

Seepage and Effective Stress

Q1.

From the question: $\Delta h = 30\text{cm}$

$$l_A = l_B = l_C = 15\text{cm}$$

Calculation of the rate of water supply q in cm^3/h .

$$q = Aki$$

The flow is normal to the layers, Hence:

$$k = \frac{l_A + l_B + l_C}{\frac{l_A}{k_A} + \frac{l_B}{k_B} + \frac{l_C}{k_C}} = \frac{15 + 15 + 15}{\frac{15}{3 \times 10^{-2}} + \frac{15}{4 \times 10^{-3}} + \frac{15}{8 \times 10^{-5}}} = 2.3468 \times 10^{-4} (\text{cm} / \text{s})$$

and

$$i = \frac{\Delta h}{l_A + l_B + l_C} = \frac{30}{45} = 0.667$$

$$A = 20 \times 20 = 400 (\text{cm}^2)$$

$$q = Aki = 400 \times 2.3468 \times 10^{-4} \times 0.667 \times 3600 = 0.062613 (\text{cm} / \text{s}) = 225.405 (\text{cm} / \text{h})$$

Q2.

Given:

$$\rho_{sat(clay)} = 1925 \text{ kg/m}^3$$

$$\gamma_{sat(clay)} = \frac{1925 \times 9.81}{1000} = 18.88 \text{ kN/m}^3$$

At point A

$$\sigma_A = (10 - 7.5)\gamma_{sat(clay)} + h\gamma_w = 2.5 \times 18.88 + h\gamma_w = 47.2 + h\gamma_w \text{ (kPa)}$$

$$u_A = 6\gamma_w = 6 \times 9.81 = 58.86 \text{ (kPa)}$$

For heave (For clay stability)

$$\sigma_A = u_A$$

$$47.2 + h\gamma_w = 58.86 \text{ (kPa)}$$

$$h = \frac{58.86 - 47.2}{9.81} = 1.19 \text{ m}$$

Q3.

Step 1: Calculate the unit weights;

0 - 2 m

$$S = 40\% = 0.4 ; w = 0.05$$

$$e = wG_s/S = \frac{0.05 \times 2.7}{0.4} = 0.34$$

$$\gamma = G_s \frac{(1+w)}{(1+e)} \quad \gamma_w = \frac{2.7(1+0.05)}{1+0.34} \times 9.8 = 20.7 \text{ kN/m}^3$$

2- 6 m

$$S = 1; w = 0.15$$

$$e = wG_s = 0.15 \times 2.7 = 0.405$$

$$\gamma = \left(\frac{G_s + e}{1 + e} \right) \gamma_w = \left(\frac{2.7 + 0.405}{1 + 0.405} \right) \times 9.8 = 21.658 \text{ kN/m}^3$$

6 - 14 m

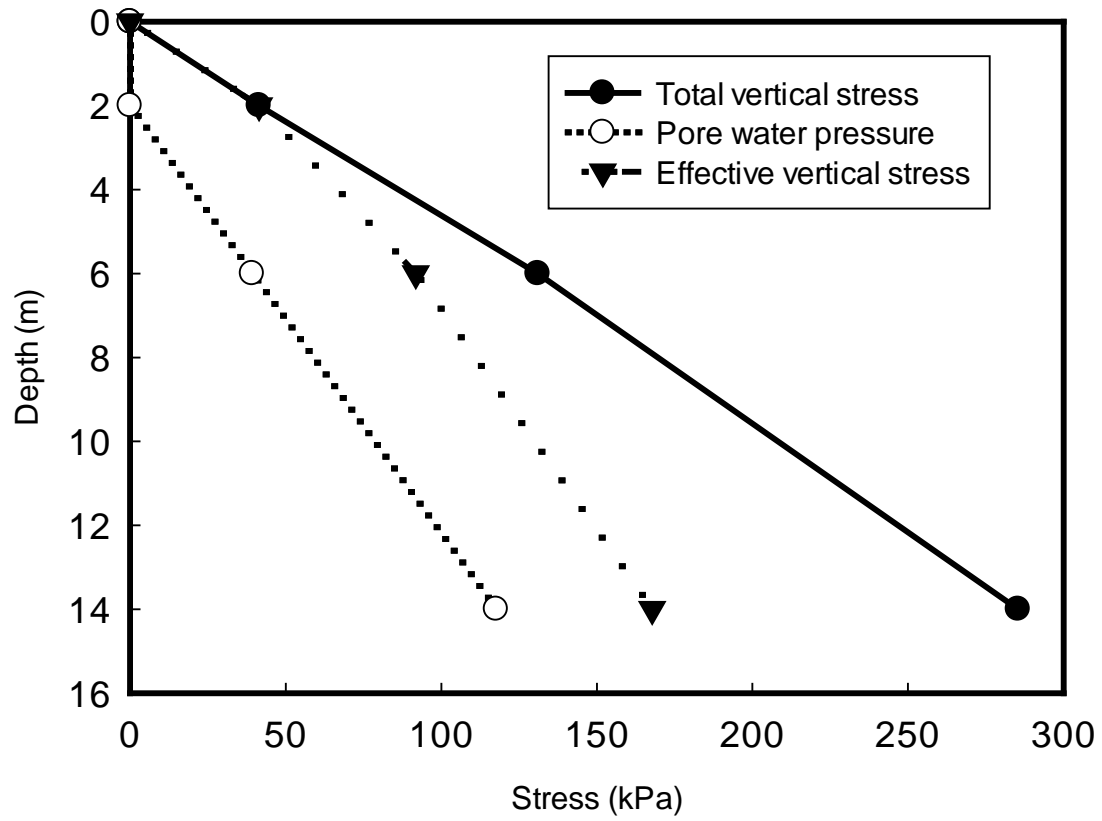
$$S = 1; w = 0.28$$

$$e = wG_s = 0.28 \times 2.7 = 0.76$$

$$\gamma = \left(\frac{G_s + e}{1 + e} \right) \gamma_w = \left(\frac{2.7 \times 0.76}{1 + 0.76} \right) \times 9.8 = 19.3 \text{ kN/m}^3$$

Step 2: calculate the stress table or spreadsheet

Depth (m)	Thickness (m)	σ (kPa)	u (kPa)	$\sigma' = \sigma - u$ (kPa)
2	2	$20.7 \times 2 = 41.4$	0	41.4
6	4	$41.4 + 21.658 \times 4 = 128.03$	$4 \times 9.8 = 39.2$	88.83
14	8	$128.03 + 19.3 \times 8 = 282.43$	$39.2 + 8 \times 9.8 = 117.6$ or $12 \times 9.8 = 117.6$	164.83



Q4.

$$S = 1; w = 0.28$$

$$e = wG_s = 0.27 \times 2.7 = 0.729$$

$$\gamma = \left(\frac{G_s + e}{1 + e} \right) \gamma_w = \left(\frac{2.7 + 0.729}{1 + 0.729} \right) \times 9.8 = 19.44 \text{ kN/m}^3$$

$$\gamma' = 19.44 - 9.8 = 9.64 \text{ kN/m}^3$$

$$FS = \frac{5 \times 8 \times 9.64}{5 \times 10 \times 9.8} = 0.787$$

The soil next to the sheet piling is subjected to heave problems.

Q5.

Calculate the unit weight

Above the groundwater level

$$\gamma = \left(\frac{G_s + Se}{1 + e} \right) \gamma_w = \frac{G_s(1 + w)}{1 + e} \gamma_w$$

$$Se = wG_s$$

$$e = \frac{0.3 \times 2.7}{0.6} = 1.35$$

$$\gamma = \frac{2.7(1 + 0.3)}{1 + 1.35} \times 9.8 = 14.6 \text{ kN/m}^3$$

Below the groundwater level

$$S = 1$$

$$e = wG_s = 0.4 \times 2.7 = 1.08$$

$$\gamma_{sat} = \frac{2.7 + 1.08}{1 + 1.08} \times 9.8 = 17.8 \text{ kN/m}^3$$

Calculate the effective stress

$$\text{Total stress: } 2 \times 14.6 + 3 \times 17.8 = 82.6 \text{ kPa}$$

$$\text{Pore water pressure: } 3 \times 9.8 = 29.4 \text{ kPa}$$

$$\text{Effective stress: } 82.6 - 29.4 = 53.2 \text{ kPa}$$

Q6.

Assuming the water head loss is soil 1 and soil 2 to be Δh_1 and Δh_2 , respectively.

$$\Delta h_1 + \Delta h_2 = 30 \text{ cm}$$

The velocity of the water flow through the soil 1 and soil 2 are the same, according to Darcy's law.

$$k_1 \frac{\Delta h_1}{l_1} = k_2 \frac{\Delta h_2}{l_2}$$

$$l_1 = l_2 = 30 \text{ cm}$$

$$\Delta h_1 = 10 \text{ cm}$$

$$\Delta h_2 = 20 \text{ cm}$$

$$q = kiA = k_1 \frac{\Delta h_1}{l_1} A = 0.2 \times \frac{10}{30} \times 200 = 13.3 \text{ cm}^3 / \text{s}$$

Assuming the water level difference is Δh .

$$\Delta h_1 + \Delta h_2 = \Delta h$$

$$k_1 \frac{\Delta h_1}{l_1} = k_2 \frac{\Delta h_2}{l_2}$$

$$\Delta h_1 = \frac{1}{3} \Delta h; \quad \Delta h_2 = \frac{2}{3} \Delta h;$$

$$i_1 = \frac{\Delta h}{3l_1}; \quad i_2 = \frac{2\Delta h}{3l_2}$$

$$\gamma'_1 = \frac{G_{s1} - 1}{1 + e_1} \gamma_w = \frac{2.72 - 1}{1 + 0.85} \times 9.8 = 9.11 \text{ kN} / \text{cm}^3$$

$$\gamma'_2 = \frac{G_{s2} - 1}{1 + e_2} \gamma_w = \frac{2.72 - 1}{1 + 0.8} \times 9.8 = 9.36 \text{ kN} / \text{cm}^3$$

When only soil 1 is subjected to liquefaction;

$$i_1 \gamma_w = \frac{\Delta h}{3l_1} \gamma_w = \gamma'_1$$

$$\Delta h = 82 \text{ cm}$$

When both soil 1 and soil 2 are subjected to liquefaction;

$$i_1 \gamma_w l_1 A + i_2 \gamma_w l_2 A = \frac{\Delta h}{3} \gamma_w A + \frac{2\Delta h}{3} \gamma_w A = \gamma' l_1 A + \gamma' l_2 A$$

$$\Delta h = 55.57 \text{ cm}$$

Chose the smaller value $\Delta h = 55.57 \text{ cm}$.