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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 | B | [illegible] | L | B | 7 | 8 | 7 |

Test Centres					Student's Signature
Delhi ☑	Bhopal ☐	Noida ☐	Jaipur ☐	Indore ☐	
Lucknow ☐	Pune ☐	Kolkata ☐	Bhubaneswar ☐	Patna ☐	
Hyderabad ☐					

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	49 − 02 ⇒ 47
Q.2	50 − 3 ⇒ 47
Q.3	48 − 4 ⇒ 44
Q.4	
Section-B	
Q.5	28 − 2 ⇒ 26
Q.6	41 + 2 ⇒ 43
Q.7	
Q.8	
Total Marks Obtained	216 − 9 ⇒ 207

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

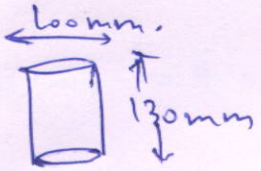
Accurately attempted and Question Selection is good

Improve handwriting

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]



$V \Rightarrow \frac{\pi}{4}(100)^2 \times (130) = 1.021 \times 10^{-3}\ m^3$

$\gamma_w = 9.81\ kN/m^3$

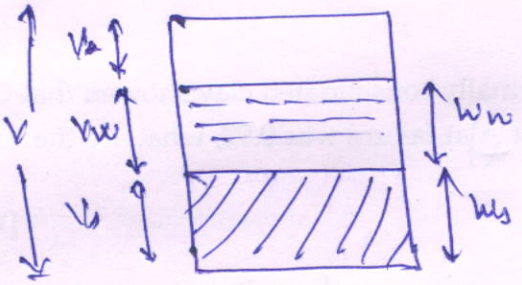
Mass of core cutter = 1.5 kg

Mass of core cutter with soil = 3.865 kg

Mass of soil = 2.365 kg.

Given $w = 11\%$

$G = 2.67$.



$\gamma_{(bulk)} = \frac{2.365\ kg}{1.021 \times 10^{-3}\ m^3} \Rightarrow \frac{2.365 \times 9.81 \times 10^3}{1.021 \times 10^3}$

$\gamma_b = 22.723\ kN/m^3$.

$\gamma_{dry} = \frac{\gamma_b}{1+w} \Rightarrow 20.471\ kN/m^3$

$\gamma_d = \frac{G\gamma_w}{1+e} \Rightarrow \frac{2.67 \times 9.81}{1+e} = 20.471$

$e = 0.279$.

12

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 ϕ' for the soil?

[12 marks]

$C_u = 0$ $\quad (A = 0.92)$ $\quad c' = ?$

$\phi_u = 15°$ $\quad \phi' = ?$

$(\bar{A} = A \cdot B)$ $\quad \left(\frac{\Delta u_d}{\Delta \sigma_d}\right) = 0.92 \left(\frac{\Delta u_c}{\Delta \sigma_c}\right)$

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

$\sigma_1 = 1.698\, \sigma_3$ $\quad (i)$

Taking $\bar{A} \simeq A$ $\Rightarrow \frac{\Delta u_d}{\Delta \sigma_d} = 0.92$

$\rightarrow \Delta u_d = 0.92 (\Delta \sigma_d)$

$\Delta H_a = 0.92 (\sigma_1 - \sigma_3)^2 = (1.5621603)$

$\therefore (\sigma_1 - \Delta H_a) = 1.6486\sigma_3$

$\sigma_1 - 0.92\sigma_3$

$(\sigma_1 - m) = \sigma_3 - m\tan^2(45 - \frac{\phi'}{2}) + 2c'\tan(45 + \frac{\phi}{2})$.

→ (c will be 0 → as c→0)

$(\sigma_1 - 1.5621603) = (\sigma_3$

4

Q.1 (c) Compare the salient features of Standard Penetration Test and Plate Load Test.

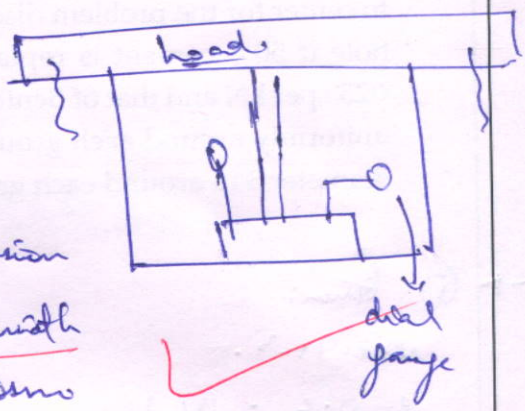
[12 marks]

→ Standard Penetration Test. →

- Standard Penetration Test is carried out to explore the subsoil to gather information about what kind of soil lies beneath the Earth's surface.
- In this test a hammer is made to fall upon a weight of standard dimensions and corresponding no. of blows are recorded which are required to penetrate into the soil. The first 150 mm penetration blows are discarded on account for seating load and the next 300 mm penetration blows are accounted to calculate the SPT No. value N.

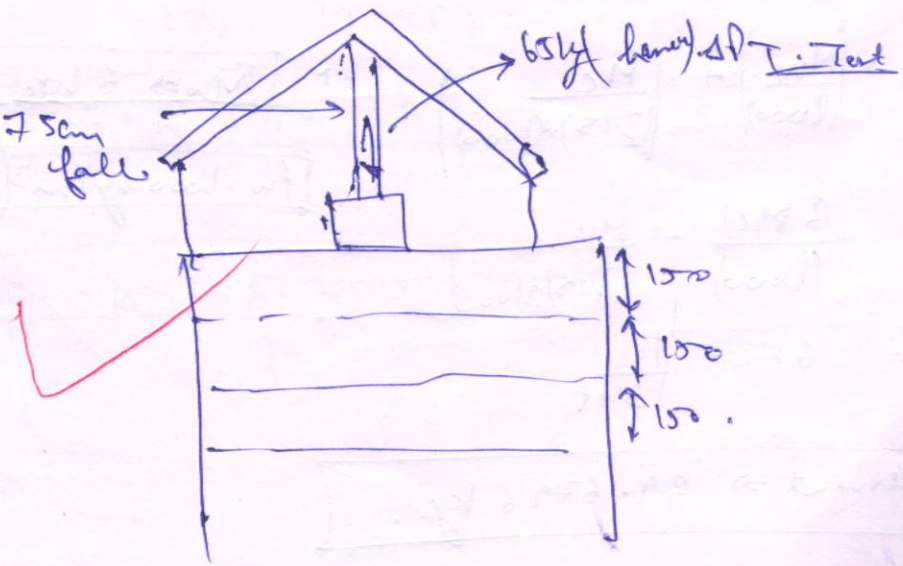
Do not write in this margin

- The SPT No. value. N-so found can help in determining the Relative density of the soil as well.
- 2 corrections namely Rise correction & overburden correction are applied to the final SPT No.



→ Plate load Test →

- In this test a plate of standard dimension is put inside an excavation of 5 × width of plate and by the screw mechanism load is applied on the plate.
- This plate simulates the foundation and it is used to determine the load settlement curve of the corresponding plate which can be directly / indirectly related with a foundation.
- This load vs penetration curve is helpful in analysis the ultimate bearing cap. of foundation and how it will react for a given soil mass.



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.

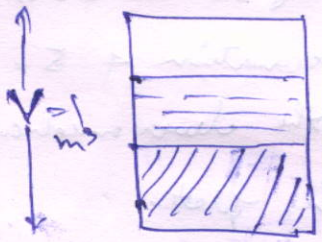
(ii) Grouting is to be carried out in 12 m deep grout holes spaced at 3 m distance center to center for the problem discussed in (i) above. What will be the saving per group hole if 50% cement is replaced by Bentonite, given that the cost of cement is ₹ 250 per kN and that of Bentonite is ₹ 120 per kN? 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) Given;

soil = $1\ m^3$.

$e = 0.6 = \left(\frac{V_v}{V_s}\right)$.



Grout mix ⇒ 6 : 1 (water) : (cement) (By weight)

$G_{cement} = 3.15$

Soil voids get filled with slurry.

$V_{slurry} \Rightarrow (0.5) \times (V_v)$.

$V_{slurry} \Rightarrow 0.1875\ m^3$.

$V_{slurry} = (V_{water}) + (V_{cement})$

$0.1875\ (m^3) \Rightarrow \left(\frac{M_w}{(1000)}\right) + \left(\frac{M_c}{(3.15)\times(1000)}\right)$

$0.1875 \quad \frac{6M_c}{(1000)} + \frac{M_c}{3.15 \times 1000}$

$187.5 = 6M_c + \frac{M_c}{3.15}$

$M_{cement} \Rightarrow 29.6796\ kg$.

$e = 0.6 = \frac{V_v}{V_s} = \frac{V_v}{V - V_v}$

$0.6(V_T - V_v) = V_v$

$0.6 - 0.6V_v = V_v$

$0.6 = 1.6V_v$

$V_v = \frac{0.6}{1.6} = 0.375\ m^3$

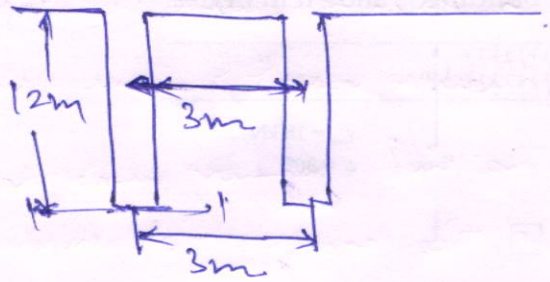
$\left[\frac{M}{V} = G\right]$.

→ $W_{(w)} \Rightarrow 6\ W_{(c)}$

$[\gamma_w = 1000\ kg/m^3]$

6

(ii)



(leaving for group hole → ?)

M(cement) → 29.6716 kg = 0.2911 KN | m^3 wheat

M(C) → $\frac{0.2911}{2}$ → 0.1455 KN

M(B) → $\frac{0.2911}{2}$ = 0.1455 KN

Initial cost →

Volume of heel → $\frac{\pi}{4} \times (3)^2 \times (12)$ = 84.823 m^3.

M(cement) → 0.2911 × 84.823 m^3 = 24.69 KN

Initial cost → Rs. 6172.99

Final → M(C) → 12.345 KN

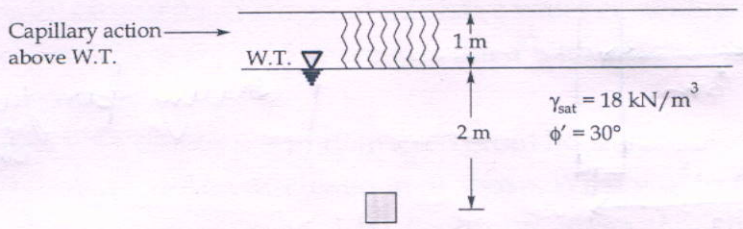
M(B) = 12.345 KN

Final cost → Rs 4567.65

Leaving → Rs. 1605.34

6

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]

$k_0 = 0.5$.

$\bar{\sigma_0} \Rightarrow 1 \times 18 + 2 \times (18 - 9.81)$

$\bar{\sigma_v} \Rightarrow 34.38$ KN/m^2 → (1)

$\sigma_h \Rightarrow k_0 \bar{\sigma_v} \Rightarrow 17.19$ KN/m^2 → (σ_3)

At failure; $\theta_c = 45 + \frac{\phi}{2} \Rightarrow (60°)$

$\therefore \sigma_1 = \sigma_3 \tan^2\left(45 + \frac{\phi}{2}\right)$

$(\sigma_1 + \Delta\sigma) = (\sigma_3 + \Delta\sigma_h) \tan^2\left(45 + \frac{\phi}{2}\right)$

$(34.38 + \Delta\bar{\sigma}) = (17.19 + 0.2\,\Delta\bar{\sigma}) \tan^2\left(45 + \frac{\phi}{2}\right)$ — (A)

$\Delta\bar{\sigma} \rightarrow \frac{17.19}{0.4} = 42.975$ KN/m^2.

$\therefore \Delta\bar{\sigma_v} \Rightarrow 42.975$ KN/m^2

12

no correction is applied in (A) as they are effective stress already.

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]

(i). Case (B) ⇒ Floating a prefabricated box caisson & lowering it to the bearing structure. Because lowering it to a small depth will be comparatively easy as with respect to high depths.

(ii) Case (A) ⇒ Cofferdam will be suitable for case of as concrete is casted in site.

(iii) Case (C) ⇒ as depth of the bed is well below the bed level, thus well foundation is best for this situation.

Well foundation is the best suited deep foundation for flow situations.

$C = 14 KN/m^2$

$\phi = 15°$ — $(m = 0.083 = \phi = 15°)$

$G = 2.7$ $(\phi = 7.3 = m = 0.122)$

$\gamma_{sat} \Rightarrow \left(\frac{2.7+0.8}{1.8}\right) \times 9.81$

$\Rightarrow 19.075 KN/m^3$

(a) ~~When canal runs full~~

$m = \frac{C}{\gamma_{Pos} H}$

$0.083 = \frac{14}{(19.075 - 9.81) P_{os} \times 5}$

$P_{os} \Rightarrow 3.6411$

(b) When canal is suddenly emptied

$\gamma = \gamma_{sat}$.

$\phi_w \Rightarrow \frac{\gamma}{\gamma_{sat}} \phi \Rightarrow 7.28 \times 7.3°$

$m = 0.122 \Rightarrow \frac{C}{\gamma_{Pos} H}$

$P_{os} \Rightarrow \frac{14}{(0.122)(19.075) \times H}$

$P_{os} \Rightarrow 1.203$

10

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

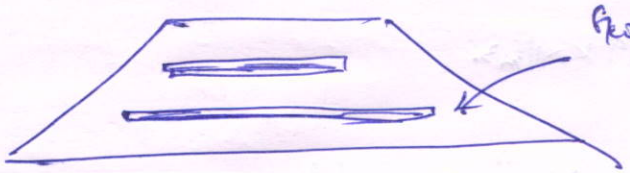
(ii) A foundation trench is to be excavated for a large project in a site. The soil investigation report shows the following details :

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]

(i) Reinforced soils are those which are reinforced with other foreign materials like steel wires, steel bars, Geotextiles, Geofabrics. As soil is weakest in tension, sometimes there is a need to reinforce the soil to allow it to bear loads. Thin steel sheeting can also be done as a soil reinforcement.



Geotextiles as a reinforcement

Nailed soil walls are those which have a very high stability with respect to function, & thus nailing is important to ensure that the soil doesn't drift.

Nailing is generally seen in Tunnel construction and Retaining wall construction where the failure of slope can happen instantaneously. Soil nailing appears to be highly efficient in case of loose soil stratum where seepage is considered to be a primal cause for failure.

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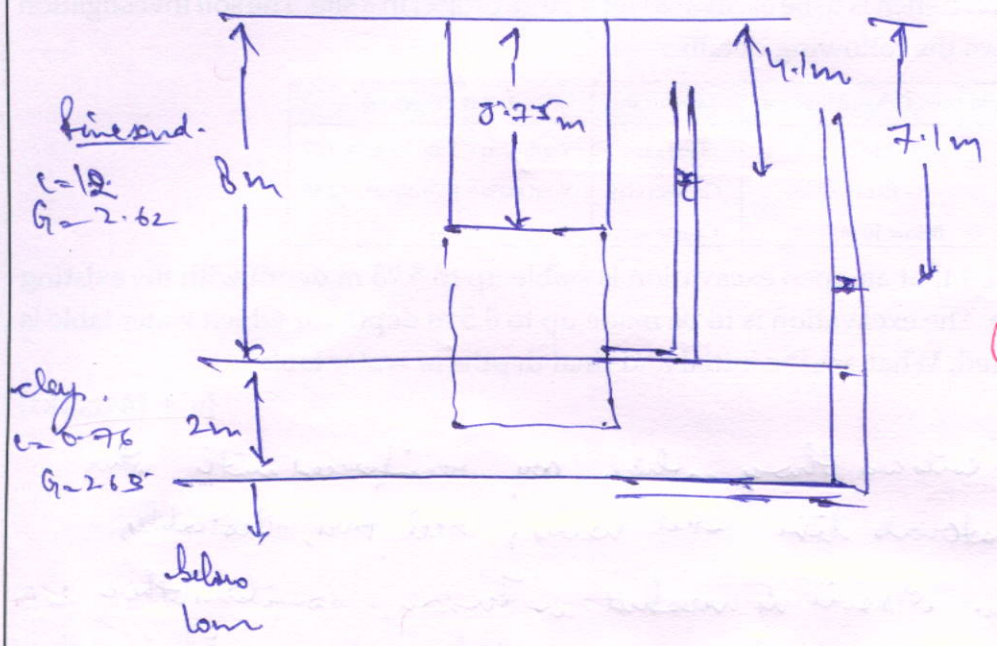
3

(ii)



improve presentation

γ_{sat}(sand) $\Rightarrow$ 17.033 KN/m3 (sat).

γ_{sat}(clay) $\Rightarrow$ 19 KN/m3.

8

Initial case $\Rightarrow$ Total stress approach

$\gamma_{sat} \times (8 - 3.75) = \gamma_w h$

$h = 3.906$ m w.r. 4.093m from top

Case-(ii) $\Rightarrow$ Total stress approach

$\gamma_{sat} \cdot \frac{1}{2}(h - 1.5) = \gamma_w h$

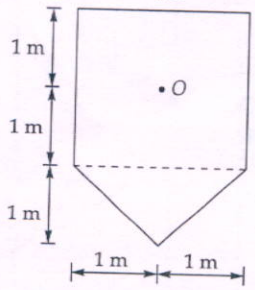
$h = 2.905$ m w.r. 7.094m from top

Initial depth = 4.093m.

Final depth = 7.1m

- from top.

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]

(i) ⇒ Total load on the area ⇒

$Q = 300 \left[2\times2 + \frac{1}{2}\times2\times1\right) = 1500\ kN$

Centroid of area ⇒ $\dfrac{(2\times2)\times1 + \left(\frac{1}{2}\times2\times1\right)\left(2+\frac{1}{3}\right)}{\left(2\times2+\frac{1}{2}\times2\times1\right)}$

$\Rightarrow 1.2667$ m from top.

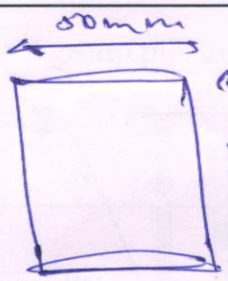
$\Rightarrow 0.2667$ m from O. $= (z)$

$\therefore \sigma(z) = \dfrac{3Q}{2\pi z^2}\left(\dfrac{1}{1+\frac{r^2}{z^2}}\right)^{5/2}$

$= \dfrac{3\times1500}{2\times\pi\times(z)^2}\left(\dfrac{1}{1+\left(\frac{0.2667}{2}\right)^2}\right)^{5/2}$

$= 171.32\ kN/m^2$

(ii)



UC test.

$P = 200$ N. → (Shear resistance = c (value))

$\sigma_3 \Rightarrow \frac{P}{A_f}$

$A_f \Rightarrow \frac{A_c}{1-0.1} \Rightarrow \frac{\frac{\pi}{4}(50)^2}{1-0.1} = 2181.66\ mm^2$.

$\frac{P}{A_f} = (\sigma_3) \Rightarrow \frac{200 \times 10^3}{2181.66 \times 10^{-6}} \Rightarrow 91.67\ kN/m^2$

$\sigma_3 = 2c \tan\left(45 + \frac{\phi}{2}\right)$

As $\phi = 0$

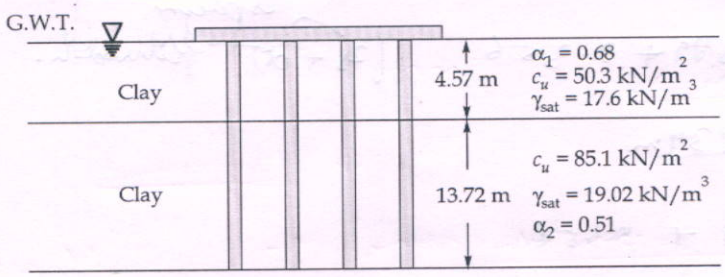
$\sigma_3 = 2c$

$\therefore c = \frac{91.67}{2} = 45.836\ kN/m^2$

(Shear resistance of soil)

10

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]

→ Total no. of piles = 12

Allowable load carrying capacity of piles = $\begin{cases} n\,Q_{ul} \\ Q_{ug} \end{cases}$ → minimum

Square pile → (356 × 356).

Individual pile action →

$Q_{ul} \Rightarrow c\,N_c\,A_b + \alpha_1 \bar{c}_u\,dl_1 + \alpha_2\,\bar{c}_u\,A_{s2}$

$\Rightarrow 85.1 \times 9 \times (0.356)^2 + 0.68 \times 50.3 \times 4 \times 0.356 \times 4.57$

$+ 0.51 \times 85.1 \times 4 \times 0.356 \times 13.72$

$\Rightarrow 1167.59$ kN

Pan whole group → $Q_{ug} \Rightarrow 12 \times Q_{ul}$

$\Rightarrow 14011.119$ kN.

Group Action of Piles. :⇒

B⇒ $2 \times 0.889 + 0.356$ $(2s + d)$ spacing, pile width.

$= 2.134\,m$

L⇒ $3 \times 0.889 + 0.356$

$= 3.023\,m$

Qug ⇒ $cNc\,A_b + \bar{c}_1 A_{s_1} + \alpha \cdot \bar{c}_2 A_{s_2}$ $(\alpha = 1)$

⇒ $85.1 \times 8.57 \times 3.023 \times 2.134 +$

$30.3\,[2 \times 2.134 \times 4.57 + 2 \times 3.023 \times 4.57] +$

$85.1\,[2 \times 2.134 \times 13.72 + 2 \times 3.023 \times 13.72]$

$= 19118.046\,kN$

∴ Qu group = min { Qug, Qug }.

⇒ 14011.12 kN

Thus allowable load carrying cap. of Pile Group = $\frac{Q_{ug}}{FOS} = (4)$

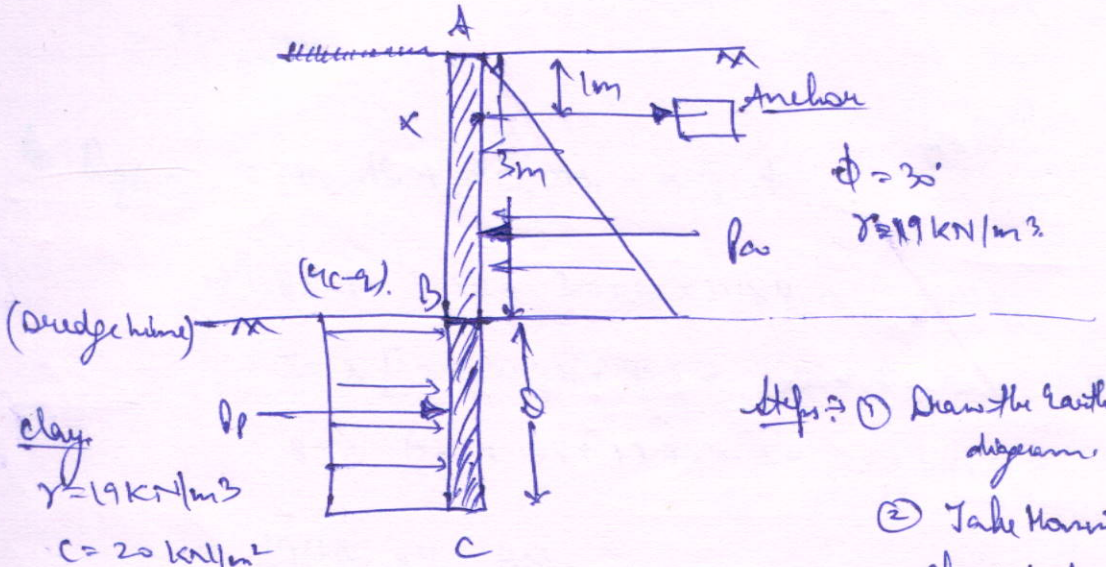
$= 3502.78\,kN.$

P.A :- Water Table has no effect on bearing capacity of Pile Group as piles are installed in clays.

20

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]



Steps: ① Draw the earth pr. diagram.

② Take Moment about x to get D

③ Equate $\Sigma F_{(Hor)} = 0$.

Anchor force, T = ?

Sheet pile Depth = ?

$K_a = \frac{1-\sin\phi}{1+\sin\phi} \Rightarrow \frac{1-\sin 30^\circ}{1+\sin 30^\circ} = \frac{1}{3}$

Pa (at 3m) $\Rightarrow K_a \gamma H \Rightarrow \frac{1}{3} \times 19 \times 3 \Rightarrow 19 KN/m^2$

Active earth pr. force $= \frac{1}{2} \times 19 \times 3 \Rightarrow$ 28.5 KN acting at 2m from top.

$q \Rightarrow 19 \times 3 = 51 KN/m^2$.

Earth pr. diagram for passive side $= 4c - q$

$= 4 \times 20 - 51$

$\Rightarrow 29 KN/m^2$

Passive earth thrust force = $29 \times D$ acting at $(1 + \frac{D}{2})$ m from top.

Taking Moments about X to

$P_a \times (1) = P_p (D+2)$

$28.5 \times 1 = 29 D (D+2)$

$29D^2 + 57D - 28.5 = 0$

$D = 0.4881$ m

Provide $1.2D$ as depth of embedment $\Rightarrow$ 0.58572 m

Provide 0.5 m as depth of embedment (extra safety)

Forces in Action $\Rightarrow$

$T + P_p = P_a$

$T + (29) \times 0.5 = 28.5$

$T \Rightarrow 14$ kN

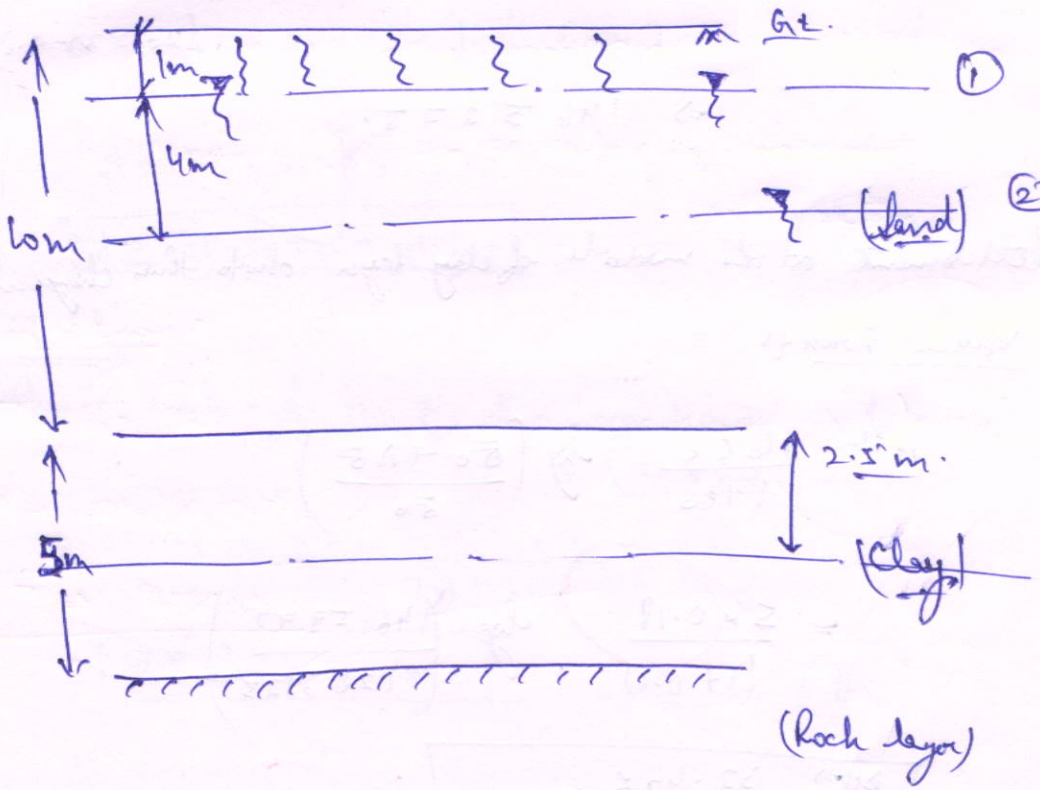
14

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 = 6×10^{-3} cm^2/s.

[20 marks]



Sand → $e = 0.75$, $G = 2.65$, $\gamma_d \Rightarrow 14.85 \approx 14$ kN/m^3 $\left(\frac{G}{1+e}\gamma_w\right)$, $\gamma_{sat} \Rightarrow 19.059$ kN/m^3 $\left(\frac{G+e}{1+e}\right)\gamma_w$

Clay → $e = 0.6$, $G = 2.7$, $\gamma_{sat} \Rightarrow 20.233$ kN/m^3.

$w_L = 40\%$, $C_c \Rightarrow 0.18$. $(w_L - 20)0.009$

$C_v = 6 \times 10^{-3}$ cm^2/s.

Calculate all settlements at the middle of clay layer.

$\bar{\sigma_0}$ (initial) $\Rightarrow 1\times(\gamma_{sat})_A + 9(\gamma_{sub})_B + 2.5(\gamma_{sub})_C$

$\Rightarrow 1\times 19.059 + 9\times(19.059-9.81) + 2.5(20.233-9.81)$

$\Rightarrow 128.3575\ KN/m^2$

$\bar{\sigma}$ (final) $\Rightarrow 5\times(\gamma_d)_B + 5(\gamma')_B + 2.5(\gamma_{sub})_C$

$\Rightarrow 5\times 14.855 + 5(19.059-9.81) + 2.5\times(20.233-9.81)$

$\Rightarrow 146.5775$

Settlement at the middle of clay layer due to this change in vertical stress is

$$\Delta H = \frac{H_0 C_c}{1+e_0} \log\left(\frac{\bar{\sigma_0}+\Delta\bar{\sigma}}{\bar{\sigma_0}}\right)$$

$$= \frac{5\times 0.18}{(1+0.6)} \log\left(\frac{146.5775}{128.3575}\right)$$

$\Delta H \Rightarrow 32.426$ mm

Now- Time required for 25 mm settlement.

$U = \left(\frac{25}{32.42}\right)\times 100 \Rightarrow 77.0988\%$

$T_v = 1.781 - 0.9332 \log_{10}(100-77.0)$

$\Rightarrow 0.511198$

By the relation;

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

$$0.51198 = \frac{6 \times 10^{-3} (cm^2/s) \times t}{d^2}$$

As clay is underlain by Rock, assuming that the rock layer is Granite rock, therefore two way drainage is possible.

$d = (2.5\ m)$

$$\therefore 0.51198 = \frac{6 \times 10^{-3} \times 10^{-4}\ (m^2/s) \times t}{(2.5)^2}$$

$$t = 5333125\ s$$

$$\boxed{t = 61.7259\ days} \quad \text{(A)}$$

Alternatively;

If bottom rock is of Granite, then 1 way drainage is possible,

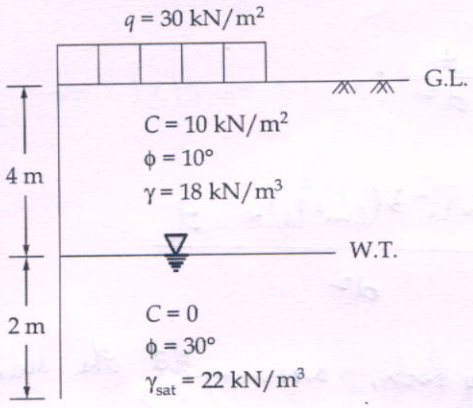
$(d = 5\ m)$

$$0.51198 = \frac{6 \times 10^{-3} \times 10^{-4} \times t}{(5)^2}$$

$$\boxed{t = 246.9\ days.} \quad \text{(B)}$$

10

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]

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]

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.

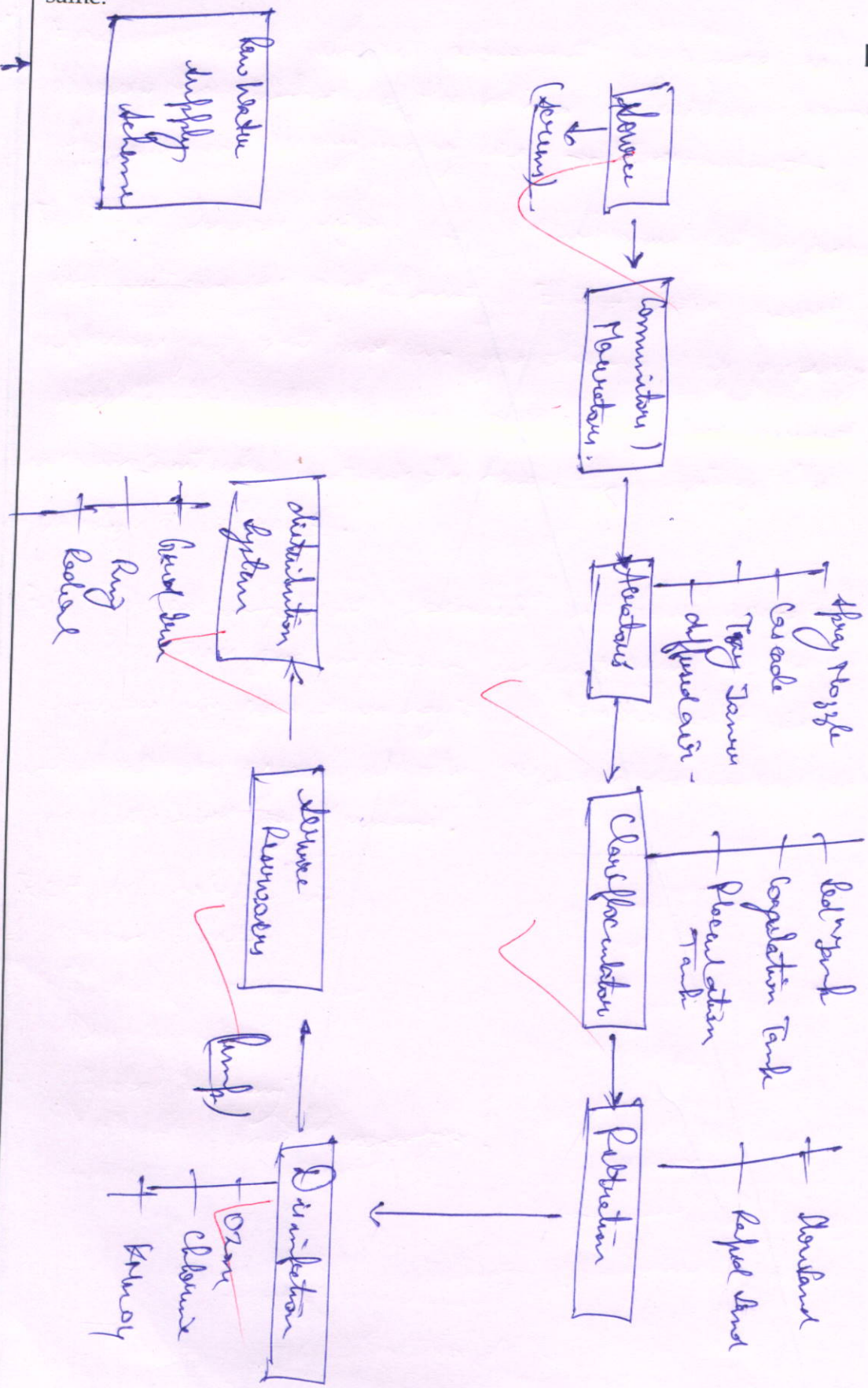
(ii) Find an expression for the unconfined compressive strength q_u in terms of c', ϕ' and A_f (pore pressure parameter at failure). Take parameter $B = 1$ and initial capillary tension = U_c.

[5 + 15 marks]

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]



- Raw water supply scheme consists of the different elements as shown in the flowchart.
- The designing of all elements before/prior to the service reservoir is for Max^m daily demand & after service Reservoir is of Max^m of { Max^m Hourly demand or Coincident draft }.
- Water supply scheme mentioned in the flowchart is not general, it could contain other elements also.
- Screens are directly installed at the source.

6

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

[12 marks]

~ Environmental impact assessment is defined as assessing the impact of the various activities human perform in their day to day life on Environment

For the proper future of the upcoming future generation and sustainable development; EIA is the most precious gift that we can give them. By properly assessing the impacts of our doings in the environment, we can control / mitigate the danger of putting the lifestyle at threat

EIA is also important because we derive everything from Mother Nature and in return we don't value all the precious gifts given to us by it. Therefore, it is important to assess all the Negative parameter which are contributed by Humans.

EIA is helpful in

- Ozone depletion
- Glacial receding
- Desertification
- Global warming
- Variable Climate Change etc

EIA of Thermal power Plants :-

Thermal power plants have a positive yet highly negative impact on environment. It is to be decided properly that the location of Thermal power plant is the main contributing factor of all negative reactions to Environment. Thermal power plant derive their energy from coal / other burning products.

Therefore, it is important to note the type of effluent / kind of smoke they emit to keep a check on the Environment that is degrading at a rate so uncontrollable that measures be able to stop it.

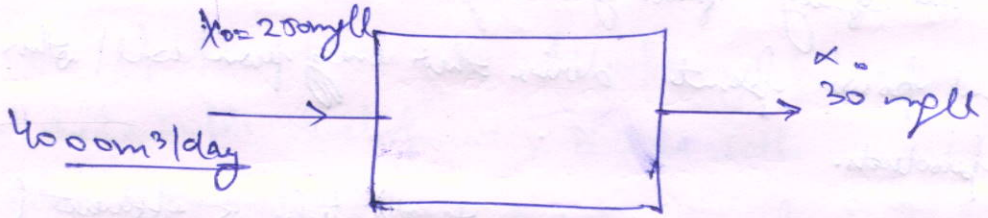
- Analyse the raw materials to Thermal power plant.
- Frequent checks on the effluent of the plants albeit in the form of smoke / liquid / solid effluent.
- Using properly cleaned apparatus for inspection of raw material
- Frequent servicing of machinery.
- Proper checks in the working atmosphere of the Thermal power plant.

8

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 θ_c and F/M.

[12 marks]

→ Net solids = ?



(Y = 0.5), K_d = 0.09/day.

fraction of BOD utilised converted into solids = 0.5.

(BOD) reduced = (250 − 30) = 220 mg/l,

(BOD) reduced per day ⇒ 220 mg/l × 4000 × 10^3 l/day × 10^{-6} kg/mg

= 880 kg/day.

Mass of solids produced = 0.5 × 880

⇒ 440 kg/day

θ_c → (Sludge age) $\frac{XV}{Q_w X_r}$ $\frac{\text{(Mass of Biomass inside the system)}}{\text{(Mass of Biomass leaving the system)}}$.

⇒ $\frac{3000 \times 700 \times 10^3}{4000 \times 10^3 \times 30/8}$

⇒ 17.5 days.

$\left(\frac{F}{M}\right) \Rightarrow \frac{Q_0 S_0}{XV} \Rightarrow \frac{4000 \times 65 \times 250}{3000 \times 706 \times 65}$ mg/l day / mg/l

$\Rightarrow 0.476$

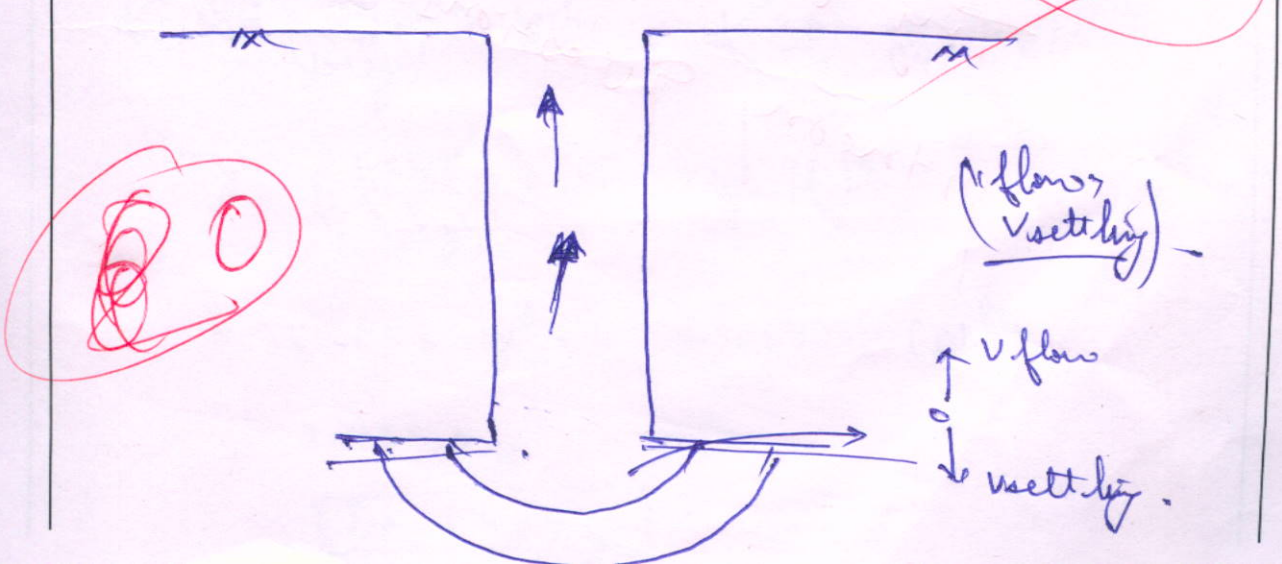
P.S $\Rightarrow$ This answer doesn't include the efficiency of the primary clarifier. which is about (60-70%)

6

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

[12 marks]

Shrouding of well is the most common phenomenon associated with the well. In deep type / shallow type wells what happens is that due to high (Q) pump capacity, sometimes the velocity of the flow is greater than settling velocity of particles at bottom.



6

As the velocity of flow reduces the lining of the well is disturbed and ultimately the well sinks in. This sinking in of well is termed as blowing of well. If this problem is not rectified in a short duration of time, the discharge capacity of a well can reduce by a large amount. Thus, it is important for the engineers to properly seal the wall of the well so that it may not develop.

This is generally seen in loose strata soil. Therefore for designing a well in a loose strata soil, it is important to properly stabilize the soil first

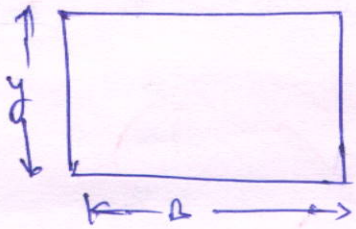
Write the answer related to the question. Try to improve handwriting in theory questions

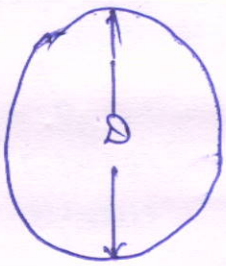
Q.5 (e) A rectangular sewer with width 1.5 times its depth is hydraulically equivalent to a circular one. Find the relation between the width of the rectangular sewer and the diameter of the circular sewer.

[12 marks]

→ Hydraulically equivalent sewers are the ones which carry same discharge for same slope (hydraulic gradient) and roughness.

Given:





$B = 1.5y$.

As both sewers are hydraulically equivalent, they carry same discharge.

$Q_\square = \frac{1}{n} A R^{2/3} S^{1/2}$ $\qquad Q_O = \frac{1}{n} A R^{2/3} S^{1/2}$

$Q_\square = \frac{1}{n} By \left(\frac{By}{B+2y}\right)^{2/3} S^{1/2}$. $\qquad Q_O = \frac{1}{n} \frac{\pi D^2}{4} \left(\frac{D}{4}\right)^{2/3} S^{1/2}$

$Q_\square = Q_O$

$\frac{1}{n} By \left(\frac{By}{B+2y}\right)^{2/3} S^{1/2} = \frac{1}{n} \frac{\pi D^2}{4} \left(\frac{D}{4}\right)^{2/3} S^{1/2}$

$1.5y^2 \left(\frac{1.5y^2}{3.5y}\right)^{2/3} = \frac{\pi D^2}{4} \left(\frac{D}{4}\right)^{2/3}$

$0.852655\, y^{8/3} = 0.311685\, (D)^{8/3}$

$2.7356\, y^{8/3} = D^{8/3}$

$\boxed{D = 1.4584y}$

$\therefore D = 1.45846\,59\,y$

$B = 1.5\,y$

$B = 1.5 \left(\frac{D}{1.45846\,59}\right)$

$\boxed{B = 1.02847\,D}$

6

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]

→ (i).

Time (hr).	Demand (m^3/s)	Cum. Demand (m^3) (CD)	Supply (m^3/s)	Cum supply (CS)
0	0	0	0.	0
2	0.1	0.1	0.245833	0.2458
4	0.15	0.25	0.245833	0.49167
6	0.2	0.45	〃	0.7374
8	0.5	0.95	〃	0.9832
10	0.6	1.55	〃	1.229
12	0.4	1.95	〃	1.4748
14	0.3	2.25	〃	1.7206
16	0.15	2.4	〃	1.9664
18	0.2	2.6	〃	2.2122
20	0.25	2.85	〃	2.458
22	0.1	2.95	〃	2.7038
24	0	2.95	〃	2.95

(P.T.O)

Total Demand ⇒ $2.95 (m^3/s)$ for 24 hr.

$= 2.95 \times 24 \times 60 \times 60$

$\Rightarrow 254880\ m^3$.

As supply is uniform,

∴ supply for 1 hr $\Rightarrow \frac{254880}{24 \times 60 \times 60} = 0.245833\ m^3/s$.

2 hr.

$C_D - C_S$ (m3/h)
0
−0.1458
−0.24167
−0.2874 B.
−0.0332
+0.321
+0.4952
+0.5294 A.
+0.4336
+0.3878
+0.392
+0.2482
0

Minimum Reservoir capacity = $(C_D - C_S) + (C_S - C_D)$

= (Accumulated Demand − Supply) + (Acc. Supply − Acc. Demand)

= (0.2874) + (0.5294)

= 0.8168 m3/h for 2 hrs.

⇒ 0.8168 × 2 × 60 × 6

Reservoir capacity ⇒ 5880.96 m3

6

(b) The flow in sewers is the Gravity type flow and sewers flow contains lot of suspended impurities. Due to fluctuations in flow, sometimes, the sedimentation of the particles take place in the sewers. Thus, it is important to remove this silt for proper functioning & design discharge carrying capacity for sewers.

Therefore self cleaning velocity comes into picture, it needs to be developed at least once a day to account for non-silt action.

The self cleaning velocity should be such that it does not scour the bed of the sewer so that the design life of sewer is not altered with.

Thus, sewers are primarily designed for self cleaning velocity & non scouring velocity. with $q = \frac{1}{3}$ (peak flow) once in a day.

The velocity attained at this discharge is called self cleaning velocity | Non-scouring velocity.

3

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]

→ (i). Given; ~~ppm~~ (mg/l)

Alkalanity = 200 mg/l $\frac{200}{50} = 4$ meq/l.

$CaCl_2$ = 50 mg/l $\frac{50}{(111/2)} = 0.9$ meq/l.

$MgSO_4$ = 75 mg/l $\frac{75}{60} \Rightarrow 1.25$ meq/l

As Non Carbonate hardness is present, therefore sodium alkalanity will be absent, thus Alkalanity is equal to Carbonate Hardness.

lime reacts with — all the Carbonate hardness — α

— it converts Non-Carbonate hardness of Mg to Carbonate Hardness — β

— CO_2 — γ

Soda reacts with Non Carbonate Hardness.

Qty of lime $\Rightarrow$ $(\alpha + \beta + \gamma)$.

(CaO).

$\Rightarrow (4 + 1.25) \Rightarrow 5.25$ meq/l.

lime required as per 1 Mld. $\Rightarrow 5.25 \times 28 \times 1 \times kg \times kg$

$\Rightarrow$ 147 kg/day.

Soda required $\Rightarrow (0.9 + 1.25) = 2.15$ meq/l.

Soda required as per 1 Mld = $2.15 \times 53 \times 1 \times kg \times kg$

$\Rightarrow$ 113.95 kg/day.

Slaked lime $Ca(OH)_2$ [with 85% purity] $\Rightarrow \dfrac{(5.25)\ meq/l \times 37 \times 10^6 \times 10^{-6}}{0.85}$

$\Rightarrow 228.53\ kg/day.$

10+2 $\Rightarrow$ 12

(iv) There are a lot of disadvantages in Zeolite process of hardening which includes:-

- It makes the water completely hardless, due to ion exchange mechanism the resultant hardness is zero from this process. Thus it is difficult for drinking properly hardened water.
- If salts of iron are present inside the solution / Raw water sample, then regeneration of the Zeolite Bed can't take place, as it is completely destroyed due to the reaction with iron salts.
- Completely treated water is demanded of all minerals nutrients, therefore this isn't considered as a good way to treat hard water.
- The depth of zeolite bed required can be high in certain cases which proves it to be an uneconomical justification.

4

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

[20 marks]

→ Given,

$Q = 10\ MLd$ $\quad G = 2.65$

$\frac{B}{L} = \frac{1}{3}$. $\quad T = 20°C$

$d = 0.04\ mm$ $\quad H = 3.5\ m$

$(t_d = ?)$.

Settling velocity for the concerned particles =>

$V_s = \frac{418(G-1)d^2}{\text{(temp)}}\left(\frac{3T+70}{100}\right)$

$\Rightarrow 418\ (2.65-1)\ (0.04^2)\left(\frac{3\times 20+70}{100}\right)$

$= 1.434576 \text{ mm/s}$. $\quad 1.434576\ mm/s$

$V_s = 0.123947\ m^3/m^2/day$.

Q (required to be treated) = 10 MLd

$= 10 \times 10^6$ l/day

$\Rightarrow 10 \times 10^3$ m³/day

Plan area = $\frac{Q}{\text{surface overflow rate (SOR)}} = \frac{10 \times 10^3}{123.947}$

$= 80.679 \text{ m}^2$.

$L \times B = 80.679$.

$3B \times B = 80.679$ — (Given).

$B = 5.1858$ m

$L = 15.557$ m

$H = 3.5$ m.

Detention time $\Rightarrow \frac{V}{Q} \Rightarrow \frac{5.1858 \times 15.557 \times 3.5}{10 \times 1000}$

td $\Rightarrow$ 40.66 minutes

Formulas used :-

$$V_s = \frac{418 (G-1) d^2 \left(\frac{3T+70}{100}\right)}{(\text{mm/s})}$$ (*).

Plan area = $\frac{Q}{\text{surface overflow rate}}$ (*).

18

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)

σ_y and σ_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, σ_z = 130, σ_y = 220

[20 marks]

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]

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]