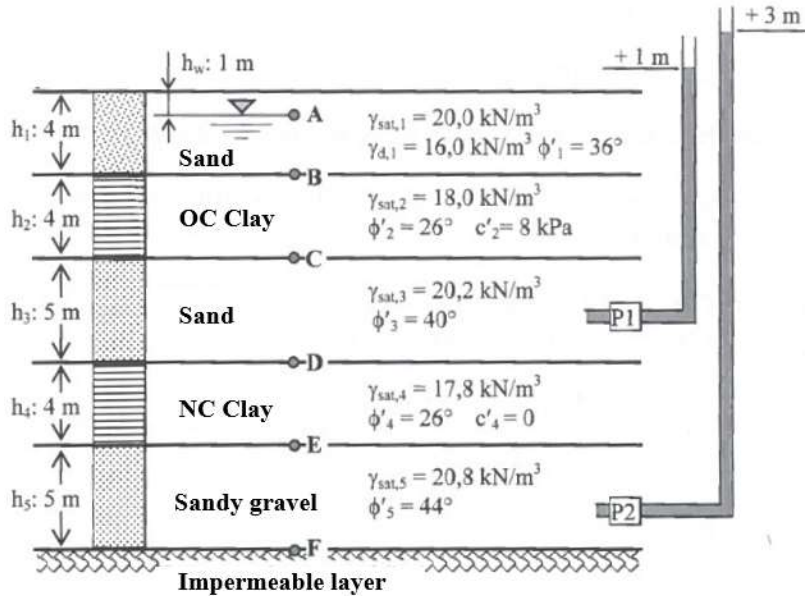
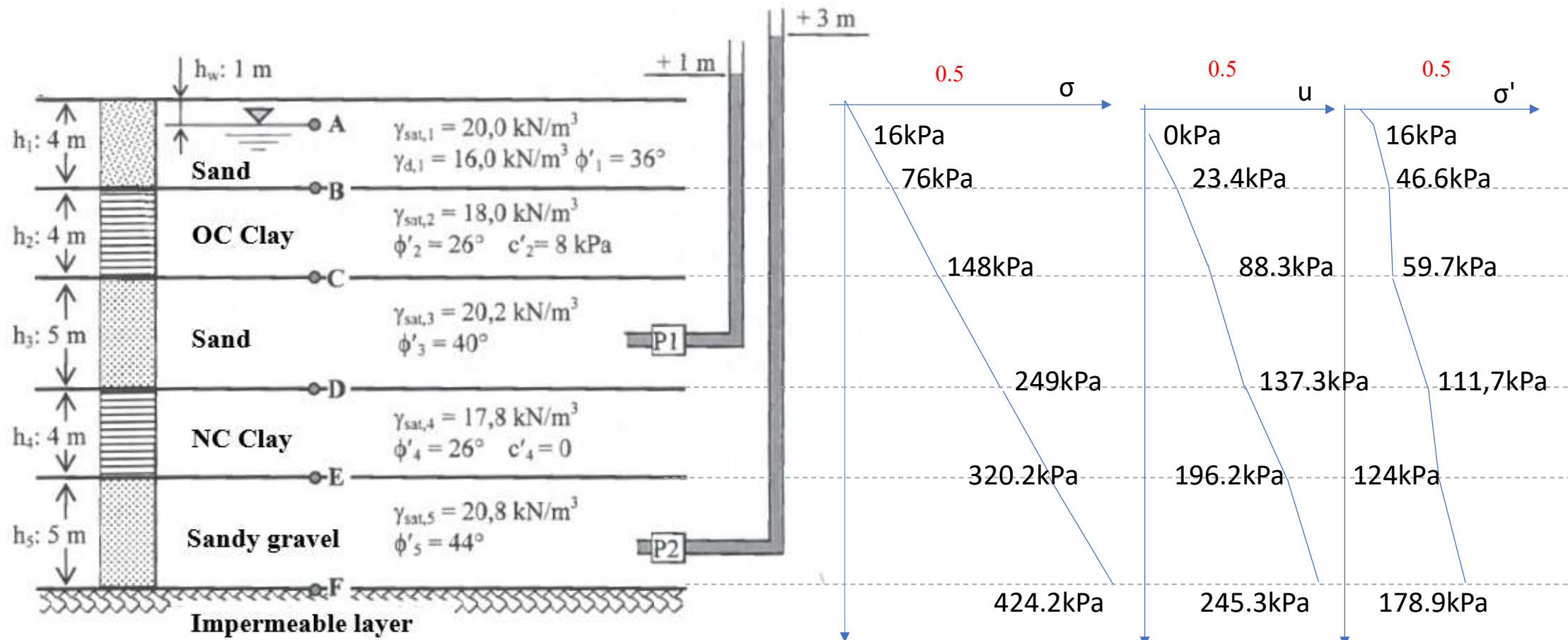


EXERCISE 1- WORKING SOLUTION

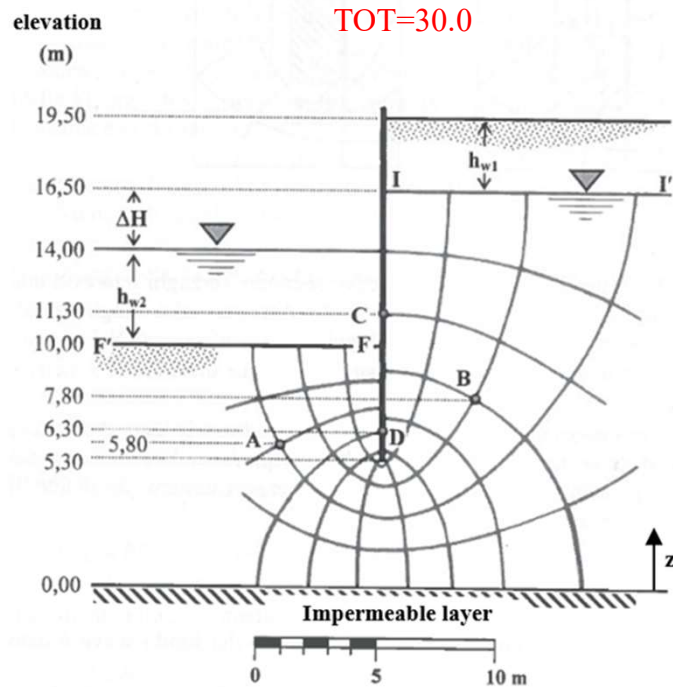
TOT=30.0



A	$\sigma_A = \gamma_{dry} * h_w = 16 \frac{kN}{m^3} * 1m = 16kPa$	2.0
	$u_A = 0$	0.5
	$\sigma'_A = \sigma_A - u_A = 16kPa$	2.0
B	$\sigma_B = \gamma_{dry} * h_w + \gamma_{sat,1} * (h_1 - h_w) = 16 \frac{kN}{m^3} * 1m + 20 \frac{kN}{m^3} * (4 - 1)m = 76kPa$	2.0
	$u_B = \gamma_w * (h_1 - h_w) = 9.81 \frac{kN}{m^3} * 3m = 29.43kPa$	1.0
	$\sigma'_B = \sigma_B - u_B = 76kPa - 29.43kPa = 46.57kPa$	1.0
C	$\sigma_C = \sigma_B + \gamma_{sat,2} * (h_2) = 76kPa + 18 \frac{kN}{m^3} * 4m = 148kPa$	2.0
	$u_C = \gamma_w * (h_1 + h_2 + 1m) = 9.81 \frac{kN}{m^3} * 9m = 88.29kPa$	2.0
	$\sigma'_C = \sigma_C - u_C = 148kPa - 88.3kPa = 59.95kPa$	1.0
D	$\sigma_D = \sigma_C + \gamma_{sat,3} * (h_3) = 148kPa + 20.2 \frac{kN}{m^3} * 5m = 249kPa$	2.0
	$u_D = \gamma_w * (h_3 + h_2 + h_1 + 1m) = 9.81 \frac{kN}{m^3} * 25m = 137.34kPa$	2.0
	$\sigma'_D = \sigma_D - u_D = 249kPa - 137.34kPa = 111.66kPa$	1.0
E	$\sigma_E = \sigma_D + \gamma_{sat,4} * (h_4) = 249kPa + 17.8 \frac{kN}{m^3} * 4m = 320.2kPa$	2.0
	$u_E = \gamma_w * (h_4 + h_3 + h_2 + h_1 + 3m) = 9.81 \frac{kN}{m^3} * 20m = 196.2kPa$	2.0
	$\sigma'_E = \sigma_E - u_E = 320.2kPa - 196.2kPa = 124.0kPa$	1.0
F	$\sigma_F = \sigma_E + \gamma_{sat,5} * (h_5) = 320.2kPa + 20.8 \frac{kN}{m^3} * 5m = 424.2kPa$	2.0
	$u_F = \gamma_w * (h_5 + h_4 + h_3 + h_2 + h_1 + 3m) = 9.81 \frac{kN}{m^3} * 25m = 245.25kPa$	2.0
	$\sigma'_F = \sigma_F - u_F = 424.2kPa - 245.25kPa = 178.95kPa$	1.0



EXERCISE 2- WORKING SOLUTION



1. Assuming we place two piezometers in A and B, what would be the water level?

14

$$\Delta H = 16.5m - 14m = 2.5m$$

$$N_f = 5; N_d = 12$$

$$\Delta h = \frac{\Delta H}{N_d} = \frac{2.5m}{12} = 0.21m$$

$$h_{in} = 16.5m; h_{fin} = 14m$$

$$z_A = 5.8m \quad z_B = 7.8m$$

$$\Delta h_A = n_{dA} \Delta h = 10 * 0.21m = 2.1m$$

$$h_A = h_{in} - \Delta h_A = (16.5 - 2.1)m = 14.4m \leftarrow \text{piezometer height}$$

$$h_{pA} = h_a - z_a = (14.4 - 5.8) = 8.6m$$

$$\Delta h_B = n_{dB} * \Delta h = 3 * 0.21m = 0.63m$$

$$h_B = h_{in} - \Delta h_B = (16.5 - 0.63)m = 15.87m \leftarrow \text{height piezometer}$$

$$h_{pB} = h_B - z_B = (15.87 - 7.8)m = 8.07m$$

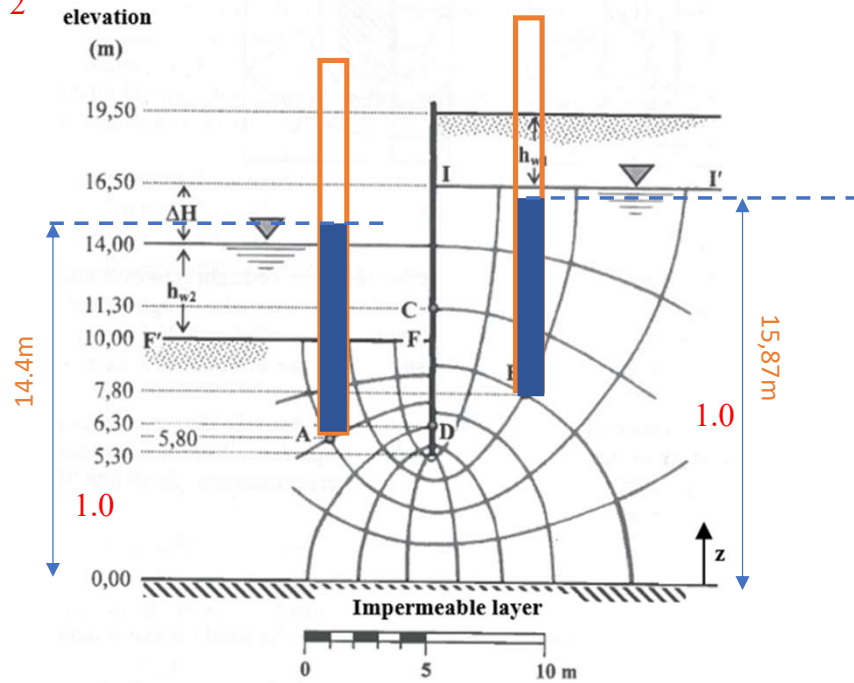
2. Measure the equipotential drop between A and B

1

$$\Delta h_{AB} = (15.87 - 14.4)m = 1.47m$$

3. Sketch the piezometers in A and B and indicate their water level

2



4. Calculate the vertical effective stress in A and B

$$\sigma_A = \gamma_w * h_{w2} + \gamma_{sat} * (z_F - z_A) = 9.81 \frac{kN}{m^3} * 4m + 19.8 \frac{kN}{m^3} * (10 - 5.8)m = 122.4 kPa$$

$$u_A = \gamma_w * h_{pA} = 9.81 \frac{kN}{m^3} * 8.6m = 84.37 kPa$$

$$\sigma'_A = \sigma_A - u_A = 38.03 kPa$$

$$\sigma_B = \gamma_{dry} * h_{w1} + \gamma_{sat} * (z_I - z_B) = 16 \frac{kN}{m^3} * 3m + 19.8 \frac{kN}{m^3} * (16.5 - 7.8)m = 220.26 kPa$$

$$u_B = \gamma_w * h_{pB} = 9.81 \frac{kN}{m^3} * 8.07m = 79.17 kPa$$

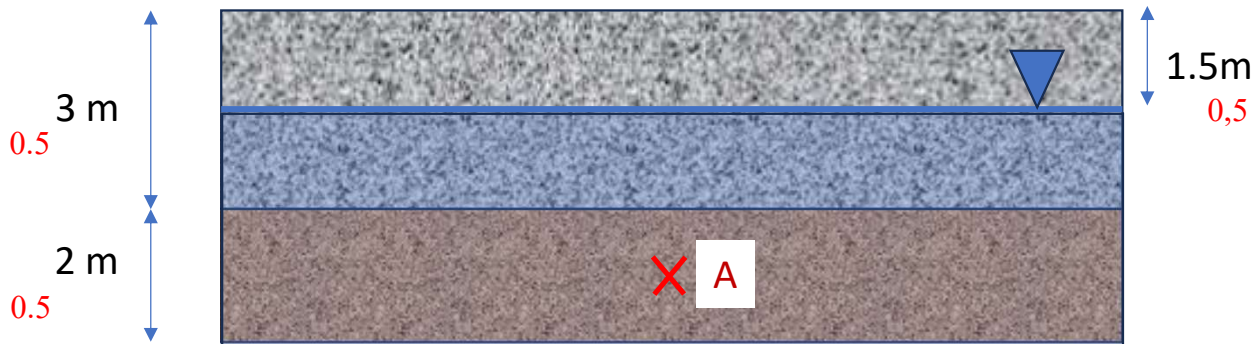
$$\sigma'_B = \sigma_B - u_B = 141.09 kPa$$

2 5. What is the total flow rate q?

$$q = k \Delta H \frac{N_f}{N_d} = 10^{-5} \frac{m}{s} * 2.5m * \frac{5}{12} = 1.04 * 10^{-5} \frac{m^2}{s}$$

6. Explain the difference found in the piezometers level 1.0

1.5 1. Sketch the stratigraphy explained above.



12 2. Calculate the vertical effective stress of the point A situated at the middle of the clay layer (4m from the top surface). If the constant of lateral earth pressure K_0 is 0.4, determine the horizontal total and effective stresses in the same point.

$$\sigma_A = \gamma_{dry}^{sand} * 1.5m + \gamma_{sat}^{sand} * 1.5m + \gamma_{sat}^{clay} * 1m = 16 \frac{kN}{m^3} * 1.5m + 20 \frac{kN}{m^3} * 1.5m + 18 \frac{kN}{m^3} * 1m = 72kPa$$

$$u_A = \gamma_w * 2.5m = 9.81 \frac{kN}{m^3} * 2.5m = 24.5kPa$$

$$\sigma'_A = \sigma_A - u_A = 47.5kPa$$

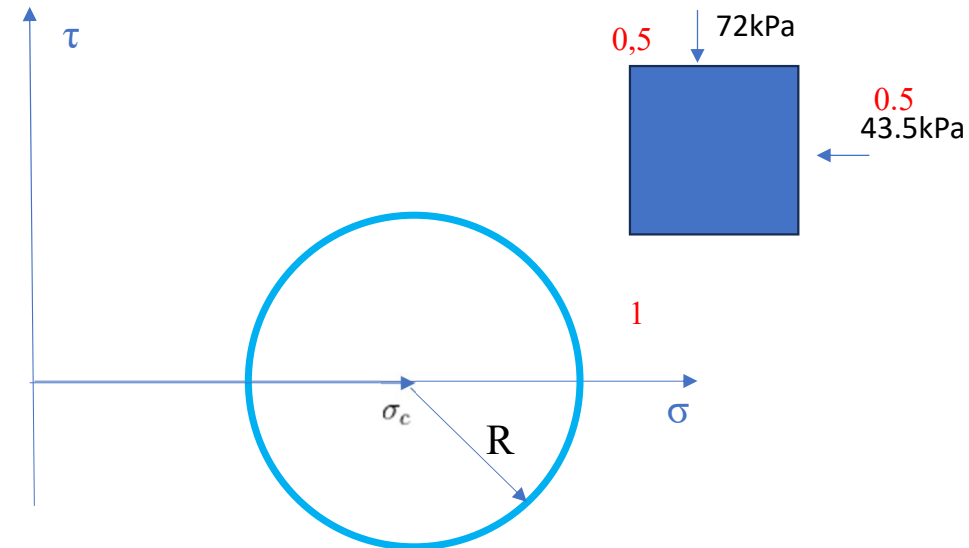
$$\sigma'_{HA} = K_0 * \sigma'_A = 0.4 * 47.5kPa = 19kPa$$

$$\sigma_{HA} = \sigma'_{HA} + u_A = (19 + 24.5)kPa = 43.5kPa$$

EXERCISE 3 - WORKING SOLUTION

TOT=40.0

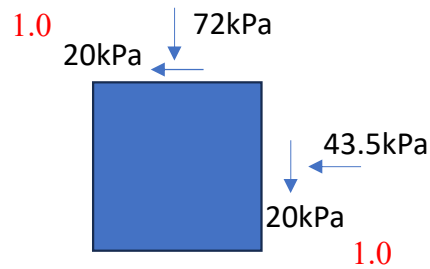
Draw the soil element with the corresponding stresses and the Mohr circle representing such stress state.



$$\sigma_c = \frac{\sigma_x + \sigma_y}{2} = \frac{(43.5 + 72)kPa}{2} = 57.8kPa$$

$$R = \sqrt{\left(\frac{\sigma_y - \sigma_x}{2}\right)^2 + \tau_{xy}^2} = \sqrt{\left(\frac{72 - 43.5}{2}kPa\right)^2 + 0kPa} = 14.25kPa$$

- 11.0 3. In a soil sample around point A, the stress state on a horizontal plane is (σ_V, τ_{xy}) , and on a vertical plane $(\sigma_H, -\tau_{xy})$. Draw the soil element with the corresponding stresses and the Mohr circle representing such stress state. Considering σ_V and σ_H as the total stresses calculated in the previous point and $\tau_{xy} = 20 \text{ kPa}$.



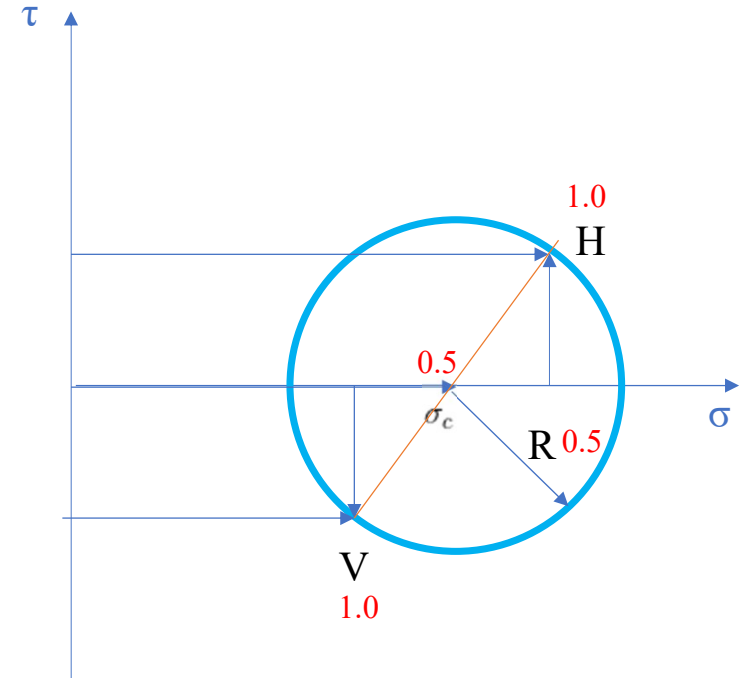
$$V = (43.5, -20)$$

$$H = (72, 20)$$

2.0

$$\sigma_c = \frac{\sigma_x + \sigma_y}{2} = \frac{(43.5 + 72) \text{ kPa}}{2} = 57.8 \text{ kPa} \quad 2.0$$

$$R = \sqrt{\left(\frac{\sigma_y - \sigma_x}{2}\right)^2 + \tau_{xy}^2} = \sqrt{\left(\frac{72 - 43.5}{2} \text{ kPa}\right)^2 + 20^2 \text{ kPa}} = 24.6 \text{ kPa} \quad 2.0$$



- 8 4. Determine the maximum and minimum principal stresses along with the maximum shear stress. Represent them on the Mohr circle

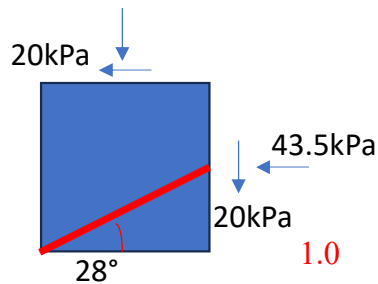
$$\sigma_1 = \sigma_c + R = (57.8 + 24.6)kPa = 82.4kPa \quad 2.0$$

$$\sigma_2 = \sigma_c - R = (57.8 - 24.6)kPa = 33.2kPa \quad 2.0$$

$$\tau_{max} = \tau(\sigma_c) = R = 24.6kPa \quad 2.0$$

5. Finally, determine normal and shear stresses on a plane that makes an angle of 28 degrees with respect to the horizontal face of the soil element. Detect them graphically by using Mohr circle to check your results.

7.5



$$\sigma_n = \frac{\sigma_y + \sigma_x}{2} + \frac{\sigma_y - \sigma_x}{2} \cos 2\vartheta + \tau_{xy} \sin 2\vartheta = \frac{72 + 43.5}{2} + \frac{72 - 43.5}{2} \cos(2 * 28) + (-20) \sin(2 * 28) = 49.14kPa \quad 2.5$$

$$\tau_n = \frac{\sigma_y - \sigma_x}{2} \sin 2\vartheta - \tau_{xy} \cos 2\vartheta = \frac{72 - 43.5}{2} \sin(2 * 28) - (-20) \cos(2 * 28) = 23kPa \quad 2.5$$

