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# ESE 2019 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

## Civil Engineering

### Test-1: Geo-technical & Foundation Engg. + Environmental Engg.

Name : .. .....

Roll No : C E 1 9 M T D L A 6 6 8

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**Student's Signature**

**Instructions for Candidates**

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. Answer must be written in English only.
3. Use only black/blue pen.
4. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
5. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
6. Last two pages of this booklet are provided for rough work. Strike off these two pages after completion of the examination.

**FOR OFFICE USE**

| Question No. | Marks Obtained |
|---|---|
| Section-A | |
| Q.1 | 56 |
| Q.2 | 54 - 6 = 48 |
| Q.3 | |
| Q.4 | 29 |
| Section-B | |
| Q.5 | 14 |
| Q.6 | |
| Q.7 | |
| Q.8 | 46 |
| **Total Marks Obtained** | 199 - 6 = (193) |

Signature of Evaluator ..... Cross Checked by .....

Your Accuracy 15 good.
Try to improve theory.

## Section A : Geo-technical & Foundation Engineering

**Q.1 (a)** A core-cutter of diameter 100 mm and height 130 mm having weight 1.5 kg was pushed into embankment under construction and mass of core cutter with soil was found to be 3.865 kg. The soil has water content of 11% and specific gravity of soil is 2.67. Determine the bulk unit weight, dry unit weight and void ratio of soil sample. The unit weight of water is 9.81 kN/m$^3$.

**[12 marks]**

Given: core - cutter

$D = 100mm$ $W_1 = 1.5kg$ → Mass of core cutter

$H = 130mm$ $W_2 = 3.865\ kg$ → Mass of core cutter + soil

$w = 11\%$ $G = 2.67$

Find $\gamma_t = ?$ $\gamma_d = ?$ $e = ?$ $\gamma_w = 9.81\ kN/m^3$

$$V = \frac{\pi}{4} \times D^2 \times H = \frac{\pi}{4} \times 0.1^2 \times 0.13 = 1.021 \times 10^{-3}\ m^3$$

$$M = W_2 - W_1 = 3.865 - 1.5 = 2.365\ kg$$

$$\gamma_t = \frac{M}{V} = \frac{2.365}{1.021 \times 10^{-3}} = 2316.36\ kg/m^3$$

or $22.72\ KN/m^3$ Ans

$$\gamma_d = \frac{\gamma_t}{1+w} = \frac{22.72}{1+0.11} = 20.47\ KN/m^3$$ Ans

$$e = \frac{G\gamma_w}{\gamma_d} - 1 = \frac{2.67 \times 9.81}{20.47} - 1 = 0.280$$ Ans

92

**Q.1 (b)** $\overline{CU}$ tests carried out on a saturated normally consolidated clay showed that $C_u = 0$ and $\phi_u = 15°$. If the pore pressure coefficient A at failure was 0.92, what are the values of $c'$ and $\phi'$ for the soil?

**[12 marks]**

Given Cu test Saturated NC clay $c_u = 0$

$\phi_u = 15°$

$A = 0.92$ $c'$ & $\phi'$

Soil → Fully saturated $B = 1$

$$\Delta u = B[\Delta\sigma_3 + A[\Delta\sigma_1 - \Delta\sigma_3]]$$

$\Delta\sigma_3 = 0$, $B = 1$ $u_i = 0$ (as Consolidated under drained condition)

$$u_f - u_i = 0.92[\Delta\sigma_d]$$

$$u_f = 0.92 \times \Delta\sigma_d$$

$\sigma_1' = \sigma_3' \tan^2(45 + \phi'/2)$

$\sigma_1 = \sigma_3 \tan^2(45 + \phi'/2)$

$\sigma_1 = \sigma_3 \tan^2(52.5)$

$c' = 0$, For Normally consolidated clay

$\sigma_d = \sigma_1 - \sigma_3$

$U_f = 0.92[\sigma_1 - \sigma_3]$

$U_f = 0.92[1.698 - 1]\sigma_3$

$U_f = 0.642\,\sigma_3$

$\sigma_1 = \sigma_3 \times 1.698$

$(\sigma_1 - U_f) = (\sigma_3 - U_f)\tan^2(45 + \phi'/2)$

$(1.698 - 0.642)\sigma_3 = (1 - 0.642)\sigma_3 \tan^2(45 + \phi'/2)$

$1.056 = 0.358 \tan^2(45 + \phi'/2)$

$\phi' = 29.58°$ Ans

$c' = 0$

(12)

**Q.1 (c)** Compare the salient features of Standard Penetration Test and Plate Load Test. **[12 marks]**

| | SPT Test (Standard Penetration Test) | Plate Load Test |
|---|---|---|
| Nature of Test | Dynamic Test (i.e. Dynamic or Impact Load is applied) | Static Test (i.e static Pressure is applied till Failure or Permissible Settlement. |
| Suitability | Suitable For cohesionless soils | Suitable For Both Cohesive & cohesionless Soils |
| Apparatus | → Hammer 65 Kg | Plate → Mild steel ϕ → 300 – 750mm |
| Use | Correlation to $R_D$ (Relative density) & $\phi'$ & Bearing capacity | Find Bearing Capacity of Foundation Settlements at Particular Loading Intensity |

Test Procedure

Calculation

N → No. of Blows For 300mm penetration is calculated.

neglected first 150mm penetration below

Formula:-

| N | $R_D$ |
|---|---|
| 0–4 | Very loose |
| 4–10 | Loose |
| 10–30 | Medium Dense |
| 30–50 | Dense |
| >50 | Very Dense |

Teng's Equation

$$q_{all} = 1.4(N-3) S_w C_d C_D \left[\frac{B+0.3}{2B}\right]^2$$

Calculation

Load Applied → Noted

Settlement → Noted

Graph is Plotted Between them.

Formula:-

$$S_f = S_p \left\{\frac{B_f[B_p+0.3]}{B_p[B_f+0.3]}\right\} \rightarrow \text{cohesionless soil}$$

$$S_f = S_p \frac{B_f}{B_p} \rightarrow \text{cohesion soil}$$

$$\frac{q_{uf}}{q_{up}} = \frac{B_f}{B_p} \rightarrow \text{cohesionless soil}$$

$$q_{uf} = q_{up} \rightarrow \text{clay soil}$$

$$\textcircled{C} + 2 = 8$$

Q.1 (d) (i) What quantity of cement per $m^3$ of soil is required for permeation grouting in soil, having void ratio of 0.6, if the grout mix has a water cement ratio of 6 : 1 by weight? Assume that 50% of the void space gets filled with the grout slurry. Take specific gravity of cement as 3.15.

(ii) Grouting is to be carried out in 12 m deep grout holes spaced at 3 m distance center to center for the problem discussed in (i) above. What will be the saving per group hole if 50% cement is replaced by Bentonite, given that the cost of cement is ₹ 250 per kN and that of Bentonite is ₹ 120 per kN? Assume that grout will permeate uniformly around each group hole, the volume soil grouted will be a cylinder of diameter 3 m around each grout hole.

**[6 + 6 = 12 marks]**

(i) Find cement = ? per $m^3$ of soil

$e = 0.6$ (soil)

Grout Mix $w/c \rightarrow 6:1$ by weight.

50% void space → filled with grout slurry

$G = 3.15$

$1\,m^3$ = soil

$\frac{V_v}{V} = n$

$n = \frac{e}{1+e} = \frac{0.6}{1+0.6} = 0.375$

$V_v = 0.375 \times 1 = 0.375\,m^3$

$V_1$ → volume of cement grout $= 0.5 \times 0.375 = 0.1875\,m^3$

~~$M_1$ (cement)~~ = $\frac{d_0}{-}$

w : c

6 : 1 (By Mass)

$\frac{6}{1} : \frac{1}{3.15}$ (By volume) ($\because \rho = \frac{M}{V}$)

18.9 : 1 (By volume $\frac{M}{G\rho_w}$)

Volume of cement = $\frac{1}{18.9} * 0.1875$

Volume of cement = 9.422 litre / $m^3$ of soil

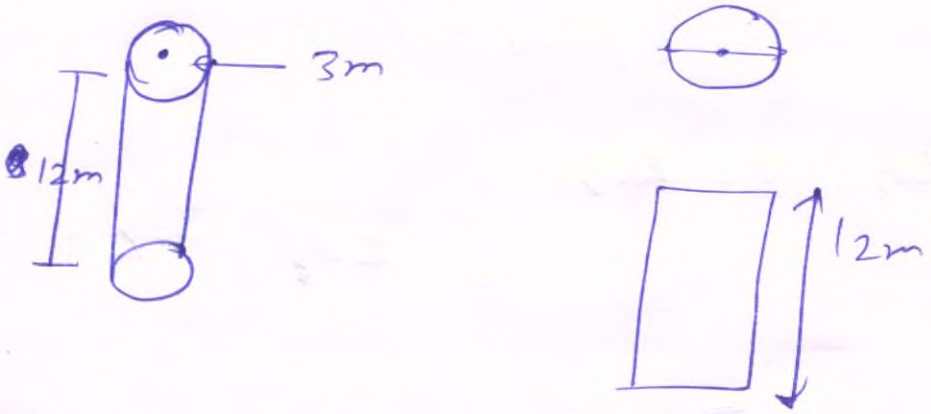
Ans

(6) Mass of cement = $9.422 \times 10^{-3} \times 3.15 \times 1000$

Mass of cement = 29.679 Kg

(11) D = 12m Deep grout

S = 3m




For $V_2 = \frac{\pi}{4} \times 3^2 \times 12 = 84.823\ m^3$

Mass of cement required = 84.823 × 29.679 = 2517.46 Kg

or 24.696 KN (ie 2517.46 × 9.81)

Cost of cement ($C_1$) = 24.696 × 250

$C_1$ = ₹ 6174.07

(6) Now 50% cement is replaced with Bentonite.

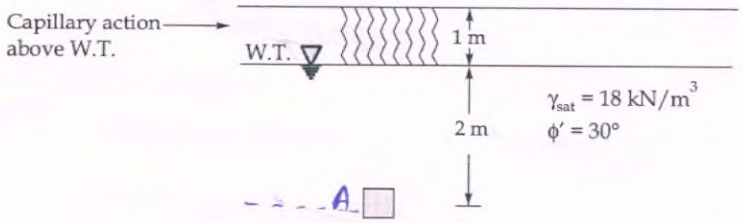
$C_2$ = 24.696 × 0.5 × 250 + 24.696 × 0.5 × 120

$C_2$ = ₹ 4568.76

Saving $C_1 - C_2$ = 6174.07 − 4568.76

Saving = ₹ 1605.31 per Group holes

**Q.1 (e)** The soil profile at a site for a proposed building is shown in figure.




The soil is a homogeneous, poorly graded sand. Determine, the increase in vertical effective stress at which a soil element at a depth of 3 m, under the center of the building will fail if the increase in lateral effective stress is 20% of the increase in vertical effective stress. The coefficient of lateral earth pressure at rest $k_0$ is 0.5. Assume all stresses are principal stresses.

**[12 marks]**

Given:-

Soil → Homogeneous, poorly graded sand.

$\Delta\sigma_h = 0.2\,\Delta\sigma_v$

$K_0 = 0.5$ i.e. $\Delta\sigma_3 = 0.2\,\Delta\sigma_1$

At AA before loading

$(\bar{\sigma_1})_1 = 18 + (18 - 9.81) \times 2 = 34.38\ kN/m^2$

$(\bar{\sigma_3})_2 = 0.5 \times 34.38 = 17.19\ kN/m^2$

Now At AA after loading

$(\bar{\sigma_1})_2 = (\bar{\sigma_1})_1 + \Delta\bar{\sigma_1}$

$(\bar{\sigma_3})_2 = (\bar{\sigma_3})_1 + \Delta\bar{\sigma_3}$

$(\bar{\sigma_1})_2 = 34.38 + \Delta\bar{\sigma_1}$

$(\bar{\sigma_3})_2 = 17.19 + 0.2\,\Delta\bar{\sigma_1}$

$$\frac{\sigma_1 - \sigma_3}{\sigma_1 + \sigma_3} = \sin\phi$$

$$\frac{(\bar{\sigma}_1)_2 - (\bar{\sigma}_3)_2}{(\bar{\sigma}_1)_2 + (\bar{\sigma}_3)_2} = \sin\phi$$

$$\frac{34.38 - 17.19 + 0.8\Delta\bar{\sigma}_1}{34.38 + 17.19 + 1.2\Delta\sigma_1} = \sin 30$$

$$\frac{17.19 + 0.8\Delta\bar{\sigma}_1}{51.57 + 1.2\Delta\bar{\sigma}_1} = 0.5$$

17

~~$17.19 - 0.5 \times 51.57 = 1.4\Delta\bar{\sigma}_1$~~

$\Delta\bar{\sigma}_1 = 42.975\ kN/m^2$ Ans

Increase in vertical effective stress at which soil fails

Q.2 (a) **(i)** Consider the following options:

*(i)* Constructing a cofferdam and casting the concrete in situ.

*(ii)* Floating a prefabricated box caisson and lowering it is to the bearing stratum.

*(iii)* Sinking a well foundation and plugging it.

Which of the above options would be most appropriate for constructing a 10 m wide foundation on a strong bearing stratum beneath a river bed for the following three cases?

**Case A :**

Depth of water above bed = 2 m, depth of strong bearing stratum below bed = 2 m.

**Case B :**

Depth of water above bed = 20 m, depth of strong bearing stratum below bed = 3 m.

**Case C :**

Depth of water above bed = 10 m, depth of strong bearing stratum below bed = 20 m.

**(ii)** A new canal is excavated to a depth of 5 m below ground level, through a soil having the following characteristics : $c = 14\ kN/m^2$, $\phi = 15°$, $e = 0.8$ and $G = 2.7$. The slope of banks is 1 in 1. Calculate the factor of safety with respect to cohesion when the canal runs full. If it is suddenly and completely emptied, what will be the factor of safety? [Take, for $i = 45°$, $\phi = 15°$, $s_n = 0.083$ and for $i = 45°$, $\phi = 7.3°$, $s_n = 0.122$]

**[10 + 10 marks]**

Q.2 (b) **(i)** What are the differences between reinforced soil walls and nailed soil walls?

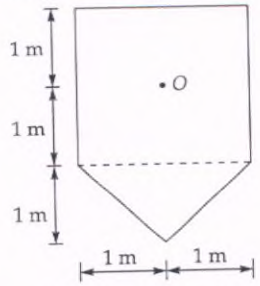
**(ii)** A foundation trench is to be excavated for a large project in a site. The soil investigation report shows the following details :

| Depth from Ground Surface | Type of soil | Index Properties |
|---|---|---|
| 0 - 8 m | Fine sand | Void ratio = 1.20, Sp.gr. = 2.62 |
| 8 - 10 m | Greyish clay | Void ratio = 0.76, Sp.gr. = 2.65 |
| Below 10 m | Coarse sand | -- |

It is observed that an open excavation is stable up to 5.75 m depth with the existing water table. The excavation is to be made up to 8.5 m depth for which water table is to be lowered. What are the initial and final depths of water table?

**[6 + 14 marks]**

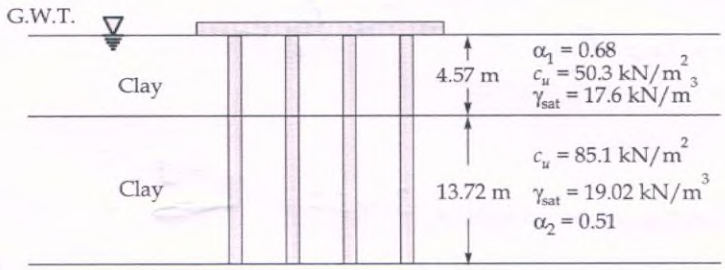
Q.2 (c) **(i)** Compute the vertical stress on a horizontal plane situated at a depth of 2 m below point O in the figure shown below. The area is loaded uniformly to an intensity of 300 kN/m$^2$. [Use Boussinesq's theory]




**(ii)** In an unconfined compression test, a sample of clay 100 mm long and 50 mm in diameter fails under a load of 200 N at 10% strain. Calculate the shear resistance of the soil sample by taking into account the effect of change in cross-section of the sample.

**[10 + 10 marks]**

**Q.3 (a)** The section of a 3 × 4 group pile in a layered saturated clay is shown in figure.

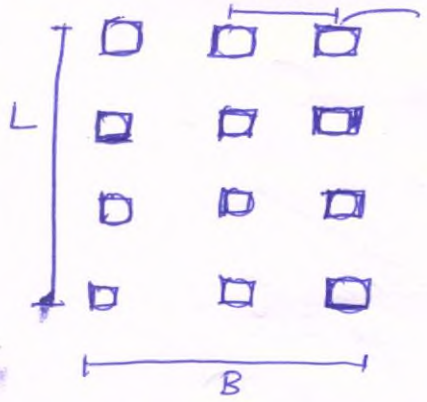



The piles are square in cross-section (356 mm × 356 mm). The center-to-center spacing, $d$ of the piles is 889 mm. Determine the allowable load carrying capacity of the pile group. Use FOS = 4.

[**Note :** Ground water table coincides with the ground surface. For group action of piles take $N_c = 8.57$]

**[20 marks]**

889mm 0.356m FOS = 4




$B = 0.889 \times 2 + 0.356 = 2.134$ m

$L = 0.889 \times 3 + 0.356 = 3.023$ m

Consider Individual pile Failure

$Q_u = Q_{ps} + Q_f$

$Q_u = c N_c A_b + \alpha \bar{C_u} P \times L$

Assume $N_c = 8.57$ For Both cases $\bar{C_u} = C_u$

$Q_u = 85.1 \times 8.57 \times 0.356^2 + [0.51 \times 85.1 \times 4 \times 0.356 \times 13.72 + 0.68 \times 50.3 \times 4 \times 0.356 \times 4.57]$

For Individual pile Action $N_c = 9$

$Q_u = 1162.96$ KN

$n = 3 \times 4 = 12$

$Q_{ug} = n \times Q_u$

$Q_{ug} = 13955.52$ KN

Consider Block Failure

$Q_{ug_2} = cN_c A_g + \alpha \bar{c}_u P_g L$

$Q_{ug_2} = 85.1 \times 8.57 \times 2.134 \times 3.023 + 1 \times [85.1 \times 13.72 + 50.3 \times 4.57] \times 2 \times [2.134 + 3.023]$

$\eta = 1$ (Block Failure)

$Q_{ug_2} = 19118.05\ KN$

$Q_{ug}$ (min) $Q_{ug_1}$ 13955.52 KN

$Q_{ug_2}$ 19118.05 KN

$Q_{ug} = 13955.2\ KN$ (From Failure of individual single Pile)

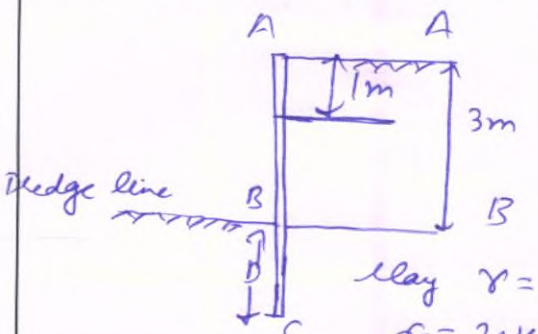
$Q_s = \frac{Q_{ug}}{FOS} = \frac{13955.2}{4} = 3488.8\ KN$ Ans

□ → We have not considered circle circumscribing effect

14 − 4 = 10

**Q.3 (b)** An anchored sheet pile supports a sandy back fill of height 3 m having angle of shearing resistance of 30° and unit weight of 19 kN/m$^3$. The soil below dredge line is clay with a unit weight of 19 kN/m$^3$, cohesion 20 kN/m$^2$ and zero angle of internal resistance. The anchor rods are placed 1 m apart and 1 m below the level surface of the backfill. Assuming free earth support, calculate the force in anchor and the depth of sheet pile. Use Rankine's theory for earth pressure.

**[20 marks]**




Sand $\phi = 30°$

$\gamma = 19\ kN/m^3$

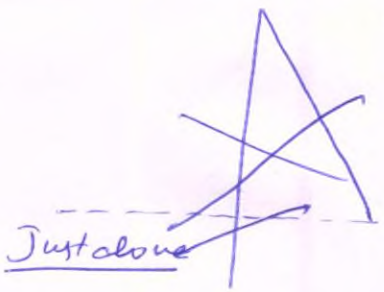
clay $\gamma = 19\ kN/m^3$

$C_u = 20\ kN/m^2$ $\phi_u = 0$

Free Earth support

Assume WT at greater Depth

Assume Free Earth support




At A – A

$p_a = 0$

$K_{a_1} = \frac{1-\sin\phi}{1+\sin\phi}$

At B B

$K_{a_1} = \frac{1-\sin 30}{1+\sin 30}$

$p_a = \frac{1}{3} \times 19 \times 3 = 19\ kN/m^2$ $K_{a_1} = \frac{1}{3}$

Just Below

$p_a = 19 \times 3 - 2 \times 20$

$p_a = 17\ kN/m^2$ $K_{a_2} = 1$

At C C

$p_a = K_a q - 2c\sqrt{K_a}$

$p_a = [19 \times 3 + 19 \times D] - 2 \times 20$

$p_a = 17 + 19 \times D$ kN/m$^2$

At B B

$p_p = K_p q + 2c\sqrt{K_p}$ $\qquad K_p = \frac{1}{K_a} = 1$

$p_p = 0 \times 1 + 2 \times 20 \times 1$

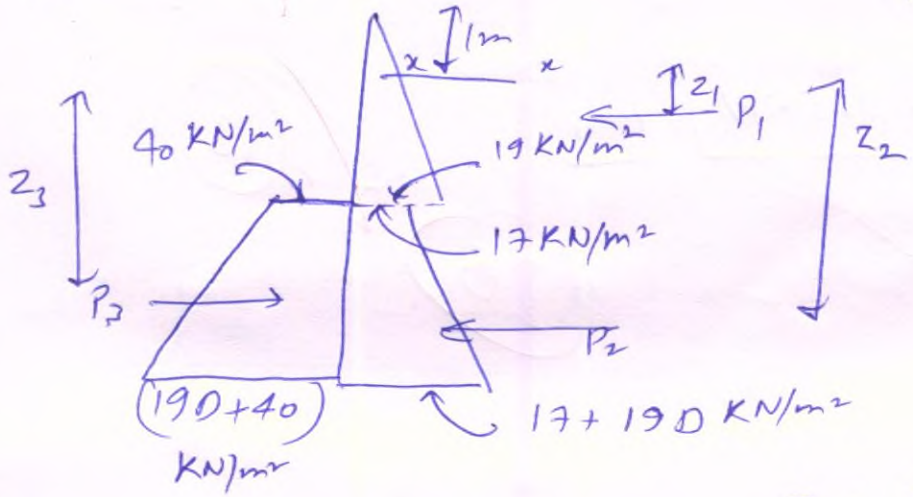
$p_p = 40$

At C C

$p_p = 19 \times D + 2 \times 20$

$p_p = 19D + 40$

The Moment about x-x equal to zero




$P_1 = 0.5 \times 3 \times 19 = 28.5$

$P_2 = 0.5 [17 + 17 + 19D] \times D$

$P_3 = 0.5 [40 + 19D + 40] \times D$

$z_1 = 3 \times \frac{2}{3} - 1$

$z_1 = 1$

$z_2 = 2 + \left[\frac{17 + 2(17+19D)}{[17+17+19D]}\right] \times \frac{D}{3}$

$z_3 = 2 + \left[\frac{40 + 2 \times (19D+40)}{40 + 19D + 40}\right] \times \frac{D}{3}$

$P_1 \times z_1 + P_2 z_2 = P_3 z_3$

$28.5 \times 1 + 0.5D[34 + 19D] \times \left[2 + \left[\frac{51 + 38D}{34 + 19D}\right] \times \frac{D}{3}\right]$

$= 0.5D[80 + 19D] \times \left[2 + \left[\frac{120 + 38D}{80 + 19D}\right] \frac{D}{3}\right]$

$D = 0.545\ m$ Ans  Depth of Embedment

Total depth $3.545$

Force in Anchor

$P_1 + P_2 - P_3 = P_a$

$28.5 + 0.5[17 + 17 + 19 \times 0.545] \times 0.545$

$- 0.5[40 + 19 \times 0.545 + 40] \times 0.545 =$

$P_a = 15.965\ KN$ Ans

20 2 18

**Q.3 (c)** A light weight building stands over a 10 m thick stratum of sand. Beneath the sand stratum a clay layer of 5 m thick exists. The clay layer is underlain by a rock stratum. The water table lies at a depth of 1.0 m below ground surface and the sand above the water table is saturated with capillary rise. The sand has a void ratio of 0.75 and sp. gravity 2.65. During dry season, water is pumped out from the sand stratum till the water table is lowered by 4.0 m and sand above water table becomes dry.

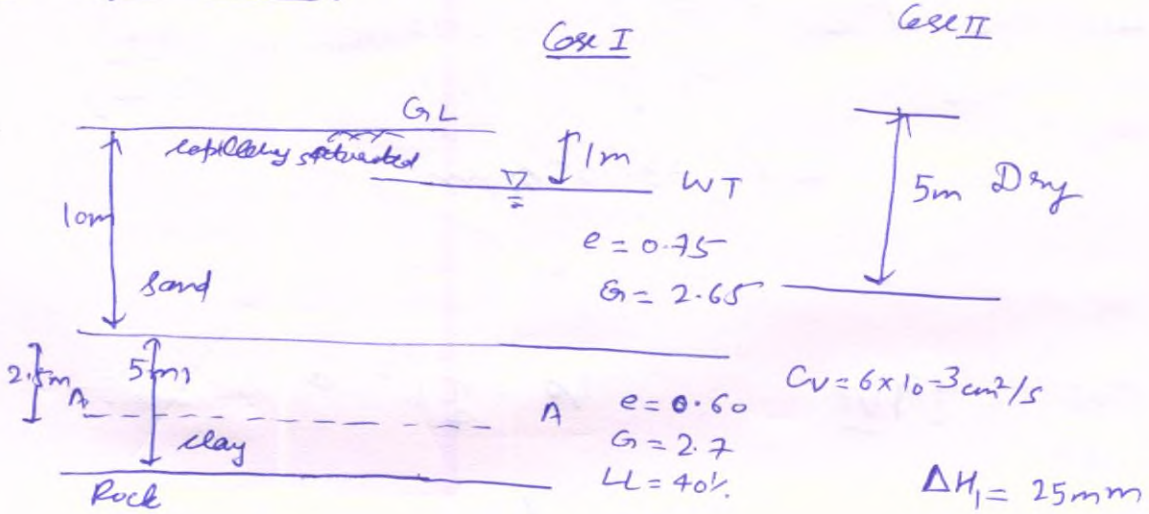
Calculate the number of days when the building settles by 25 mm. Ignore settlement during pumping operation.

Take properties of clay : Void ratio = 0.60, Specific gravity = 2.70, Liquid limit = 40%, Coefficient of consolidation = $6 \times 10^{-3}$ cm$^2$/s.

**[20 marks]**

Given:-

Light weight Building → means ignore weight of building.




clay:- Assum clay is NC

$C_c = 0.009[LL - 10]$

$C_c = 0.009[40 - 10] = 0.27$

$\gamma_{sub} = \left(\frac{G-1}{1+e}\right)\gamma_w = \frac{2.7-1}{1+0.6} \times 9.81 = 10.42\ KN/m^3$

Sand

$\gamma_d = \frac{G\gamma_w}{1+e} = \frac{2.65 \times 9.81}{1+0.75} = 14.86\ KN/m^3$

$\gamma_{sat} = \left(\frac{G+e}{1+e}\right)\gamma_w = \left[\frac{2.65+0.75}{1+0.75}\right] \times 9.81 = 19.06\ KN/m^3$

$\gamma_{sub} = \left(\frac{G-1}{1+e}\right)\gamma_w = \left(\frac{2.65-1}{1+0.75}\right) \times 9.81 = 9.25\ KN/m^3$

Before Pumping

$\bar{\sigma_1} = 19.06 \times 1 + 9 \times 9.25 + 2.5 \times 10.42$

$\bar{\sigma_1} = 128.36\ KN/m^2$

After Pumping

$\bar{\sigma_2} = 14.86 \times 5 + 5 \times 9.25 + 2.5 \times 10.42$

$\bar{\sigma_2} = 146.6\ KN/m^2$

$$\Delta H = \frac{C_c}{1+e_0} H \log_{10}\left(\frac{\bar{\sigma_2}}{\bar{\sigma_1}}\right) = \frac{0.27}{1+0.6} \times 5000 \log_{10} \frac{146.6}{128.36}$$

$\Delta H = 48.69\ mm$

$$\frac{Cvt}{H^2} = [Tv] \qquad Tv = \frac{\pi}{4} U^2 \ @\ U \le 60\%$$

$$U = \frac{\Delta H_1}{\Delta H} = \frac{25}{48.69} \times 100$$

$U = 51.35\%$

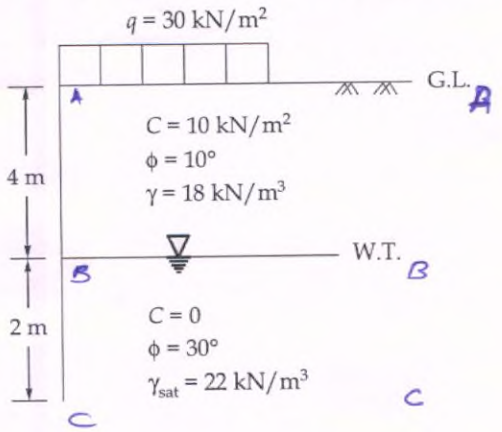
$$\frac{6 \times 10^{-3} \times 10^{-4} \times t}{5^2} = \frac{\pi}{4} \times (0.5135)^2 \quad \text{(single drainage)}$$

$$t = \frac{\pi}{4} \times \frac{(0.5135)^2 \times 5^2}{6 \times 10^{-7}} \times \frac{1}{3600 \times 24}$$

$t = \boxed{99.87\ days}$ Ans

20

**Q.4 (a)** Calculate the total active earth pressure on the retaining wall 6 m high as shown in the figure. Also calculate the line of action of the lateral force from the base of the wall.




**[20 marks]**

$$K_{a_1} = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-\sin 10}{1+\sin 10} = 0.704$$

$$K_{a_2} = \frac{1-\sin 30}{1+\sin 30} = \frac{1}{3}$$

At A-A $\qquad p_a = K_a q - 2c\sqrt{K_a}$

$$p_a = 0.704 \times 30 - 2 \times 10 \times \sqrt{0.704} = 4.339 \text{ kN/m}^2$$

~~$p_a = 0$~~ $\qquad$ ~~$z_0 = \frac{2c}{\gamma\sqrt{K_a}}$~~

~~$z_0 = \frac{2\times 10}{18\times\sqrt{0.704}} = 1.324$ m~~

~~$z_c = 2z_0 = 2.648$ m~~

At B B Just Above

$$p_c = 0.704 \times [30 + 18 \times 4] - 2 \times 10 \times \sqrt{0.704}$$

$$p_c = 55.027 \text{ kN/m}^2$$

Just Below

$$p_a = \frac{1}{3} \times [30 + 18 \times 4] - 2 \times 0 \times \sqrt{0.704}$$

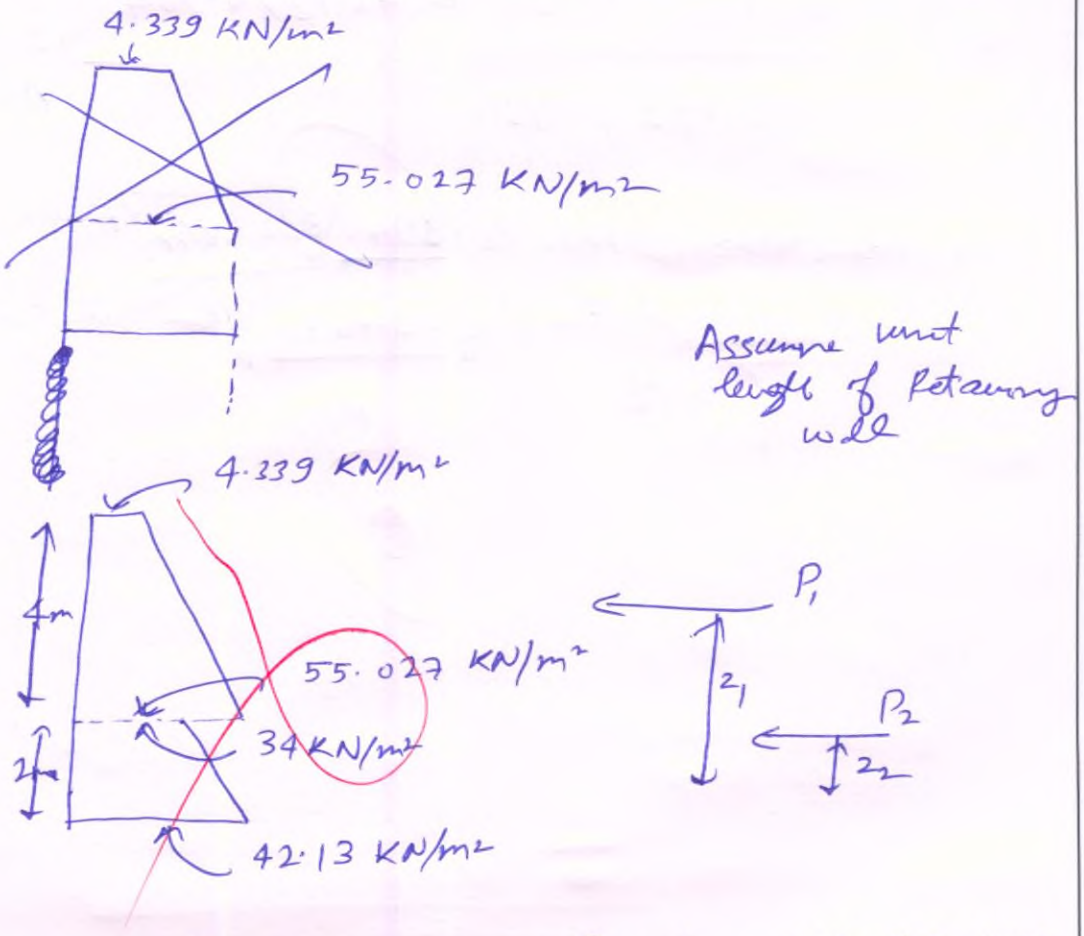
$$p_a = 34 \text{ kN/m}^2$$

$C = 0$

At CC

$$\phi_c = \frac{1}{3}\left[30 + 18\times 4 + (22 - 9.81)\times 2\right]$$

$$\phi_c = 42.13 \text{ KN/m}^2$$




Assume unit length of Retaining wall

$$P_1 = 0.5\times\left[4.339 + 55.027\right]\times 4 = 118.732 \text{ KN/m}$$

$$P_2 = 0.5\times\left[34 + 42.13\right]\times 2 = 76.13 \text{ KN/m}$$

$$P_a = P_1 + P_2 = \boxed{194.862 \text{ KN/m}} \quad \text{Ans}$$

$$z_1 = 2 + \frac{4.339\times 2 + 55.027}{4.339 + 55.027}\times\frac{4}{3} = 3.431 \text{ m}$$

$$z_2 = \frac{34\times 2 + 42.13}{34 + 42.13}\times\frac{2}{3} = 0.964 \text{ m}$$

$$\bar{z} = \frac{P_1 z_1 + P_2 z_2}{P_1 + P_2}$$

$$\bar{z} = \frac{118.732 \times 3.431 + 76.13 \times 0.964}{118.732 + 76.13} = 2.467\text{m}$$ Ans

Total Active Pressure Force $P_a$ = 194.862 kN/m Ans

∴ act at a distance of 2.467m from Bottom of wall Ans

10

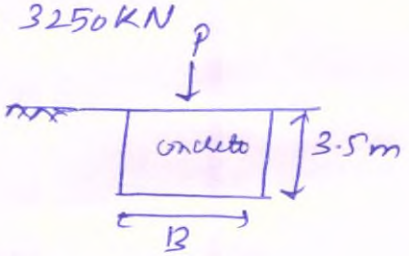
**Q.4 (b)** A square mass concrete in footing usually implies raft concrete footing supporting a load of 3250 kN extends from ground level to 3.5 deep into a clay stratum. What will be the size of the footing allowing for a factor of safety of 4? Unit weight of concrete is 25 kN/m$^3$. Unit weight of soil 21 kN/m$^3$. Cohesion of soil 0.12 N/mm$^2$. Adhesion of clay with footing is 25 kN/m$^2$. The adhesion may be supposed to act over a depth of 2 m from the bottom of the foundation. For $\phi = 0°$, $N_C = 5.7$, $N_q = 1$, $N_\gamma = 0$

**[20 marks]**

Given:-

Square Mass concrete Footing → Raft concrete footing

$P = 3250\,kN$




clay stratum

$FOS = 4$

$\gamma_c = 25\,kN/m^3$

$\gamma = 21\,kN/m^3$

$C_u = 0.12\,N/mm^2$

$C_u = 0.12 \times 1000\,kN/m^2$

$C_u = 120\,kN/m^2$

$\phi = 0°$

$N_c = 5.7,\ N_q = 1,\ N_\gamma = 0$

Assume water Table at greater Depth

Adhesion $= 25\,kN/m^2$

$D = 2m$ from bottom

Assume $3250\,kN \rightarrow$ ~~net~~ external allowable load

$$q_{nu} = 1.3cN_c + q(N_q - 1) + 0.4B\gamma N_\gamma$$

($N_q \rightarrow 1$, $N_\gamma \rightarrow 0$)

$$q_{nu} = 1.3cN_c$$ (From Terzaghi's Theory)

~~[illegible]~~

$$q_s = q_{ns} + \gamma D_f$$

$$\frac{P}{B^2} + [\gamma_c] \times D_f = q_{ns} + \gamma D_f$$

~~$q_{ns} = \frac{1.3cN_c + 25}{FOS}$~~ ~~Adhesion (not)~~

$q_{net\ effective} = \frac{1.3cN_c + \frac{25 \times 2}{B}}{FOS}$

$\frac{3250}{B^2} + 25 \times 3.5 = 1.3 \times 120 \times 5.7 + 25$

$q_{net\ effective} = 1.3cN_c + \frac{25 \times 2 \times 4 \times B}{B^2}$

$q_{ns} = \frac{1.3cN_c + \frac{25 \times 2 \times 4}{B}}{4}$

Apply FOS to both & calculate Adhesion from Terzaghi's theory

(8)

$\frac{3250}{B^2} + 25 \times 3.5 = \frac{1.3 \times 120 \times 5.7 + \frac{25 \times 2 \times 4}{B}}{4} + 21B.5$

$B = \boxed{3.832\,m}$

Ans Adopt $B = \boxed{3.9\,m}$

Safe Gross Bearing Pressure = Safe Gross Bearing Capacity

**Q.4 (c)** **(i)** Draw contact pressure distribution under the following cases:

*(a)* Rigid footing on cohesionless soil at shallow depth.

*(b)* Rigid footing on cohesive soil.

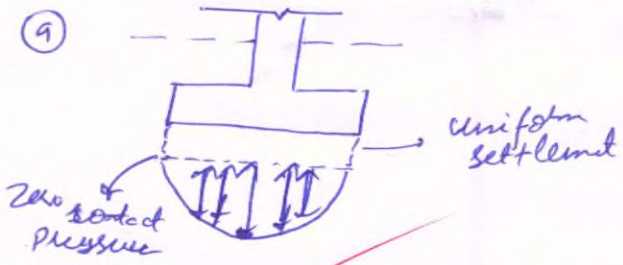
*(c)* Rigid footing on cohesionless soil at deeper depth.

**(ii)** Find an expression for the unconfined compressive strength $q_u$ in terms of $c'$, $\phi'$ and $A_f$ (pore pressure parameter at failure). Take parameter $B = 1$ and initial capillary tension = $U_c$.

**[5 + 15 marks]**

Contact Pressure Distribution

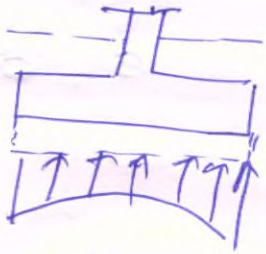
(a)




Rigid Footing on cohesionless soil at Shallow Depth

min at edges
max at centres

(b)



Rigid Footing of cohesive soil.

Max at ends, → contact
min at centre Pressure

3

(c)


Rigid Footing on cohesionless soil at deeper depth

$q_u = 2c_u \tan^2(45 + \phi_u/2)$

$q_u = \sigma_1$ $\quad \sigma_3 = 0$ (Unconfined compression Test)

Skempton's Pore Pressure Equation

$$U = A[B\sigma_3 + A(\sigma_1 - \sigma_3)]$$

$$\Delta U = B[\Delta\sigma_3 + A\Delta(\sigma_1 - \sigma_3)]$$

$\sigma_3 \to 0$

$$\Delta U = A_f \Delta\sigma_1$$

$B \to 1$ (For saturated soil)

$AB = A_f$ $\quad \Delta\sigma_3 = 0$

$B = 1$ $\quad A = A_f$ $\quad \Delta\sigma_3 = 0$

$\Delta\sigma_1 = q_u$

$v_f - (-v_c) = A_f \Delta\sigma_1$

$v_f + v_c = A_f q_u$

$\sigma_1' = \sigma_3^{0\prime} \tan^2(45 + \phi'/2) + 2c' \tan(45 + \phi'/2)$

$\sigma_3' = 0 - v_f$

$\sigma_3' = -v_f$

$\sigma_3 = 0$

$\sigma_3' = \sigma_3 - v_f$

$$\sigma_1' = \sigma_1 - u_f$$

$$\sigma_1' = q_u - u_f$$

$$q_u - u_f = (+u_f)\tan^2\left(45+\frac{\phi'}{2}\right) + 2c\tan\left(45+\frac{\phi'}{2}\right)$$

$$u_f = A_f q_u - u_c \qquad N_\phi = \tan^2\left(45+\frac{\phi'}{2}\right)$$

(2)

$$q_u - A_f q_u + u_c = [A_f q_u + u_c]\tan^2\left(45+\frac{\phi'}{2}\right) + 2c\tan\left(45+\frac{\phi'}{2}\right)$$

$$q_u[1 - A_f + A_f N_\phi] = u_c[N_\phi - 1] + 2c\sqrt{N_\phi}$$

$$q_u = \frac{u_c[N_\phi - 1] + 2c'\sqrt{N_\phi}}{[1 - A_f + A_f N_\phi]}$$ Ans

Desired Ans

## Section B : Environmental Engineering

**Q.5 (a)** State the salient features of a water supply scheme and also draw a flow chart for the same.

**[12 marks]**

Salient Features of water supply scheme :-

① Source selected should be reliable & uniform supply of water.
i.e. should provide water even in case of dry weather.

② ~~Source~~ ~~For~~ Water supplied should satisfy all IS Code Standard i.e IS 10500
i.e. 1st satisfy desirable standards if not possible satisfy permissible standard.
i.e water should be clean
" " " free of odour
free of colour

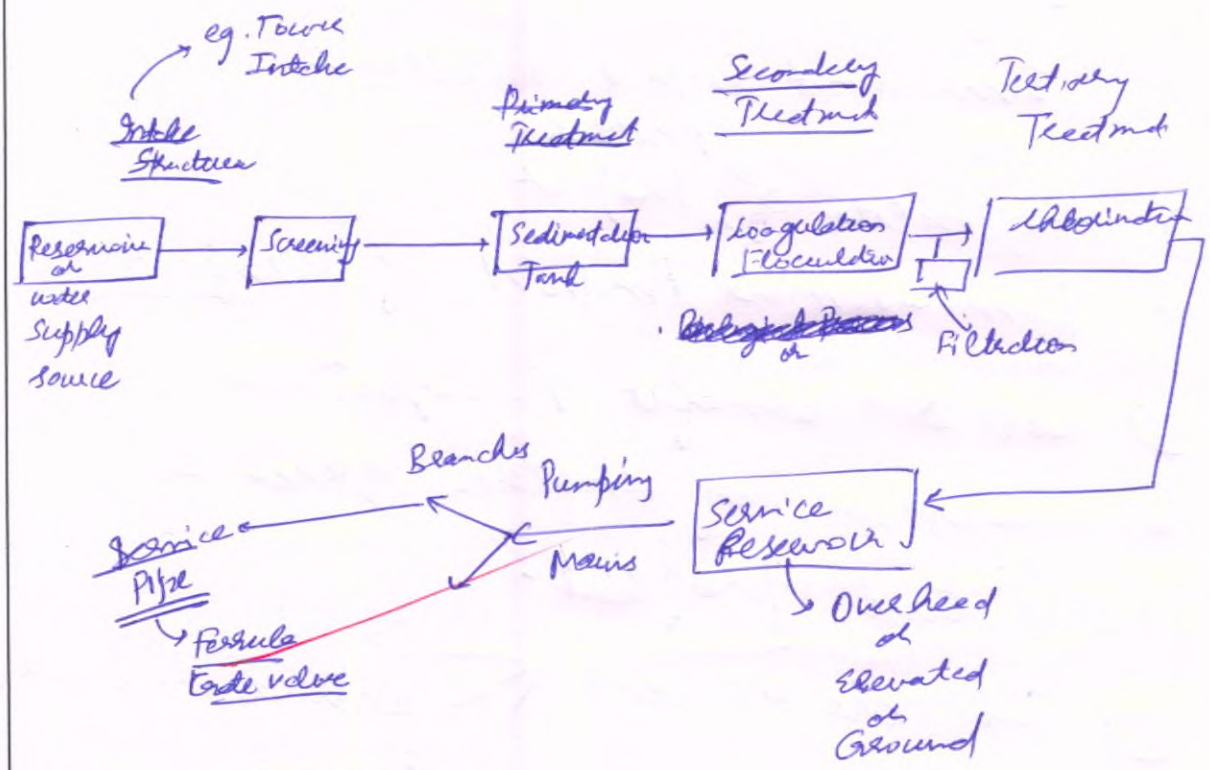
③ Water supplied should be free from contamination of ~~organic~~ Biological organisms

④ Location of Intake Structure should be such ~~that~~ that like ① upstream point of addition of effluent
② should be in deep water so as allow for throughout year availability

⑤ Location of source should be close to treatment plant to save costs

⑥ Water Supply scheme should provide minimum residual pressure at service connections.

⑦ There should be provision for Break-down & Fire Fighting measures




Flow chart → Water Supply Scheme

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Q.5 (b) Discuss the need of environmental impact assessment. Also discuss the environmental impact of thermal power plants.

**[12 marks]**

Need of EIA :-

↓

Environmt Impact Assessment

① Feasibility of Another Project

② Environmt Impact of Project

③ Cost & Benefit Analysis

④ Suggestion of another green & alternative project.

⑤ Take into account → Social, Environment cost, Economic

~~EIA~~ → Environment Impact of Thermal Power Plants :-

① Air pollution → Fly ash, SO2 etc.

② Thermal Pollution

③ Water Pollution

④ Contributes to Acid Rain

⑤ Land Degradation

4

**Q.5 (c)** Estimate the weight of net solids (sludge) produced per day in an activated sludge aeration system in which the influent BOD is reduced from 250 mg/$l$ to 30 mg/$l$. The flow, $Q$ = 4000 m$^3$/day; aeration tank volume = 700 m$^3$ and MLVSS = 3000 mg/$l$. Assume Y = 0.5, $K_d$ = 0.09/day. Also compute $\theta_c$ and F/M.

**[12 marks]**

~~$\theta_c = \frac{VX}{Q(\quad)}$~~

$X$ = MLVSS

$\frac{F}{M} = \frac{Q_o(S_o)}{VX}$

$Q_o = 4000 m^3/day$

$S_o = 250 mg/l$

$V = 700 m^3$

$X$ = MLVSS = 3000 mg/l

~~$\frac{F}{M} =$~~ $\frac{4000 \times 1000 \times 250 \times [\quad]}{700 X}$

$\frac{F}{M} = \frac{4000 \times 250}{700 \times 3000}$

$\frac{F}{M} =$ **0.476/day** Ans

Weight of net solids (sludge) produced per day

Approach I → Y based on BOD Applied

$Q_o S_o \times Y$

$4000 \times 1000 \times 250 \times 10^{-6} \times 0.5$

$=$ **500 kg/day** Ans

Approach II ~~Y based on~~ Based on BOD removed

$Q_o (S_o - S_e) Y$

$4000 \times 1000 [250 - 30] \times 10$

$=$ **440 kg/day** An

[illegible] =

$\theta_c = \frac{VX}{Q_u X_e}$

Sludge Age

[illegible]

**Q.5 (d)** What is shrouding of well? Explain with figure.

**[12 marks]**

Shrouding of well means opening of poles of well & well-strainer which may get clogged over period of time.

Done by :-

1. Jetting
2. Backwashing etc

Q.5 (e) A rectangular sewer with width 1.5 times its depth is hydraulically equivalent to a circular one. Find the relation between the width of the rectangular sewer and the diameter of the circular sewer.

**[12 marks]**

Given:-

Rectangular sewer

$B = 1.5y$

Circular sewer

$D$

$Q = \frac{1}{n} R^{2/3} S^{1/2}$ → Manning equation

For Hydraulic equivalence → on same slope & same surface characteristics.

Q Discharge should be same.

Assume → Circular sewer Running Full (For Uniform Flow case)

$\Rightarrow R_1 = R_2$

$Q_1 = Q_2$

(1) → Rectangle $\Rightarrow R_1 = R_2$

$R = \frac{A}{P}$

$R_1 = \frac{By}{B+2y}$

$R_2 = \frac{\pi D^2}{4 \times \pi D} = \frac{D}{4}$

$= \frac{D}{4}$

$\frac{B \times B}{1.5 \left[B + \frac{B \times 2}{1.5}\right]}$

$\Rightarrow \frac{B}{1.5 \left[1 + \frac{2}{1.5}\right]}$

$\frac{B}{3.5} = \frac{D}{4} \Rightarrow \boxed{B = \frac{7}{8} D}$ Ans

$\Rightarrow B = \frac{3.5}{} D$

Q.6 (a) **(i)** Demand of domestic water for a certain city is observed to follow the following pattern :

| Time (hr) | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Demand at the stated time ($m^3/s$) | 0.00 | 0.10 | 0.15 | 0.20 | 0.50 | 0.60 | 0.40 | 0.30 | 0.15 | 0.20 | 0.25 | 0.10 | 0 |

Assuming uniform rise or fall in demand in the successive time interval, calculate the minimum required capacity of service reservoir, if treated water supply by pumping is constant throughout the day.

**(ii)** Explain self cleansing velocity and non-scouring velocity and their importance in the design of sewers.

**[14 + 6 marks]**

Q.6 (b) (i) A sample of raw water contains, 200 mg/$l$ alkalinity, 50 mg/$l$ hardness as $CaCl_2$ and 75 mg/$l$ hardness as $MgSO_4$. Compute the quantities of lime and soda required to treat 1 million litres of water. If slaked lime of 85% purity is available in place of pure lime, what will be the required quantity of slaked lime?

(ii) State various disadvantages of Zeolite process of water softening.

**[12 + 8 marks]**

Q.6 (c) A rectangular sedimentation basin is required to handle 10 million litres/day of ra water. A detention basin of width to length ratio of $\frac{1}{3}$ is proposed to trap all partic larger than 0.04 mm in size. Assuming a relative density of 2.65 for the particles and 20 as the average temperature, compute the basin dimensions. If the depth of tank is 3.5 calculate the detention time.

**[20 mar**

Q.7 (a) The main sanitary sewer is to serve a population of 76000. Calculate the size and slope of the sewer for the following data:

Ratio of maximum flow in sewer to average flow is given by:

$$\frac{Q_{\max}}{Q_{avg}} = \frac{18+\sqrt{P}}{4+\sqrt{P}}$$

where '$P$' is the population in thousand

Average per capita water supply = 140 lpcd,

Average sewage flow = 80% of water supply.

Manning's roughness coefficient (for concrete sewer) = 0.013. Sewer should run half full while carrying the maximum flow. Velocity in sewer at maximum daily flow = 0.8 m/s.

**[20 marks]**

Q.7 (b) **(i)** A river with saturation DO (at 25°C) 8.4 mg/$l$ and self purification ratio, (f) 2.4 receives treated wastewater. Find the permissible BOD in the treated wastewater if rate constant $k_1$ (at 25°C) is 0.1/day (at base 10). The sewage flow is 80 cumecs and the river flow is 1200 cumecs.

**(ii)** Write a brief note on 'Tropospheric ozone' and 'Stratospheric ozone'?

**[14 + 6 marks]**

Q.7 (c) What do you understand by development of well? Describe the various methods used for development of well.

**[20 marks]**

**Q.8 (a)** Pollutant concentration distribution for a continuous single emission source follows Gaussian distribution given as

$$C_{x,y} = \frac{Q}{\pi u \sigma_z \sigma_y} e^{-\frac{1}{2}\left[\frac{H^2}{\sigma_z^2} + \frac{y^2}{\sigma_y^2}\right]}$$

where $C$ = Concentration of pollutant (in gm/m$^3$)

$Q$ = Pollutant emission rate (in gm/sec)

$u$ = Mean wind velocity (in m/sec)

$x$ and $y$ = downwind and crosswind horizontal distances (in m)

$\sigma_y$ and $\sigma_z$ = Plume's standard deviation

$H$ = Effective height of stack

A coal fired thermal power plant burns 6.25 tonnes of coal per hour and discharges the combustion product through a stack having an effective height of 80 m.

The coal has a sulphur content of 4.7% and the wind velocity is 8 m/sec. Determine the ground level concentration at a distance of 2 km downwind at

**(i)** the centre line of plume.

**(ii)** a crosswind distance of 0.5 km on either side of the centre line.

Given at $x$ = 2 km, $\sigma_z$ = 130, $\sigma_y$ = 220

**[20 marks]**

$W_1$ = 6.25 t / hour (Coal)

$H$ = 80m

$u$ = 8m/s

$Q = \frac{6.25 \times 1000 \times 1000}{3600} \times \frac{4.7}{100} \times 2 = 163.194$ g/sec of $SO_2$

$S + O_2 \rightarrow SO_2$

32 32 → 64

$x$ = 2km

32 → 64

1 → 64/32

x → (64/32) x

(i) $y = 0$ at centre line of plume

$$C_{xy} = \frac{Q}{\pi U \sigma_z \sigma_y} e^{-\frac{1}{2}\left[\frac{H^2}{\sigma_z^2} + \frac{y^2}{\sigma_y^2}\right]}$$

$H \rightarrow m$

$$C_{xy} = \frac{163.194}{\pi \times 8 \times 130 \times 220} \times e^{-\frac{1}{2}\left[\frac{80^2}{130^2}\right]}$$

$\sigma_y = 220$

$\sigma_z = 130$

$$C_{xy} = \boxed{1.879 \times 10^{-4} \quad gm/m^3} \text{ Ans}$$

(ii) $y = 500\,m$

$$C_{xy} = \frac{163.194}{\pi \times 8 \times 130 \times 220} e^{-\frac{1}{2}\left[\frac{80^2}{130^2} + \frac{500^2}{220^2}\right]}$$

$$C_{xy} = \boxed{1.4198 \times 10^{-5} \quad gm/m^3} \text{ Ans}$$

20

**Q.8 (b)** Design an oxidation pond for treating sewage from a hot climatic residential colony with 5000 persons, contributing sewage @ 120 litres per capita per day. The 5-day BOD of sewage is 300 mg/*l*.

**[20 marks]**

Oxidation Pond

$P = 5000$ person

$Q_s = 120$ l per capita per day

$S_o = 300$ mg/l

Assume organic loading Rate as

$y = 300$ kg/d/Ha

Total BOD generated per day $(x) = \frac{5000 \times 120 \times 300}{10^6}$

$x = 180$ kg/day

$\therefore$ Area Required $= \frac{x}{y} = \frac{180}{300} = 0.6$ Ha

It is between 0.5 Ha – 1 Ha so Okay

Assume L : B as 3 : 1

1 Ha $= 10^4$ m$^2$

$(3B)(B) = 0.6$

$3B^2 = 0.6$

$B = 44.72$ & Adopt $B = 45$ m

$L = 135$ m

Adopt Depth of Pond as 1.2m → Effective Depth

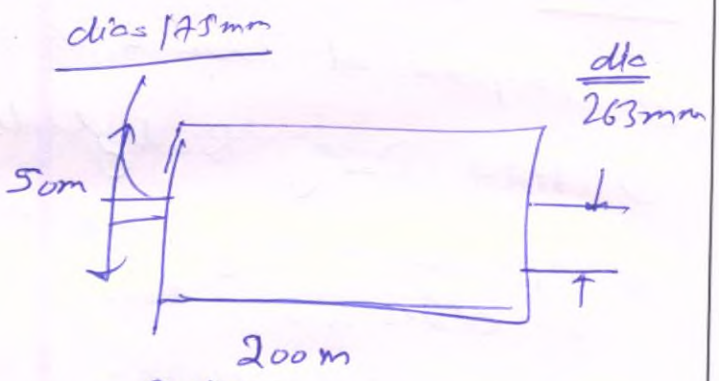
Give 0.3 → as Freeboard.

Total Depth = 1.5m

$V_{\Phi} = Q \times t_d$

$$\frac{45 \times 135 \times 1.2}{120 \times 10^{-3} \times 5000} = 12.15 < 15 \text{ days}$$

Design Diagram




Go For

L : B as 4 : 1

$4B \times B = 0.6$

$B = 38.73m$

Adopt $B = 40m$

$L = 160m$

$$t_d = \frac{40 \times 160 \times 1.2}{120 \times 10^{-3} \times 5000} \approx 12.8 \text{ day} < 15 \text{ days}$$

$15 \text{ day} < t_d < 30 \text{ days}$

Adopt

$B = 50m$

$L = 200m$

$t_d = 20$ days okay

(16)

1. $B = 50m$ $D = 1.5m$

$L = 200m$


Outlet

dia → $1.5d_1 =$

$d_o = \boxed{263mm}$

$D_{eff} = 1.2m$

Assume ① → inlet velocity as 0.3m/s

$A = \frac{Q}{V}$

$$d_1 = \sqrt{\frac{4}{\pi} \times \frac{120 \times 10^{-3} \times 5000}{3600 \times 24 \times 0.3}}$$

$d_1 = 171.68mm$

Adopt $d_1$ (inlet dia) as → $\boxed{175mm}$

Q.8 (c) (i) What is Vermi-composting? State various steps involved in Vermi-composting.

(ii) State the merits and demerits of incineration method of solid waste disposal.

**[12 + 8 marks]**

Vermi-composting → organic Method of waste Decomposition of Biodegradable waste using Earthworms or worms → as an additional Addend.

Steps involved in Vermi-composting:-

1. Prepare a Trench or ditch
2. Add Daily Biodegradable waste in it
3. After some days → add earthworms & other Bio-active organisms
4. Apply Layer of soil above it.
5. Leave the Pit for some months
6. After 6 months → Pit is ready for use.

Digested waste → can be use as manure

Incineration → Burning High calorific value waste to generate energy & reduce waste volume

Merits of Incineration Method of Solid waste Disposal

- If calorific value is High, energy can be obtained.
- It reduced waste to minimal volume, therefore Handling cost is reduced

③ Suitable if there is shortage of land for sanitary Landfill.
(eg urban area)

④ Low cost (In

Demerits:-

① Burning creates Lot of Pollution
Air Pollution eg Dioxins.

② Leads to Global Warming

③ Can affect health of people living nearby.

Not adopted in India generally because of low calorific value of Indian wastes

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