06/03/12

Unit - 2

SOIL WATER

Soil water:

Water present in the voids of soil mass is called soil water. It can be classified into

i) Free water (or) Gravitational water (or) Ground H_2O

ii) Held water

↳ Structural water

↳ Adsorbed water

↳ Capillary water

Free Water:

The water which moves freely between the voids of solid particles under the forces of gravity is called free water or Gravitational water or Ground H_2O.

Such a water has a free surface which can be easily absorbed in wells and bore holes.

Held water:

The water which is strongly held between the solid particles by the adhesive force.

i) Structural Water:

↳ The water which is chemically present within the soil structure.

↳ It cannot be removed even by oven drying and it removed only by breaking the soil particles.

ii) Absorded water:

It is the water absorbed from the atmosphere by the physical forces of attraction and is held by the forces of adhesion.

iii) Capillary water:

↳ Capillary water is the soil moisture located within the interstices and voids of capillary size of soil.

↳ Capillary water held in the interstices of soil due to capillary force.

↳ The capillary force depends upon various factors such as surface tension of water, pressure in water, relation to atmosphere pressure and the size and the conformation of soil pores is also called as void pores.

Stress condition in soil:

Generally, stress is defined as force per unit area.

$$\text{Stress } (\sigma) = \frac{F}{A} \text{ in } kN/m^2$$

This is governed by two factors in Soil Mechanics.

↳ Self-weight of soil

↳ Over-burden pressure or the stress on the soil.

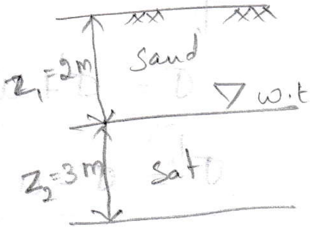
$$\sigma = \gamma . z \text{ in } kN/m^2$$

Total pressure = Effective pressure + pore water pressure

$$\sigma = \sigma' + u$$

$$\sigma' = \gamma_b \times z_1 + \gamma_{sat} \times z_1$$

$$u = \gamma_w \times h_w$$



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

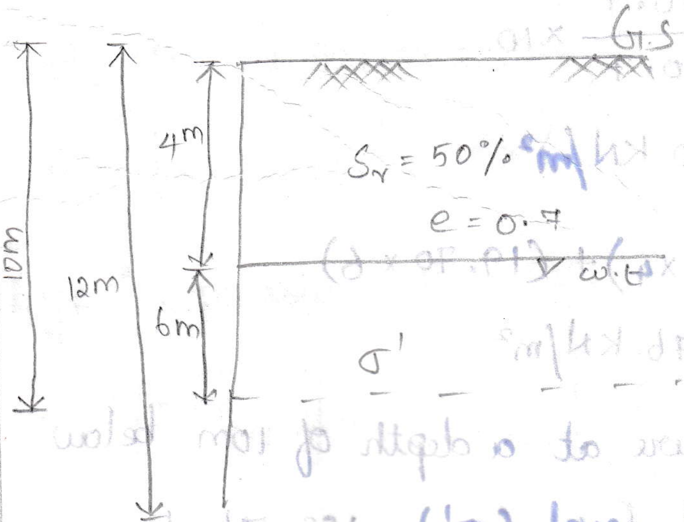
$$\sigma = \sigma' + u$$

where, σ is total pressure

σ' is effective pressure

u is neutral stress (or) pore H_2O pressure

1. The water table in a certain area at a depth of 4 m below the ground surface to a depth of 12m, a soil consist of very fine sand having an average void ratio 0.7. Above the H_2O table, Sand an average degree of saturation 50%. Calculate the effective pressure on a horizontal plane at a depth of 10 m below the Ground surface. Take, ~~G = 2.5~~ $G = 2.65$



Solution:

Effective pressure at 1and depth below ground Surface.

$\sigma = \sigma' + u$

$\boxed{\sigma' = \sigma - u}$

$\sigma = \gamma_b \times 4 + \gamma_{sat} \times 6$

(upto 10m depth)

$u = \gamma_w \times h_w$

$= 10 \times 6$

$\therefore u = 60 \, KN/m^2$

$\boxed{\gamma_b = \frac{G+es}{1+e} \cdot \gamma_w}$ $\gamma = \frac{dd}{}(1+w)$

$= \frac{2.65 + (0.7 \times 0.5)}{1+0.7} \times 10$

$\therefore \gamma_b = 17.64 \, KN/m^2$

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

$= \frac{2.65 + 0.7}{1+0.7} \times 10$

$\therefore \gamma_{sat} = 19.70 \, KN/m^2$

$\sigma = (17.64 \times 4) + (19.70 \times 6)$

$\therefore \sigma = 188.76 \, KN/m^2$

Effective pressure at a depth of 10m below Ground level $(\sigma') = 188.76 - 60$

$= 128.76 \, KN/m^2$

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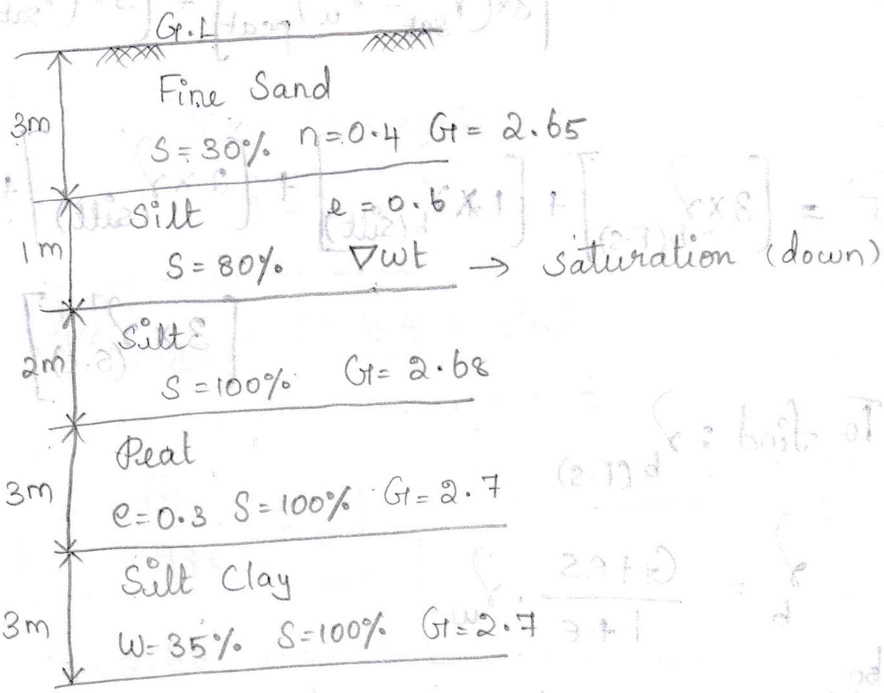
2. Compute the effective pressure at a depth of 12 m shown in figure.



Solution:

Effective pressure at a depth of 12 m $(\sigma') = \sigma - u$

Find, Total Stress (σ)

$$\sigma = \left[3 \times \gamma_{b(F.S)}\right] + \left[1 \times \gamma_{b(silt)}\right] + \left[2 \times \gamma_{sat(silt)}\right] + \left[3 \times \gamma_{sat(peat)}\right] + \left[3 \times \gamma_{sat(silt\ clay)}\right]$$

Find, Neutral Pressure (u)

$$u = \left[2 \times \gamma_{w(silt)}\right] + \left[3 \times \gamma_{w(peat)}\right] + \left[3 \times \gamma_{w(silt\ clay)}\right]$$

Effective pressure $(\sigma') = \sigma - u$

$$\sigma' = \left\{\left[3 \times \gamma_{b(F.S)}\right] + \left[1 \times \gamma_{b(silt)}\right] + \left[2 \times \gamma_{sat(silt)}\right] + \left[3 \times \gamma_{sat(peat)}\right] + \left[3 \times \gamma_{sat(S.C)}\right]\right\} - \left\{\left[2 \times \gamma_{w(s)}\right] + \left[3 \times \gamma_{w(p)}\right] + \left[3 \times \gamma_{w(S.C)}\right]\right\}$$

$$\sigma' = [3 \times \gamma_{b(F.S)}] + [1 \times \gamma_{b(silt)}] + [2 \times (\gamma_{sat} - \gamma_w)_{slit}] +$$

$$[3 \times (\gamma_{sat} - \gamma_w)_{peat}] + [3 \times (\gamma_{sat} - \gamma_w)_{S.C}]$$

$$[\because \gamma_{sat} - \gamma_w = \gamma']$$

$$\sigma' = [3 \times \gamma_{b(F.S)}] + [1 \times \gamma_{b(silt)}] + [2 \times \gamma'_{(silt)}] + [3 \times \gamma'_{(peat)}] +$$

$$[3 \times \gamma'_{(S.C)}] \longrightarrow ①$$

To find : $\gamma_{b(F.S)}$

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

Also

Given : $G = 2.65$, $S = 30\% = 0.3$, $n = 0.4$

WKT,

$$e = \frac{n}{1-n}$$

$$= \frac{0.4}{1-0.4}$$

$$\therefore e = 0.67$$

$$\gamma_{b(F.S)} = \frac{2.65 + [0.67 \times 0.3]}{1 + 0.67} \times 10$$

$$\therefore \gamma_{b(F.S)} = 17.07 \text{ kN/m}^3$$

$$\gamma_{b(silt)} = \frac{G + eS}{1+e} \cdot \gamma_w$$

Also Given : $G = 2.68$, $e = 0.6$, $S = 80\%$
$= 0.8$

$$\gamma_{b(silt)} = \frac{2.68 + (0.6 \times 0.8)}{1 + 0.6} \times 10$$

$$\therefore \gamma_{b(silt)} = 19.75 \ kN/m^3$$

$$\gamma'_{(silt)} = \frac{G-1}{1+e} \gamma_w$$

Also Given: $G = 2.68$, $e = 0.6$

$$\gamma'_{(silt)} = \frac{2.68 - 1}{1+0.6} \times 10$$

$$\therefore \gamma'_{(silt)} = 10.5 \ kN/m^3$$

$$\gamma'_{(peat)} = \frac{G-1}{1+e} \gamma_w$$

Also Given : $G = 2.7$, $e = 0.3$

$$\gamma'_{(peat)} = \frac{2.7 - 1}{1+0.3} \times 10$$

$$\therefore \gamma'_{(peat)} = 13.07 \ kN/m^3$$

$$\gamma'_{(s.c)} = \frac{G-1}{1+e} \cdot \gamma_w$$

Also Given : $G = 2.7$, $W = 35\% = 0.35$, $S = 100\% = 1$

WKT,

$$eS = WG$$

$$e = \frac{WG}{S}$$

$$= \frac{0.35 \times 2.7}{1}$$

$$\therefore e = 0.945$$

$$\gamma'_{(s.c)} = \frac{2.7-1}{1+0.945} \times 10$$

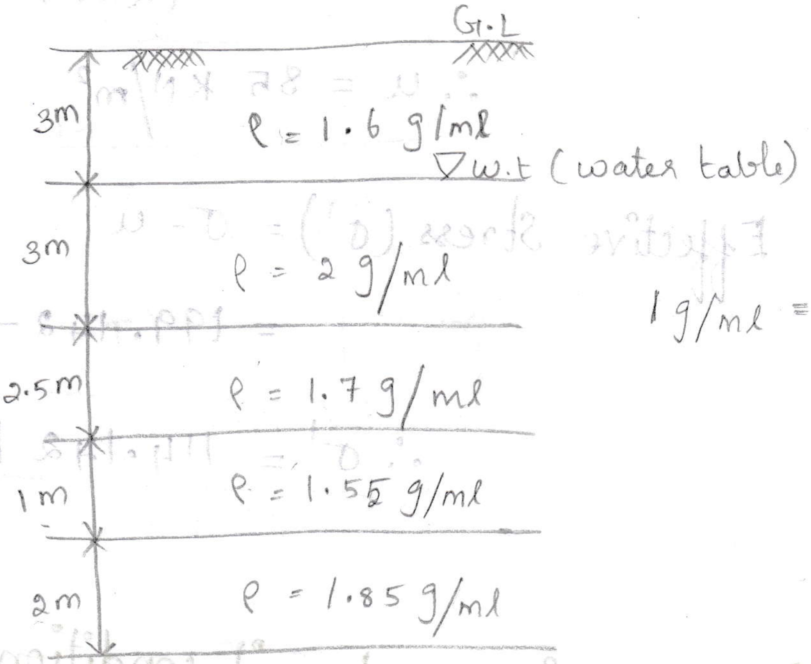
$$\therefore \gamma'_{(s.c)} = 8.74 \text{ kN/m}^3$$

Sub all unit weight (γ) values in ①,

$$\sigma' = (3 \times 17.07) + (1 \times 19.75) + (2 \times 10.5) + (3 \times 13.07) + (3 \times 8.74)$$

$$\therefore \sigma' = 157.39 \text{ kN/m}^2$$

3. Compute total stress, effective, neutral stress at the bottom of the soil deposit as shown in figure.



$1\ g/ml = 9.81\ kN/m^3$

Solution:

Given:

$\rho_1 = 1.6\ g/ml \Rightarrow \gamma_1 = 15.696\ kN/m^3$

$\rho_2 = 2\ g/ml \Rightarrow \gamma_2 = 19.62\ kN/m^3$

$\rho_3 = 1.7\ g/ml \Rightarrow \gamma_3 = 16.677\ kN/m^3$

$\rho_4 = 1.55\ g/ml \Rightarrow \gamma_4 = 15.2055\ kN/m^3$

$\rho_5 = 1.85\ g/ml \Rightarrow \gamma_5 = 18.148\ kN/m^3$

Total Stress (σ) $= (3\times\gamma_1) + (3\times\gamma_2) + (2.5\times\gamma_3) + (1\times\gamma_4) + (2\times\gamma_5)$

$= (3\times 15.696) + (3\times 19.62) + (2.5\times 16.677) + (1\times 15.2055) + (2\times 18.148)$

$$\therefore \sigma = 199.142\ kN/m^2$$

(only saturated portion) $u = \gamma_w \times h_w$

Neutral Stress $(u) = (3\times10) + (2.5\times10) + (1\times10) + (2\times10)$

$\therefore \boxed{u = 85 \text{ kN/m}^2}$

Effective Stress $(\sigma') = \sigma - u$

$= 199.142 - 85$

$\therefore \boxed{\sigma' = 114.142 \text{ kN/m}^2}$

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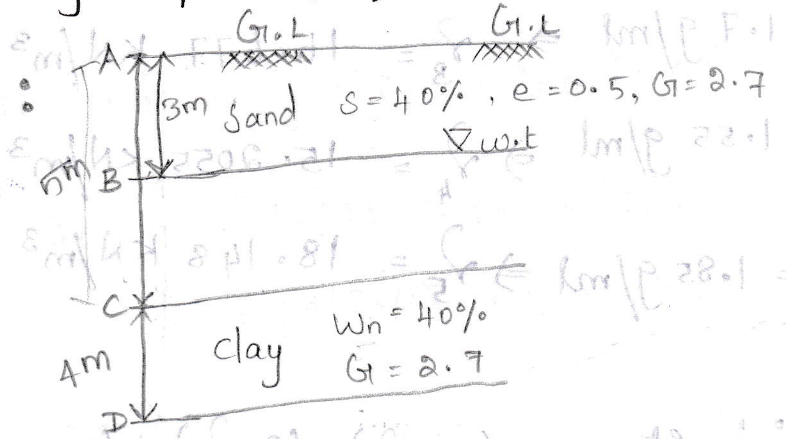
4. For the given sub-soil condition as shown in figure, draw the total stress, neutral stress, effective stress upto the depth of 9m neglecting capillary flow.

Soil Profile :



Solution:

To find, Total Stress (σ) $\boxed{\sigma = \gamma \times z}$

At point A $(\sigma_A) = 0$ $(z=0)$

At point B $(\sigma_B) = 3\times \gamma_b$ $(z=3)$

$$\boxed{\gamma_b = \frac{G+eS}{1+e} \cdot \gamma_w}$$

$$= \frac{2.67 + (0.5\times0.4)}{1+0.5} \times 10$$

$\therefore \gamma_b = 19.13\ kN/m^3$

$\sigma_B = 3 \times \gamma_b$

$= 3 \times 19.13$

$\therefore \boxed{\sigma_B = 57.39\ kN/m^2}$

At point C (σ_c) = $[(3\times\gamma_b) + (2\times\gamma_{sat})]$ (z=5)

$= (3\times 19.13) + (2\times\gamma_{sat})$

$\sigma_c = 57.39 + 2\gamma_{sat}$

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

$= \frac{2.7+0.5}{1+0.5} \times 10$

$\therefore \gamma_{sat} = 21.13\ kN/m^3$

$\sigma_c = 57.39 + 2\gamma_{sat}$

$= 57.39 + 2\times 21.13$

$= 57.39 + 42.26$

$\therefore \boxed{\sigma_c = 99.65\ kN/m^3}$

At point D (σ_D) = $3\times\gamma_b + 2\times\gamma_{sat\,(sand)} + 4\times\gamma_{sat\,(clay)}$ (z=9)

$\boxed{\gamma_{sat\,(clay)} = \frac{(1+w)G\gamma_w}{1+wG}}$

$= \frac{(1+0.4)\,2.7\times 10}{1+(0.4\times 2.7)}$

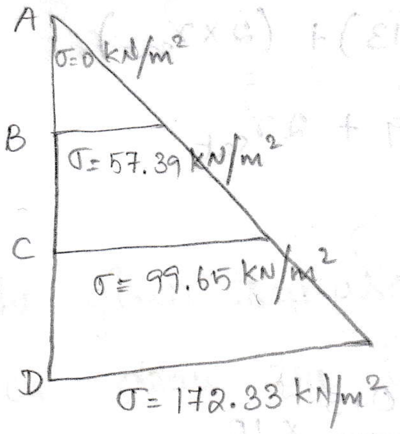
$\therefore \gamma_{sat\,(clay)} = 18.17\ kN/m^3$

$$\sigma_D = 3\times\gamma_b + 2\times\gamma_{sat(Sand)} + 4\times\gamma_{sat(Clay)}$$

$$= (3\times 19.13) + (2\times 21.13) + (4\times 18.17)$$

$$\therefore \sigma_D = 172.33 \ kN/m^2$$

Total Stress diagram :



To find, neutral stress (u):

$u = Z\times\gamma_w$

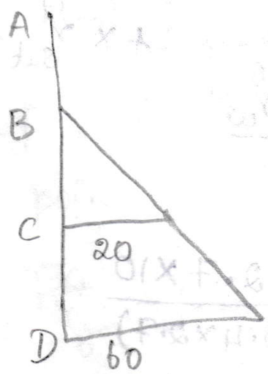
At point A, $u_A = 0$ $(Z=0)$

At point B, $u_B = 0$ $(Z=3)$

At point C, $u_c = 2\times10 = 20 \ kN/m^2$ $(Z=5)$

At point D, $u_D = 2\times10 + 4\times10 = 60 \ kN/m^2$ $(Z=9)$

Neutral Stress diagram :



To find effective stress (σ'): $\sigma' = \sigma - u$

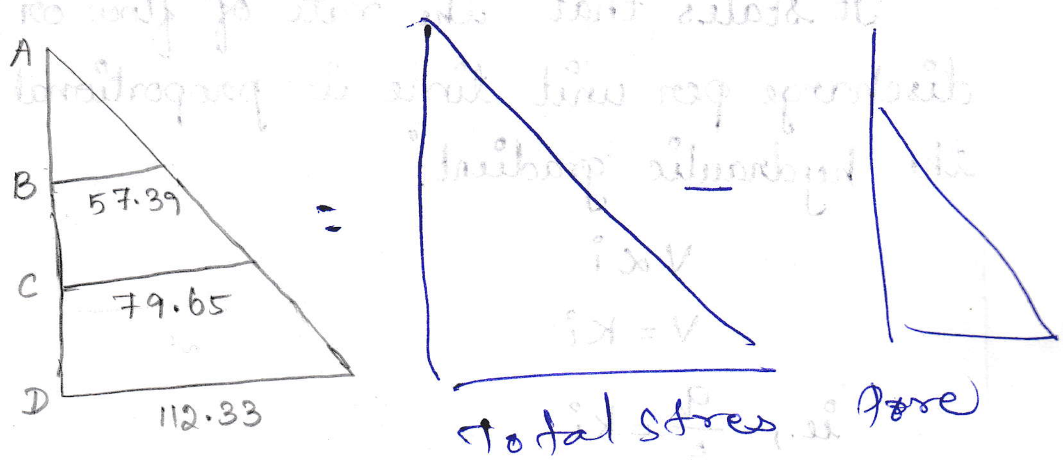
At point A, $\sigma'_A = \sigma_A - u_B = 0$ $(z=0)$

At point B, $\sigma'_B = \sigma_B - u_B = 57.39\ kN/m^2$ $(z=3)$

At point C, $\sigma'_C = \sigma_C - u_B = 79.65\ kN/m^2$ $(z=5)$

At point D, $\sigma'_D = \sigma_D - u_D = 112.33\ kN/m^2$ $(z=9)$

Effective stress diagram:



18/02/23 **Permeability:**

It is defined as the property of a porous material which permits the passage or seepage of water through its inter connecting voids.

Eg: Gravels are highly permeable while stiff clay is least permeable.

The flow water through soils may either be laminar or turbulent flow.

The study of seepage of water through soil is important for the following engineering problems.

↳ Determination of rate of settlement

↳ Calculation of seepage through the body of earth dams and stability of slopes

↳ Calculation of uplift pressure under hydraulic structures.

↳ Groundwater flow towards wells and drainage of soil.

Darcy's law:

It states that "the rate of flow or the discharge per unit time is proportional to the hydraulic gradient."

$$V \propto i$$

$$V = ki$$

ie., $\frac{q}{A} = ki$

$$\boxed{q = kiA}$$

$$V = \frac{q}{A} = ki$$

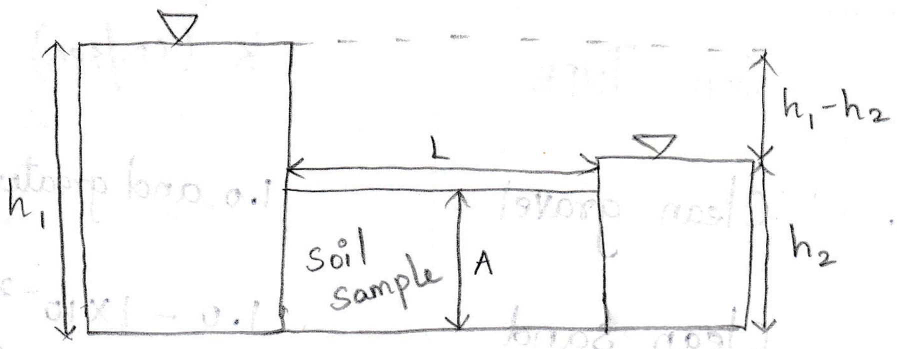
where, q = discharge per unit time

A = total c/s area of soil mass

i = hydraulic gradient

K = Darcy's Coefficient of permeability

V = Velocity of flow (or) average discharge velocity.



Flow of water through soil

If a soil sample of length (L) and c/s area (A) is subjected to differential head of water $(h_1 - h_2)$, the hydraulic gradient (i),

$$i = \frac{h_1 - h_2}{L}$$

ie, $q = KiA$

$$q = K \cdot \frac{h_1 - h_2}{L} \cdot A$$

Coefficient of Permeability :

It is defined as the average velocity of flow, that will occur through the total cross section area of soil under unit hydraulic gradient. It is generally expressed as cm/s (or) m/day (or) feet/day.

Typical values of 'K':

	Soil Type	K (cm/sec)
1.	Clean gravel	1.0 and greater
2.	Clean sand	$1.0 - 1\times10^{-2}$
	Sand	$1\times10^{-2} - 5\times10^{-2}$
3.	Fine Sand	$5\times10^{-2} - 1\times10^{-3}$
4.	Silt	$5\times10^{-4} - 1\times10^{-5}$
5.	Clay	1×10^{-6} and Smaller

Discharge Velocity:

The Velocity of flow 'V' is the rate of discharge of water per unit total c/s (Cross section) area of soil.

i.e., $\boxed{q = AV}$

Seepage Velocity or Actual Velocity:

It is defined as the rate of discharge of percolating water per unit c/s (cross section) area of voids to the direction of flow.

$$\boxed{q = V_s A_v}$$

$$q = AV \rightarrow (1)$$

$$q = A_v V_s \rightarrow (2)$$

$$(1) = (2)$$

$$AV = A_v V_s$$

$$\frac{AV}{A_v} = V_s$$

We know that

$$\boxed{n = \frac{V_v}{V} = \frac{A_v}{A}}$$

$$V \times \frac{1}{n} = V_s$$

$$\boxed{V_s = \frac{V}{n}}$$

$$\boxed{V_s = V.\frac{(1+e)}{e}} \quad \left[\because n = \frac{e}{1+e}\right]$$

Factors affecting permeability :

↳ Grain Size

↳ Properties of the porous fluid

↳ Void ratio of Soil

↳ Structural arrangement of soil particles.

↳ Observed water in clay soil

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Determination of co-efficient of permeability:

The coefficient of permeability by determining the following method

1. Direct Method
   a) Laboratory method
      - Constant head permeability test method
      - Falling head permeability test method
   b) Field method
      - Pumping out test
      - Pumping in test
2. Indirect Method
   a) Computation by grained size
   b) Horizontal capillary test
   c) Consolidation test

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Falling head permeability test method:

Coefficient of permeability

$$K = 2.3 \frac{aL}{At} \log_{10} \frac{h_1}{h_2}$$

where, a = Stand pipe area in cm^2

h_1 = Initial head, h_2 = Final head } at time interval t_1 and t_2

To find 't':

$$t = 2.3 \frac{aL}{AK} \log \frac{h_1}{h_2}$$

Here, $m = 2.3 \frac{aL}{AK}$

Constant for the setup

i.e., $t = m \log \frac{h_1}{h_2}$

5. Calculate the coefficient of permeability of soil sample, 6cm in height and 50 cm^2 in cross sectional area. If quantity of water is 430ml passed down in 10min under an effective constant head of 40cm, on oven drying the test specimen as a mass of 498 gm. Take G = 2.65. Calculate seepage velocity of water during a test.

Given:

$L = 6cm$

$A = 50cm^2$

$h = 40cm$

$Q = 430ml$

$t = 10min$

mass of dry soil sample = 498gm

$G = 2.65$

To find:

K, V_s

Solution:

$$K = \frac{Q}{t} \times \frac{L}{h} \times \frac{1}{A}$$

$$= \frac{430}{600} \times \frac{6}{40} \times \frac{1}{50}$$

$$\therefore K = 2.15 \times 10^{-3} \text{ cm/s}$$

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

From darcy's law,

$$V = ki$$

$$= 2.15 \times 10^{-3} \times \frac{h}{L} \qquad \left[\because i = \frac{h}{L}\right]$$

$$= 2.15 \times 10^{-3} \times \frac{40}{6}$$

$$= 0.0143$$

$$\therefore V = 1.43 \times 10^{-2} \text{ cm/sec}$$

$$\rho_d = \frac{\rho_w G}{1+e}$$

$$\rho_d = \frac{M_d}{V}$$

$$= \frac{498}{50 \times 6}$$

$$\therefore \rho_d = 1.66 \text{ g/cm}^3$$

$$\rho_d = \frac{\rho_w G}{1+e}$$

$$1.66 = \frac{1 \times 2.65}{1+e}$$

$$1+e = \frac{1 \times 2.65}{1.66}$$

$$\therefore e = 0.59$$

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

$$= \frac{0.59}{1+0.59}$$

$$\therefore n = 0.37$$

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

$$= \frac{1.43 \times 10^{-2}}{0.37}$$

$$\therefore V_s = 3.7 \times 10^{-2} \text{ cm/sec}$$

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

Given:

$L = 6cm$

$A = 50cm^2$

Stand pipe area (a) $= 0.5cm^2$

$t = 10\ mins = 10 \times 60 = 600 sec$

To find:

1. k

2. Time required to run the test for final head = 20cm

In a time interval 10 min, the head drops from initial value $h_1 = 40cm$ to $h_2 = 40-5 = 35cm$.

Solution:

1. For falling head test

$$K = 2.3 \frac{aL}{At} \log_{10} \frac{h_1}{h_2}$$

$$= 2.3 \times \frac{0.5 \times 6}{50 \times 600} \log_{10} \frac{40}{35}$$

$$\therefore K = 1.33 \times 10^{-5}\ cm/sec$$

2. Time required (t) to run the test for final head = 20 cm.

$$K = 2.3 \frac{aL}{At} \log_{10} \frac{h_1}{h_2}$$

$$t = 2.3 \frac{aL}{Ak} \log_{10} \frac{h_1}{h_2}$$

$$m = 2.3 \frac{aL}{Ak}$$

$$t = m \log_{10} \frac{h_1}{h_2} \rightarrow (1)$$

By given,

$h_1 = 40cm$

$h_2 = 35cm$

$t = 10 min$

$$m = \frac{t}{\log_{10} \frac{h_1}{h_2}}$$

$$= \frac{10}{\log_{10} \frac{40}{35}}$$

$$\therefore m = 172.5 \text{ units}$$

Sub m value in equ (1),

Here,

$h_1 = 40cm$

$h_2 = 20cm$

$$t = m \log_{10} \frac{h_1}{h_2}$$

$$= 172.5 \log_{10} \frac{40}{20}$$

$$\therefore t = 51.9 \text{ min}$$

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Seepage Pressure:

By Virtue of the viscous friction exerted on water flowing through the soil pores, an energy transfer is called seepage pressure.

$$P_s = i z \gamma_w$$

where, i = hydraulic gradient

z = length over which the head 'h' is lost.

P_s = Seepage pressure.

It is responsible for the quick sand and is of vital importance in the stability analysis is the earth structure subjected to the actions of seepage.

Quick Sand Condition:

When flow takes place in an upward direction, the seepage pressure also acts in the upward direction and the effective pressure is reduce. If the seepage pressure becomes equal to the pressure due to submerged weight of the soil, the effective pressure is reduced to zero. In such a case, cohesion soil losses all its shear strength and the soil particles have a tendency to move up in the direction of flow. This phenomenon of lifting of soil particles is called as quick sand condition or boiling condition.

i.e., $\sigma' = 0$

$$z\gamma' - P_s = 0$$

$$z\gamma' = P_s$$

$$z\gamma' = iz\gamma_w$$

$$\gamma' = i\gamma_w$$

$$i = i_c = \frac{\gamma'}{\gamma_w}$$

$$= \frac{\frac{G-1}{1+e} \cdot \gamma_w}{\gamma_w}$$

$$\therefore \boxed{i_c = \frac{G-1}{1+e}}$$

where,

i_c = critical hydraulic gradient.

Critical hydraulic gradient:

The hydraulic gradient at such critical state is called as critical hydraulic gradient.

Two dimensional flow:

Laplace equation:

The quantity of water flowing through a saturated soil mass as well as the distribution of water pressure can be estimated by the theory of flow of fluid through porous medium.

Assumption :

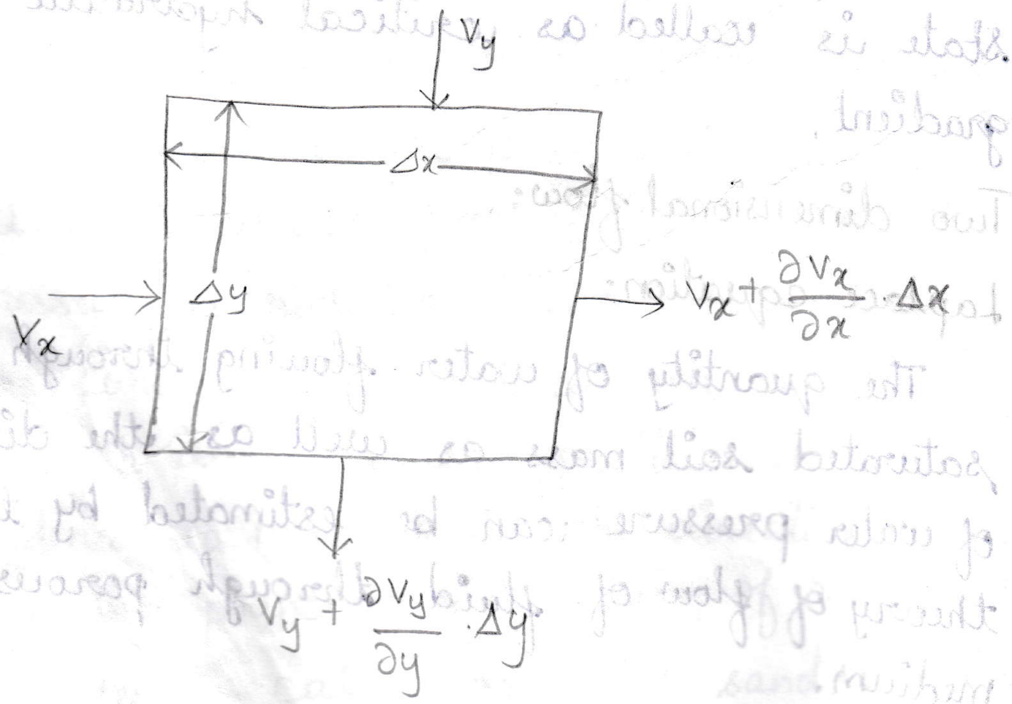
↳ The saturated porous medium is incompressible. The size of the porous spaces does not change with time regardless of water pressure.

↳ The seeping H_2O flow under a hydraulic gradient which is due to gravity head loss or Darcy law for flow through porous medium is valid.

↳ There is no change in the degree of saturation in the zone of soil through which H_2O seeps and the quantity of water flowing into any element of volume is equal to the quantity which flows out in the same length of time.

↳ The hydraulic boundary conditions at entry and exit are known.

↳ Water is incompressible.



Consider an element of soil size Δx, Δy and unit thickness perpendicular to the plane.

Let V_x and V_y be the entry velocity components in x and y direction.

Then, $V_x + \frac{\partial V_x}{\partial x} \cdot \Delta x$ and $V_y + \frac{\partial V_y}{\partial y} \cdot \Delta y$ will be the corresponding velocity components at the exit of the element.

According to assumption ③, the quantity of water is entering the element is equal to the quantity of water leaving it.

$$V_x(\Delta y.1) + V_y(\Delta x.1) = \left(V_x + \frac{\partial V_x}{\partial x}\Delta x\right)(\Delta y.1) + \left(V_y + \frac{\partial V_y}{\partial y}\Delta y\right)(\Delta x.1)$$

$$\cancel{V_x \Delta y} + \cancel{V_y \Delta x} = \cancel{V_x \Delta y} + \frac{\partial V_x}{\partial x}\Delta x \Delta y + \cancel{V_y \Delta x} + \frac{\partial V_y}{\partial y}\Delta x \Delta y$$

$$\frac{\partial V_x}{\partial x}\Delta x \Delta y + \frac{\partial V_y}{\partial y}\Delta x \Delta y = 0$$

$$\Delta x \Delta y\left(\frac{\partial V_x}{\partial x} + \frac{\partial V_y}{\partial y}\right) = 0$$

$$\boxed{\frac{\partial V_x}{\partial x} + \frac{\partial V_y}{\partial y} = 0} \longrightarrow ①$$

This above equation is known as continuity equation.

According to assumption ②,

WKT, Darcy's law

$$V = ki$$

$$V_x = k_x i_x \quad ; \quad V_y = k_y i_y$$

$$i_x = \frac{\partial h}{\partial x} \quad ; \quad i_y = \frac{\partial h}{\partial y}$$

where,

k_x, k_y = Coefficient of permeability in x and y direction.

h = hydraulic head under which water flows.

From equ ①,

$$\frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} = 0$$

$$\frac{\partial (k_x i_x)}{\partial x} + \frac{\partial (k_y i_y)}{\partial y} = 0$$

$$\frac{\partial \left(k_x \frac{\partial h}{\partial x}\right)}{\partial x} + \frac{\partial \left(k_y \frac{\partial h}{\partial y}\right)}{\partial y} = 0$$

$$\frac{\partial^2 h}{\partial x^2} k_x + \frac{\partial^2 h}{\partial y^2} k_y = 0$$

Here, For an isotropic soil

$$k_x = k_y = k$$

$$\frac{\partial^2 h}{\partial x^2} k + \frac{\partial^2 h}{\partial y^2} k = 0 \longrightarrow ②$$

$$\left(\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2}\right) k = 0$$

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} = 0 \longrightarrow (3)$$

Sub $kh = \phi$ in (2),

$$\boxed{\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} = 0}$$

where, ϕ = Velocity potential.

This is laplace equation for flow in two dimensions.

Velocity Potential:

It may be defined as a scalar function space and time such that its derivative with respect to any direction gives the fluid velocity in that direction.

$$\boxed{\phi = kh}$$

where, K = Coefficient of permeability

h = hydraulic head.

Flow net: (refer book)

↳ Properties

↳ Application

↳ Flow net by electrical analysis.

A horizontal soil deposit consists of 3 layer each has its own uniform flow 'k' of those layers are 8×10^{-4}, 52×10^{-4}, 6×10^{-4} cm/s. The thickness of each layers are 7, 3 x 10cm. Find the ae 'k' of the soil deposit in the horizontal & vertical.

$k_1 = 8\times10^{-4}$ cm/s, $k_2 = 52\times10^{-4}$ cm/s, $k_3 = 6\times10^{-4}$ cm/s

$z_1 = 7$ cm, $z_2 = 3$ cm, $z_3 = 10$ cm.

$$k_x = \frac{k_1 z_1 + k_2 z_2 + k_3 z_3}{z}$$

$z = z_1 + z_2 + z_3 = 20$ cm

$$k_x = \frac{(8\times7) + (52\times3) + (6\times10)\times10^{-4}}{20}$$

$k_x = 0.014$ cm/s

$k \Rightarrow 1.4\times10^{-3}$ cm/s

$$k_z = \frac{z}{\frac{z_1}{k_1} + \frac{z_2}{k_2} + \frac{z_3}{k_3}} \Rightarrow \frac{20}{(7/8 + 3/52 + 10/6)\times10^4}$$

$= 0.0008$

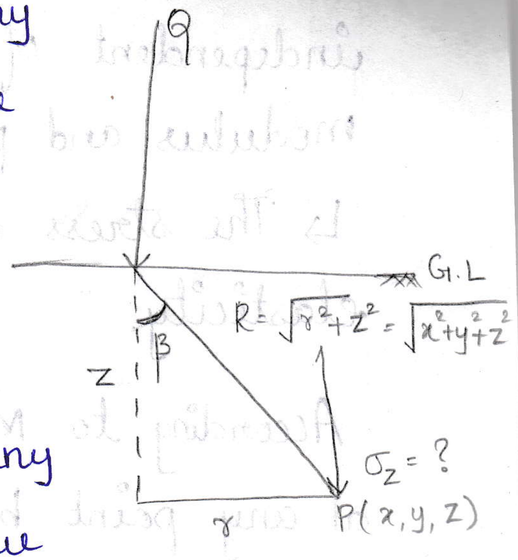
$k = 8\times10^{-4}$ cm/s

12/03/13

Unit - 3

Stress Distribution

A stress distribution at any point below ground surface due to concentrated load plays an important role calculation of Consolidation.



A stress distribution at any point below ground surface due to point load has been developed by the following scientist.

1. Mr. Boussinesq – Widly adopted
2. Mr. Westerguard – Mainly for Stratified Soil.
3. Newmark (Influence chart) – Irregular footing
4. 2:1 method (Approximate method) – Where the slope of stress is 2 vertical : 1 Horizontal

Assumption :

↳ The applied load is truely vertical and concentrated point load.

↳ The soil mass is weight less.

↳ The soil mass is homogeneous.