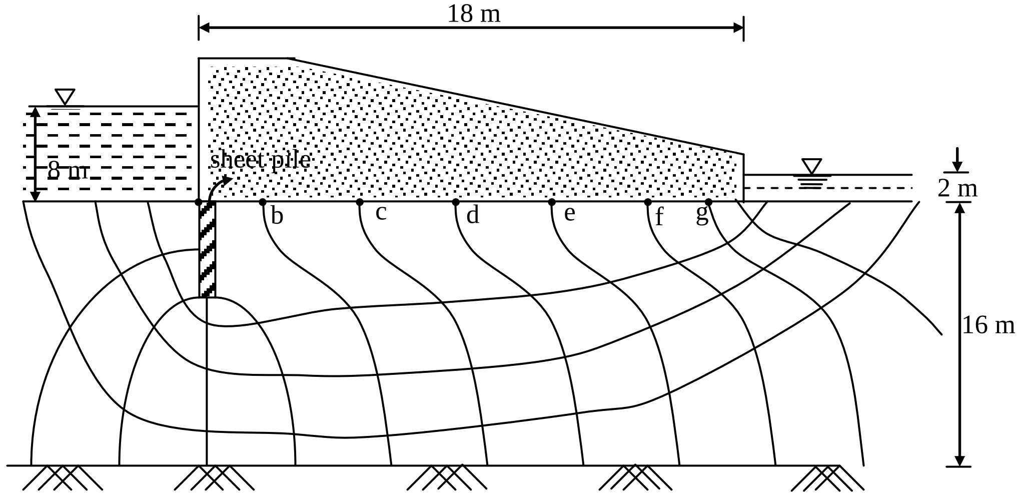
The minimum storage is the maximum of cumulative surplus and cumulative deficit. Thus the minimum storage in storage reservoir = 281.578 Mm^3 = 28157.8 ha-m

Design discharge in m^3/s for the conduit

$$= \frac{821.9232 \times 10^6}{24 \times 3600 \times 365} = 26.06\ m^3/s$$

05(a).

Sol:



Impervious Rock

(a) $q = KH\dfrac{N_f}{N_d}$

K = coefficient of permeability = 2×10^{-3} cm/s

$= 2 \times 10^{-5}$ m/s

H = 8 – 2 = 6 m

N_f = Number of flow channels = 4

N_ϕ = Number of potential drops = 12

$$q = 2\times10^{-5}\times6\times\frac{4}{12} = 4\times10^{-5}\ m^3/s/m$$

(b) Δh = drop across two equipotential lines $= \dfrac{H}{N_d} = \dfrac{6}{12} = 0.5$ m

Point	**No. of drops (n)**	**Available net Seepage head (h_w) = H – nΔh**
b	5	3.5
c	6	3
d	7	2.5
e	8	2
f	9	1.5
g	10	1

05(b). (i)

Sol: Given: V = 80 kmph, f = 0.13

Wheel base = W = 18 m

Tread of main landing gear = 7 m

Width of taxiway, T = 25 m

(i) Turning radius based on lateral friction:

$$R = \frac{V^2}{125f}$$

$$= \frac{80^2}{125 \times 0.13} = 393.85 \text{ m}$$

(ii) Based on Horonieff equation:

$$R = \frac{0.388W^2}{\frac{T}{2} - S}$$

S = distance between point midway of main gears and edge of taxiway

Assuming distance of oleo struct from landing gear = 6 m

$$S = 6 + \frac{7}{2} = 9.5 \text{ m}$$

$$R = \frac{0.388 \times 18^2}{\frac{25}{2} - 9.5} = 41.904 \text{ m}$$

(iii) For a supersonic aircraft, minimum radius of taxiway = 180 m

$\therefore$ Taxiway turning radius is maximum of above three = 393.85 m

05(b). (ii)

Sol: Wind rose:

For the airport, the average wind data of 5 to 10 years period are collected and represented graphically in the form of a chart known as wind rose. The diagram is given the name wind rose because of its irregular shape resembling a rose. The study of wind rose helps in determining the most suitable orientation of the runway. It is also a useful device for estimating the runway capacity.

Type I: Showing direction and duration of wind.

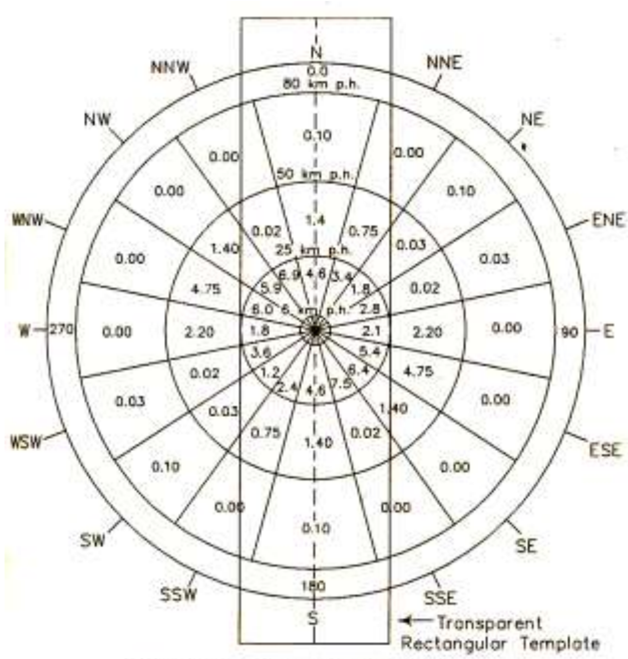
Type II: Showing direction, duration and intensity of wind.

Type I wind rose:

Figure shows the wind rose diagram of this type. The radial lines indicate the wind direction and each circle represents the duration of wind to a certain scale. From the wind data of the total percentage of wind blowing in north is 6.10 and accordingly, this point is marked along north direction. Similarly, all other values are plotted and then joined by the straight lines. The best direction of runway is indicated along the direction of the longest line on the wind rose diagram. WNW – ESE is the best orientation for the runway. This type of wind rose does not consider the effect of the cross wind component.

Type II wind rose:

From the wind data of table it is observed that the percentage of time during which the wind velocity is less than 6 kmph works out to (100 – 88) = 12. This period is called the calm period and it does not influence the operations of landing and take off because of low wind velocity. Thus, the wind velocities below 6 kmph have no effect on the fixing of orientation of a runway.



Wind rose diagram showing direction, duration and intensity of wind

05(c).

Sol: Volume of water to be raised per day in two shifts of 8 hours each = 18000 m^3

$\therefore$ Volume of water to be raised in each shift $=\frac{18000}{2}$ m^3 = 9000 m^3

Discharge of water per shift of 8 hours, $Q=\frac{9000}{8\times60\times60}m^3/s$ = 0.3125 m^3/s

Q = 0.3125 m^3/s, f' = 0.01, L = 40 + 150 = 190 m, d = 50 cm = 0.5 m

Static head = 21 m, efficiency of motor and pump, η = 80%

The head loss due to friction may be given by Darcy-Weisbach equation as $h_f=\frac{fLV^2}{2gd}$

Where, V = velocity of water in pipe $=\frac{Q}{V}=\frac{4Q}{\pi d^2}$

$$\therefore h_f=\frac{fL}{2gd}\times\left(\frac{4Q}{\pi d^2}\right)^2$$

$$\Rightarrow h_f=\frac{8fLQ^2}{\pi^2 gd^5}=\frac{8\times4f'\times LQ^2}{\pi^2 gd^5} \qquad [\because f=4f']$$

$$\Rightarrow h_f=\frac{8\times4\times0.01\times190\times(0.3125)^2}{\pi^2\times9.81\times(0.5)^2}$$

$\Rightarrow h_f$ = 1.96 m

Total head against which pumping is done = Static head + head loss due to friction

= 21 + 1.96

= 22.96 m

Now, if η is the efficiency of the pump set, then brake horse power (BHP) of the pump is given by

$$BHP=\frac{\gamma_w QH}{\eta\times0.735}$$

Where, γ_w is unit weight of water in kN/m^3

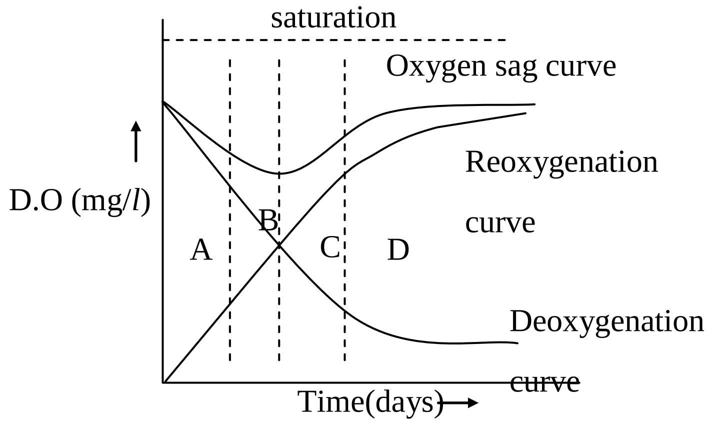
$$\therefore BHP=\frac{9.81\times0.3125\times22.96}{0.8\times0.7457}=117.99\text{ HP}$$

Number of units of pumps of 30 BHP each $=\frac{117.99}{30}=4$

Thus, 4 units of pumps each having BHP of 30 can be used

05(d). (i)

Sol: In a polluted river streams, there is deoxygenation to meet the biological requirement of organic sewage along with deoxygenation, reoxygenator also occurs as oxygen is absorbed at water surface from at moisture. Both reoxygenation & deoxygenation occur simultaneously. Algebraically adding the reoxygenation & deoxygenation curve gives oxygen sag curve.



Zone A = zone of Degradation

Zone B = zone of Active decomposition

Zone C = zone of recovery

Zone D = zone of clear water

05(d). (ii)

Sol: Total solid waste Generated per year = $2 \times 10^6 \times 365$

$= 7 \times 10^8$ kg

Volume of solid waste = $\dfrac{7 \times 10^8}{500}$

$= 1.4 \times 10^6\ m^3$

Assume height of solid waste as 2 m

Area of solid waste = $\dfrac{1.4 \times 10^6}{2}$

$= 7 \times 10^5\ m^3$

As 80% of Area is covered with S.W

Area of land Required $= \dfrac{7\times10^5}{0.8}$

$= 8.75 \times 10^5\ m^2$

$= 87.5$ hectare

05(e).

Sol: The EIA Cycle and Producers:

The EIA process in India is made up of the following phases:

1. Screening
2. Scoping
3. Baseline Data
4. Impact Prediction
5. Consideration of alternatives
6. Delineation of Mitigation Measures
7. Environmental Impact Assessment Report
8. Environment management plan (EMP)
9. Public Hearing
10. Decision Making
11. Monitoring the Clearance Conditions
12. Environmental impact statement (EIS)

1. Screening

- Screening is done to see whether a project requires environmental clearance as per the statutory notifications. Screening Criteria are based upon:

Scales of investment:

Type of development; and

Location of development

- A project requires statutory environmental clearance only if it is mentioned either in the provisions of EIA notifications or in any law.

2. Scoping

- This step seeks to identify, at an early stage, the key, significant environmental issues from among a host of possible impacts of a project and all the available alternatives.
- Quantifiable impacts are to be assessed on the basis of magnitude, prevalence, frequency and duration and non quantifiable impacts (such as aesthetic or recreational value), significance is commonly determined through the socio economic criteria.
- After the areas, where the project could have significant impact, are identified, the baseline status of these should be monitored and then the likely changes in these on account of the construction and operation of the proposed project should be predicted.

3. Baseline Data

- Baseline data describes the existing environmental status of the identified study area. The site-specific primary data should be monitored for the identified parameters and supplemented by secondary data if available.

  This includes the establishment of both the present and future state of the environment, in the absence of the project, taking into account the change resulting form other human activities.

4. Impact Prediction

- Impact prediction is a way of mapping the environmental consequences of the significant aspects of the project and its alternatives. Environmental impact can never be predicted with absolute certainty and this is all the more

Air

- Change in ambient levels and ground level concentrations due to total emissions from point, line and area sources.
- Effects on soils, materials, vegetation, and human health.

Noise

- Change in ambient levels due to noise generated from equipment and movement of vehicles
- Effect on fauna and human health.

Water

- Availability to competing users
- Changes in quality
- Sediment transport
- Ingress of saline water

Land

- Changes in land use and drainage pattern
- Changes in land quality including effects of waste disposal
- Changes in shoreline/riverbank and their stability.

Biological

- Impact on the local community including demographic changes.
- Impact on economic status
- Impact on human health.
- Impact of increased traffic

5. Consideration of alternatives:

- This seeks to ensure that the proponent has considered other feasible approaches, including alternative project locations, scales, processes, layouts, operating conditions and the no-action option.

6. Delineation of Mitigation Measures

- Once alternatives have been reviewed, a mitigation plan should be drawn up for the selected option and it supplemented with an Environmental Management Plan (EMP) to guide the proponent towards environmental improvements. The EMP is a crucial input to monitoring the clearance conditions and therefore details of monitoring should be included in the EMP.

7. Environmental Impact Assessment Report

- An EIA report should provide clear information to the decision-maker on the different environmental scenarios without the project, with the project and with project alternatives. Uncertainties should be clearly reflected in the EIA report.

8. Environment management plane (EMP);

- Delineation of mitigation measures including prevention and control for each environmental component and rehabilitation and resettlement plane.
- Delineation of monitoring scheme for compliance of conditions.

9. Public Hearing

- Law requires that the public must be informed and consulted on a proposed development after the completion of EIA report.
- Any one likely to be affected by the proposed project is entitled to have access to the Executive Summery of the EIA.

The affected persons may include:

Bonafide local residents;

Local associations

Environmental groups active in the area

Any other person located at the project site/sites of displacement

- They are to be given an opportunity to make oral/written suggestions to the State Pollution Control Board.

10. Decision Making

- Decision making process involve consultation between the project proponent (assisted by a consultant) and the impact assessment authority (assisted by an expert group if necessary)
- The decision on environmental clearance is arrived at through a number of steps including evaluation of EIA and EMP.

11. Monitoring the Clearance conditions

- Monitoring should be done during both construction and operation phases of a project. This is not only to ensure that the commitments made are complied with but also to observe whether the predictions made in the EIA reports were correct or not. Where the impacts exceed the predicted levels, corrective action should be taken. Monitoring will enable the regulatory agency to review the validity of predictions and the conditions of implementation of the Environmental Management Plan (EMP).

12. Environmental impact statement (EIS)

- EIA exercise culminates in an environmental impact statement (EIS). EIS provides the decision makers with valuable information that could ultimately contribute to either the abandonment or substantial modification of a proposed development action.

06(a). (i)

Sol: Effective length and width of footing are

$B' = B - 2\,e_y = 6 - 2 \times 0.75 = 4.5$ m

$L' = L - 2\,e_x = 6 - 2 \times 0.6 = 4.8$ m

Effective area $A' = L' \times B' = 21.6\ m^2$

As per Meyerhoff equation

$q_u = C\,N_C\,S_C\,i_C\,d_C + \gamma\,D_f\,N_q\,S_q\,i_q\,d_q + 0.5\,\gamma\,B'\,N_\gamma\,S_\gamma\,i_\gamma\,d_\gamma$

s, i, d are shape, inclination and depth factor

$S_q = 1.61$, $S_\gamma = 0.63$

$d_q = 1.183$, $d_\gamma = 1$

Assuming load to be vertical $i_q = i_c = i_\gamma = 1$

$C = 0$, $N_q = 26.3$, $N_\gamma = 26.55$

$q_u = \gamma\,D_f\,N_q\,S_q\,d_q + 0.5\,B'\,\gamma\,N_\gamma\,S_\gamma\,d_\gamma$

$= 18.5 \times 3 \times 26.3 \times 1.61 \times 1.183 + 0.5 \times 4.5 \times 26.55 \times 18.5 \times 0.63 \times 1$

$q_u = 3476\ kN/m^2$

Gross ultimate load = $A'\,q_u = 21.6 \times 3476 = 75082$ kN

06(a). (ii)

Sol: Rate of flow $q = 3.2\ cm^3/s$

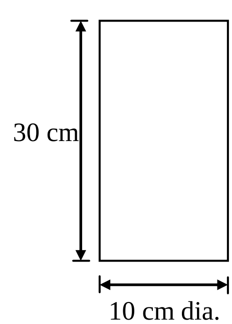
As per Darcy's law

$q = k\,i\,A$

In constant head test

h = 120 cm (head difference)

L = Drainage length = 30 cm



i = hydraulic gradient = $\frac{h}{L} = \frac{120}{30} = 4$

Area $A = \frac{\pi}{4} \times 10^2.\ cm^2$

$q = k\ i\ A$

$\Rightarrow k = \frac{q}{i\ A} = \frac{3.2}{4 \times \frac{\pi}{4} \times 10^2}\ cm/s$

$= 1.019 \times 10^{-2}$ cm/s

Since falling head test is conducted on same sample at same.

Void ration, k will be same

Head falls from 9.8 cm (h_1) to 50 cm (h_2)

a = Area of stand pipe

= 2.5 cm

$k = \frac{aL}{At} \ln\left(\frac{h_1}{h_2}\right)$ [In falling head test]

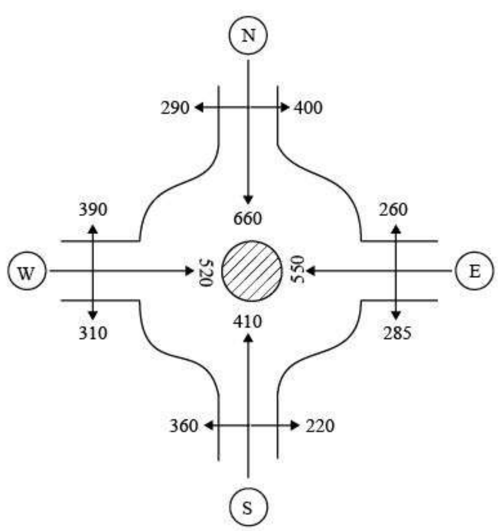
$\Rightarrow 1.019 \times 10^{-2} cm/s = \frac{\frac{\pi}{4} \times 2.5^2 \times 30}{\frac{\pi}{4} \times 10^2 \times t} \ln\left(\frac{98}{50}\right)$

$t = \left(\frac{2.5}{10}\right)^2 \times \frac{30 \times 10^2}{1.019} \ln \frac{98}{50}$

= 123.85 sec

06(b). (i)

Sol:



Weaving Ratio (P) $= \dfrac{b+c}{a+b+c+d}$

For North-East:

$P_{N\text{-}E}$, a = 400, b = 660 + 290 = 950

c = 520 + 220 = 740, d = 310

$$P_{N-E} = \frac{950+740}{400+950+740+310} = 0.7042$$

For East-South:

$P_{E\text{-}S}$, a = 285, b = 550 + 260 = 810

c = 660 + 310 = 970, d = 290

$$P_{E-S} = \frac{810+970}{285+810+970+290} = 0.7558$$

For South-West:

$P_{S\text{-}W}$, a = 360, b = 410 + 220 = 630

c = 550 + 290 = 840, d = 260

$$P_{S-W} = \frac{630+840}{360+630+840+260} = 0.7034$$

For West-North:

$P_{W\text{-}N}$, a = 390, b = 520 + 310 = 830

c = 410 + 260 = 670, d = 220, d = 220

$$P_{W-N} = \frac{830+670}{390+830+670+} = 0.711$$

Practical capacity, $C = \dfrac{280W\left(1+\dfrac{e}{W}\right)\left(1-\dfrac{p}{3}\right)}{\left(1+\dfrac{W}{L}\right)}$

$$e = \frac{e_1 + e_2}{2} = 10 \text{ m}$$

e_1 = Entry width = 10 m

e_2 = exit width = 10 m

W = width of weaving section = e + 3.5 = 13.5 m

L = Length of weaving section

$\frac{L}{W} = 3.5\,(\text{Given})$ L = 3.5 W = 47.25 m

p = Max weaving ratio = 0.7558

$$C = 280 \times 13.5 \frac{\left(1+\frac{10}{13.5}\right)\left(1-\frac{0.7558}{3}\right)}{\left(1+\frac{13.5}{47.25}\right)} = 3828 \text{ PCU/hr}$$

Urban Area is given:

Design speed = 30 kmph

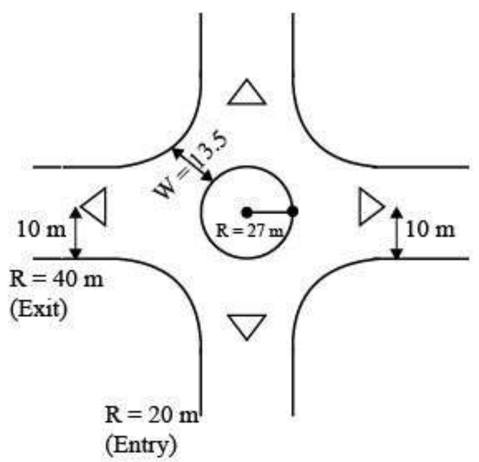
Entry and exit angle = 45^o

Entry radius = 20 m

Exit radius = 40 m

Radius of central Island = 1.33 × Entry radius $\simeq 1.33 \times 20$

R $\simeq$ 27 m



06(b). (ii)

Sol: Difference Between Flexible And Rigid Pavements:

The major differences between the type of pavements can be tabulated below:

(i) Flexible pavements

1. It consists of a series of layers with the highest quality materials at or near the surface.
2. It reflects the deformations of sub grade and subsequent layers on the surface.
3. Its stability depends upon aggregate interlock particle friction and cohesion.
4. Pavement design is greatly influenced by the subgrade strength
5. It functions by way of load distribution through the component layers.
6. Design is based on **IRC: 37-2001**

(ii) Rigid pavements

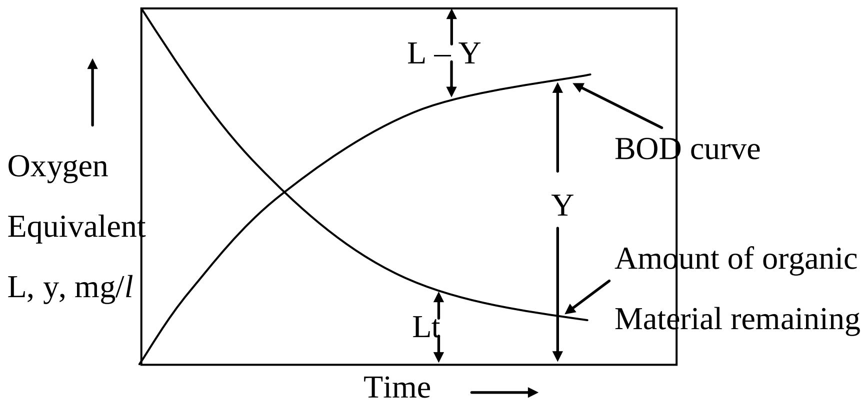
1. It consists of one course Portland concrete slab of relatively high bending resistance.
2. It is able to bridge over localized failures and areas of inadequate support.
3. Its structural capacity is supplied by the pavement slab itself by beam action.
4. Flexural strength of concrete is major factor for design.
5. It distributes load over a wide area of sub grade because of its rigidity and high modulus of elasticity.
6. Design is based on **IRC: 58-2002**

06(c). (i)
Sol:

Concentration in ambient air					
Sl. No.	**Pollutants**	**Time weighted average**	**Industrial, residential, rural and other areas**	**Ecologically sensitive area (Notified by Central Govt.)**	**Methods of measurement**
1	Sulphur dioxide (SO_2), μg/m^3	Annual* 24 Hours*	50 80	20 80	1. Improved West and Gacke 2. Ultraviolet fluorescence
2	Nitrogen dioxide (NO_2), μg/m^3	Annual* 24 Hours*	40 80	30 80	1. Modified Jacoh & Hochheiser (Na-Arsenite)
3	Particulate matter (Size < 10 μm) or PM_{10} μg/m^3 Particulate matter	Annual* 24 Hours*	60 100	60 100	1. Gravimetric 2. TEOM 3. Beta attenuation
4	(Size < 25 μm) or $PM_{2.5}$ μg/m^3	Annual* 24 Hours*	40 60	40 60	Gravimetric TEOM Beta Attenuation
5	Ozone (O_3), μg/m^3	8 Hours** 1 hour**	100 180	100 180	UV photometric Chemiluminescence Chemical method
6	Lead (Pb), μg/m^3	Annual* 24 Hours*	0.50 1.00	0.50 1.00	1. AAS/ICP method after sampling using EPM 2000 or equivalnet filter paper 2. ED-XRF using Teflon filter
7	Carbon monozide (CO), μg/m^3	8 Hours** 1 hour**	02 04	02 04	1. Non dispersive infra red (NDIR) spectroscop
8	Ammonia (NH_3), μg/m^3	1 hours** Annual** 24 Hours**	100 400	100 400	1. Chemiluminescence Indophernol blue method
9	Benzene (C_6H_6), μg/m^3	Annual*	05	05	1. Gas chromatography based continuous analyzer 2. Adsorption and desorption followed by GC analysis
10	Berzo(a)pyene (BaP)-particulate phase only ng/m^3	Annual*	01	01	1. Solvent extraction followed by HPLC/GC analysis
11	Arsenic (As), ng/m^3	Annual*	06	06	1. AAS/ICP method after sampling on EPM 2000 or equivalent filter paper
12	Nickel (Ni), ng/m^3	Annual*	20	20	1. AAS/ICP method after sampling on EPM 2000 or equivalent filter paper.

06(c). (ii)

Sol: The expression for biological oxidation of the organic matte is derived on the assumption that rate of BOD reaction is directly proportional to the amount of oxidizable organic amount remaining at any time i.e.,



$$\frac{dL}{dt} = -k_1 L_t$$

k_1 = first order reaction constant, days

L_t = amount of waste remaining at any time t days, expressed in oxygen equivalent

-ve sign means rate of reaction gradually decreases as concentration of organic matter decreases.

$$\frac{dL}{L_t} = -k_1 dt$$

Integrating

$\log_e L_t = - k_1 t + c$ ------ (1)

at t = 0, $L_t = L_o$

$\log_e L_o = c$ ----substitute in equation (1)

$$\log_e \frac{L_t}{L_o} = -k_1 t$$

$$L_t = L_0 \left(10^{-k_1 t}\right)$$

Where L_o = total or ultimate BOD

BOD exerted upto time f is

$y = L_o - L_t$

$$y = L_o \left(1 - 10^{k_1 t}\right)$$

07(a). (i)

Sol: (a) Boring:

The methods of boring or drilling are: auger, auger and shell, wash boring, percussion boring, and rotary boring.

1. Auger boring:

- Augers are used in cohesive and other soft soils above water table. Hand augers are used for depths upto about 6 m.
- Mechanically operated augers are used for greater depths and they can also be used in gravely soils.
- Samples recovered from the soil brought up by augers are badly disturbed and are useful for identification purposes only.
- Auger boring is fairly satisfactory for highway explorations at shallow depths and for exploring borrow pits.

2. Auger and shell boring:

- Cylindrical augers and shell with cutting edge on teeth at the lower end can be used for making deep borings.
- Hand operated rings are used for depth upto about 25 m and the mechanized rings upto 50 m.
- Augers are suitable for soft to stiff clays, shells for very stiff and hard clays and shells or sand pumps for sandy soils.
- Small boulders, thin softy strata or rock or cemented gravel can be broken by chisel bits attached to drill rods. The hole usually requires a casing.

3. Wash boring:

- Wash boring is a fast and simple method for advancing holes in all types of soils. Boulders and rock cannot be penetrated by this method.
- The method consists in first driving a casing through which a hollow drill rod with a sharp chisel or chopping bit at the lower end is inserted.
- Water is forced under pressure through the drill rod which is alternatively raised and dropped, and also rotated. The resulting chopping and jetting action of the bit and water disintegers the soil. The cuttings are forced up to the ground surface in the form of soil-water slurry through the annular space between the drill rod and the casing.

- The change of soil stratification could be guessed form the rate of progress and the colour of the wash water. The samples recovered from the wash water are almost valueless for interpreting the correct geotechnical properties of soil.

4. Percussion boring:

- In this method, soil and rock formations are broken by repeated blows of heavy chisel or bit suspended by a cable or drill rod.
- Water is added to the hole during boring, if not already present, and the slurry or pulverized material is bailed out at intervals.
- The method is suitable for advancing a hole in all types of soil, boulders and rock. The formations, however, get disturbed by the impact.

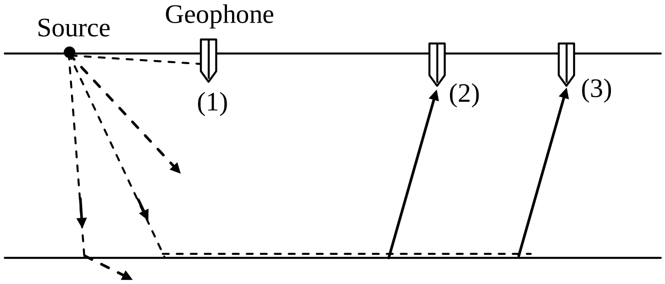
5. Rotary Boring:

- Rotary boring or rotary drilling is a very fast method of advancing hole in both rocks and soils.
- A drill bit, fixed to the lower end of drill rods, is rotated by a suitable chuck and is always kept in firm contact with the bottom of the hole.
- A drilling mud, usually a water solution of bentonite, with or with-out other admixtures, is continuously forced down the hollow drillrods. The mud returning upwards brings the cuttings to the surface.
- The method is also known as mud rotary drilling and the hole usually require no casing.

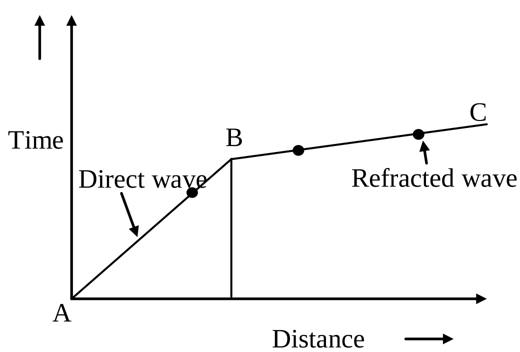
(b) SEISMIC REFRACTION METHOD

- This method is fast and reliable in establishing profiles of different strata provided that deeper layers have increasingly greater density.
- This method is based on the fact that
- Seismic waves have different velocities indifferent types of soil (or) rock.
- The waves are refracted when they cross the boundary between different types of soils.
- This method consists of inducing impact in by striking a plate on the soil with a hammer. The radiating shock waves are recorded by vibration detector (geophone) which records time of travel of waves.

- These geophones are arranged along a line or the shock producing device is moved away from the geophone to produce shock waves at given intervals.
- Different waves travel in different direction. Direct or primary waves travel directly from source along the ground surface to the location of geophone.
- If the subsoil consists of two or more distinct layers, some of the primary waves travel downwards to the lower layer and get refracted at the interface.



- The results are plotted as a graph between time of travel vs distance. The break in the curve represents the point of simultaneous arrival of the primary and refracted waves, and its distance is known as the critical distance.
- The time-distance relationship is represented by a straight line at different slopes. These slopes are seismic velocities. The general type of soil is determined form these velocities.



07(a) (ii).

Sol: (a) Sensitivity:

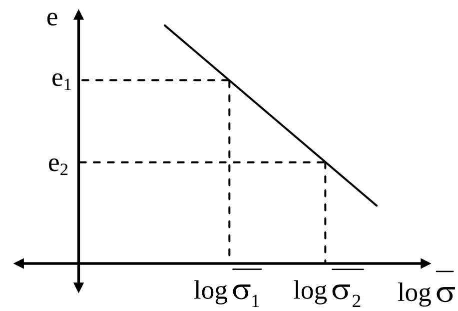
It is defined as the ratio of unconfined compressive strength of an undisturbed sample of soil to the unconfined compressive strength of remoulded one.

$$S\ (\text{Sensitivity}) = \frac{q_u\,(\text{undisturbed})}{q_u\,(\text{Remoulded})}$$

(b) Compression index:

It is the slope of void ratio(e) vs ($\log\bar{\sigma}$) plot.

For normally consolidated clay, a straight line is obtained.



$$C_C = \frac{\Delta e}{\log\bar{\sigma}_2 - \log\bar{\sigma}_1} = \frac{e_1 - e_2}{\log_{10}\left(\frac{\bar{\sigma}_2}{\bar{\sigma}_1}\right)}$$

It is independent of effective stress and constant for a particular type of soil.

(c) Liquefaction:

In loose saturated sand, on shear disturbance, there is decrease in volume of soil and increase in pore water pressure decreasing effective stress which results in loss of shear strength and behaviour similar to liquid. Liquefaction mostly occurs due to earthquake forces.

(d) Area Ratio:

In a soil sample, area ratio (A_r) can be expressed as

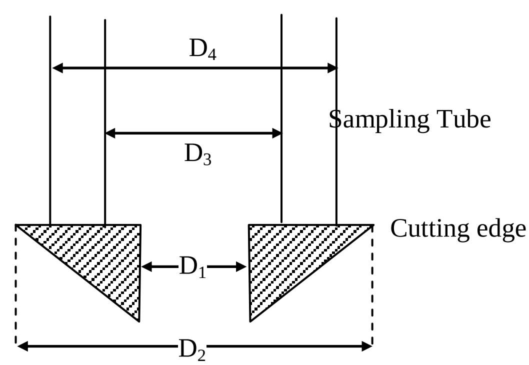
$$A_r = \left(\frac{A_2 - A_1}{A_1}\right)\times 100 = \left[\frac{D_2^{\,2} - D_1^{\,2}}{D_1^{\,2}}\right]\times 100$$

D_1 = Inside diameter of cutting edge

D_2 = Outside diameter of cutting edge

D_3 = Inside diameter of sampling tube

D_4 = Outer diameter of sampling tube



07(b). (i)

Sol: $Q = \dfrac{30\times10^6\times10^{-3}}{24\times60\times60} = 0.346\ m^3/sec$

V_a = 0.9 m/sec

Depth H = 1 m

Cross sectional area of screen = $B\times H = \dfrac{Q}{V_a}$

$$B\times1 = \frac{0.346}{0.9}$$

B = 0.385 m

Assume size of opening

S = 25 mm

Diameter of screen Bar D = 10 mm

$1 \times B = n \times 5 + (n + 1) S$

$1 \times 0.385 \times 10^3 = n\times 25 + (n + 1)\ 25$

$n = 7.2 \simeq 8$

number of bars = 8 + 1 = 9

$$V_s = \frac{Q}{n\times s\times\dfrac{H}{\sin\theta}}$$

$$= \frac{0.346}{9\times25\times10^{-3}\times\dfrac{1}{\sin 60^o}}$$

V_s = 1.33 m/sec

Head loss through screen

$$H_s = \frac{V_s^2 - V_a^2}{2g}\times\frac{1}{0.7}$$

$$= \frac{1.33^2 - 0.9^2}{2\times9.81}\times\frac{1}{0.7}$$

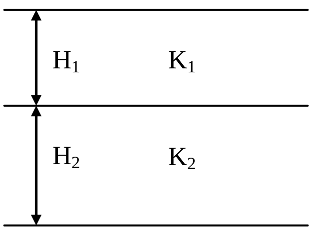
= 0.0698 m

H_s = 69.8 mm

07(b). (ii)

Sol: Consider a two layered soil strata shown in the figure.

$H = H_1 + H_2$



We know that,

$$K_H = \frac{K_1H_1 + K_2H_2}{H_1 + H_2} \qquad K_v = \frac{H_1 + H_2}{\frac{H_1}{K_1} + \frac{H_2}{K_2}}$$

$$\frac{K_H}{K_v} = \frac{K_1H_1 + K_2H_2}{H_1 + H_2} \times \frac{\left(\frac{H_1}{K_1} + \frac{H_2}{K_2}\right)}{H_1 + H_2}$$

$$= \frac{H_1^2 + H_2^2 + \left(\frac{K_1^2 + K_2^2}{K_1K_2}\right)H_1H_2}{H_1^2 + H_2^2 + 2H_1H_2} \text{ ....(a)}$$

$K_1, K_2 \geq 0$

$(K_1 - K_2)^2 \geq 0$

$K_1^2 + K_2^2 \geq 2K_1K_2$

So, in equation (a)

$$\left(\frac{K_1^2 + K_2^2}{K_1K_2}\right) \geq 2$$

So, Numerator will always be greater than denominator

$$\therefore \frac{K_H}{K_v} \geq 1$$

$K_H \geq K_v$

$K_H = K_v$ when $K_1 = K_2$

This proves the statement given in question

07(c). (i)

Sol: Super elevation Required:

Step 1:

a) Degree of curve = 2

Radius of curve $= \frac{1720}{D} = \frac{1720}{3}$ = 573.33 m

Super elevation for maximum speed = $\frac{GV^2}{127R}$

$$= \frac{1.676 \times 80^2}{127 \times 573.33}$$

= 0.147 m = 14.7 cm

Maximum permissible cant deficiency for BG tracks upto 100 kmph = 75 mm

= Actual super elevation = 14.7 – 7.5 = 7.2 cm

Step 2:

Superelevation required for goods train = $\frac{GV^2}{127R}$

$$= \frac{1.676 \times 50^2}{127 \times 573.33} = 0.057\,\text{m}$$

= 5.75 cm

Permissible can excess = 7.5 cm

$\therefore$ Actual cant = 7.2 cm

Cant excess = 7.2 – 5.75 = 1.45 cm < 7.5 cm

Hence safe

Step 3:

Maximum Permissible Speed:

a) From Martin's formula

$V = 4.35\sqrt{R - 67}$

$= 4.35\sqrt{573.33 - 67}$ = 97.88 kmph

b) Maximum speed = 80 kmph

$\therefore$ Maximum permissible speed = 80 kmph (smaller of above)

Step 4: length of transition curve: Is maximum of (D = Cant deficiency = 7.5 cm)

a) L = 7.2e = 7.2 × 7.2 = 51.84 m

b) L = 0.073 DV_{max} = 0.073 × 7.5 × 80 = 43.8 m

c) L = 0.073e V_{max} = 0.073 × 7.2 × 80 = 42.048 m

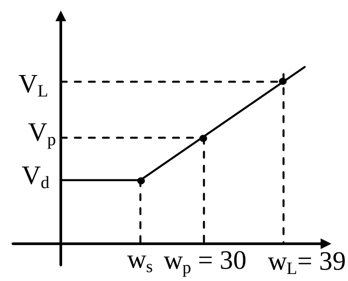
(e, D in cm; V_{max} in kmph, L in m)

∴ Provide length of transition curve = 51.84 m

07(c). (ii)

Sol: Since after w_s, the graph is a straight line

$$\frac{V_L - V_P}{w_L - w_p} = \frac{V_L - V_d}{w_L - w_s}$$



$$\frac{1.31V_d - 1.18V_d}{0.39 - 0.3} = \frac{1.31V_d - V_d}{0.39 - w_s}$$

$$\Rightarrow \frac{0.13V_d}{0.09} = \frac{0.31V_d}{0.39 - w_s}$$

0.0507 – 0.13 w_s = 0.0279

w_s = 0.1754 i.e. 17.54%

b) Shrinkage Ratio:

$$R = \frac{\frac{V_L - V_P}{V_d} \times 100}{w_L - w_P} = \frac{\frac{1.31V_d - 1.18V_d}{V_d} \times 100}{39 - 30}$$

= 1.44

c) Shrinkage Index = $I_s = w_p - w_s$

= 30 – 17.54 = 12.46%

08(a). (i)

Sol: a)

$$e + f = \frac{V^2}{gR} \qquad \text{(V in m/sec)}$$

$$= \frac{V^2}{127\ R} \qquad \text{(V in kmph)}$$

$$\Rightarrow \quad e + 0.15 = \frac{80^2}{127 \times 200} = 0.25$$

$$\therefore\ e = 0.10$$

Maximum permissible superelevation in hilly areas = 10%

$\therefore$ Provide e = 0.1 i.e., 1 in 10

b) For the pressure to be equal on inner and outer wheel; centrifugal force should be fully counteracted by superelevation i.e., f = 0

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

$$= \frac{80^2}{127 \times 200} = 0.2519$$

08(a). (ii)

Sol: From Green shield's flow model

$$V = V_{max}\left(1 - \frac{K}{K_j}\right)$$

V_{max} = free mean speed = 60 kmph

K = density

K_j = jam density = $\frac{1000}{7}$

$$\therefore V = 60\left(1 - \frac{7K}{1000}\right)$$

Traffic volume q = VK

$$= V_{max}\left(1-\frac{K}{K_j}\right)\times K$$

$$= V_{max}\left(K-\frac{K^2}{K_j}\right)$$

$$q = 60\left(K-\frac{K^2}{\left(\frac{1000}{7}\right)}\right)$$

For maximum volume $\frac{dq}{dK}=0$

$$\Rightarrow 60\left(1-\frac{2K}{\left(\frac{1000}{7}\right)}\right)=0$$

$$K=\frac{K_j}{2}; \qquad U=\frac{U_{max}}{2}$$

$$\therefore \qquad q_{max} = \frac{1}{4}U_{max}\,K_j = \frac{1}{4}\times 60\times\frac{1000}{7}$$

$$= 2142.85 \text{ veh/hr}$$

Case – II

When $V=\frac{3}{4}U_{max} = U_{max}\left(1-\frac{K}{K_j}\right)$

$$\Rightarrow \qquad K=\frac{K_j}{4}$$

$\therefore$ Volume = VK = $\frac{3}{4}U_{max}\times\frac{K_j}{4}$

$$=\frac{3}{16}\times 60\times\frac{1000}{7}=1607 \text{ veh/hr s}$$

08(a). (iii)

Sol: Δe_a = change in void ratio of sample A

= 0.572 – 0.505 = 0.067

Δe_b = change in void ratio of sample B

= 0.610 – 0.557 = 0.053

$\overline{\Delta\sigma_a} = \text{Increase in effective stress(for A)}$

= 180 – 122 = 58 kN/m^2

$\overline{\Delta\sigma_b} = \text{Increase in effective stress(for B)}$

$= \overline{\Delta\sigma_a}$ (Given)

H_a (Thickness of sample A) = 1.5 H_b

$t_b = 3\ t_a$ (t is time far 50% consolidation)

$$T_V = \frac{C_V t}{H^2} \qquad C_V = \frac{T_V H^2}{t}$$

$$\frac{C_{Va}}{C_{Vb}} = \left[\frac{T_a}{T_b}\frac{H_a^2}{H_b^2}\frac{t_b}{t_a}\right] \qquad T_a = T_b = T_{50} \text{ (Time factor)}$$

$$\frac{C_{Va}}{C_{Vb}} = (1.5)^2 \times 3 = 6.75$$

$$C_V = \frac{K}{\gamma_w m_V} \qquad m_V = \frac{\Delta e}{\overline{\Delta\sigma}(1+e_o)}$$

$$\frac{C_{Va}}{C_{Vb}} = \frac{K_a}{K_b}\frac{m_{Vb}}{m_{Va}}$$

$$\frac{m_{Va}}{m_{Vb}} = \left(\frac{\Delta e_a}{\Delta e_b}\right)\left(\frac{\overline{\Delta\sigma_b}}{\overline{\Delta\sigma_a}}\right)\left(\frac{1+e_{ob}}{1+e_{oa}}\right)$$

$$= \left(\frac{0.067}{0.053}\right)\left(\frac{1+0.61}{1+0.572}\right) = 1.29$$

$$\frac{C_{Va}}{C_{Vb}} = \frac{K_a}{K_b}\frac{m_{Vb}}{m_{Va}}$$

$$\frac{K_a}{K_b} = \left(\frac{C_{Va}}{C_{Vb}}\right)\left(\frac{m_{Va}}{m_{Vb}}\right) = 6.75 \times 1.29 = 8.7$$

Ratio is 8.7 : 1

08(b).

Sol: First specimen:

d = 5 cm

Initial area $A_1 = \frac{\pi \times 5^2}{4} = 19.63 cm^2$

Initial volume $V_1 = 19.63 \times 10$

$= 196.35\ cm^3$

$\Delta L_1 = 0.5$ cm

$\Delta V_1 = 1.5\ cm^3$

Area of failure, $A_2 = \frac{V + \Delta V}{L - \Delta L} = \frac{196.35 + 1.5}{10 - 0.5} = 20.83\ cm^2$

Deviatric stress at failure

$\sigma_d = \frac{750}{20.83} = 36\ N/cm^2 = 360\ kN/m^2$

$\sigma_3 = \sigma_c = 100\ kN/m^2$

$\sigma_1 = 360 + 100 = 460$ kPa

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

$460 = 100 \tan^2 \alpha_f + 2C \tan \alpha_f \rightarrow (1)$

Second specimen:

$\Delta L_2 = 0.75$ cm

$\Delta V_2 = 1.8$ m*l*

$A_f = \frac{V + \Delta V}{L - \Delta L} = \frac{196.35 + 1.8}{10 - 0.75} = 21.42\ cm^2$

$\sigma_d = \frac{Q_f}{A_f} = \frac{1000}{21.42} = 46.68\ N/cm^2$

$= 466.81\ kN/m^2$

$\sigma_3 = \sigma_c = 200\ kN/m^2$

$\sigma_1 = \sigma_c + \sigma_d = 666.81\ kN/m^2$

$666.81 = 200\tan^2\alpha_f + 2c\tan\alpha_f \rightarrow (2)$

$460 = 100\tan^2\alpha_f + 2c\tan\alpha_f \rightarrow (1)$

(–) (–) (–)

$266.81 = 100\tan^2\alpha_f$

$\tan\alpha_f = 1.633$

$\alpha_f = 58.52^o$

$45 + \frac{\phi}{2} = 58.52^o$

$\phi = 27.05^o$

From (1) $460 = 266.81 + 2C \times 1.633$

$\therefore C = 59.15$ kPa

08(c). (i)

Sol: Potassium permanganate ($KMnO_4$) is used as a popular disinfectant for disinfecting well water supplies in villages which are generally contaminated with lesser amounts of bacteria. Besides killing bacteria, it also helps in oxidising the taste producing organic matter. It is therefore, sometimes added in small doses (such as 0.05 to 10 mg/L) even to filtered and chlorinated water. It has also been used as an algicide and for removing colour and iron from water.

For treating well water supplies, small amount of potassium permanganate is dissolved in a bucket of water and is mixed with well water, thoroughly. The addition of potassium permanganate to water produces pink colour. However, if the pink colour disappears, it shows that organic matter is present in water, and more quantity of $KMnO_4$ should be added until the pink colour stands. The well should not be used for at least 48 hours after the addition of $KMnO_4$. The normal doses of this disinfection varies between 1 to 2 mg/L with a contact period of 4 to 6 hours.

$KMnO_4$ though cheap, handy and quite useful, yet cannot guarantee 100% removal of bacteria. It can remove about 98% bacteria. It can possibly remove 100% organisms causing cholera, but is of little use against other disease organisms. Moreover, the water treated with $KMnO_4$, with the passage of time, produces a dark brown precipitate, which is noticeable as a coating on porcelain vessels and is difficult to remove without scouring this method of disinfection is therefore not satisfactory and not recommended except for rural areas.

08(c). (ii)

Sol: (a) Cl_2 dose = 1 mg/L

pH = 7

Ionization constant, $k_i = 2.7 \times 10^{-8}$ mol/lit

$$\%HOC\ell = \frac{1}{1+\frac{k}{[H^+]}} \times 100$$

$$= \frac{1}{1+\frac{2.7\times10^{-8}}{10^{-7}}} \times 100 = 78.7\%$$

Concentration of HOCl = 1 × 78.7 = 78.7 mg/L

at pH = 8

$$\%HOC\ell = \frac{1}{1+\frac{k_i}{[H^+]}} \times 100$$

$H^+ = 10^{-8}$

$$\%HOC\ell = \frac{1}{1+\frac{2.7\times10^{-8}}{10^{-8}}} \times 100 = 27.2$$

(Cl_2 dose × HOCl) @ 8 = (Cl_2 dose × HOCl) @ 8

1 × 78.7 = Cl_2 dose @ 8 × 27.02

Cl_2 dose = 2.91 mg/L

(b) Taking pH as constant

$c^{1.5}t = \mu$

$$c_1^{1.5} \times t_1 = c_2^{1.5} \times t_2$$

$$c_1^{1.5} \times 15 = (1)^{1.5} \times t_2$$

$(2.92)^{1.5} \times 15 = (1)^{1.5} \times t_2$

∴ Contact time = 74.845