POSTAL Book Package 2021

CIVIL ENGINEERING

Soil Mechanics and Foundation Engineering

Conventional Practice Sets

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4 CHAPTER Effective Stress, Capillarity and Permeability

Q.1 Top layer of a soil deposit consists of a clay layer of 4 m thickness overlaying a very thick layer of sand. Even though the water table is at middle of clay layer, the clay soil above the water table is saturated. The water content of clay strata is 30% while that of sand strata is 26%. If the specific gravity of clay and sand are 2.72 and 2.64 respectively. Calculate the total stress, pore water pressure and effective stress at a depth of 8 m from ground surface.

Solution:

Given: For clay,

Thickness, $H_1 = 4$ m

Specific gravity, $G = 2.72$

Water content, $w = 30\% = 0.3$

Void ratio, $\boxed{e = \frac{Gw}{s}} = \frac{2.72 \times 0.3}{1} = 0.816$

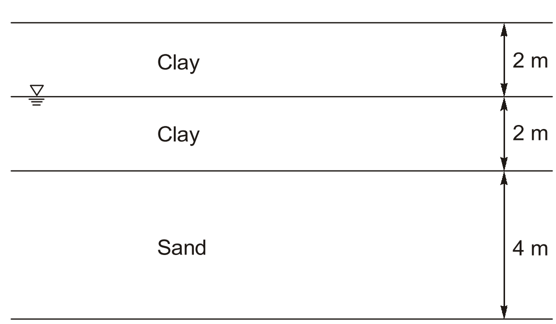
Saturated unit weight, $\boxed{\gamma_{sat} = \left(\frac{G + se}{1 + e}\right)\gamma_w} = \left(\frac{2.72 + 1 \times 0.816}{1 + 0.816}\right) \times 9.81 = 19.1 \text{ kN/m}^3$

Similarly for sand,

Void ratio, $e_2 = \frac{2.64 \times 0.26}{1} = 0.6864$ $\left\{\because e = \frac{wG}{S}\right\}$

Saturated unit weight, $\gamma_{sand} = \left(\frac{2.64 + 0.6864}{1 + 0.6864}\right) \times 9.81 = 19.35 \text{ kN/m}^3$

For given condition

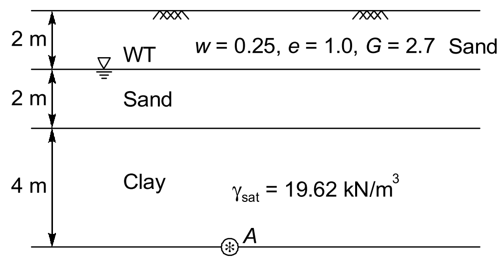


Total stress, $\sigma = 19.1 \times 4 + 19.35 \times 4 = 153.8 \text{ kN/m}^2$

Pore water pressure, $U = 9.81 \times 6 = 58.86 \text{ kN/m}^2$

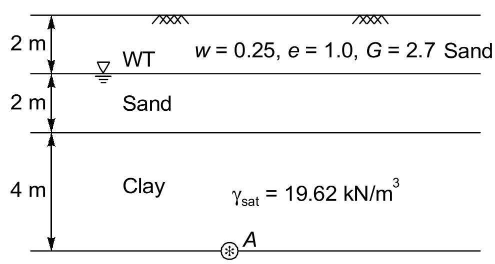
Effective stress, $\bar{\sigma} = \sigma - u = 153.8 - 58.86 = 94.94 \text{ kN/m}^2$

Q.2 For the soil profile given below, determine the total and effective stresses at point '*A*". What will be the total, neutral and effective stresses at point '*A*', if the ground water table rises to the ground surface? Will there be only change in effective stress at point '*A*', if the water table rises 2 m above the ground surface? Answer with justification.



Solution:

(i)



Unit weight of the partially saturated sand above the water table.

$$\gamma_{t(\text{sand})} = \left(\frac{G_s + Se}{1+e}\right)\gamma_w = \frac{G_s(1+w)\gamma_w}{1+e}$$

$$= \frac{2.70(1+0.25)\times 9.81}{1+1} = 16.55 \text{ kN/m}^3$$

Unit weight of saturated sand,

$$\gamma_{\text{sat(sand)}} = \left(\frac{G_s + e}{1+e}\right)\gamma_w = \left(\frac{2.7+1}{1+1}\right)\times 9.81 = 18.15 \text{ kN/m}^3$$

Given, $\gamma_{\text{sat (clay)}} = 19.62 \text{ kN/m}^2$

At point A;

Total stress, $\sigma = \gamma_{t\,(\text{sand})} \times 2 + \gamma_{\text{sat (sand)}} \times 2 + \gamma_{\text{sat (clay)}} \times 4$

$= 16.55 \times 2 + 18.15 \times 2 + 19.62 \times 4$

$= 147.88 \text{ kN/m}^2$

Effective stress, $\bar{\sigma} = \sigma - u$

$u = 10 \times 6 = 60 \text{ kN/m}^2$

$\therefore$ $\bar{\sigma} = 147.88 - 60 = 87.88 \text{ kN/m}^2$

(ii) If the ground water table rises upto ground surface, the soil mass changes its state from partially saturated to submerged state.

At point *A*;

Total stress, $\sigma = \gamma_{\text{sat (sand)}} \times 4 + \gamma_{\text{sat (clay)}} \times 4$

$= 18.15 \times 4 + 19.62 \times 4$

$= 151.08 \text{ kN/m}^2$

Neutral stress, $u = 8 \times 10 = 80 \text{ kN/m}^2$

Effective stress, $\bar{\sigma} = 151.08 - 80 = 71.08 \text{ kN/m}^2$

(iii) A rise in free water level above the ground surface by 2 m would result in increase in total stress at any every location by $2\gamma_w$ or 20 kN/m^2.

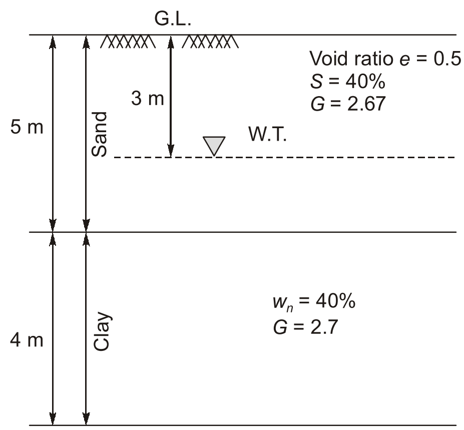
Similarly, the pore water pressure would also increase at every location by same magnitude i.e., 20 kN/m^2. Thus, effective stress distribution will remain same.

At point;

$$\therefore \qquad \bar{\sigma} = 71.08 \text{ kN/m}^2$$

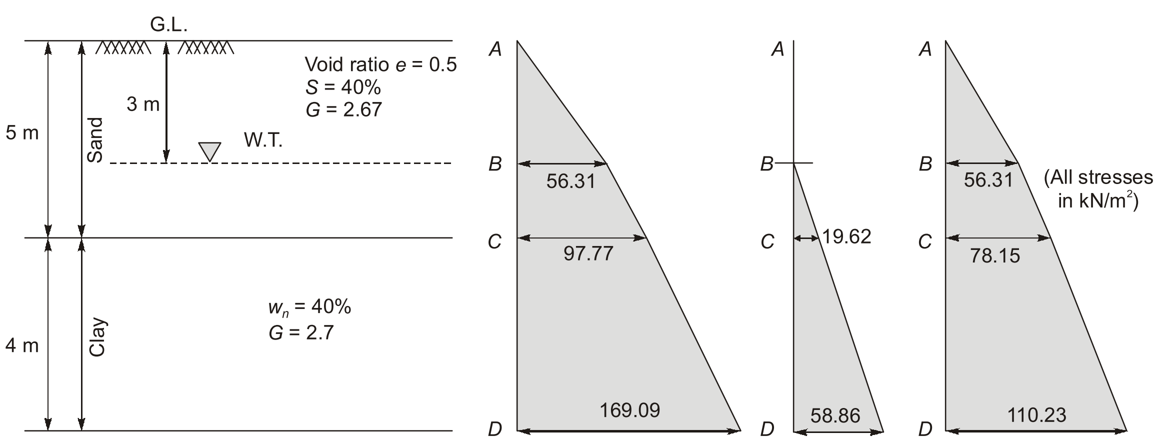
Any fluctuation in the level of free water above the ground surface would not result in any change in effective stress at any depth within the soil deposit.

Q3 For the subsoil conditions shown in fig (a) below, draw the total, neutral and effective stress diagrams upto a depth of 9 m, neglecting capillary flow.



(a) Soil profile

Solution:



(a) Soil profile **(b) σ-diagram** **(c) u-diagram** **(d) σ′-diagram**

(a) For sand:

$$\boxed{\gamma_d = \frac{G.\gamma_w}{1+e}} = \frac{2.67 \times 9.81}{1+0.5} = 17.462 \text{ kN/m}^3$$

$$\boxed{w_{wet} = \frac{eS}{G}} = \frac{0.5 \times 0.4}{2.67} = 0.0749$$

$$w_{sat} = \frac{0.5 \times 1}{2.67} = 0.1873$$

$$\gamma_{wet} = 17.462\,(1 + 0.0749) = 18.77 \text{ kN/m}^3$$

$$\gamma_{sat} = 17.462\,(1 + 0.1873) = 20.732 \text{ kN/m}^3$$

(b) For clay:

$$\boxed{e = \frac{wG}{S}} = \frac{0.4 \times 2.70}{1} = 1.08$$

$$\boxed{\gamma_{sat} = \frac{G\gamma_w}{1+e}(1+w_{sat})} = \frac{2.7 \times 9.81}{1+1.08}(1+0.4) = 17.828 \text{ kN/m}^3$$

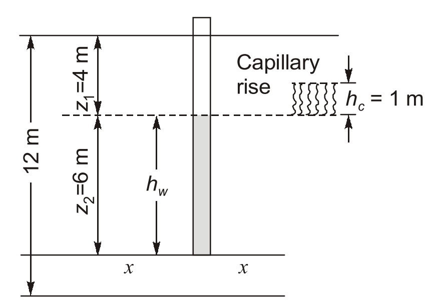
The computation for total stress, pore pressure and effective stress are shown in tabular form below. The distribution of these stresses are shown in figure (a) (b), (c), and (d) respectively

Point	Level below G.L. (m)	Total stress σ (kN/m^2)	Pore pressure u (kN/m^2)	Effective stress (kN/m^2) $\sigma' = \sigma - u$
A	0	0	0	0
B	3	18.77 × 3 = 56.31	0	56.31
C	5	56.31 + 2.0732 × 2 = 97.77	9.81 × 2 = 19.62	78.56
D	9	97.77 + 17.828 × 4 = 169.09	9.81 × 6 = 58.86	110.23

Q.4 The water table in a certain area is at a depth of 4 m below the ground surface. To a depth of 12 m, the soil consists of very fine sand having an average voids ratio of 0.7. Above the water table the sand has an average degree of saturation of 50%. Calculate the effective pressure on a horizontal plane at a depth 10 metres below the ground surface. What will be the increase in the effective pressure if the soil gets saturated by capillarity upto a height of 1 m above the water table? Assume G = 2.65.

Solution:

Height of sand layer above water table = Z_1 = 4 m
Height of saturated layer = 12 – 4 = 8 m
Depth of point X, where pressure is to be computed = 10 m
Height of saturated layer above X = Z_2 = 10 – 4 = 6 m



Now
$$\gamma_d = \frac{G\gamma_w}{1+e} = \frac{2.65 \times 9.81}{1+0.7}$$
$$= 15.29 \text{ kN/m}^3$$

(i) For sand above water table.

$$\boxed{e = \frac{wG}{S_r}}$$

$$\boxed{w = \frac{eS_r}{G}} = \frac{0.7 \times 0.5}{2.65} = 0.132$$

$$\boxed{\gamma_1 = \gamma_d(1+w)}$$

$$= 15.29 \times 1.132 = 17.31 \text{ kN/m}^3$$

(ii) For saturated sand below water table

$$w_{sat} = \frac{e}{G} = \frac{0.7}{2.65} = 2.64$$
$$\gamma_2 = \gamma_d(1 + w_{sat}) = 15.29 \times 1.264 = 19.33 \text{ kN/m}^3$$
$$\gamma_2' = 19.33 - 9.81 = 9.52 \text{ kN/m}^3$$

Effective pressure at X

$$\sigma = Z_1\gamma_1 + Z_2\gamma_2 = 4 \times 17.31 + 6 \times 19.33 = 185.22 \text{ kN/m}^2$$
$$u = h_w\gamma_w = 6 \times 9.81 = 58.86 \text{ kN/m}^2$$
$$\therefore \quad \sigma' = \sigma - u = 185.22 - 58.86 = 126.36 \text{ kN/m}^2$$