| Mid-term fall Exam for IPSE of CSE, 2015 | | 18th, Nov., Wednesday | From: 18:15 to 19:45 |
|---|---|---|---|
| Subject: Soil Mechanics<br>Department, Year: Civil & Env., 2nd year<br>Instructors: Dr. Konishi, Dr. Nakayama, Dr. Tsuno, Dr. Afshani | | | ● Free<br>● Nothing<br>● Partly permitted<br>• ~~Textbook~~<br>• ~~Reference book~~<br>• Calculator<br>• PowerPoint handouts<br>• Personal notes |
| Student ID: | Student name: | Mark: | |

**Answer all questions (1) to (6).**

**Note that:** The density of water is $\rho_w$ = 1 g/cm$^3$ and the water unit weight is $\gamma_w$ = 9.81 kN/m$^3$ . Specific volume of soil $v = V/V_S$ and void ratio of soil $e = V_V/V_S$, in which $V$ is the volume of soil, $V_V$ is the void volume of soil and $V_S$ is the volume of soil particle.

---

1. A sample of saturated clay weighs 1526 g in its natural state, and 1053 g after drying. a) Determine the natural water content. If the specific gravity of the solid constitute was 2.7. b) What is the void ratio? c) What is the porosity? d) What is the unit weight? (16 points)

Total weight: 1526 g, Dry weight: 1053 g, Water weight: 473 g, G= 2.7

Water content $(\omega) = \frac{W_w}{W_s} \times 100 = \frac{473}{1053} \times 100 = 44\%$ (4 points)

Void ratio $(e) = \frac{V_V}{V_S} = 1.21$ (4 points)

Prosity $(Sr) = \frac{e}{1+e} = 0.54$ (4 points)

Saturated unit weigth $\gamma_{sat} = (1 - n)\gamma_s + n\gamma_w = 1.76$ (4 points)

---

2. Table 1 shows the sieves analysis test. a) Draw grading curve on the Fig. 1 with the given data in the table, b) find the uniformity coefficient Uc and then fine particle content. c) Is the soil well graded or poor graded? (16 points)

**Table 1. Sieves analysis test results**

| Size (mm) | 9.5 | 4.75 | 2.0 | 0.85 | 0.425 | 0.250 | 0.106 | 0.075 | 0.050 | 0.038 | 0.012 | 0.0025 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Percentage finer than a given size P (%) | 100 | 97.1 | 90.1 | 85.3 | 74.7 | 65.0 | 56.7 | 42.5 | 24.1 | 15.6 | 8.8 | 2.3 |

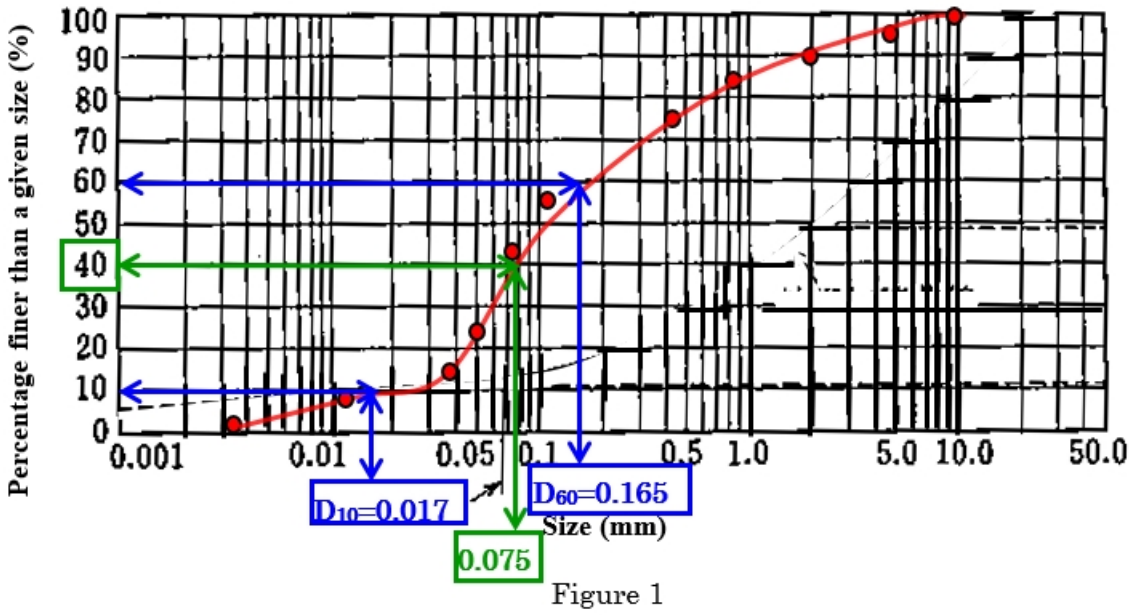



Figure 1

Graph (4 points)

Uniformity coefficient $U_c = D_{60}/D_{10} = 0.165/0.017 = 9.7$ (4 points)

Fine fraction content = 40% (4 points)

For a sand to be classified as well graded, the following criteria must be met:

$U_c \geq 6$ and $1 < C_c < 3$

$U_c = D_{60}/D_{10} = 9.7 > 6$ and $C_c = \frac{D_{30}^2}{D_{60} \times D_{10}} = \frac{0.06^2}{0.165 \times 0.017} = 1.28$ → Well graded (4 points)

3. In a one-directional consolidation test, the total stress was increased to 100 kPa. The sample was initially 20 mm thick and it was drained from both ends. The coefficient of consolidation of soil is $C_v = 2\ \frac{m^2}{year}$ and coefficient of compressibility is $m_v = 5 \times 10^{-4}\ \frac{m^2}{kN}$.
   a) After completion of settlement, how much is the final settlement ($\rho_{final}$)? (8 points)
   b) How much is soil permeability?

a) $S_f = m_v \,.H\,.\Delta\sigma = 5 \times 10^{-4} \times 20 \times 10^{-3} \times 100 = 1\ mm$ (4 points)

b) $C_v = \frac{k}{\gamma_w . m_v} \rightarrow k = 2 \times 9.81 \times 5 \times 10^{-4} = 0.01\ m/year$ (4 points)

4. In a flow water test through a soil sample, two following cases shown in Fig. 2 and 3 are set up. In case a, total discharge passing through the sample is $Q_a$ and in case 2, total discharge passing through the sample is $Q_b$. Test setup and soils in both cases are the same. a) If $Q_a = Q_1 + Q_2$ and $Q_b = Q_3 = Q_4$, what is ratio of $\frac{Q_a}{Q_b}$? b) In case b, how many cm is water head at point c ($h_c$)?

(24 points)

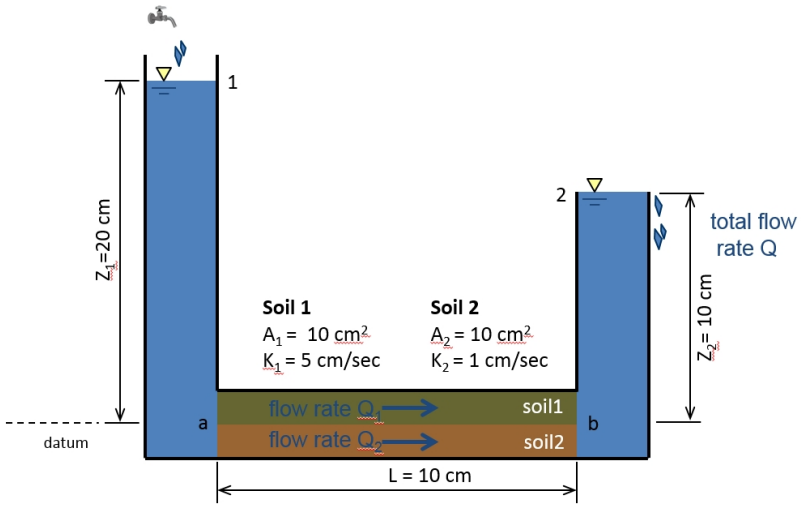



Fig. 2. Flow water test- Case a

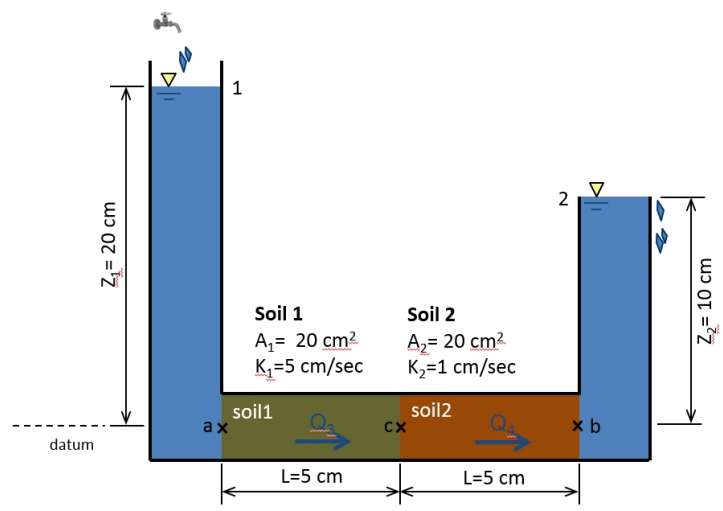



Fig. 3. Flow water test- Case b

$Q_m = k_m i_m A_m$

$i_{ab} = \frac{20 - 10}{10} = 1$

$Q_1 = kiA = 5 \times 1 \times 10 = 50(\frac{cm^3}{sec})$ (4 points)

$Q_2 = kiA = 1 \times 1 \times 10 = 10(\frac{cm^3}{sec})$ (4 points)

$\rightarrow\ Q_{case-a} = Q_1 + Q_2 = 60\ (\frac{cm^3}{sec})$ (2 points)

$Q_3 = Q_4 \rightarrow 5 \times \frac{20 - h_c}{L=5\ cm} \times 20 = 1 \times \frac{h_c - 10}{5} \times 20 \rightarrow h_c = 18.33\ cm$ (6 points)

$Q_3 = kiA = 5 \times \frac{20 - 18.33}{5} \times 20 = 33.4\ (\frac{cm^3}{sec})$ (2 points)

$Q_4 = kiA = 1 \times \frac{18.33 - 10}{5} \times 20 = 33.4\ (\frac{cm^3}{sec})$ (2 points)

$Q_{case-b} = Q_4 = Q_3 = 33.4\ (\frac{cm^3}{sec})$ (2 points)

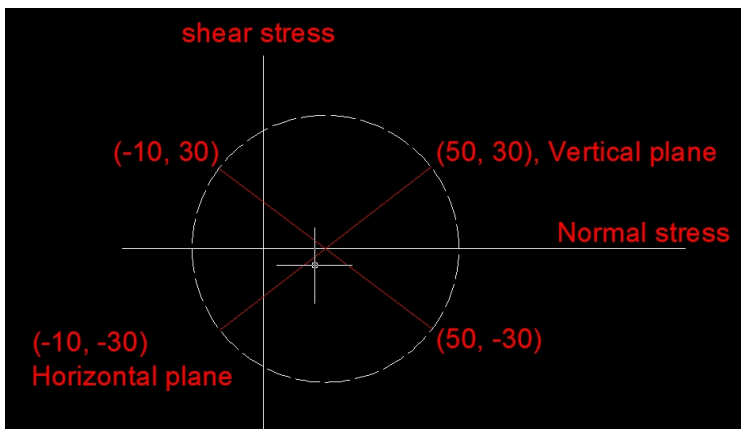
$\frac{Q_{case-a}}{Q_{case-b}} = \frac{60}{33.4} = 1.796$ (2 points)

5. Fig. 4 shows the stresses of a soil element (units in kPa). (Positive angles indicate counterclockwise motion.)

a) Using Mohr circle, calculate the maximum and minimum principal stresses.

b) Using Mohr circle, calculate the angle formed by the plane of the maximum principal stress and the horizontal plane.

c) The angle between plane A and horizontal plane is - 45° clockwise as shown in Fig. 4. Calculate normal and shear stresses acting on the planes of A and B and show it on the corresponding planes of soil element. (24 points)




Graph (4 points)

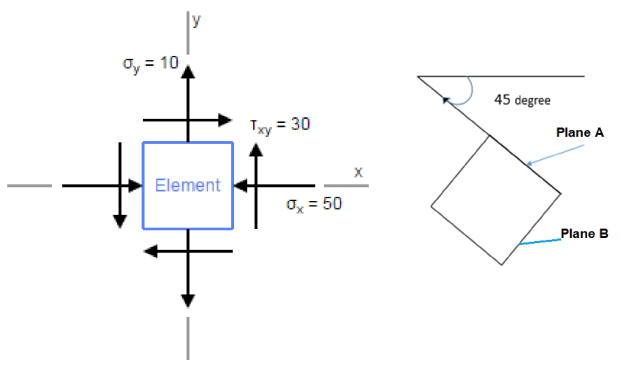



**Fig. 4. Stress of a soil element**

a) Center of Mohr-circle = 50 + (-10) / 2 = 20 → (20, 0) (2 points)

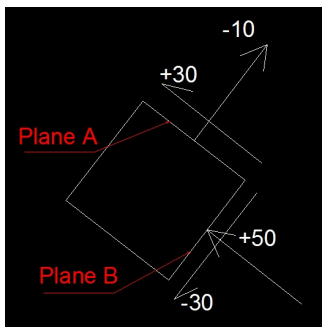
$\text{Radius} = \sqrt{(50-20)^2 + (30-0)^2} = 30\sqrt{2} = 42.42\ m$ (2 points)

$Max\ \text{principal stresses} = 20 + 30\sqrt{2} = 62.42 \rightarrow (62.42, 0)$ (2 points)

$Min\ \text{principal stresses} = 20 - 30\sqrt{2} = -22.42 \rightarrow (-22.42, 0)$ (2 points)

b) $\tan 2\theta = \frac{30}{30} \rightarrow \theta = 22.5°$ (4 points)

c) $Plane\ A \rightarrow (-10, +30)$ $Plane\ B \rightarrow (+50, -30)$ (8 points)




---

6. Compute the total stress, effective stress and pore water pressure at a depth of 15 m below the bottom of a lake with 6 m deep. Unit weight of the soil at the bottom of lake is $\gamma$=17 kN/m$^3$.
(12 points)

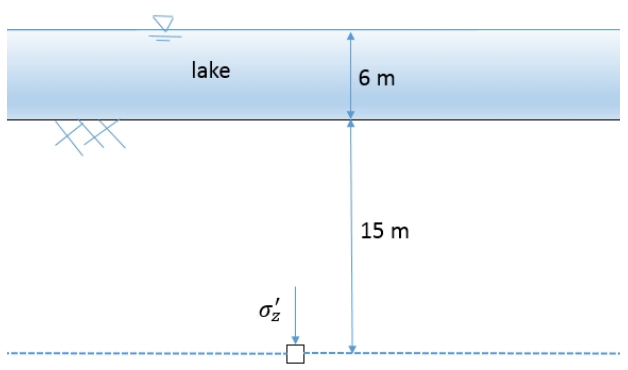



**Fig. 5. Lake**

$\sigma_t = 6 \times 9.81 + 15 \times 17 = 313.86\ kN/m^2$ (4 points)

$u = 21 \times 9.81 = 206\ kN/m^2$ (4 points)

$\sigma' = 313.86 - 206 = 107.86\ kN/m^2$ (4 points)