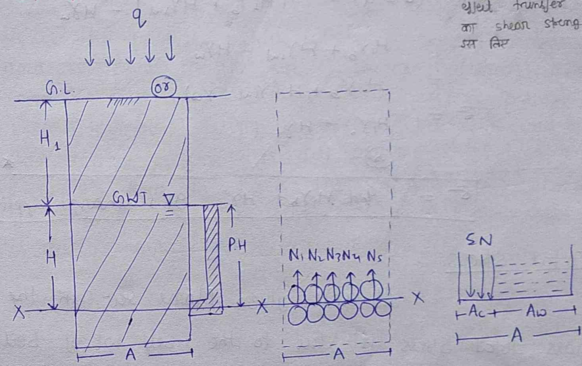
Lecture 5
7/11/19

CHAPTER-3

load लगने से grain to grain direct transfer होगा क्योंकि पानी का shear strength '0' होता है इस लिए



(σ) total stress = $\dfrac{\text{total wt}}{\text{Area}} = \dfrac{\text{wt of (solids + water)}}{\text{Area}}$

$\sigma = \dfrac{V\gamma'}{\text{Area}} = \dfrac{\text{depth} \times \text{Area} \times \gamma}{\text{Area}} = \text{depth} \times \gamma$

$\sigma = q + \text{depth} \times \gamma$

On Plane (X–X) $\quad \sigma = H_1\gamma_b + H\gamma_{sat}$

(or)

$\sigma = q + H_1\gamma_b + H\gamma_{sat}$ (if surcharge is applied)

total stress (σ) = Eff. stress + $H\gamma_{sat}$

$$\sigma = \bar{\sigma} + u$$

(u) Pore water pressure = $\dfrac{\text{wt of water column}}{\text{Area}}$

$u = \dfrac{\text{vol} \times \gamma_w}{\text{Area}} = \dfrac{A_w . H . \gamma_w}{A_w} = H\gamma_w$

(or)

$$u = \text{Pressure Head} \times \gamma_w = H\gamma_w$$

Effective stress = total stress − Pore water pressure

$\bar{\sigma} = (\sigma - u) = (H_1\gamma_b + H\gamma_{sat}) - H\gamma_w$

$= H_1\gamma_b + H\gamma_{sat} - H\gamma_w$

$= H_1\gamma_b + H(\gamma_{sat} - \gamma_w)$

$\bar{\sigma} = H_1\gamma_b + H\gamma'$

(or)

★★

$\bar{\sigma} = q + H_1\gamma_b + H\gamma'$ if surcharge applied

* **Total stress**

At any given plane sec^n in the soil mass total stress is due to the self wt of soil (wt of (solids + water + air)) all due to the applied overburden pressure (uniform surcharge)

→ This total stress further consist of two different component

1) Effective stress (Intergranular pressure)
2) Pore water pressure (Neutral pressure)

Effective stress ($\bar{\sigma}$)

It is the stress which is being transferred in the soil mass by grain to grain contact which tend to force the particles to come into closure state of contact resulting in it's decreased void ratio, increase degree of denseness and mobilization of shear strength.

These stresses r also termed as inter-granular stresses.

Pore water pressure (u)

It is the pressure which is being transmitted by pore field and is equal to the wt of water column above the concern sec^n in soil mass. This water pressure can also be determined using Piezometer (Pressure head × γ_w) this water pressure acts all around the soil solid Hence does not tend to force the soil solid into closure state of contact. It does not have any shear component. It is also termed as Neutral pressure

Approach II

Total stress $(\sigma) = \frac{\text{total force}}{\text{Area}} = \frac{\Sigma N + uA_w}{A} = \frac{\Sigma N}{A} + \frac{uA_w}{A}$

$\because A = A_c + A_w \quad A_c <<< A_w$

$A \simeq A_w$

$\sigma = \frac{\Sigma N}{A} + \frac{uA_w}{A}$

Total stress = $\bar{\sigma} + u$

effective stress ($\bar{\sigma}$) = $\frac{\Sigma N}{A}$

Note-①

Contact stress = $\frac{\Sigma N}{A_c}$

Eff. stress = $\frac{\Sigma N}{A}$

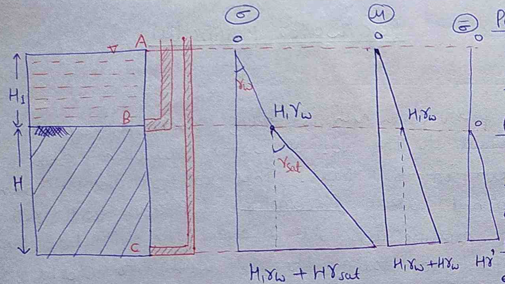
$\because A_c <<< A$

$\frac{\Sigma N}{A_c} >>> \frac{\Sigma N}{A}$

Note ② Consolidation (settlement)
(shear strength and bearing capacity r the fun^n of eff. stress)

Case-①

Submerge soil Mass (GWT is above the ground level)



Point A

$\sigma = 0$

$u = 0$

$\bar{\sigma} = \sigma - u = 0$

Point B

$\sigma = H_1\gamma_w$

$u = (P.H)\gamma_w = H_1\gamma_w$

$\bar{\sigma} = \sigma - u = 0$

Point C

$\sigma = H_1\gamma_w + H\gamma_{sat}$

$U = (P.H)\gamma_w = (H+H_1)\gamma_w$

$\bar{\sigma} = \sigma - u$

$= (H_1\gamma_w + H\gamma_{sat}) - (H+H_1)\gamma_w$

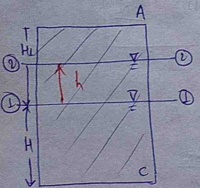
$= H\gamma'$

Note

⇒ If water table is above the ground level then variation of ~~gro~~ water table will not affect the effective stress.

⇒ But if water table is below the ground level then variation of water table will affect the effective stress

Case-② change in effective stress due to variation of GWT level (GWT is below the ground level)



effective stress at C when GWT is at ①-①

$(\bar{\sigma}_c)_{1-1} = \sigma - u = (H_1\gamma_b + H\gamma_{sat}) - H\gamma_w$

$= H_1\gamma_b + H\gamma'$

effective stress at C when GWT is at ②-②

$(\bar{\sigma}_c)_{2-2} = \sigma - u = [(H_1-h)\gamma_b + (H+h)\gamma_{sat}] - (H+h)\gamma_w$

$= (H_1-h)\gamma_b + (H+h)\gamma'$

Change in effective stress

$\Delta\bar{\sigma} = (\bar{\sigma}_c)_{2-2} - (\bar{\sigma}_c)_{1-1} = [(H_1-h)\gamma_b + (H+h)\gamma'] - [H_1\gamma_b + H\gamma']$

$\Delta\bar{\sigma} = -h\gamma_b + h\gamma'$

$\boxed{\Delta\bar{\sigma} = h(\gamma' - \gamma_b) = -ve}$

Note If G.W.T is below the G.L

GWT rises → Effective stress decreases

GWT lowered → Effective stess increases

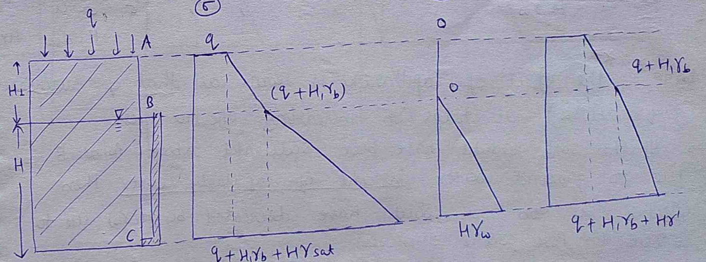
Note ⓐ When water table is lowered due to pumping out of water then :- immediateling after the lowering soil will be treated as saturated in lowered water table zone

$\boxed{\Delta\bar{\sigma} = (\gamma_{sat} - \gamma')h}$

ⓑ In long term (after a long time soil will achieve the bulk cond in lower water table zone

$\boxed{\Delta\bar{\sigma} = (\gamma_{bulk} - \gamma')h}$ LOGIC

Case-③ Soil Mass with uniform surcharge (GWT is H_1 depth below the ground level :-



Point A

$\sigma = q$

$u = 0$

$\bar{\sigma} = \sigma - u = q$

Point B

$\sigma = q + H_1\gamma_b$

$u = 0$

$\bar{\sigma} = \sigma - u = q + H_1\gamma_b$

Point C

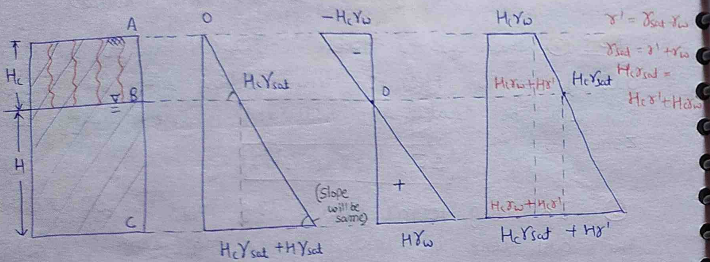
$\sigma = q + H_1\gamma_b + H\gamma_{sat}$

$u = (P.H)\gamma_w = H\gamma_w$

$\bar{\sigma} = \sigma - u$

$= q + H_1\gamma_b + H\gamma'$

Case ④ Soil mass with capillarity fringes (soil is saturated above GWT under capillary action.) Imp



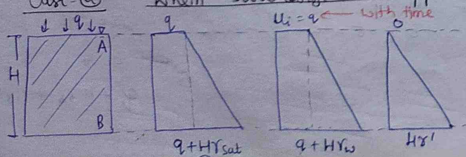
Point A	Point B	Point C
$\sigma = 0$	$\sigma = H_c\gamma_{sat}$	$\sigma = \gamma_{sat}H_c + H\gamma_{sat}$
$u = -H_c\gamma_w$	$u = 0$	$u = H\gamma_w$
$\bar{\sigma} = \sigma - u = 0 - (-H_c\gamma_w) = H_c\gamma_w$	$\bar{\sigma} = \sigma - u = H_c\gamma_{sat}$	$\bar{\sigma} = \sigma - u = H_c\gamma_{sat} + H\gamma'$

Note*** the effect of capillarity is same as that of surcharge ($q = H_c\gamma_w$). It helps in increasing effective stress.

→ If the soil would have been saturated above point B due to ground water instead of capillary water then effective stress in soil would have decreased by ($H_c\gamma_w$) due to increased pore water pressure.

Case-⑤ Application of uniform surcharge (GWT is at ground level)

Case-ⓐ When surcharge is applied suddenly



Point A

$\sigma = q$

$u = 0 + u_i = 0 + q$

$\bar{\sigma} = \sigma - u = 0$

Point B

$\sigma = q + H\gamma_{sat}$

$u = H\gamma_w + u_i = H\gamma_w + q$

$\bar{\sigma} = \sigma - u = H\gamma'$

Note

at $t = 0$

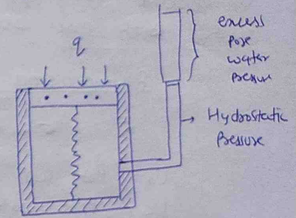
$F = K \cdot x$ → (It tends to 0)

$u_i = q$

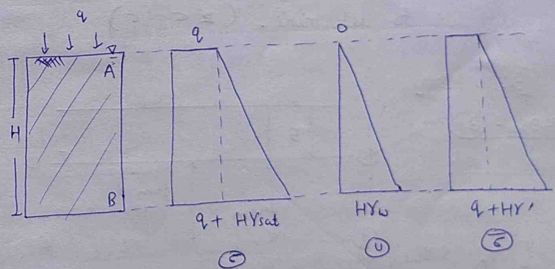
at any time (t)

$\downarrow u_i$

$\uparrow F = Kx$



Case ⓑ When surcharge is applied Gradually (कुछ नहीं होता तो gradual)



Point A

$\sigma = q$

$u = 0 + u_A = 0$

$\bar{\sigma} = \sigma - u = q$

Point B

$\sigma = q + H\gamma_{sat} = 0$

$u = H\gamma_w + u_i = H\gamma_w$

$\bar{\sigma} = \sigma - u = H\gamma' + q$

Note When W.T present at ground level and surcharge is applied gradually it is being carried by soil solid.

→ If surcharge is applied suddenly then firstly it will be taken by water in it due to which excess pore water developed that causes water to seep and during which it transfer a part of surcharge on the ~~solid~~ soil solid and when excess pore water pressure is being dissipate. When total surcharge is being carried by soil solid.

Case-⑥ Partially saturated Soil

1) If soil is partially saturated then air is also present in the soil along with the water. Hence, in the analysis of effective stress pore air pressure should also considered along with pore water pressure

Bishop and lambe

$$\bar{\sigma} = \sigma - U_a + \chi(U_a - U_w) \quad \left[\chi = \frac{A_w}{A}\right]$$

U_a = Pore air pressure

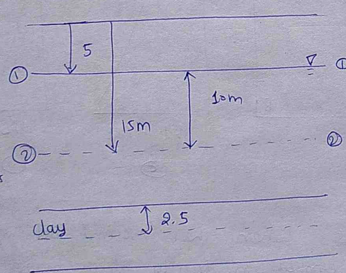
U_w = Pore water pressure

χ = fraction of the area of soil occupied by the water $= \left[\frac{A_w}{A}\right]$

Note: In partially saturated cond^n pore pressure is neglected bcoz it is difficult to determine. ($\therefore \sigma = \bar{\sigma}$)

Lecture 6 [3:30 hour]
8/11/19

Page 21 - ㊲ Ans



① When GWT is at ①-①

$\bar{\sigma} = \sigma - U = [5\gamma_b + 15(\gamma_{sat})_s + 2.5(\gamma_{sat})_c] - 17.5\gamma_w$

$= 5\times19 + 15\times20 + 2.5\times20 - 17.5\times9.81$

$= 268.325$

② When GWT is at ②-②

$\bar{\sigma} = 15\gamma_w + 5(\gamma_{sat})_s + 2.5(\gamma_{sat})_c - 7.5\gamma_w$

$= 15\times18 + 5\times20 + 2.5\times20 - 7.5\times9.81 = 346.425$

$\Delta\bar{\sigma} = 346.425 - 268.325 = 78.1\ kN/m^2$

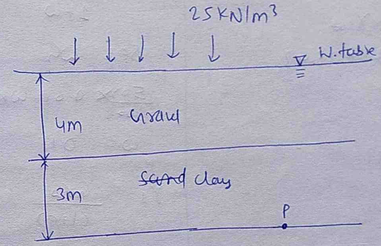
II^nd

$\Delta\bar{\sigma} = (\gamma_b - \gamma')h = (18 - (20 - 9.81))\times10 = 78.1\ kN/m^2$

Solution ㉟ Page ㉑

$\gamma_{clay} = 19\ kN/m^3$

$\gamma_{grav} = 20\ kN/m^3$



$\sigma = 4\times(\gamma_{Gra}) + 3\times(\gamma_{scw}) + q$

$\sigma = 25 + 4\times(20) + 3(19)$

$\sigma = 162$

$U = 0 + 4\times10 + 7\times10$

$U = 40 + 70 = 110$

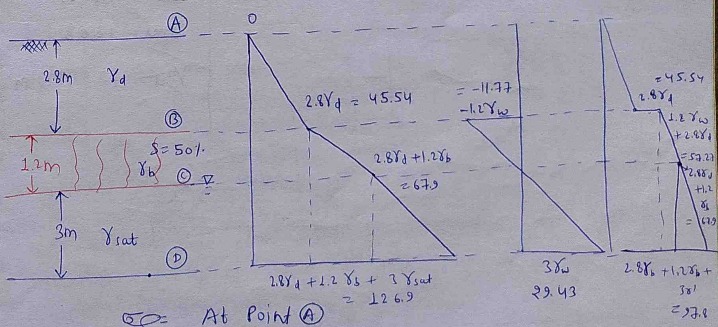
$\bar{\sigma} = \sigma - U = 162 - 110 = 52$

$\sigma = 162$

$U = 110$

and $\bar{\sigma} = 52$ Ans

Solution ㊱ Page ㉑



$\bar{\sigma}$ = At Point Ⓐ

$\sigma = 0$
$U = 0$
and $\bar{\sigma} = 0$

At Point B

$\sigma = 2.8 \times (\gamma_d) = 2.8 \times 16.56 = 46.375$
$U = -1.2 \times (\gamma_w) = -12$
$\bar{\sigma} = 46.375 + 12 = 58.375$

At Point C

$\sigma = 2.8 \times \gamma_d + 1.2 \times \gamma_{sat}$
$= 2.8 \times 16.56 + 1.2 \times 18.43$
$= 68.48$

$U =$

~~At Point D~~

Solution (37)

$\gamma_d = \frac{\gamma_b}{1+w}$

$Se = wG$

$\frac{50}{100} \times 0.6 = w \times 2.65$

$w = 0.11$

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

$\gamma_d = \frac{2.65 \times 10}{(1+0.6)}$

$\gamma_d = 16.56\ kN/m^2$

$\gamma_{bulk} = \frac{(G+Se)\gamma_w}{(1+e)}$

~~$\gamma_{sat} = (2.65+$~~

$\gamma_{sat} = 18.08$

$\gamma_{sat} = 19.93\ kN/m^3$

CHAPTER-4

PERMEABILITY

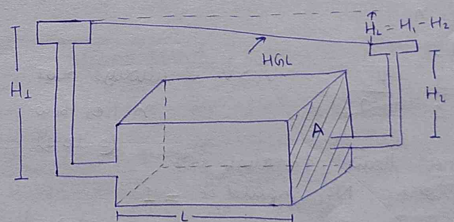
Permeability is the property of soil by virtue of which soil allows the flow of fluid through it.

⇒ It is also termed as hydraulic conductivity

⇒ Permeability of coarse grain soil is more than that of fine grain soil.

Type of Soil	Permeability
1) Gravel	> 1 cm/sec
2) Sand	$1 - 10^{-3}$ cm/sec
3) Silt	$10^{-3} - 10^{-7}$ cm/sec
4) Clay	$< 10^{-7}$ cm/sec

DARCY'S LAW



Hydraulic gradient = $\frac{\text{Seepage Head}}{\text{length}} = \frac{\text{Head loss}}{\text{length}}$

$$i = \frac{H_1 - H_2}{L} = \frac{H_L}{L}$$

As per darcy's law for laminar flow in saturated soil mass, velocity of flow is directly proportional to hydraulic gradient.

$$V \propto i$$

$$V = Ki$$ **

K → coefficient of permeability $\left(\frac{m}{sec}, \frac{cm}{sec}\right)$

Discharge = Area × velocity

$$\boxed{q = KiA}^{**} \quad m^3/sec$$

Limitations

1) The velocity of flow considered above the avg or discharge velocity b/w total area of c/s is considered but in actual flow takes place through the inter connected void of medium, area of which is much less than total area of c/s of flow. Hence actual/true / seepage velocity of flow is much ~~less~~ max than avg or discharge velocity consider above.

$$\text{Discharge } (q) = \frac{\text{Volume}}{\text{time}} = A \times V = A_v \times V_s$$

$$\frac{V}{V_s} = \frac{A_v}{A} = \frac{A_v}{A} \times \frac{L}{L} = \frac{\text{vol}^m \text{ of voids}}{\text{total vol}^m} = \text{Porosity } (n)$$

$$V = V_s \cdot n$$

Seepage velocity

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

$V_s > V$ { always b/w
n lies b/w
(0 to 1)

Note: For laminar flow through soil mass Reynold's No. should be ≤ 1

(4.2) METHODS TO DETERMINE PERMEABILITY

1) LAB METHODS

A) At constant Head permeability test
B) Variable Head permeability test
C) Capillarity Head permeability test

(2) Field Method

A) Dupit's theory
B) Thiem's theory

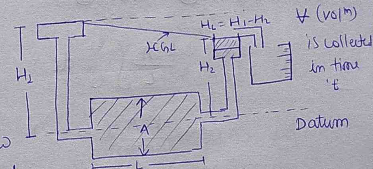
(3) Indirect Method

A) Kozney - carman eqn
B) Allen Hazen eqn
C) Consolidation eqn
D) Terzaghi's eqn

A) Constant Head permeability test

* Suitable for coarse grained soil

Substantial for coarse grained soil: Substantial discharge can be collected in small time



* Water is allowed to flow under constant head and let volume ∀ is flowing through soil mass in time (t)

⇒ Discharge $(q) = \frac{\text{Volume}}{\text{time}} = \frac{\forall}{t}$ --- (A)

⇒ As per darcy's law $q = KiA$ --- (B)

from (A) and (B)

$$\boxed{KiA = \frac{\forall}{t}}$$

$$K = \frac{\forall}{t \cdot iA} = \frac{\forall}{t \frac{H_L}{L} \cdot A}$$

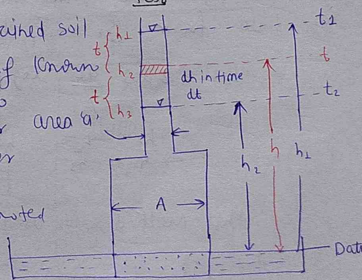
$$\boxed{K = \frac{\forall L}{t \cdot H_L A}}$$

B) Falling Head / Variable Head Permeability test

⇒ Suitable for fine grained soil

⇒ An open stand pipe of known area 'a' is inserted into the soil mass and water is allowed to flow under variable head

⇒ Head in stand pipe is noted at different time



→ let in time dt head fall by 'dh' under the head of h

→ volume of water flows in time dt (dV) = $a \cdot dh$

→ Discharge through soil mass in time dt.

$$q = \frac{dV}{dt} = \frac{-a\,dh}{dt} \quad \text{--- (A)}$$

→ As per darcy's law $q = KiA = K \times \frac{h}{L} \cdot A$ --- (B)

from (A) and (B) $K \cdot \frac{h}{L} \cdot A = -a \cdot \frac{dh}{dt}$

$$\frac{K \cdot A}{L} \int_{t_1}^{t_2} dt = -a \int_{h_1}^{h_2} \frac{dh}{h}$$

$$\frac{K \cdot A}{L} (t_2 - t_1) = -a \ln h \Big|_{h_1}^{h_2} \quad (\because t_2 - t_1 = t \text{ time interval})$$

$$\frac{KA}{L} \cdot t = -a (\ln h_2 - \ln h_1) = a \ln\left(\frac{h_1}{h_2}\right)$$

$$K = \frac{a \cdot L}{At} \ln\left(\frac{h_1}{h_2}\right)$$

$$\boxed{K = 2.303 \frac{a \cdot L}{At} \log_{10}\left(\frac{h_1}{h_2}\right)}$$ ★★★

Note Let in given time interval t (height of water in tented pipe falls from h_1 to h_2 and in the same time it falls from (S_2 to S_3) then.

$$K = 2.303 \frac{aL}{At} \log\left(\frac{h_1}{h_2}\right) = 2.303 \frac{a \cdot L}{A \cdot t} \log\left(\frac{h_2}{h_3}\right)$$

$$\frac{h_1}{h_2} = \frac{h_2}{h_3} \qquad h_2^2 = h_1 h_3$$

$$\boxed{h_2 = \sqrt{h_1 h_3}}$$

this Method is used to check consistency of readings

(C) capillary permeablity test (Not too much important)

this test is used to find permeability of medium and capillary rise in it. It is suitable for partially saturated soil

⇒ Partially saturated soil is placed in cylindrical glass tube and Horizontal distance travelled by the water (x) at different time is noted.