Soil Mechanics - Tutorial 4 Solution

Theory

Please refer to class notes for theory portion.

Numericals

1. In falling head permeameter test, the initial head (t=0) is 40 cm. The head drops by 5 cm in 10 minutes. Calculate the time required to run the test for the final head to be at 20 cm. If the sample is 6 cm in height and 50 cm^2 in x-sectional area, calculate the coefficient of permeability, taking area of stand pipe as 0.5 cm^2.

Solution;

Given; $h_1 = 40$ cm.

$h_2 = 35$ cm. (As the head falls by 5 cm)

$t = 10$ minutes.

$= 600$ seconds.

We have;

$$k = \frac{aL}{At} \log_e \frac{h_1}{h_2}$$

where; a is the area of the stand pipe.

L is the height of the sample.

A is the CSA of sample.

$$\text{or, } k = \frac{0.5 \times 6}{50 \times 600} \times \log_e \frac{40}{35}$$

$$= 1.1537 \text{ cm/day}.$$

Again; for calculation of time for $h_2 = 20$ cm;

we have;

$$k = \frac{aL}{At} \log_e \frac{h_1}{h_2}$$

$$\text{or, } 1.1537 = \frac{0.5 \times 6}{50 \times 600} \log_e \frac{40}{20}$$

$$\therefore t = 0.036048 \text{ day}.$$

$$= 51.90 \text{ minutes}.$$

2. The capillary rise in soil A with D_{10} = 0.06 mm is 60 cm. Estimate the capillary rise in soil B with D_{10} = 0.1 mm. Assume the same void ratio in both the soils.

Solution;

If d_A and d_B denotes the size of voids in soil A and B respectively

then;

$$e = \frac{V_v}{V_s} \propto \frac{d_A^3}{D_A^3} = \frac{d_B^3}{D_B^3} \quad \text{— a).}$$

for soil A;

$$d_A = \frac{4T_s \cos\alpha}{h_{cA} \times \gamma_w}$$

where;

T_s = Surface tension.

α = Angle of contact.

d_A = diameter of capillary tube A.

Assume that;

$T_s = 75 \times 10^{-6}$ kN/m.

$\alpha = 0$.

$\gamma_w = 9.81$ kN/m^3

$$d_A = \frac{4 \times 75 \times 10^{-6} \times \cos 0^\circ}{0.6 \times 9.81} = 50.96 \times 10^{-6} \text{ m.}$$

From a).

$$d_B = \frac{d_A}{D_A} \times D_B = 50.96 \times 10^{-6} \times \frac{0.1}{0.06}$$

$$d_B = 84.9 \times 10^{-6} \text{ m.}$$

Calculation of capillary rise in soil B is;

$$h_{cB} = \frac{4T_s \cos\alpha}{d_B \times \gamma_w}$$

$$= \frac{4 \times 75 \times 10^{-6} \times \cos 0^\circ}{84.9 \times 10^{-6} \times 9.81}$$

$$= 0.36 \text{ m.}$$

3. A 3 m thick soil stratum has a coefficient of permeability of $3*10^{-7}$ m/sec. A separate test gave porosity 40% and bulk unit weight 21KN/m^3 at a moisture content of 31%. Determine the head at which upward seepage will cause quick sand condition. What is the flow required to maintain critical condition?

Solution;

Given;

$k = 3\times10^{-7}$ m/secs.

$n = 40\%$

$\gamma = 21 KN/m^3$.

$w = 0.31$.

We have;

$$e = \frac{n}{1-n} = \frac{0.4}{1-0.4} = 0.667.$$

$$\gamma_d = \frac{\gamma}{1+w} = \frac{21}{1.31} = 16.031 KN/m^3.$$

Also;

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

$$\text{or, } 16.03 = \frac{9.81 \times G}{1+0.667}$$

$$\Rightarrow G = 2.724.$$

Now;

$$i_c = \frac{G-1}{1+e} = \frac{2.724-1}{1+0.667} = \frac{1.724}{1.667} = 1.034.$$

Again;

$$i_c = \frac{h}{L} \text{ or; } 1.034 = \frac{h}{3} \Rightarrow h = 3.10 m.$$

Flow required $= q = kiA$

$= 3\times10^{-7} \times 1.034 \times A$

$= 3.1\times10^{-7}$ $m^3/sec/m^2$.

4. Calculate the coefficient of permeability of soil sample 8 cm height and cross-sectional area 60 cm^2. It is observed that in 12 minutes, 600 ml of water passed down under constant head of 50 cm. The test specimen weighs 750 gm in dry condition. Take specific gravity of soil solids as 2.7. Calculate the seepage velocity.

Solution;

Given;

Length of specimen = 8cm.

Area of specimen (A) = $60 cm^2$.

time (t) = 12 min = 12×60 = 720 seconds.

Volume collected = 600ml. = 600 c.c

head (h) = 50cm.

we have;

$$k = \frac{VL}{hAt} = \frac{600 \times 8}{50 \times 60 \times 720} = 0.00222 \text{ cm/sec}$$

Discharge velocity, $v = \frac{q}{A} = \frac{V}{At} = \frac{600}{60 \times 720} = 0.0138 \text{ cm/sec}$

Volume of specimen (V) = 60 × 8 = 480 cm^3.

= 480 000 mm^3.

$$\gamma_d = \frac{W_d}{V} = \frac{7.35N}{480000} = 1.53 \times 10^{-5} N/mm^3 = 15.31 kN/m^3.$$

$$e = \frac{G\gamma_w}{\gamma_d} - 1 = \frac{2.7 \times 9.81}{15.3} - 1 = 0.73.$$

we have;

$$n = \frac{e}{1+e} = \frac{0.73}{1+0.73} = \frac{0.73}{1.73} = 0.422.$$

Seepage velocity $(V_s) = \frac{v}{n}$

$$= \frac{0.0138}{0.422}$$

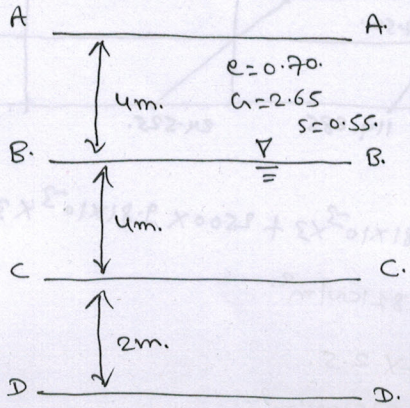
$$= 0.0327 \text{ cm/sec}.$$

5. A fine sand deposit is located between the ground surface to a depth of 10 m. The soil has an average void ratio of 0.70 and a specific gravity of 2.65. The water table is found at a depth of 4 m below the ground surface. ~~Calculate also the change in the effective stress if the soil gets saturated upto a height of 1 m above the water table due to capillary.~~

Calculate also the change in the effective stress if the water table rises 1m above the original level.

Solution;

case-1.



Calculation of bulk density.

$$\gamma_b = \frac{\{G+Se\}\gamma_w}{1+e}$$

$$= \frac{\{2.65+0.55\times0.7\}\times9.81}{1.70}$$

$$= 17.51\ KN/m^3.$$

For; γ_{sat};

$$\gamma_{sat} = \frac{\{G+e\}\gamma_w}{1+e}$$

$$= \frac{\{2.65+0.7\}\times9.81}{1.70}$$

$$= 19.33\ KN/m^3.$$

At a depth 8 m below ground surface. (At C-C).

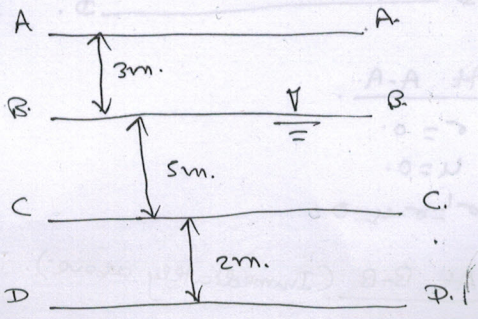
$\sigma = (17.51\times4 + 19.33\times4) = 147.32\ KN/m^2.$

$u = 9.81\times4 = 39.24\ KN/m^2.$

$\sigma' = \sigma - u = 147.32 - 39.24 = 108.08\ KN/m^2.$

Case-II

When the water table rises by 1m above from the previous condition.



At C-C

$\sigma = 17.51\times3 + 19.33\times5.$

$= 149.18\ KN/m^2.$

$u = 9.81\times5.$

$= 49.05\ KN/m^2.$

$\sigma' = \sigma - u$

$= 149.18 - 49.05$

$= 100.18\ KN/m^2.$

Now;

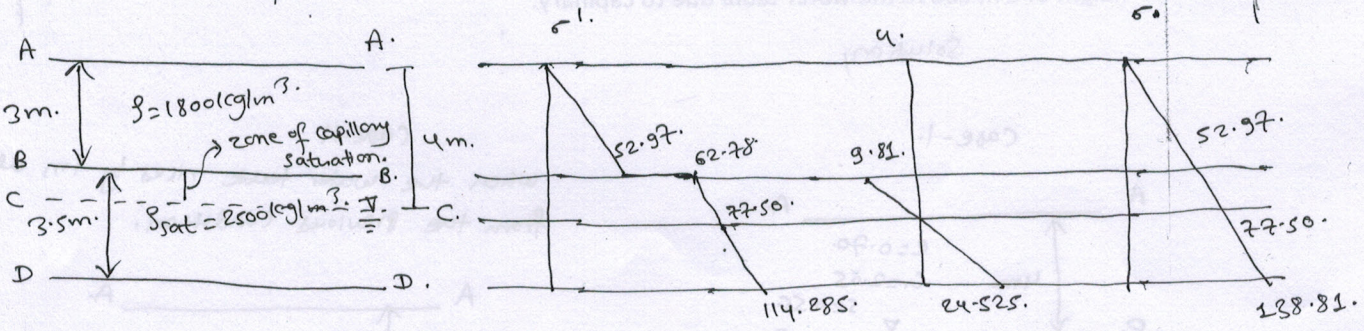
Change in effective stress

$= 108.08 - 100.18$

$= 7.91\ KN/m^2.$

6. A sand deposit consists of two layers. The top layer is 3m thick (ρ=1800 kg/m^3) and the bottom layer is 3.5m thick (ρ_{sat} = 2500 kg/m^3). The water table is at a depth of 4m from the surface and zone of capillary saturation is 1 m above the water table. Draw the diagram showing the variation of total stress, neutral stress (pore water pressure) and effective stress.

Solution;



At A-A.

$\sigma = 0.$

$u = 0.$

$\sigma' = \sigma - u = 0.$

At B-B (Immediately above).

$\sigma = \gamma \times 3.$

$= 1800 \times 9.81 \times 10^{-3} \times 3.$

$= 52.97 kN/m^2.$

$u = 0.$

$\sigma' = \sigma - u = 52.97 kN/m^2.$

At B-B. (Immediately below).

$\sigma = \gamma \times 3.$

$= 1800 \times 9.81 \times 10^{-3} \times 3.$

$= 52.97 kN/m^2.$

$u = -9.81 \times 1.$

$= -9.81.$

$\sigma' = \sigma - u = 52.97 + 9.81. = 62.78 kN/m^2.$

At C-C.

$\sigma = 1800 \times 9.81 \times 10^{-3} \times 3 + 2500 \times 9.81 \times 10^{-3} \times 1.$

$= 77.50 kN/m^2.$

$u = 0.$

$\sigma' = 77.50 kN/m^2.$

At D-D.

$\sigma = 1800 \times 9.81 \times 10^{-3} \times 3 + 2500 \times 9.81 \times 10^{-3} \times 3.5.$

$= 138.81 kN/m^2.$

$u = 9.81 \times 2.5.$

$= 24.525 kN/m^2.$

$\sigma' = \sigma - u.$

$= 138.81 - 24.525$

$= 114.285 kN/m^2.$

7. A horizontal stratified deposit consists of 3 layers with coefficient of permeability as $8*10^{-4}$ cm/sec, $50*10^{-4}$ cm/sec and $15*10^{-4}$ cm/sec and their thickness are 6m, 3m and 18m respectively. Find the effective average permeability of the deposit in horizontal and vertical direction.

Solution;

Given;

$k_1 = 8\times10^{-4}$ cm/sec. $\quad h_1 = 6$m.

$k_2 = 50\times10^{-4}$ cm/sec. $\quad h_2 = 3$m.

$k_3 = 15\times10^{-4}$ cm/sec. $\quad h_3 = 18$m.

For;

Effective avg. permeability in horizontal direction;

$$k_h = \frac{k_1h_1 + k_2h_2 + k_3h_3}{h_1 + h_2 + h_3}$$

$$= \frac{(8\times600 + 50\times300 + 15\times1800)\times10^{-4}}{600+300+1800}$$

$$= 17.33\times10^{-4} \text{ cm/sec}$$

For;

Effective avg. permeability in vertical direction;

$$k_v = \frac{h_1 + h_2 + h_3}{\frac{h_1}{k_1} + \frac{h_2}{k_2} + \frac{h_3}{k_3}}$$

$$= \frac{2700}{\frac{600}{8\times10^{-4}} + \frac{300}{50\times10^{-4}} + \frac{1800}{15\times10^{-4}}}$$

$$= \frac{2700}{750000 + 60000 + 1200000}$$

$$= \frac{2700}{2010000}$$

$$= 13.43\times10^{-4} \text{ cm/sec}$$

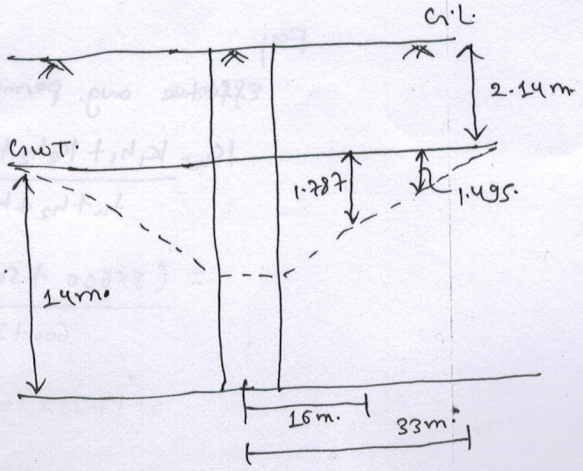
8. In order to determine the average coefficient of permeability of a bed of sand 14 meters thick, overlying an impervious stratum, a well was sunk through the sand and a pumping test was carried out. After a certain interval, the discharge was 12.4 liters per second and drawn down in the observation wells at 16 meters and 33 meters respectively from the test well were found to be 1.787 m and 1.495 m respectively. If the GWT was originally 2.14m below the ground surface, find a) the permeability of sand layers, b) an approximate value for the effective grain size. (Take C = 125).

Solution;

Given;

$q = 12.4$ litres/second.

$= 12.4 \times 10^{-3}\ m^3/sec.$



we have;

$$K = \frac{q \log_e \frac{r_2}{r_1}}{\pi (z_2^2 - z_1^2)} \quad -a)$$

Given; $r_1 = 16m.$

$r_2 = 33m$

$z_1 = (14 - 2.14 - 1.787)$

$= 10.073m.$

$z_2 = 14 - 2.14 - 1.495$

$= 10.365m.$

$\therefore K$ from a)

$$= \frac{12.4 \times 10^{-3} \times \log_e \frac{33}{16}}{\pi \times (10.365^2 - 10.073^2)}$$

$= 4.79 \times 10^{-4}\ m/sec.$

we have;

$K = C D_{10}^2.$

or, $4.79 \times 10^{-4} = 125 \times D_{10}^2.$

$\therefore D_{10} = 1.96\ mm.$

9. A layer of sand 6m thick lies beneath a clay stratum 5m thick and above a thick shale. In order to determine the permeability of the sand, a well was driven to the top of the shale and water was pumped out at the rate of $10*10^{-3}$ m^3/secs. Two observations well were driven through the clay at 15m and 30m from the pump well and drawn down in the wells were found to be 3m and 2.5m respectively. Calculate the coefficient of permeability of the soil.

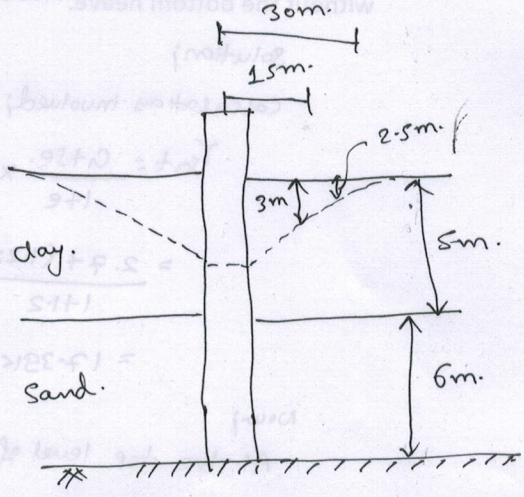
Solution;

Given;

$q = 10\times10^{-3}\ m^3/secs.$

$r_1 = 15m.$

$r_2 = 30m.$



We have;

$$k = \frac{q}{2\pi b}\cdot\frac{\log_e \frac{r_2}{r_1}}{z_2 - z_1}$$

$$= \frac{10\times10^{-3}}{2\pi\times6}\times\frac{\log_e \frac{30}{15}}{z_2 - z_1}$$

Calculation of z_1 and z_2.

$z_1 = 11 - 3 = 8m.$

$z_2 = 11 - 2.5 = 8.5m.$

$$\therefore k = \frac{10\times10^{-3}}{2\pi\times6}\times\frac{\log_e \frac{30}{15}}{8.5 - 8}$$

$$= 3.67\times10^{-4}\ m/secs.$$

10. A 12m thick layer of relatively impervious stratum of clay lies over a bed of gravel aquifer. Piezometer tubes introduced to the level standing in the tubes 3 m above the top surface of the clay strata. The properties of the clay soil are e = 1.2 and G = 2.7. Determine: the effective stress at the top level of the gravel strata, the depth of excavation that can be made in the clay strata without the bottom heave.

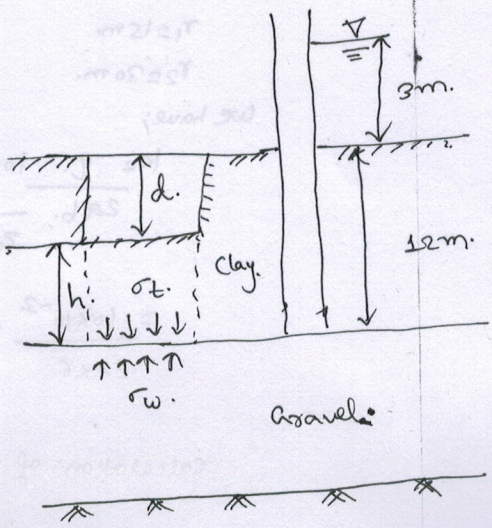
Solution;

Calculations involved;

$$\gamma_{sat} = \frac{G+Se}{1+e} \times \gamma_w$$

$$= \frac{2.7+(1.2\times1)}{1+1.2} \times 9.81$$

$$= 17.39 \text{ KN/m}^3.$$



Now;

At the top level of the gravel strata;

$$\sigma = 12\times17.39$$

$$= 208.68 \text{ KN/m}^2.$$

$$u = 15\times9.81 = 147.15 \text{ KN/m}^2.$$

$$\sigma' = \sigma - u.$$

$$= 61.53 \text{ KN/m}^2.$$

Again;

Depth of excavation must be such that; heave occurs only when $\sigma' = 0$

i.e. $\sigma = u_w$.

Let h be the ~~depth~~ height of bottom of excavation from gravel.

$$\sigma = \gamma_{sat} \times h = 17.39 \times h.$$

$$u = 147.15 \text{ KN/m}^2.$$

Then; $\sigma = u$.

or, $17.39 \times h = 147.15$

$\therefore h = 8.462$m.

Depth of excavation (d) = 12 - 8.462

= 3.538m.