

Solution Exercise 1 – tot:40pt

1.1 $\sigma_1 = ? \quad \sigma_3 = 20kPa \quad \sigma_1 - \sigma_3 = 28kPa \Rightarrow \sigma_1 = 28 + 20 = 48kPa$ 1

1.1 $\tau = R \sin(2\theta) = \frac{\sigma_1 - \sigma_3}{2} \sin(2\theta) = \frac{48 - 20}{2} \sin(2 * 57) = 12,8kPa$ 1

1.2 $\sigma = \frac{\sigma_1 + \sigma_3}{2} + \frac{\sigma_1 - \sigma_3}{2} \cos(2\theta) = \frac{48 + 20}{2} + \frac{48 - 20}{2} \cos(2 * 57) = 28,3kPa$ 1

1.3 $\tau_{max} \rightarrow \theta = 45$ 1

1.3 $\tau_{max} = \frac{\sigma_1 - \sigma_3}{2} * \sin(2 * \theta) = \frac{48 - 20}{2} * \sin(2 * 45) = 14kPa$ 1

1.4 On the failure plane: $\sigma' = \sigma - u = (28 - 18)kPa = 10kPa$ 1

$\tau_f = c' + \sigma' \tan(\varphi') = 8 + 10 * \tan(24) = 12.5kPa$ 1

τ at 57° is 12.8 kPa, and the τ at failure is 12.5, which means that the soil failed.

1.5

1

At the plane of maximum shear stress ($\theta=45^\circ$), the normal stress is:

$$\sigma = \frac{\sigma_1 + \sigma_3}{2} + \frac{\sigma_1 - \sigma_3}{2} \cos(2\theta) = \frac{48 + 20}{2} + \frac{48 - 20}{2} \cos(2 * 45) = 34 \text{ kPa}$$

$$\sigma' = \sigma - u = 34 - 18 = 16 \text{ kPa}$$

$$\tau_{f45} = c' + \sigma' * \tan(\phi') = 8 + 16 * \tan(24) = 15.1 \text{ kPa}$$

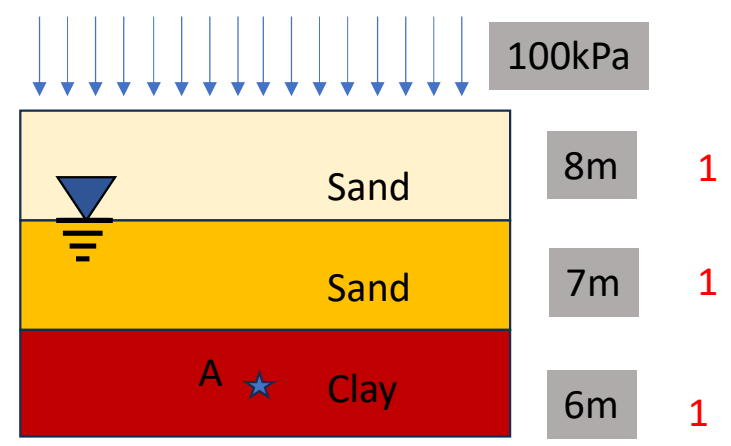
$$\tau_{45} = \frac{48 - 20}{2} \sin(2 * 45) = 14 \text{ kPa} \Rightarrow \tau_{45} < \tau_{f45}$$

At the plane of maximum shear stress ($\theta=45^\circ$), the failure shear stress is bigger than the shear stress so the soil is safe

3

Solution Exercise 2 – tot:40pt

2.1



We use the point A in the middle of the clay layer to calculate the stresses within the layer

2.2 $C_c = 0,009(LL - 10) = 0,009(50 - 10) = 0,36 \Rightarrow C_e = 0,15C_c = 0,054$

$S = S_r = 1$ $Se = wG_s \rightarrow e = \frac{wG_s}{S} = 0,34 * 2,67 = 0,91$

$\sigma_o = \gamma_{dry}^{sand} * 8m + \gamma_{sat}^{sand} * 7m + \gamma_{sat}^{clay} * (6/2) = 15 * 8 + 19 * 7 + 21 * 3 = 316kPa$

$u = \gamma_w * (7 + \frac{6}{2}) = 100kPa$ $\sigma'_0 = \sigma_o - u = 316kPa - 100kPa = 216kPa$

$\sigma'_f = \sigma'_0 + \Delta\sigma = 216kPa + 100kPa = 316kPa$

2.3

Case 1 = NC

$$\Delta e = -C_c \log\left(\frac{\sigma_f}{\sigma_0}\right) = -0,059$$

$$\epsilon_a = -\frac{\Delta e}{1 + e_0}$$

$$s_{oed} = \epsilon_a H$$

$$\epsilon = -\frac{-0,059}{1 + 0,91} = 0,031$$

$$S = 0,031 * 6m = 0,18m$$

2.4 Case 2 = OC

OCR=3

$$OCR = \frac{\sigma_{max}}{\sigma_0} = 3 \Rightarrow \sigma_{max} = 3 * 216kPa = 648kPa$$

$$\Delta e = -C_e \log\left(\frac{\sigma'_F}{\sigma'_0}\right) \quad OCR > 1; \sigma'_{max} > \sigma'_F \Rightarrow \Delta e = -0,054 \log\left(\frac{316}{216}\right) = -0,00089$$

$$\epsilon = -\frac{-0,0009}{1 + 0,91} = 0,00046$$

$$S = \epsilon H = 0,00046 * 6m = 0,0028m$$

2.5

Case 3: $\sigma_{max} = 400\text{kPa}$ $OCR = \frac{400\text{kPa}}{216\text{ kPa}} = 1,85$

$$\Delta e = -C_e \log\left(\frac{\sigma'_F}{\sigma'_0}\right) \quad OCR > 1; \sigma'_{max} > \sigma'_F$$

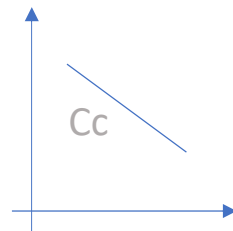
$$\Delta e = -0.054 * \log\left(\frac{316}{216}\right) = 0,00089$$

$$\epsilon = -\frac{0,0009}{1 + 0,91} = 0,0047$$

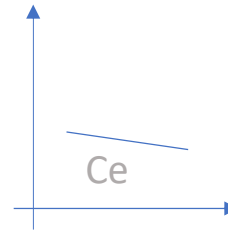
$$S = \epsilon * H = 0,028$$

2.6

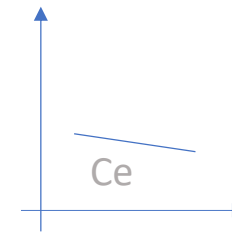
Case 1:



Case 2:



Case 3:



2.7

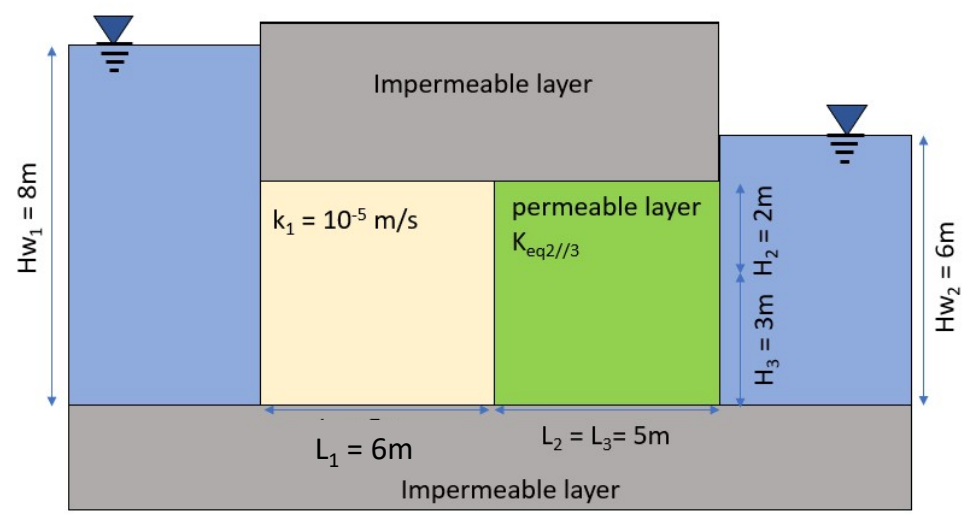
When $OCR=3$ and the higher σ_{max} we have the smallest settlement, Hence safest condition.

Solution Exercise 3 – tot:20pt

3.1 The hydraulic gradient is $i = \frac{\Delta h_{AB}}{L_{AB}} = 0,18$

3.2 calculate the equivalent permeability across the 3 permeable layers

- a. we calculate the parallel equivalent permeability ($k_{eq2//3}$) between layer 2 and layer 3.
- b. we calculate the perpendicular equivalent permeability ($k_{eq1_|_2//3}$) between the layer 1 and the other two layers

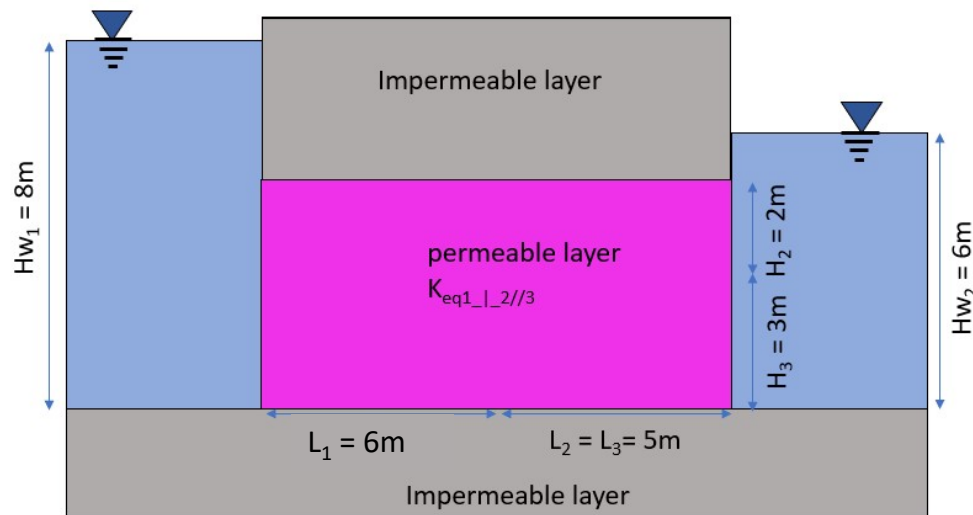


$$k_{eq}^{\parallel} = \frac{\sum_i k_i H_i}{\sum_i H_i}$$
$$k_{eq_23}^{\parallel} = \frac{10^{-8} \cdot 2 + 0.5 \cdot 10^{-8} \cdot 3}{2 + 3} = 0.7 \cdot 10^{-8} \text{ m/s}$$

calculate the equivalent permeability across the 3 permeable layers

a. we calculate the parallel equivalent permeability ($k_{eq2//3}$) between layer 2 and layer 3.

b. we calculate the perpendicular equivalent permeability ($k_{eq1_2//3}$) between the layer 1 and the other two layers 1



$$\frac{1}{k_{eq}} = \frac{\sum_i L_i}{\sum_i \frac{L_i}{k_i}} \quad 1$$

$$\frac{1}{k_{eq_123}} = \frac{6+5}{\frac{6}{10^{-5}} + \frac{5}{0.7 \cdot 10^{-8}}} = 1.54 \cdot 10^{-8} \text{ m/s} \quad 1$$

3.3

the flow rate is: $Q = k_{eq_123} \cdot A \cdot \frac{\Delta h_{AB}}{L_{AB}} = -1.54 \cdot 10^{-8} \frac{\text{m}}{\text{s}} * (11\text{m} * 5\text{m}) * \frac{8\text{m} - 6\text{m}}{11\text{m}} = 1.54 \cdot 10^{-7} \frac{\text{m}^3}{\text{s}}$ 2 1 1