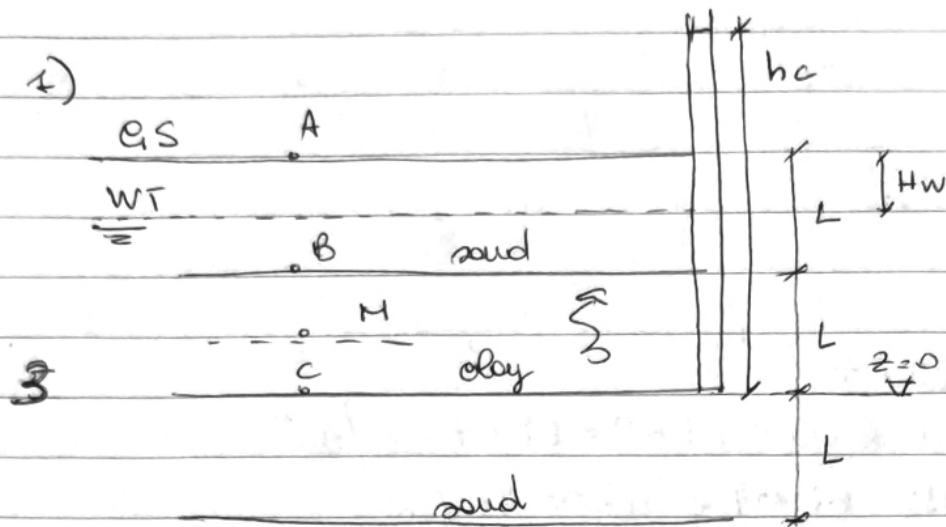


EXERCISE 1 [40 pt]



$$L = 4 \text{ m}$$

$$H_w = 2 \text{ m}$$

$$h_c = 12 \text{ m}$$

artesian pressure in C

$$\gamma_c = 20 \text{ kN/m}^3$$

$$\gamma_s^{(1)} = 16,5 \text{ kN/m}^3$$

$$\gamma_s^{(2)} = 19 \text{ kN/m}^3$$

2) Top of the clay layer (point B):

$$\sigma_B = \gamma_s^{(1)} H_w + \gamma_s^{(2)} (L - H_w) = (2 \times 16,5) + (2 \times 19) = 71 \text{ kN/m}^2$$

$$5 \quad u_B = \gamma_w (L - H_w) = 9,81 \times 2 = 19,6 \text{ kN/m}^2$$

$$\sigma'_B = \sigma_B - u_B = 71 - 19,6 = \underline{51,4 \text{ kN/m}^2}$$

Bottom of the clay layer (point C):

$$\sigma_C = \sigma_B + \gamma_c L = 71 + (20 \times 4) = 151 \text{ kN/m}^2$$

$$u_C = h_c \times \gamma_w = 12 \times 9,8 = 117,6 \text{ kN/m}^2$$

7 L pressure head in C due to artesian pressure

$$\sigma'_C = \sigma_C - u_C = 151 - 117,6 = \underline{33,4 \text{ kN/m}^2}$$

Explain that the pore pressure and effective stress in the clay layer are influenced by the flow in the clay due to the artesian pressure in C:

$$\Delta h^{BC} = h_c - h_B$$

$$h_c = 12 \text{ m (piezometer measure)} \quad 2$$

$$h_B = z_B + u_B / \gamma_w = z_B + H_w^{\text{above B}} = 4 + 2 = 6 \text{ m} \quad 2$$

$$\Delta h^{BC} = h_C - h_B = 12 - 6 = 6 \text{ m}^2$$

$h_C > h_B \rightarrow$ upward flow $\uparrow$

hydraulic gradient in the clay $i = \frac{\Delta h^{BC}}{L^{BC}} = \frac{6}{4} = 1,5$

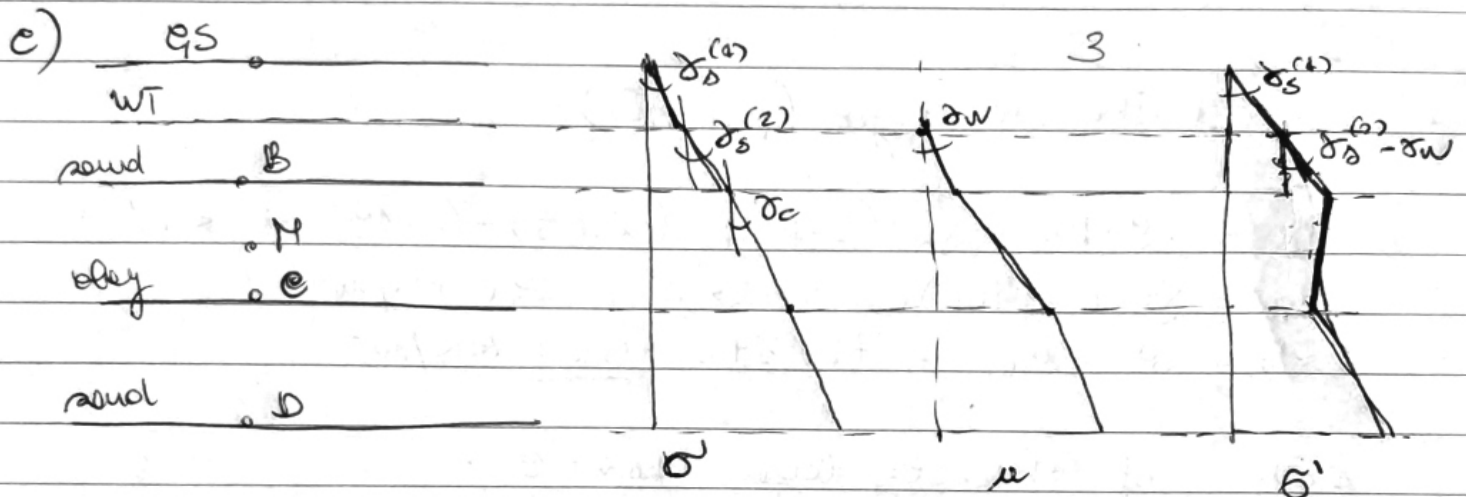
Now we can calculate σ'_M, u_M & σ'_N

$$\sigma'_M = \sigma_B + \sigma_c L_{BM} = 71 + 20 \times 2 = 111 \text{ kN/m}^2$$

$$u_M = \sigma_w H_w^{BM} + i \sigma_w H^{BN}$$

$$= 9,81 \times 4 + 1,5 \times 9,81 \times 2 = 68,67 \text{ kN/m}^2$$

$$\sigma'_N = \sigma'_M - u_M = 111 - 68,67 = 42,33 \text{ kN/m}^2$$



d) At the bottom of the clay layer: $\sigma'_C = 33,4 \text{ kN/m}^2 > 0$

If the top sand layer is removed: safe!

$$\sigma'_C = \sigma_c L + \sigma_w L_w = 20 \times 4 + 19,8 \times 2 = 117,6 \text{ kN/m}^2$$

3 u_C does not change because dominated by artesian pressure

$$\rightarrow u_C = 117,6 \text{ kN/m}^2$$

$$\sigma'_C = \sigma_C - u_C = 2 \text{ kN/m}^2 \quad \text{not close to boiling, high risk.}$$

e) the artesian pressure, if higher than the hydrostatic pressure, can induce upward seepage $\Rightarrow$ higher $u \Rightarrow \sigma' \rightarrow 0 =$ boiling.

4 the surcharge (like the upper sand) increases the total stress and helps limiting the risk: $\sigma' = \sigma - u$

EXERCISE (2) [35 points]

Saturated clay: $e_c = 0.92$ $e_e = 0.04$ $OER = 4.5$

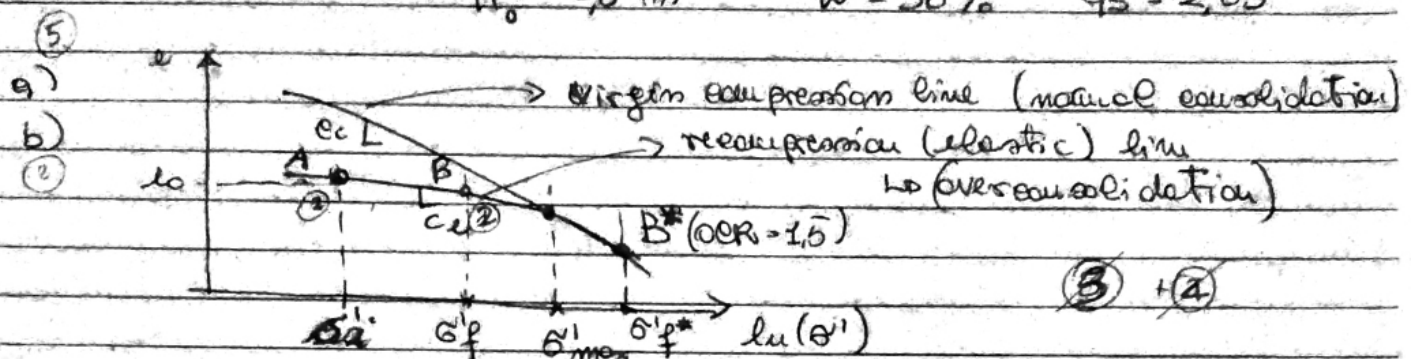
$$\sigma'_i = 120 \text{ kPa}$$

$$\Delta \sigma' = 8 \text{ kPa}$$

$$H_0 = 15 \text{ m}$$

$$w = 36\%$$

$$q_s = 2.65$$

 $e_c = \text{slope of compression line}$ $e_e = \text{slope of recompression line}$

c) $OER = 4.5 = \frac{\sigma'_{max}}{\sigma'_i} = \frac{\sigma'_{max}}{120} \Rightarrow \sigma'_{max} = 4.5 \cdot 120 \text{ kPa}$

$= 540 \text{ kPa}$

15

$$e_0 = w q_s = 0.36 \cdot 2.65 = 0.954 \quad (2)$$

$$\sigma'_f = \sigma'_i + \Delta \sigma' = (120 + 80) \text{ kPa} = 200 \text{ kPa} \quad (2)$$

↓ since the process is slow, the total stress ~~increase~~ measurement is taken by the solid skeleton

$$\sigma'_f < \sigma'_{max} :$$

1

$$\Delta H = \frac{\Delta e}{1 + e_0} H_0$$

2

$$\Delta e = e_c \ln \left(\frac{\sigma'_f}{\sigma'_i} \right) = 0.04 \ln \left(\frac{200}{120} \right) = 0.0204 \quad (1) \quad [0.0089]$$

$$(2) \Delta H = \left[\frac{0.0204}{1 + 0.954} \right] \cdot 15 \text{ m} = 0.157 \text{ m} = 157 \text{ mm} \quad (2) \quad [0.81]$$

d) $OCR = 1,5$

$\sigma'_{max} = 1,5 \times 120 \text{ kPa} = 180 \text{ kPa}$ (2)

$\sigma'_p = 200 \text{ kPa}$ (2)

$OCR > 1 \quad \sigma'_{max} < \sigma'_p$ (1)

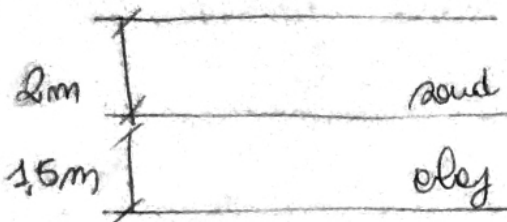
$$\begin{aligned} \Delta e &= C_c \ln \left(\frac{\sigma'_{max}}{\sigma'_u} \right) + C_c \ln \left(\frac{\sigma'_p}{\sigma'_{max}} \right) \\ &= 0,04 \ln \left(\frac{180}{120} \right) + 0,2 \ln \left(\frac{200}{180} \right) \\ &= 0,016 + 0,021 = 0,037 \end{aligned} \quad \begin{matrix} (2) \\ [0,016] \\ (4) \end{matrix}$$

$$\Delta H^* = \frac{\Delta e}{1+e_0} H_0 = \frac{0,037}{1+0,954} \cdot 1,5 = 0,0286 \text{ m} = 28,6 \text{ mm} \quad [12,4] \quad (2)$$

difference in settlements

$\Delta H > \Delta H^*$

e)



$\sigma'_0 = \sigma_{\text{sand}} + \sigma'_0 = 14 \text{ kN/m}^3 \cdot 2 \text{ m} + 120 \text{ kPa} = 148 \text{ kPa}$ (1)

$\sigma'_f = \sigma'_0 + \Delta \sigma = (148 + 80) = 228 \text{ kPa}$ (1)

$OCR = 1,5$

$\sigma'_{max} = OCR \sigma'_0 = 1,5 \times 148 = 222 \text{ kPa}$

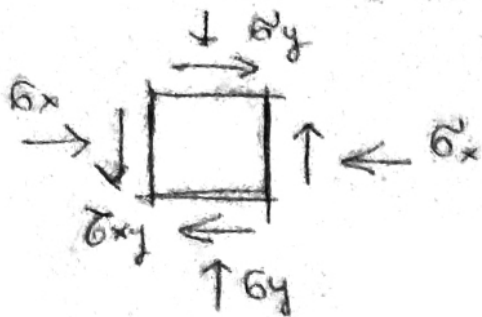
$\Rightarrow \sigma'_f > \sigma'_{max}$ (1)

$$\begin{aligned} \Delta e &= +C_c \ln \left(\frac{\sigma'_{max}}{\sigma'_0} \right) + C_c \ln \left(\frac{\sigma'_f}{\sigma'_{max}} \right) \\ &= +0,04 \ln \left(\frac{222}{148} \right) + 0,2 \ln \left(\frac{228}{222} \right) = +0,02 \end{aligned} \quad \begin{matrix} (2) \\ [e_0 = 0,954] \end{matrix}$$

$\epsilon_v = \frac{0,02}{1+0,954} = 0,01$

$S_c = \epsilon_v H_c = 0,01 \times 1,5 = 0,0153 \text{ m} \quad [e_0 = 0,954]$

EXERCISE 3 [25 pt]



$$A = 100 \text{ mm} \times 100 \text{ mm} = 0,01 \text{ m}^2$$

$$\theta_m = -20^\circ (\text{clockwise})$$

$$A = 0,1 \times 0,1 = 0,01 \text{ m}^2$$

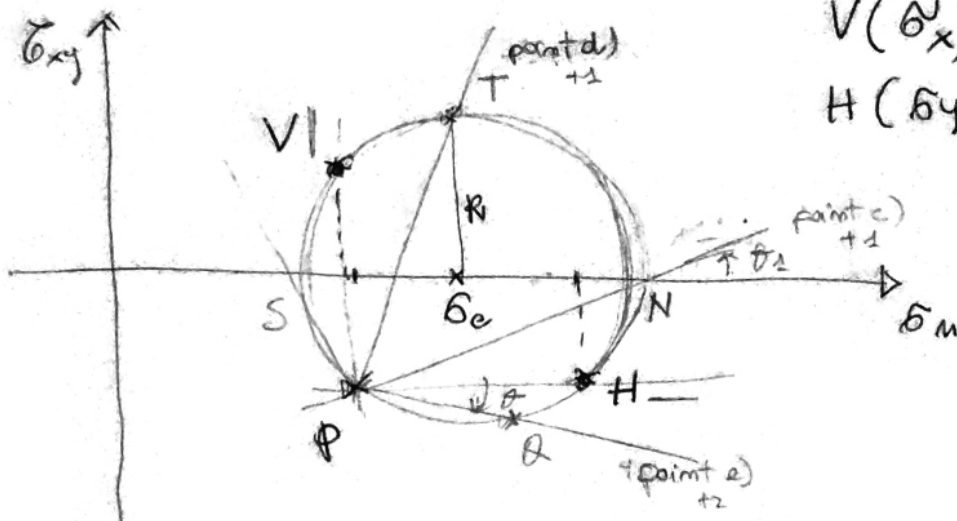
$$\sigma_y = \frac{F_y}{A} = \frac{8 \text{ kN}}{0,01 \text{ m}^2} = \underline{800 \text{ kPa}}$$

$$\sigma_x = \frac{F_x}{A} = \frac{4 \text{ kN}}{0,01 \text{ m}^2} = \underline{400 \text{ kPa}}$$

$$\sigma_{xy} = \frac{2 \text{ kN}}{0,01 \text{ m}^2} = \underline{200 \text{ kPa}}$$

positive on V-faces
negative on H-faces.

a)



$$V(\sigma_x, \sigma_{xy})$$

$$H(\sigma_y, -\sigma_{xy})$$

$$b) \sigma_c = \frac{\sigma_x + \sigma_y}{2} = \frac{400 + 800}{2} = \underline{600 \text{ kPa}} \quad (2)$$

$$R = \sqrt{\left(\frac{\sigma_y - \sigma_x}{2}\right)^2 + \sigma_{xy}^2} = \sqrt{\left(\frac{800 - 400}{2}\right)^2 + 200^2} = \underline{282,8 \text{ kPa}} \quad (2)$$

$$\sigma_1 = \sigma_c + R = 600 + 282,8 = \underline{882,8 \text{ kPa}} \quad (\text{point N}) \quad (1)$$

$$\sigma_2 = \sigma_c - R = 600 - 282,8 = \underline{317,2 \text{ kPa}} \quad (\text{point S}) \quad (1)$$

$$c) \theta_{1/2} = \frac{1}{2} \tan^{-1} \left(\frac{2\sigma_{xy}}{\sigma_y - \sigma_x} \right) = \frac{1}{2} \tan^{-1} \left(\frac{2 \times 200}{800 - 400} \right) = \frac{1}{2} \tan^{-1}(1) \quad (2)$$

On the circle you can connect P with N $\rightarrow$ angle $= \theta_1 = 22,5^\circ$ see circle.

$$d) = \sigma_{max} = R = \underline{289,8 \text{ kPa}} \quad (2)$$

this is the point (σ_c, R) T
on the circle - +2
the circle

$$\begin{aligned} e) \quad \sigma_m &= \frac{\sigma_y + \sigma_x}{2} + \frac{\sigma_y - \sigma_x}{2} \cos(2\theta_m) + \tau_{xy} \sin(2\theta_m) \\ &= \frac{800+400}{2} + \frac{800-400}{2} \cos(2 \times (-20)) + 200 \sin(2 \times (-20)) \\ &= \underline{694,7 \text{ kPa}} \end{aligned}$$

$$\begin{aligned} \sigma_m &= \frac{\sigma_y - \sigma_x}{2} \sin(2\theta_m) - \tau_{xy} \cos(2\theta_m) \\ &= \frac{800-400}{2} \sin(2 \times (-20)) - 200 \cos(2 \times (-20)) \\ &= \underline{-281,8 \text{ kPa}} \end{aligned}$$

this is the point Q on the Mohr's circle -

You can obtain it by sending a line inclined
of -20° (clockwise) from the horizontal
reference PH - the line should start from
the pole P -

+2
the circle