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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 D L B 7 4 6

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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	47-2=45
Q.2	
Q.3	58-2=56
Q.4	42+2=44
Section-B	
Q.5	32-2=30
Q.6	31
Q.7	
Q.8	
Total Marks Obtained	210-4=206

Signature of Evaluator .....

Cross Checked by .....

→ Your numerical solving ability is good.

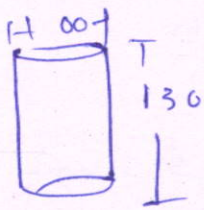
→ You could have done better in Section-B.

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]

Sol →



Cutter weight = 1.5 kg

Volume of soil in cutter

$= \frac{\pi}{4} d^2 \times H$

$= \frac{\pi}{4} \times (10)^2 \times (13)$

$= 1021$ cc

wt. of soil + cutter $= 3.865$ kg

wt. of soil $= 3.865 - 1.5$

$= 2.365$ kg

bulk unit wt. of soil $= \frac{M_s}{V_T}$

$= \frac{2365}{1021}$ g/cc

$= \boxed{2.316 \text{ g/cc}}$

$w = 0.11 \quad G = 2.67$

γ_d (dry unit weight) $= \frac{\gamma_b}{1+w}$

$= \frac{2.316}{1+0.11}$

$= \boxed{2.087 \text{ g/cc}}$

now

$\gamma_b = \frac{G\gamma_w(1+w)}{1+e}$

$\gamma_d = \frac{G\gamma_w}{1+e} = 2.087$

$\gamma_w = 9.81 \text{ kN/m}^3 = 1 \text{ g/cc}$

$$\frac{2.67 \times 1}{1+e} = 2.087$$

$$e = 0.279$$

void ratio $= 0.279$

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]

$C = 0 \qquad \phi_u = 15°$

$$A_f = \frac{U_f}{\sigma_{1f} - \sigma_{3f}}$$

σ_{1f} = Major Principle stress at failure

σ_{3f} = Minor "

$\because \quad \bar{A} = AB$

$B = 1$ for saturated soil

$\bar{A} = A = 0.92$

$$0.92 = \frac{U_f}{\sigma_{1f} - \sigma_{3f}} \quad \text{—} \quad (1)$$

now for Undrained Parameter

$$\sigma_{1f} = \sigma_{3f} \tan^2\left(45 + \frac{\phi}{2}\right) + 0$$

$$\sigma_{1f} = \sigma_{3f} \times \tan^2\left(45 + \frac{15}{2}\right)$$

$$\sigma_{1f} = 1.7\,\sigma_{3f} \quad - (2)$$

for eff. parameter

$$(\sigma_{1f} - u_f) = (\sigma_{3f} - u_f) \tan^2\left(45 + \frac{\phi'}{2}\right) + 2c \tan\left(45 + \frac{\phi'}{2}\right) \quad - (4)$$

from (1) and (2)

$$0.92 = \frac{u_f}{1.7\sigma_{3f} - \sigma_{3f}}$$

$$\sigma_{3f} \times 0.7 \times 0.92 = u_f$$

$$\boxed{u_f = 0.644\,\sigma_{3f}}$$

now if $c' = 0$ for C-U test

by eq (4)

$$1.7\,\sigma_{3f} - 0.644\,\sigma_{3f} = (\sigma_{3f} - 0.644\sigma_{3f}) \times \tan^2\left(45 + \frac{\phi}{2}\right)$$

$$\tan^2\left(45 + \frac{\phi}{2}\right) = 2.966$$

$\tan\left(45+\frac{\phi}{2}\right) = 1.73$

$\phi' = 29.719°$

If $c' = 0$ then $\phi' = 29.719°$

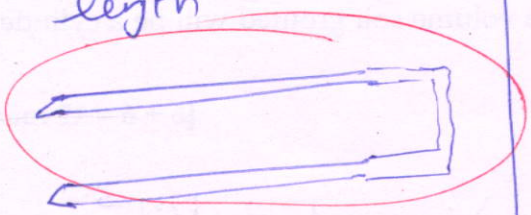
12

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

[12 marks]

	SPT	PLT
(a)	SPT is mostly used for sandy soil but also gives approximate results for clayey soil	This is used for sandy (non-cohesive) soils only bcz for cohesive soils loading duration must be longer.
(b)	for SPT 55 MM - 110mm diameter hole is made up to depth where we are required to determine soil Properties.	(c) a hole of width = 5 times depth is made for this plate load test and water table is lowered by Purping

(c) Sampler size used is 35 MM inner dia, 50.5 MM Outer dia and 650 MM length



(d) 65 kg hammer is used for blows from 75 cm height for finding no. of blows

(f) no. of blows are ~~Mea~~ taken for successive 3, 150 MM Penetration and last two 150 MM Penetration blows are used for finding shear Parameters

(d) Plate of size 30CM x 30CM or 75CM x 75CM is used and load is applied gradually.

(e) initial load of 0.7 t/m² is applied by Jacking mechanism and gradually Increased.

(g) 3 gauge are applied on plate at 120° and deflection / Settlement is measured

7

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)

$e = 0.6$ $\quad V_{total} = 1\,m^3$

$w : c = 6 : 1$ by weight

Ratio of their volume $\quad d = \frac{m}{V}$ $\quad V = \frac{m}{d}$

$V_w : V_c = \frac{6}{3.15} : 1$

$= 1.905 : 1$

$e = 0.6$ $\quad$ Porosity $= \frac{e}{1+e} = 0.375$

vol. of voids per m^3 of soil

$= 0.375\,m^3$

Volume of slurry $= \frac{0.375}{2}$

$= 0.1875\,m^3$

2

$V_w + V_c = 0.1875$

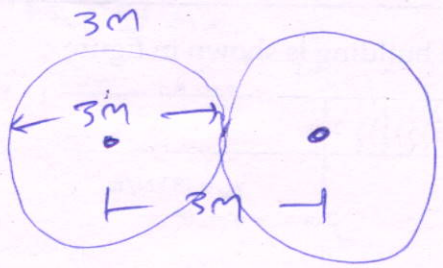
$2.905\,V_c = 0.1875$

$V_c = 0.0645\,m^3$

wt. of Cement $= 0.0645 \times 3150$ kg

$= 203.31$ kg

(ii)



Volume of soil Per grout hole

$= \frac{\pi}{4} d^2 \times H$

$= \frac{\pi}{4} \times 3^2 \times 12$

$= 84.82 \text{ m}^3$

Volume of voids to fill $= 0.1875 \times 84.82$

$= \boxed{15.90 \text{ m}^3}$

here wt. of Cement read

$= 15.9 \times 3150 \text{ kg}$

$= 50085 \text{ kg}$

$= 491.33 \text{ kN}$

cost of Cement $= 491.53 \times 250$

$= 122853.46 \text{ rs}$

If 50% Cement replaced by Bentonite

$= 245.65 \text{ kN (C)} + 245.65 \text{ kN (Bentonite)}$

Total revised Cost $= 245.65 \times 250$

$+$

$245.65 + 120$

$= 90896.05$

Saving Per grout hole

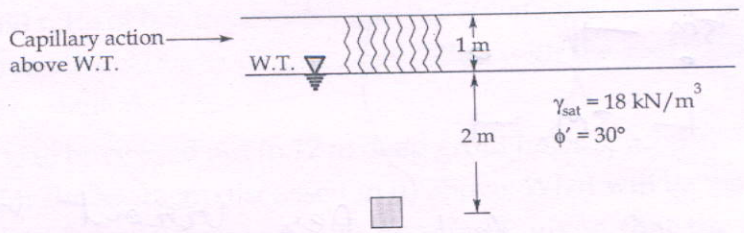
$= 122833.46$

$- 90896.05$

$= 31937.41 \text{ rs/-}$

$\boxed{\text{In \%} = 26\%}$

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]

Sol:-

eff. Vertical stress at 3m.

$\Rightarrow \gamma_{sat} \times 1 + (\gamma_{sub}) \times 2$

$= 18 \times 1 + (18 - 9.81) \times 2$

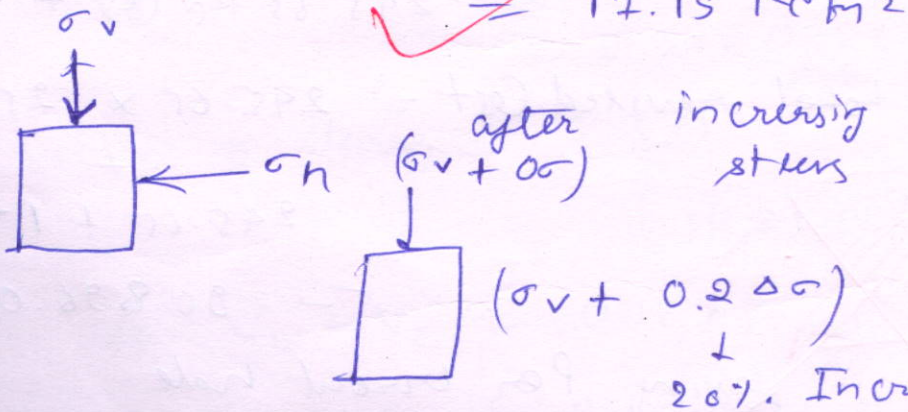
$\sigma_v = 34.38$ kN/m^2

soil is at rest so

$\sigma_h = k_0 \sigma_v$

$= 0.5 \sigma_v$

$= 17.19$ kN/m^2



at failure ⇒

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

$\because c = 0 \quad \phi = 30°$

$$(34.38 + \Delta\sigma) = (17.19 + 0.2\Delta\sigma) \times \tan^2(45 + 15)$$

$$34.38 + \Delta\sigma = 51.57 + 0.6\Delta\sigma$$

$$0.4\Delta\sigma = 17.19$$

$$\Delta\sigma = 42.975 \text{ kN/m}^2$$

12

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?

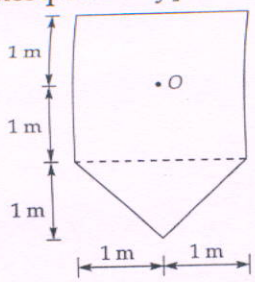
(ii) A foundation trench is to be excavated for a large project in a site. The soil investigation report shows the following details :

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]

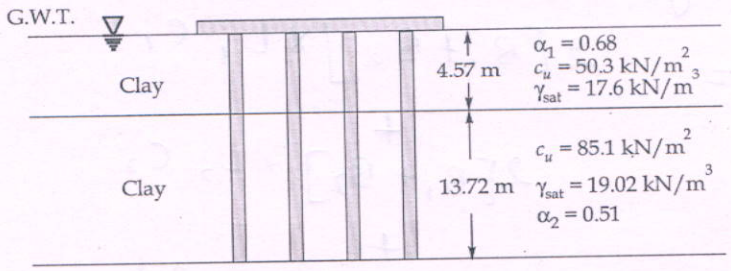
Q.2 (c) (i) Compute the vertical stress on a horizontal plane situated at a depth of 2 m below point O in the figure shown below. The area is loaded uniformly to an intensity of 300 kN/m^2. [Use Boussinesq's theory]



(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.

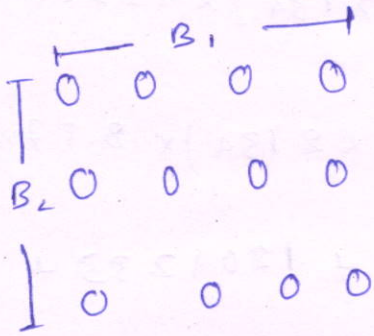


The piles are square in cross-section (356 mm × 356 mm). The center-to-center spacing, d of the piles is 889 mm. Determine the allowable load carrying capacity of the pile group. Use FOS = 4.

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

[20 marks]

Solution



width of Pile Group

$B_1 = 356 + (3 \times 889)$

$= 3023$ mm

$B_2 = 356 + [2 \times 889]$

$= 2134$ mm

(i) Load Carrying Cap as Individual piles

$Q_{up} = n[4B \times L \times q_s + B^2 \times q_b]$

$= 12[4 \times 0.356 \times [4.57 \times 0.68 \times 50.3] + 4 \times 0.356 [13.72 \times 0.51 \times 85.1] + (0.356)^2 \times 8.57 \times 85.1]$

q_b

$= 12[222.588 + 897.93 + 92.43]$

q_s of top clay; q_s of bottom clay; end Bearing resist

$= 13955.37$ KN

FOS = 4 $\quad Q_{allowed} = \frac{13955.37}{4} = 3488.9$ kN

Capacity of Pile Group as Creep

$$Q_{up} = 2[B_1 + B_2] \times L_1 C_1 + 2[B_1 + B_2] \times L_2 C_2 + (B_1 B_2) \times C N_c$$

$$= 2[3.023 + 2.134] \times 4.57 \times 50.3 + 2[3.023 + 2.134] \times 13.72 \times 85.1 + (3.023 \times 2.134) \times 8.57 \times 85.1$$

$$= 2370.89 + 12042.33 + 4709.8 \text{ kN}$$

$$= 19118 \text{ kN}$$

$$Q_{allowable} = \frac{Q_{up}}{FOS} = 4779.5 \text{ kN}$$

taking minimum of both

allowable load = 3488.9 kN

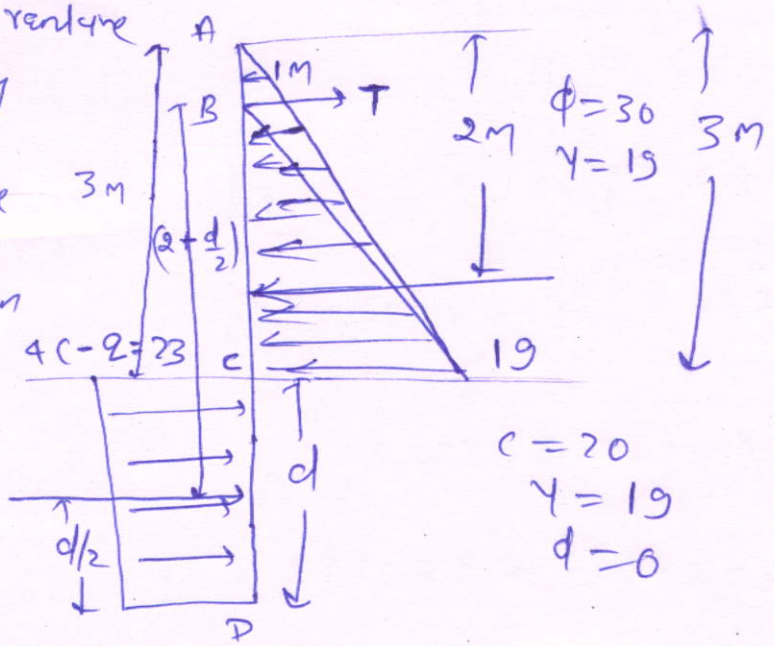
18

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/m³. The soil below dredge line is clay with a unit weight of 19 kN/m³, cohesion 20 kN/m² 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.

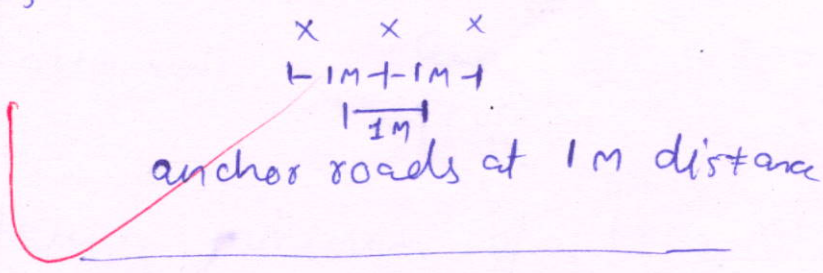
[20 marks]

as per venture

Theory Earth Pressure dist. diagram



C-5



anchor roads at 1m distance

$$K_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1}{3}$$

$q(\sigma_v)$ at C = 19 × 3 = 57

σ_h (active earth Pressure)

$= 57 \times \frac{1}{3}$

$= 19 \text{ kN/m}^2$

Passive stress at C on ~~Right~~ side = 4C − q

$= 4 \times 20 - 57$

$= 23 \text{ kN/m}^2$

$\Sigma M_B = 0$

$\frac{1}{2} \times 3 \times 19 \times (2-1) = 23 \times d \times \left[2 + \frac{d}{2}\right]$

$28.5 = 46d + 11.5d^2$

$d = 0.545m$ → This is embedded depth not total depth.

Total depth = 3 + 0.545 = 3.545m

$\Sigma H = 0$

T + Passive Pressure force = active Pressure force

$\frac{1}{2} K_a \gamma H^2 = (4c-2) \times d + T$

$\frac{1}{2} \times 3 \times 19 = 23 \times 0.545 + T$

$T = 15.965 \text{ kN/m}$

× 1m × 1m ×

spacing between anchors = 1m

so load carried by one anchor

$= T \times 1$

$= 15.965 \text{ kN}$

Q8 − 2 = (18)

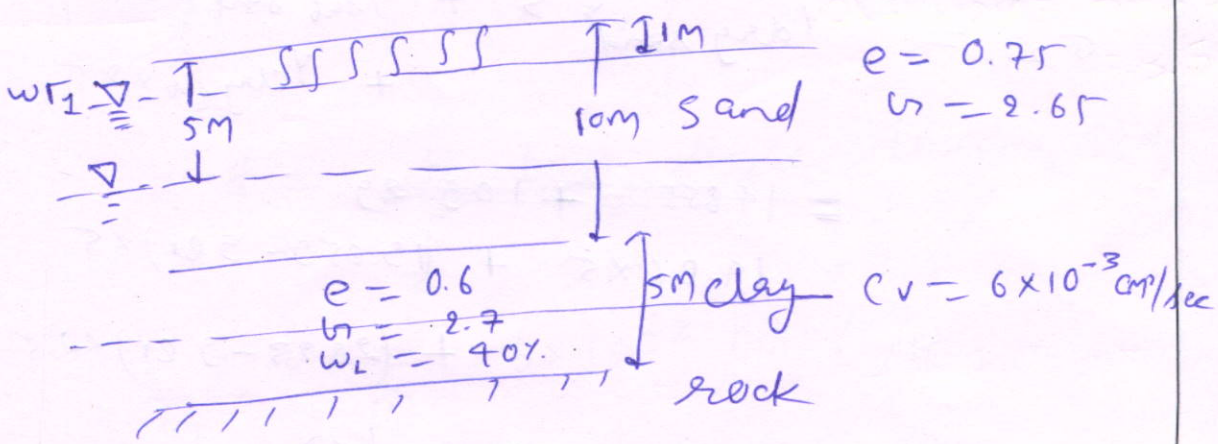
Q.3 (c) A light weight building stands over a 10 m thick stratum of sand. Beneath the sand stratum a clay layer of 5 m thick exists. The clay layer is underlain by a rock stratum. The water table lies at a depth of 1.0 m below ground surface and the sand above the water table is saturated with capillary 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 = 6×10^{-3} cm^2/s.

[20 marks]

(1) (2)



new before lowering stress at mid Point of clay

$$= \gamma_{sat} \times 1 + (\gamma_{sub} \times 9) + [\gamma_{sub\ clay} \times 2.5]$$

$$\gamma_{sat\ sand} = \frac{G\gamma_w(1+w)}{1+e} = \frac{\gamma_w(G+e)}{1+e}$$

$$= 19.059\ kN/m^2$$

$$\gamma_{dry\ sand} = \frac{G\gamma_w}{1+e} = 14.855\ kN/m^2$$

$$\gamma_{sat\ clay} = \frac{\gamma_w(G_c+e)}{1+e} = \frac{9.81(2.7+0.6)}{1.6}$$

$$= 20.23\ kN/m^2$$

$$\sigma_1 = 19.059 + (19.0599 - 9.81) \times 9 + (20.23 - 9.81) \times 2.5$$

$$= 128.35 \text{ KN/M}^2$$

after Pumping top soil becomes dry

$$\sigma_2 = \gamma_{dry\ sand} \times 5 + \gamma_{sub\ sand} \times 5 + \gamma_{clay\ sub} \times 2.5$$

$$= 14.855 + 109.89$$

$$= 14.86 \times 5 + (19.059 - 9.81) \times 5 + (20.23 - 9.81) \times 2.5$$

$$= 146.59 \text{ KN/M}^2$$

new ultimate settlement

$$\Delta H = \frac{H_0 C_c}{1 + e_0} \log \frac{\sigma_2}{\sigma_1}$$

$$C_c = 0.009 (w_L - 10)$$

$$= 0.27$$

$$\Delta H_{ult} = \frac{5000 \times 0.27}{1.6} \log \frac{146.59}{128.35}$$

$$= 48.69 \text{ MM}$$

now for 25 mm settlement

deg. of consolidation

$$U\% = \frac{25}{48.69} \times 100$$

$$= 51.34\%$$

Time factor

$$T_v = \frac{\pi}{4}\left(\frac{U}{100}\right)^2 = 0.207$$

so $$T_v = \frac{C_v t}{d^2} \quad \text{—— (1)}$$

$d = \frac{H}{2}$ bcz single drainage only

$= 5\,M$

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

by eq (1)

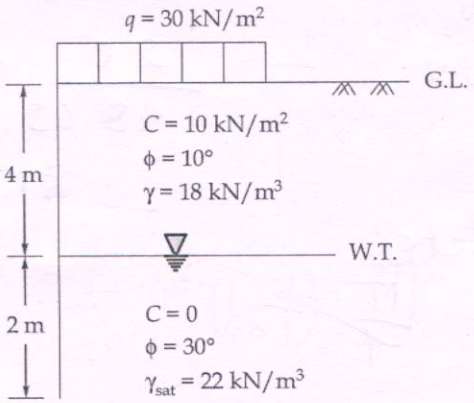
$$0.207 = \frac{6 \times 10^{-3} \times t}{(500)^2}$$

time $= 86.27 \times 10^5$ seconds

$= \boxed{99.85 \text{ days}}$

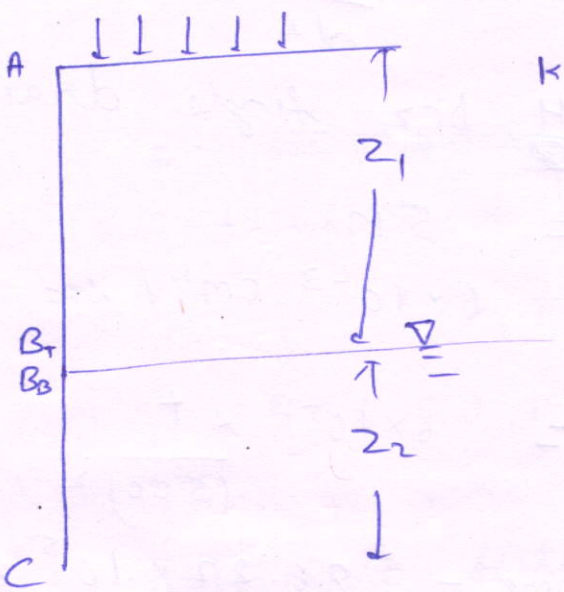
20

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]

Soln →



$K_a = \frac{1-\sin\phi}{1+\sin\phi} = 0.704$

$C = 10$

$\gamma = 18$

$\gamma_{sat} = 22$

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

at top Point A stress

$$\sigma_{H(A)} = K_a q - 2C\sqrt{K_a} + K_a \gamma z \Big|_0$$

$$= 0.704 \times 30 - 2 \times 10 \sqrt{0.704}$$

$$= 21.12 - 16.78$$

$$= 4.34 \text{ kN/m}^2$$

σ_H at top (upper side of B)

$= 21.12 - 16.78 + K_{a_1} \gamma Z$

$= 21.12 - 16.78 + 0.704 \times 18 \times 4$

$= 55.03$ kN/m²

σ_H at lower pt. of B (C=0)

$= K_{a_2} q + K_{a_2} \gamma Z$

$= \frac{1}{3} \times 30 + \frac{1}{3} \times 18 \times 4$

$= 10 + 24 = 34$ kN/m²

σ_H at lower most point (C)

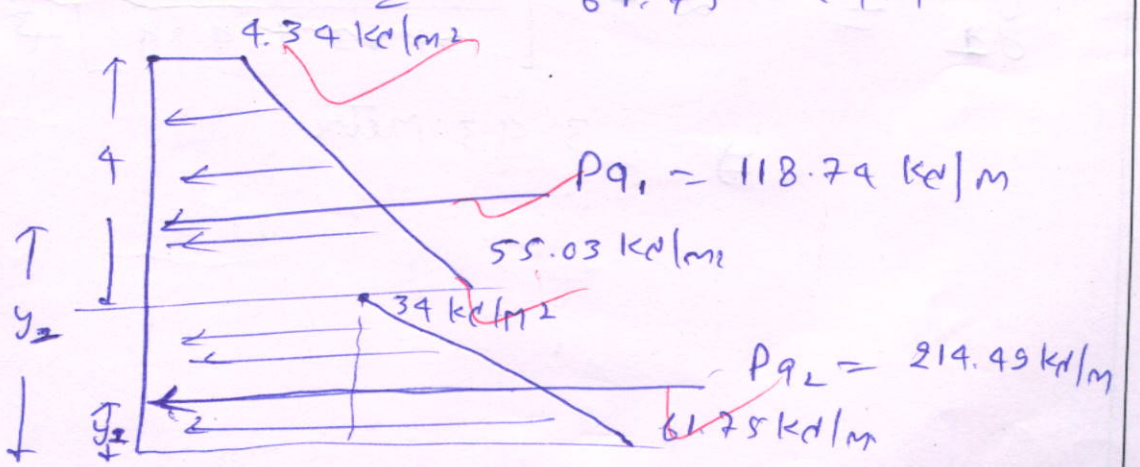
$= K_{a_2} q + K_{a_2} [\gamma_1 Z_1 + \gamma' Z_2] + \gamma_w Z_2$

(due to water table)

$= \frac{1}{3} \times 30 + \frac{1}{3} [72 + (22 - 9.81) \times 2] + 9.81 \times 2$

$= 10 + 32.13 + 19.62$

$= 61.75$ kN/m²



total force acting on wall

$$= P_{q_1} + P_{q_2}$$

$$= \frac{1}{2}\left[4.34 + 55.03\right] \times 4 + \frac{1}{2}\left[34 + 61.75\right] \times 2$$

$$= 118.74 \text{ kN/m} + 95.75 \text{ kN/m}$$

(P_{q_1} = 118.74 kN/m, P_{q_2} = 95.75 kN/m)

$$= 214.49 \text{ kN/m}$$

line of action from Base of wall

$$= \frac{P_{q_1} Y_1 + P_{q_2} Y_2}{P_{q_1} + P_{q_2}}$$

using Trapezoidal formula

$$y_2 = \left(\frac{61.75 + 2 \times 34}{61.75 + 34}\right) \times \frac{2}{3}$$

$$= 0.903 \text{ metre}$$

$$y_2 = 2 + \left[\frac{55.03 + 2 \times 4.34}{55.03 + 4.34}\right] \frac{4}{3}$$

$$\Rightarrow 3.43 \text{ metre}$$

So line of action from Base of wall

$$\Rightarrow \frac{(118.74 \times 3.43) + (95.75 \times 0.903)}{214.49}$$

$$= \frac{407.28 + 86.46}{214.49}$$

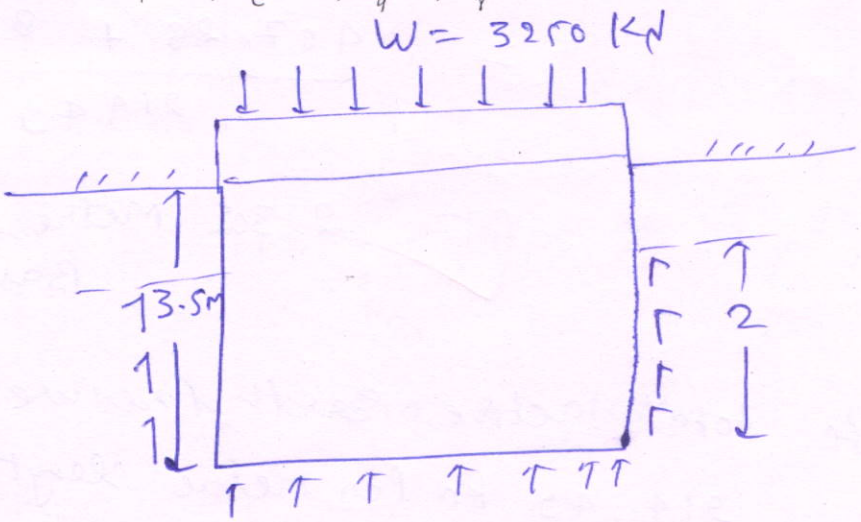
$= 2.302$ Metre from Base

So total active Earth Pressure = 214.49 kN Per metre length of wall is acting at 2.302 metre from Base of wall

20

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]



End Bearing resistance Provided by footing

$$q_4 = 1.3CN_c + qN_q + \frac{1}{2}B\gamma N_\gamma$$

$$C = 0.12\ N/mm^2 = 120\ kN/m^2$$

$$q_4 = 1.3 \times 120 \times 5.7 + 3.5 \times 21 + 0$$

$$= 962.7\ kN/m^2 \quad -(1)$$

Side resistance Provided

$$= 4B \times L \times \text{adhesion by clay}$$

$$L = 2m$$

$$q_{side} = 4 \times B \times 2 \times 25$$

$$= 200B \quad -(2)$$

Self wt. of footing

$= B^2 \times D \times \gamma_{concrete}$

$= B^2 \times 3.5 \times 25$

$= 87.5 B^2$

now total load carried

$= 87.5B^2 + 3250 kN$

For = 4

to

$4(87.5B^2 + 3250) =$ [load carrying capacity]

$4(87.5B^2 + 3250] = 962.7B^2 + 200B$

$350B^2 + 13000 = 962.7B^2 + 200B$

$612.7B^2 + 200B - 13000 = 0$

$B = 4.445 m$

so $B = 4.45$ must be provided for safely taking this load

12 + 2 = 20

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

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

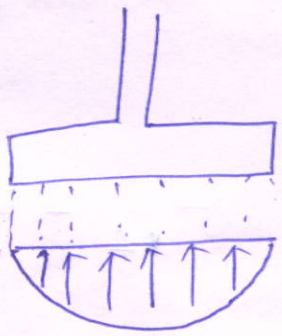
(b) Rigid footing on cohesive soil.

(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.

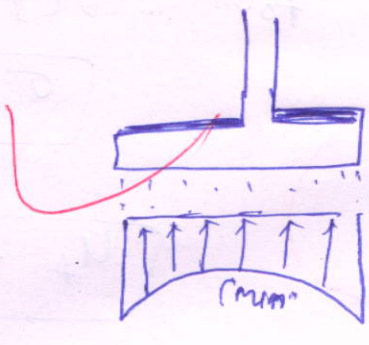
[5 + 15 marks]

(i) Rigid footing on Cohesionless soil at shallow depth

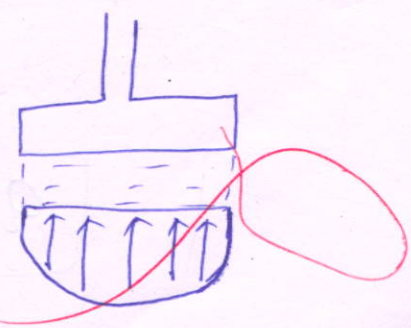


Max^m at Center and ≈0 at Corners

(ii) Rigid footing on Cohesive soil

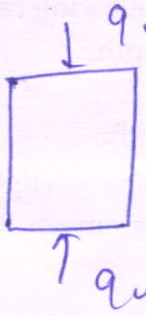


(iii) Rigid, Cohesionless at larger depth



Max^m at Center but ≠0 at Corner

(ii)



new as we know

$$A_f = \frac{u_f}{\sigma_{1f} - \sigma_{3f}} \qquad \because B = 1$$

$$\sigma_{1f} - u_f = (\sigma_{3f} - u_f)\tan^2\left(45 + \frac{\phi'}{2}\right) + 2c\tan\left(45 + \frac{\phi'}{2}\right)$$

for UCS

$$\sigma_{3f} = 0$$

$$u_f = A_f \sigma_{1f}$$

$$\sigma_{1f} - u_f = -A_f \sigma_{1f}\tan^2\left(45 + \frac{\phi}{2}\right) + 2c\tan\left(45 + \frac{\phi}{2}\right)$$

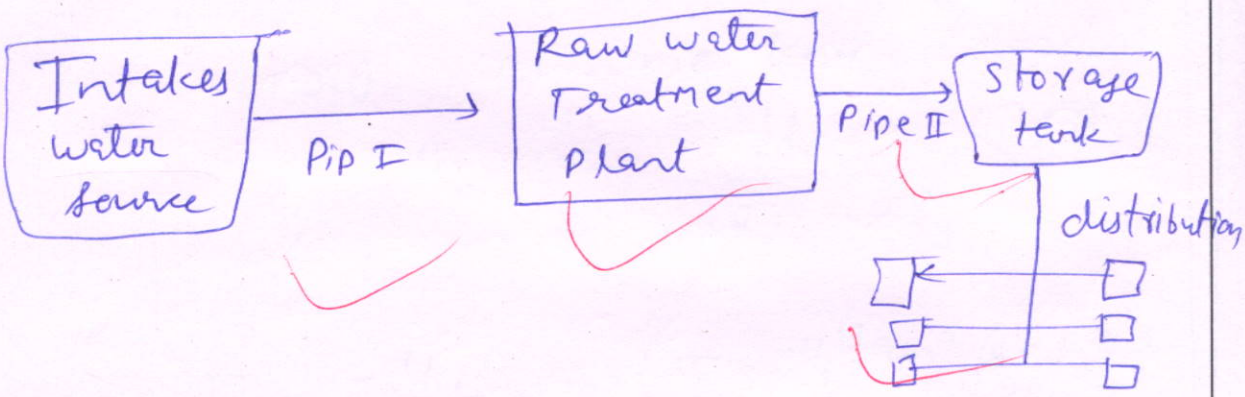
$$q = \text{Area} \times \sigma_{1f}$$

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]

→ for a water supply scheme.



- for a water supply scheme acc. to demand of city water source is located and arrangement of Intakes are made for getting water.

→ Then this raw water is supplied to WTP where it is treated

→ Then water is delieved to storage tank by pumping which Provide head to water.

→ The this water is directly supplied into City.

→ water distribution system are having many types

(i) closed end distribution (dead end)
(ii) Radial distribution.
(iii) Ring distribution system

→ Pipe I and Pipe II are designed for design discharge of max daily demand

→ distribution system is designed for Coincidental dragt.

	Pipe	WTP	storage tank
design Period	30 yrs	15 yrs	15 yrs

	Pumps
design Period.	15 yrs

→ Techniques used in water Treatment.

aeration → filteration (coagulation and flocculation) is reqd

↓

disinfection.

→ if Hardness, Fluorides are also there than Hardness removal and defluorosis is also done.

7

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

[12 marks]

Environmental Impact assessment :→

for every Project there are some challenges or Impacts on Environment that can be dangerous in short term or long term. to find these Impact and their solution a thoroughly assessment is done which is called Env. Impact Assessment.

it is reqd. to reduce these Impact so that sustainable development can take place without harming current generation and future generations.

Impact of Thermal Power plants →

→ high amt. of fly ash is generated.

→ smoke which contains Pb, CO, SO_2 is produced from thermal Power plants which causes air Pollution

→ Waste generated from thermal power plants makes water turbid.

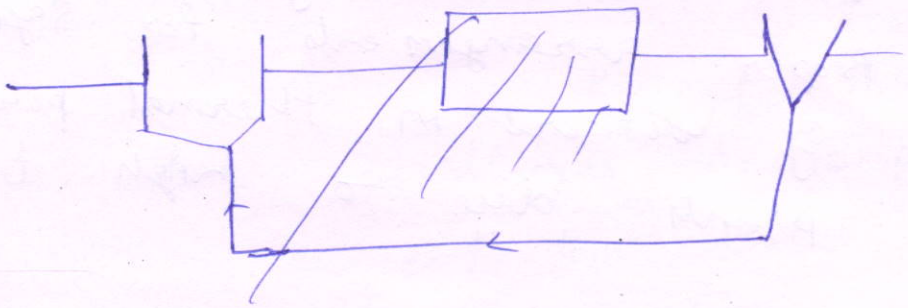
→ it is also necessary to make proper arrangements for sgety of workers in thermal power plants due to high temp.

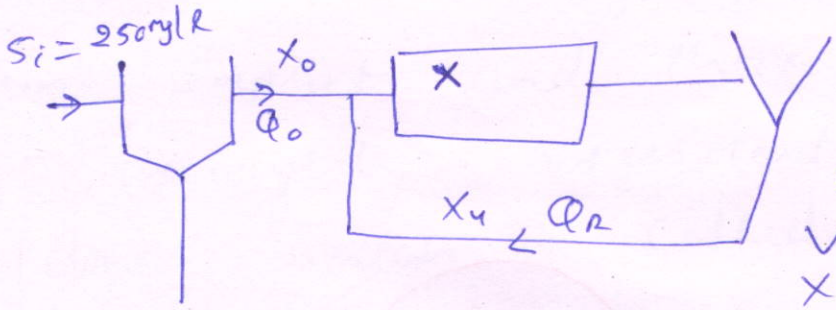
→

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]

Ans-





$Q_0 = 4000\ m^3/d$
$S_0 = 250\ mg/l$
$S = 30\ mg/l$
$V = 700\ m^3$
$X = 3000\ mg/l$

(a) mass of sludge Produced Per day

$= Q_0(S_0 - S) \times Y$

$\Rightarrow 4000 \times 10^3 \times [250 - 30] \times 0.5$ mg

$= 440 \times 10^6$ mg

$= 440$ kg / day of Net solid sludge

(b) $\theta_c = ?$

$$\frac{Q_0(S_0 - S)Y}{VX} - K_d = \frac{1}{\theta_c}$$

$$\frac{4000(250-30)\times 0.5}{700\times 3000} - 0.09 = \frac{1}{\theta_c}$$

$\theta_c = 8.367$ days

(c) f/M food by micro organism ratio

$$= \frac{Q_0 S_0}{VX}$$

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

$\frac{f}{M} = 0.476$ / day

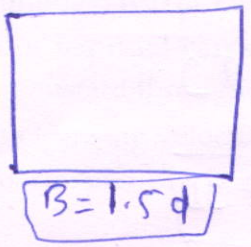
5

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

[12 marks]

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]



assume dia of sewer = D

for Hydraulically equivalent section mean discharge at full depth must be same as per Manning's theory

$$Q_{rect.} = A \times \frac{1}{n} \times R^{2/3} S^{1/2}$$

$$= [1.5d \times d] \times \frac{1}{n}\left[\frac{1.5d^2}{3d+2d}\right]^{2/3} S^{1/2}$$

$\because$ Hydraulic rad $= \frac{\text{Area}}{\text{Wetted Perimeter}}$ $\therefore \boxed{R = \frac{A}{P}}$

$$= \frac{1}{n} S^{1/2} \times 1.5d^2 \times 0.448\, d^{2/3}$$

$$= 0.6722 \frac{1}{n} S^{1/2} d^{8/3} \quad \text{---(1)}$$

$$Q_{sewer} = \frac{\pi}{4} D^2 \times \frac{1}{n} \times \left[\frac{D}{4}\right]^{2/3} S^{1/2}$$

$$= \frac{1}{n} S^{1/2} \times 0.312\, D^{8/3}$$

$$= 0.312 \frac{1}{n} S^{1/2} D^{8/3} \quad \text{---(2)}$$

eq (1) = eq (2)

$$0.6722\, d^{8/3} = 0.312\, D^{8/3}$$

$$\frac{d}{D} = 0.749$$

$$\boxed{d = 0.749D}$$

and width of rect. sewer

$$B = 1.5d$$

$$B = 1.5 \times 0.749 D$$

$$\boxed{B = 1.124D}$$

so width of Rect. sewer is 1.124 times of dia of sewer.

12

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]

Time	$Q_{avg} = \frac{Q_0+Q_1}{2}$ (m^3/sec)	demand (ML)	Cumulative demand (ML)	Cumulative supply (ML)	Δ(CD − CS) (ML)
0-2	0.05	0.36	0.36	1.77	-1.41
2-4	0.125	0.9	1.26	3.54	-2.28
4-6	0.175	1.26	2.52	5.31	-2.79
6-8	0.35	2.52	5.04	7.08	-2.04
8-10	0.55	3.96	9	8.85	0.15
10-12	0.5	3.6	12.6	10.62	1.98
12-14	0.35	2.52	15.12	12.39	2.73
14-16	0.225	1.62	16.74	14.16	2.58
16-18	0.175	1.26	18	15.93	2.07
18-20	0.225	1.62	19.62	17.7	1.92
20-22	0.175	1.26	20.88	19.47	1.41
22-24	0.05	0.36	21.24	21.24	0

water req in 2 hours = $Q\,(m^3/sec) \times 3600 \times 2 \times 1000$ ltr

$= Q_{avg} \times 7.2$ ML

demand in (ML) = $Q \times 7.2$

Total demand in 24 hrs = 21.24 ML

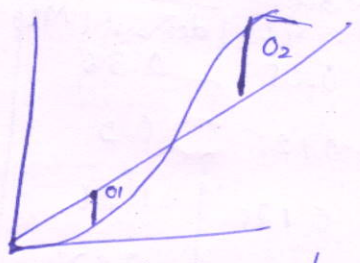
if water supply constant Per day
so rate of supply Per 2 hours

$$= \frac{21.24}{24} \times 2 \text{ ML/2hrs}$$

$$= 1.77 \text{ ML/2hrs}$$

for design of reservoir

Bal. storage
$= O_1 + O_2$



⇒ which is max^m water to be stored for entry requirement than supply and water when supply is more than demand

from table

Balancing storage = max(CD-CS) + max(CS-CD)

$= 2.79 + 2.73$ ML

$= 5.52$ Million litre

$= 5520$ (Metre)^3

14

(ii) Self cleansing velocity and scouring velocity → In designing of sewers it is required that solid particles of sludge/sewage are not get settled. So for this min velocity must be achieved even if flow is very less so. In sewer design at min discharge ($\frac{1}{3}$rd of Q_avg) it is reqd to achieve min velocity which is called self cleansing velocity

$$V_{self\ cleansing} = \sqrt{\frac{8\beta}{f}(G-1)gd}$$

β = coeff of solids. f = friction factor of Pipe, d = dia of Pipe.

Non scouring velocity is maximum velocity that can be achieved. If velocity is higher than this velocity there will be higher friction losses and loss of sewer pipes material can also takes place in longer run.

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]

Alkalinity = 200 mg/l =

$= \frac{200}{50}$ Meq. as $CaCO_3$

= 4 Meq.

eq. weight of $CaCO_3$ = 50

Hardness of $CaCl_2$ = $\frac{50}{50}$ = 1 Meq. as $CaCO_3$

Hardness as $MgSO_4$ = $\frac{75}{50}$

= 1.5 Meq as $CaCO_3$

total Hardness = 1 + 1.5 = 2.5 Meq.

Hardness $CaCl_2$ = 75 mg/l

$= \frac{50}{55} = 0.909$ Meq.

$MgSO_4$ = 75 mg/lts

$= \frac{75}{60}$ Meq.

= 1.25 Meq.

So Non Carbonate Hardness

= 0.909 + 1.25

= 2.16 Meq.

Carbonate Hardness = alkalinity here
= 4 Meq.

CH = 4 Meq. NCH = 2.16 Meq.

ant. of lime reqd ⇒ CH + NCH of Mg^{2+}

= 4 + 1.25

= 5.25 Meq. as CaO

= 5.25 × 28 = 147 Mg/ltr

if 85% Pure only then for 1 Million Water lime = $\frac{147 \times 10^6 \times 10^{-6}}{0.85}$ kg

= 172.94 kg lime

Soda reqd (Na_2CO_3) = NCH = 2.16 Meq.

= 2.16 × 42 = 90.72 Mg/ltr

for 1 ML water = 90.72 × 10^6 × 10^{-6} kg

= 90.72 kg Soda

(ii) disadvantage of Zeolite Process

→ 100% Hardness is removed in Zeolite Process which is not acceptable for domestic need of water.

→ regeneration is reqd time to time by brine solution which disturbs the continuity of Treatment.

→ if Fe^{2+} ~~and Mg~~ are Present in water, they are removed but regeneration is not Possible and Zeolite get wasted.

→ if turbidity / SS are higher in water this Process is not efficient

→

3

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]

discharge = 10×10^6 ltr/day

design discharge = $1.8 \times 10 \times 10^6$ ltr/day

$\frac{L}{B} = 3$

For $d > 0.04$ mm $G = 2.65$ $T = 20°C$

Settling velocity for $d > 0.04$

$$V_s = \frac{418}{\cancel{18}} d^2 (G-1) \frac{3T+70}{100}$$

$$V_s \text{ (mm/sec)} = 418 \times (0.04)^2 \times 1.65 \times \left(\frac{60+70}{100}\right)$$

$= 1.434$ mm/sec

for $V_s = 1.434$ mm/sec

depth of tank = 3.5 metre

assuming free board = 0.5 M

depth of water zone = 3M

so as we know

$$V_s = \frac{Q}{LB} \qquad V_{flow} = \frac{Q}{BH}$$

$$\frac{V_s}{V_f} = \frac{H}{L} \quad \text{---} \quad (1)$$

area reqd $LB = \frac{Q}{V_s}$

$Q = \frac{18000}{86400}$ m³/sec $\quad LB = \frac{18000 \times 1000}{86400 \times 1.434}$ m²

$= 145.28$ m²

$L = 3B$

$3B^2 = 145.28$

$B = 6.96$ M $\quad L = 20.87$ M

Volume $= 6.96 \times 20.87 \times 3$

$= 435.9$ m³

detension Period $= \frac{V}{Q}$

$= \frac{435.9}{18000} \times 24$ hrs

$t_d =$ 0.58 hrs

note :- for sedimentation tank detension time must be 4-6 hours but it is less here.

8

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]