| Final Exam for IPSE of CSE, 2019-20 | | 31st, Jan., Wed. | Time: 15:00 to 16:30 |
|---|---|---|---|
| Subject: **Soil Mechanics**<br>Department, Year: Civil and Environmental Engineering, 2nd year<br>Instructors: Dr. Konishi, Dr. Kikkawa, Dr. Tsuno, Dr. Afshani | | | ● Free<br>● Nothing<br>● Partly permitted<br>• ~~Textbook~~<br>• ~~Reference book~~<br>• **Calculator** (OK)<br>• ~~PowerPoint handouts~~<br>• **Personal notes- max four A4 pages** (OK) |
| Student ID: | Student name: | Mark: | |

**Questions sheets (answer the questions in questions sheets)**

**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$^3$.

1. A water content tests was done on a soil sample and following results are obtained**: (15 points)**

Mass of the container: 50 g,

Mass of the specimen and container: 95 g,

Mass of the specimen and container after drying at oven: 80 g,

Volume of the solid grains ($V_s$): 10 cm$^3$,

Volume of the specimen ($V_{total}$): 28 cm$^3$,

Obtain the **A)** water content (ω), **B)** density of solid grains ($\rho_s$), and **C)** void ratio (e) and **D)** saturation ratio ($S_r$)?

Mass of water: 95 – 80 = 15 g, Mass of solid: 80 – 50 = 30 g, Mass of specimen: 95 – 50 = 45 g,
Volume of specimen = 25 cm$^3$, Volume of solid grains = 10 cm$^3$, Volume of void = 28 –10 ($V_V$) = 18 cm$^3$,
Volume of water = $m_w/\gamma_w$ = 15/ 1 = 15 cm$^3$ (3 points)

$\text{Water content } (\omega) = \frac{W_w}{W_s} \times 100 = \frac{15}{30} \times 100 = 50\%$ (3 points)

$\text{Desity of solid grains } (\rho_s) = \frac{30}{10} = 3\ (\frac{g}{cm^3})$ (3 points)

$\text{Void ratio (e)} = \frac{V_V}{V_S} = \frac{18}{10} = 1.8\ (\frac{g}{cm^3})$ (3 points)

$\text{Sturation ratio (Sr)} = \frac{V_w}{V_V} = \frac{15}{18} \times 100 = 83\%$ (3 points)

2. Table 1 shows the sieves analysis test. Make the grading curve on the **Fig. 1** with the result. Find the **(9 points)**

(a) uniformity coefficient Uc

(b) Fine fraction content

(c) Is the soil well graded or poor graded?

Table 1

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

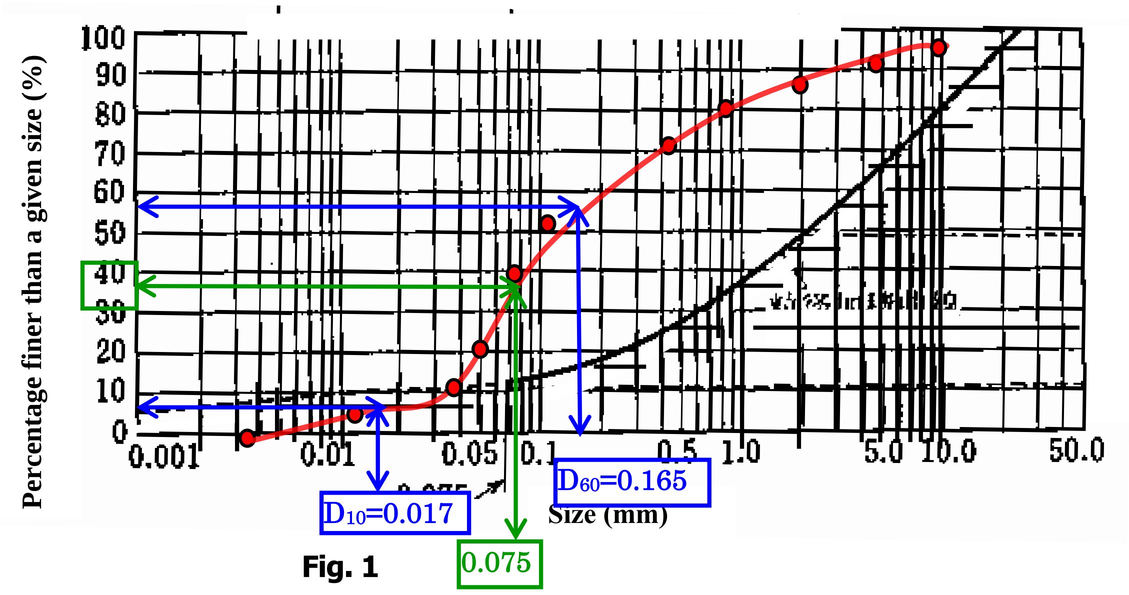



**Fig. 1**

Uniformity coefficient $U_c$ = $D_{60}/D_{10}$ = 0.165/0.017 = 9.7
Fine fraction content = 40%
The soil is poor graded, because $U_c$ < 10.

3. When consolidation of the saturated clay specimen occurred by adding the load ΔP=20 kN/m$^2$, as shown in **Fig. 2**, void ratio e changes from e = 2.060 to $e_1$=1.830. How much is compression index $C_c$. **(5 points)**

$P$=20kN/m$^2$, $P_1$=40kN/m$^2$, $e$=2.060 to $e_1$=1.830.

$e = e_0 - C_c \log \sigma'_z$ ➡ $e_1 = e - C_c \log \sigma'_z$

➡ $C_c \log \sigma'_z = C_c \log_{10}(P_1/P) = e - e_1$

$$C_c = \frac{e - e_1}{\log_{10}(P_1/P)} = \frac{2.060 - 1.830}{\log_{10}(40/20)} = \frac{0.230}{0.301} = \boxed{0.764}$$

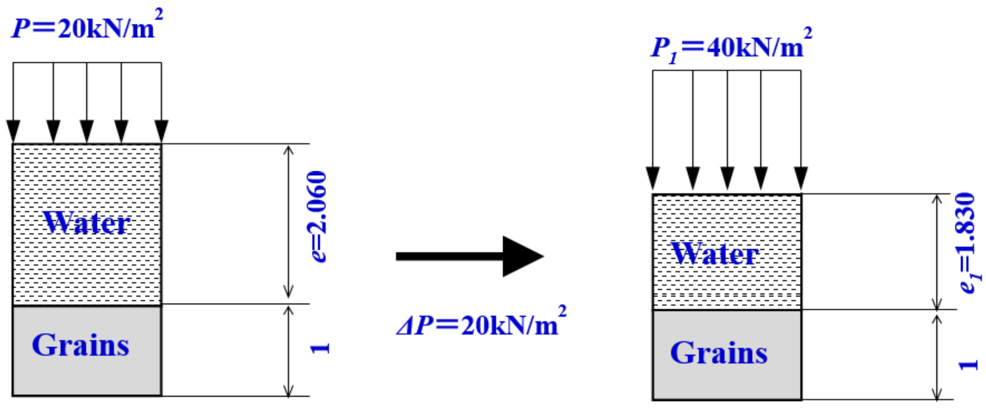



**Fig. 2**

4. **Fig. 3** shows a saturated clay layer with a thickness of 10m. It gets sandwiched between two sand layers. The void ratio of the clay layer is 1.9 now. But the void ratio estimated to be 1.15 due to a load of the upper structure in future. Find the settlement S of the clay layer. **(5 points)**

$S = H\times (e_0 - e)/(1+e_0) = 10.0\times (1.90 - 1.15)/(1+1.90) = 2.59$m

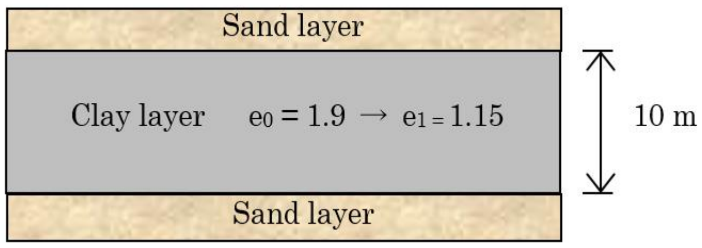



**Fig. 3**

5. In the arrangement shown in **Fig. 4**, pressure head at points A and C are 4 m and 12 m respectively. **(6×2+3=15 points)**
   a) Determine total head, elevation head, and pressure head at the point B (complete the Table-a)?
   b) Determine pore water pressure at point B and C (complete the Table-b)?
   c) If the soil permeability is $k = 0.05\frac{m}{sec}$, and sample section area $A = 1\,m^2$, how much is the total discharge passing through the sample? Hint: $H_{total} = H_{elevation} + H_{pressure}$

| Table-a | | | |
|---|---|---|---|
| Point | $H_{total}$ (m) | $H_{elevation}$ (m) | $H_{pressure}$ (m) |
| A | 0 | - 4 | 4 |
| B | | | |
| C | 3 | -9 | 12 |

| Table-b | | |
|---|---|---|
| Point | $H_{pressure}$ (m) | Uw (kPa) |
| A | 4 | 4 × 9.81 = 39.2 |
| B | | |
| C | 12 | |

(a) Determine the total head, elevation head, and pressure head at points A, B, and C.

| | Ht | He | Hp |
|---|---|---|---|
| A | 0 m | -4 m | 4 m |
| B | $\frac{3m}{5}\times 2 = 1.2m$ | -6 m | 7.2 m |
| C | 3 m | -9 m | 12 m |

(b) Determine the pore water pressures at point A, B, and C.

$U_w = H_p \gamma_w$ , $\gamma_w = 9.8$ kN/m$^3$

| | Hp | Uw |
|---|---|---|
| A | 4 m | 4×9.8 kN/m$^3$ = 39.2 kPa |
| B | 7.2 m | 7.2×9.8 = 70.56 kPa |
| C | 12 m | 12×9.8 = 117.6 kPa |

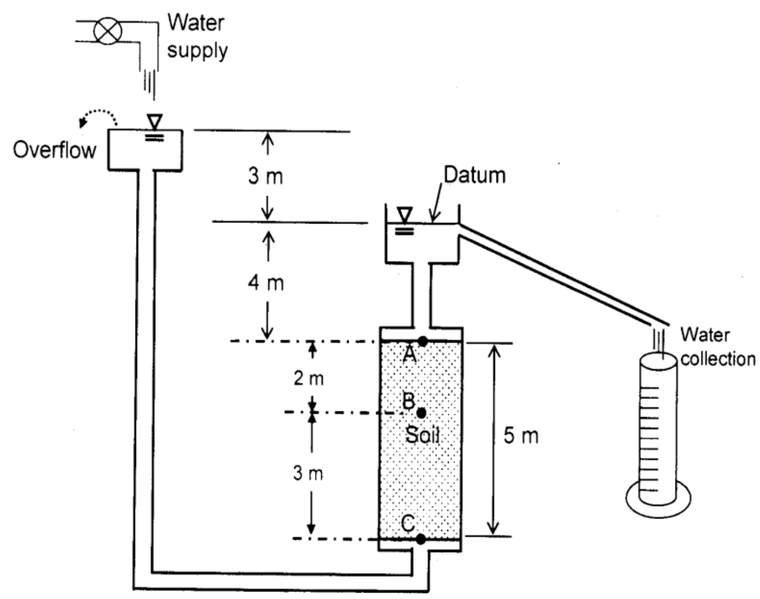



**Fig. 4**: Water flow arrangement through soil sample

6. Draw water flow net in the soil layer in **Fig. 5**. **(5 points)**

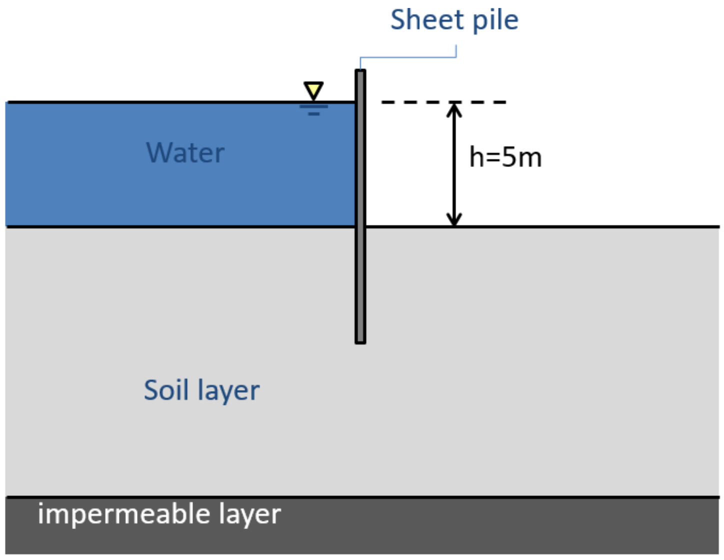
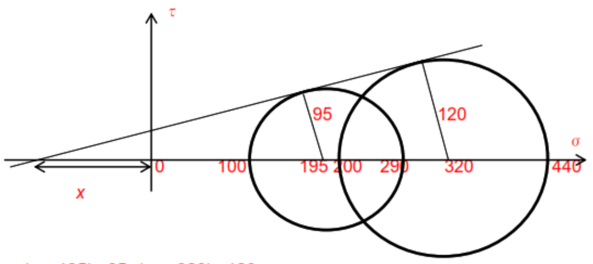



**Fig. 5:** Water flow through soil layer

7. Table 2 shows the results of consolidated-drained triaxial test (CD-test) at the time of specimen failure. Calculate cohesion $c_d$ and internal friction angle $\phi_d$ using Mohr-circle. **(10 point)**

Table 2: results of consolidated-drained triaxial test (CD-test)

| | | |
|---|---|---|
| Cell pressure [kPa] | 100 | 200 |
| Principal stress deviations $\sigma_1 - \sigma_3$ [kPa] | 190 | 240 |




$(x + 195) : 95 = (x + 320) : 120$

$x = 280$

$\sin\phi_d = 95/(280+195) = 0.2$

$\phi_d = 11.5^\circ$

$\cos\phi_d = \sqrt{1 - 0.2^2} = \sqrt{0.96}$

$\tan\phi_d = \frac{0.2}{\sqrt{0.96}} = \frac{0.2}{0.4\sqrt{6}} = \frac{1}{2\sqrt{6}}$

$c = 280 \times \tan\phi_d = 280 \times \frac{1}{2\times\sqrt{3}\times\sqrt{2}} = 57\text{kN/m}^2$

8. The layer of soil is sliding down in the slope with angle of the $\beta$. The section "abcd" is assumes to slips on sliding slip "bd". The thickness of the sliding layer is z, and unit weight of it is $\gamma$. The cohesion and internal friction angle of the soil layer is c and $\varnothing$. **<u>Using the shown parameters ($\gamma$, z, $\beta$, c, $\varnothing$)</u>** (and not actual values), obtain (**16 points**):

a) Weight of the section "abcd", (W).

b) Normal and shear component of the weight on the sliding slip "bd", ($\sigma$ and $\tau$).

c) Shear strength on the sliding slip "bd", (S).

d) Safety factor of this sliding, (SF).

a) $W = \gamma z \cos\beta$

b) $\sigma = W \cdot \cos\beta = \gamma z \cos^2\beta$ , $\tau = W\sin\beta = \gamma z \cos\beta \sin\beta$

c) $S = c + \sigma\tan\varphi = c + \gamma z \cos^2\beta \tan\varphi$

d) $F_s = \frac{2c}{\gamma z \sin 2\beta} + \frac{\tan\varphi}{\tan\beta}$

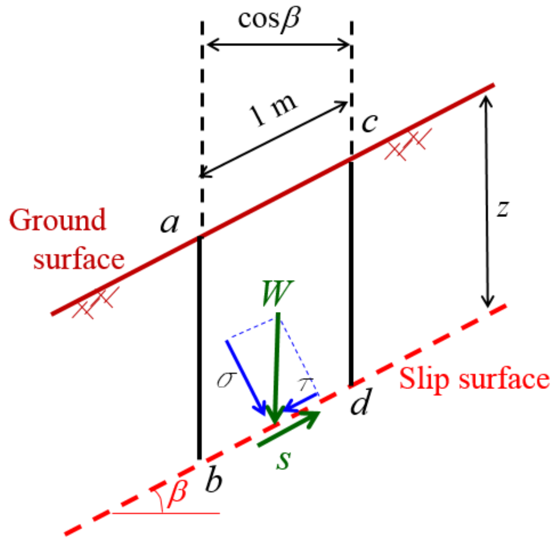



Fig. 5: Sliding soil layer

9. **Fig. 6** shows a pile foundation with diameter of 0.3 m driven into sandy soil by 13 m. The sand has cohesion C = 0 kPa, internal friction angle Φ = 32° and unit weight γ = 17.9 kN/m³. Water level is at ground surface and Nspt = 15. Calculate bearing capacity of this foundation using the modified Terzaghi's bearing capacity equation? **(20 points)**

Answer for the question of piled foundation (1)

$Q_f = q_t A_t + f_s A_s$

here, $q_t$ is equal to $q_f$ for shallow foundation and so

$q_t = q_f = \alpha c N_c + \gamma_{t1} D N_q + \beta \gamma_{t2} B N_\gamma$

here, unit weights of each layer should be

$\gamma_{t1} = \gamma_{t2} = \gamma_{sat} - \gamma_w = 17.9 - 9.81 = 8.09\ (kN/m^3)$

The pile is cylindrical shape and so shape factors are

$\alpha = 1.3\ ,\ \beta = 0.3$

and the internal friction, $\phi$, is 32° and so the bearing factors are

$N_c = 20.9\ ,\ N_q = 14.1\ ,\ N_\gamma = 10.6$

Therefore, $q_t$ should be

$q_t = 1.3 \times 0 \times 20.9 + 8.09 \times 13 \times 14.1 + 0.3 \times 8.09 \times 0.3 \times 10.6$

$= 0 + 1482.897 + 7.71786$

$= 1491\ (kN/m^2)$

The cross-sectional area, $A_t$, of the pile is

$A_t = \pi B^2/4 = 3.14 \times 0.3^2/4 = 0.07065$

The shear stress mobilized between pile and ground, $f_s$, is

$f_s = 2\bar{N}_s = 2 \times 15 = 30$

The surface area of the pile, $A_s$, is

$A_s = \pi B D = 3.14 \times 0.3 \times 13 = 12.246$

Therefore, $Q_f$, is

$Q_f = 1491 \times 0.07065 + 30 \times 12.246$

$= 105.33915 + 367.38$

$= 473\ (kN)$

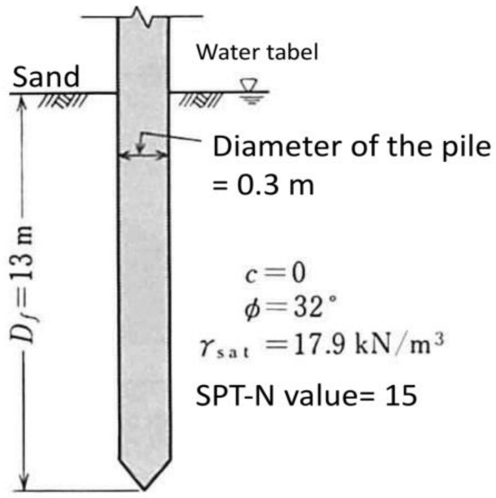



**Fig. 6**: Pile foundation

**Shape coefficients**

| Shape of foundation / Shape coefficients | Continuous footing | Circular foundation | Square | Rectangular foundation |
|---|---|---|---|---|
| $\alpha$ | 1.0 | 1.3 | 1.3 | $1.0+0.3\frac{B}{L}$ |
| $\beta$ | 0.5 | 0.3 | 0.4 | $0.5-0.1\frac{B}{L}$ |

$B$ : Width , $L$ : Length

**Bearing capacity factors**

| $\phi$ | $N_c$ | $N_\gamma$ | $N_q$ |
|---|---|---|---|
| 0° | 5.3 | 0 | 1.0 |
| 5° | 5.3 | 0 | 1.4 |
| 10° | 5.3 | 0 | 1.9 |
| 15° | 6.5 | 1.2 | 2.7 |
| 20° | 7.9 | 2.0 | 3.9 |
| 25° | 9.9 | 3.3 | 5.6 |
| 28° | 11.4 | 4.4 | 7.1 |
| 32° | 20.9 | 10.6 | 14.1 |
| 36° | 42.2 | 30.5 | 31.6 |

**End of Questions.**