2021 Soil Mechanics I and Exercises Final Exam

January 25, 2022 (Tue.) 13:15–15:15 @Kyotsu 3 Lecture Room

Attention:

- The exam consists of four questions.
- Use of non-programmable calculators are permitted. However, programmable calculators and calculator functions of mobile phones are prohibited.
- Wherever necessary, specify the units in your answers.

[In-class participants]

- Four answer sheets are provided. Write down your name and ID number on every answer sheet. Use one answer sheet per question and answer them in sequence, starting from [Question 1]. If the front page of an answer sheet is insufficient to complete your answer, use the back page of the same answer sheet after clearly indicating your intent.

[Online participants]

- You must keep your camera ON throughout Zoom connection during the exam.
- You must finish writing at 15:15 and complete submitting the answer sheets via PandA by 15:30. Your submission will not be accepted after the deadline regardless of any reason. Give yourself ample time to get through PandA for submitting the answer sheets.
- You may answer a major question over multiple answer sheets but do not answer multiple major questions on the same answer sheet. You must indicate your name and student ID on all the sheets.
- Any suspicious behavior through camera will result in failed credit of the course and serious penalties.

[Question 1]

(1) Provide concise explanations of the following terms. Graphics and equations may be used if necessary.

1) Liquidity index 2) Degree of saturation 3) Soil particle density 4) Maximum dry density

(2) Answer the following questions regarding soil compaction.

1) Compaction energy, E_c, is defined as:

$$E_c = \frac{W_R \cdot H \cdot N_L \cdot N_B}{V}$$

E_c: Compaction energy (kJ/m^3), W_R: Weight of rammer (hammer) (kN), N_L: Number of layers,
V: Volume of mold (m^3), H: Drop height of rammer (hammer) (m), N_B: Number of blows per layer

When the compaction tests are performed by the following three methods using a single well-graded soil sample, draw the positional relationships of the compaction curves generally obtained by each of the methods A to C. In addition, draw the zero-air-void curve in the same figure. Showing the outline and positional relationship of each curve is enough.

Method	Mass of rammer (kg)	Volume of mold (cm^3)	Number of layers	Number of blows per layer
A	2.5	1000	3	25
B	2.5	2200	3	55
C	4.5	1000	5	25

2) Soil with a maximum dry density of ρ_{dmax} (Mg/m^3) was adjusted to its optimum water content w_{opt} (%), and then compacted with a compaction degree D_r (%) to build an embankment. Express the dry density ρ_d and the wet density ρ_t of the embankment using mathematical symbols.

3) Define the effective stress, σ_1', at the bottom of the sand layer using mathematical symbols for the ground conditions given in Figure 1. In addition, find the effective stress, σ_2', at the bottom of the sand layer when the groundwater level rises to the ground surface due to rainfall. Then, derive the magnitude relationship of the effective stress σ_1' and σ_2'. Here, the wet unit weight γ_t (kN/m^3) and the saturated unit weight γ_{sat} (kN/m^3) of each layer are shown in the figure, and the unit weight of water is γ_w (kN/m^3). Assume that the structure of the ground does not change due to fluctuations in the groundwater level.

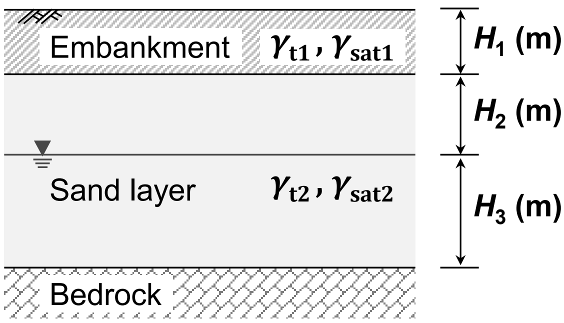

Figure 1

[Question 2]

The constant head permeability test of a sand column as shown in the Figure 2 was carried out. The measurement was performed 3 times for 10 seconds, and the average discharge was 2.30 [cm^3]. Answer the following questions regarding the water flow in a saturated sand column. The cross-sectional area of the sand column is 1.00×10 [cm^2], the specific gravity of soil particle, G_s, is 2.70, the void ratio, e, is 0.60, the density of the fluid (water), ρ_w, is 1.00×10^3 [kg/m^3], respectively. Assume that the sand column is saturated, the water flow is governed by Darcy's law, and the steady-state condition is established for all cases below. Friction loss and shape loss in pipes can be ignored, the reference plane is shown in the figure, and the gravitational acceleration is 9.81 [m/s^2].

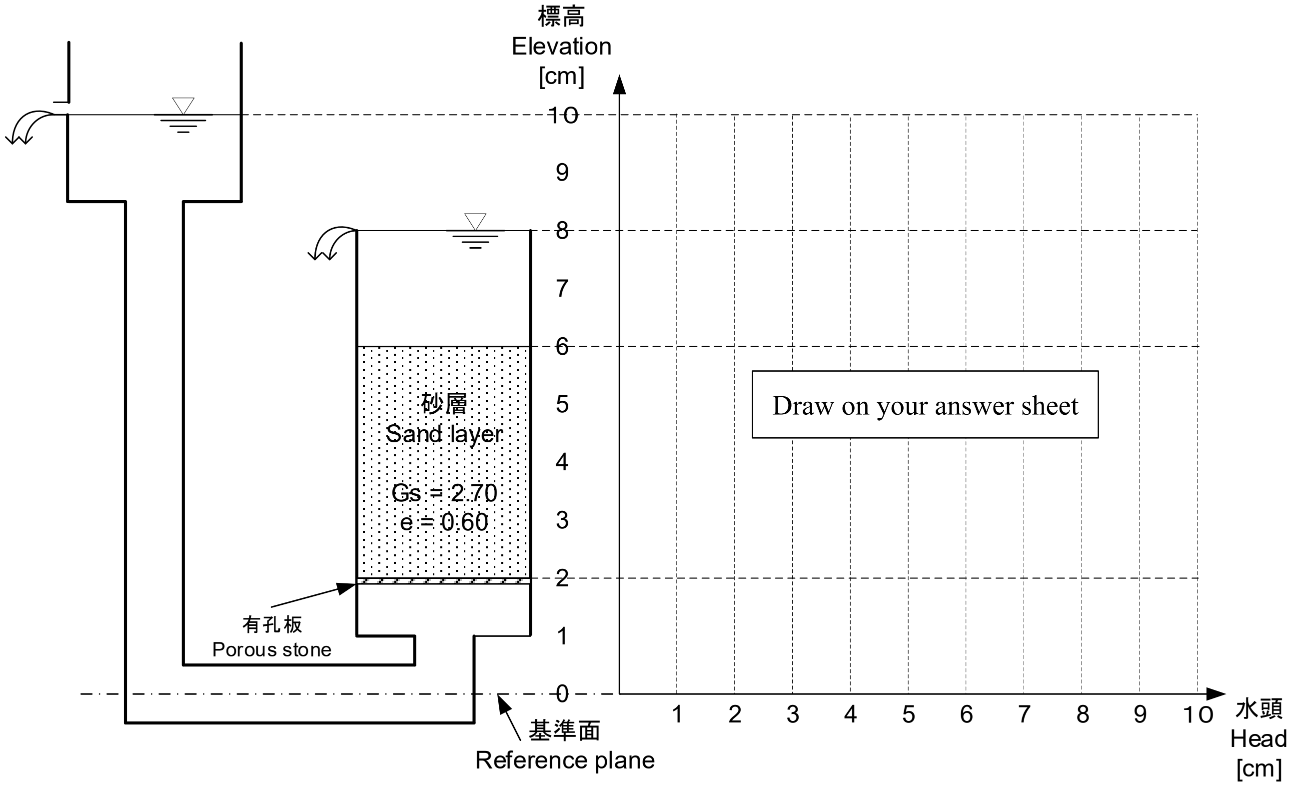

Figure 2

(1) Draw the potential head (elevation head) above the reference plane, the pressure head and the hydraulic head (total head or piezometric head) of the sand layer, respectively. In addition, write the values of each head at both top and bottom surfaces of the sand layer.

(2) Determine both hydraulic gradient and hydraulic conductivity (coefficient of permeability) of the sand layer.

(3) Determine the unit weight of the saturated sand and the vertical effective stress at the bottom surface of the sand layer.

(4) The drainage port of the upstream tank located 10 cm above the reference plane is closed and the water level is gradually raised. Determine the water level above the reference plane when the sand layer becomes quicksand.

[Question 3]

An incremental loading one-dimensional consolidation test is conducted on the saturated clay sample obtained at the center (depth of 10m from the ground surface) of a half-space ground shown in Figure 3. The test is also known as "oedometer test" with a specimen of 6 cm in diameter and 2 cm thick. The loading starts from 10 kN/m^2 and is then carried out on a 24 hour cycle with the incremental ratio $\Delta p_{n+1}/p_n = 1$ (Δp_{n+1} : stress increment at the n+1 loading step, p_n : stress at the n loading step). Answer the following questions.

(1) Assuming that the clay is normally consolidated, find the consolidation yield stress p_c.

(2) When the consolidation is completed with the stress at the 5th loading step p_5 = 160 kN/m^2 (10 → 20 → 40 → 80 → 160), the height of the specimen is found to be H_5 = 1.821 cm. Then, after the next (6th) loading step of Δp_6 = 160 kN/m^2, the settlement ΔH_6 = 0.161 cm is observed for the 6th loading p_6 = 320 kN/m^2. Calculate the average height of the specimen $\overline{H_6}$ (the arithmetic mean of the heights before and after the 6th loading step) by using H_5 and H_6 and find the volumetric (vertical) strain, ε_v generated by the 6th loading step of Δp_6 = 160 kN/m^2 with the reference of the average height of the specimen $\overline{H_6}$.

(3) When the void ratio, e_5 = 2.50 is obtained at the end of consolidation after the 5th stage loading stress of p_5 = 160 kN/m^2, find the void ratio, e_6 at the end of consolidation after the 6th stage loading stress of p_6 = 320 kN/m^2.

(4) Find the coefficient of volume change, m_v for the 6th stage loading stress of p_6 = 320 kN/m^2 (Δp_6 = 160 kN/m^2).

(5) Assuming the assumption noted in (1) is held, calculated the compression index, Cc.

(6) From the state shown in the figure, the groundwater level was lowered by 2 m to the upper surface of the clay layer. Calculate the final settlement that occurs in the clay layer due to groundwater lowering. The consolidation of the clay layer shall occur one-dimensionally, and the representative stress of the clay layer shall be the one at the central depth (sampling point). (Hint: It is necessary to find the void ratio e_0 in the center of the clay in the initial state. From question (1), the clay layer is assumed to be normally consolidated, and Cc is found in (5). By using e_5 at p_5 = 160 kN/m^2 indicated in (3), the initial void ratio e_0 can be obtained.)

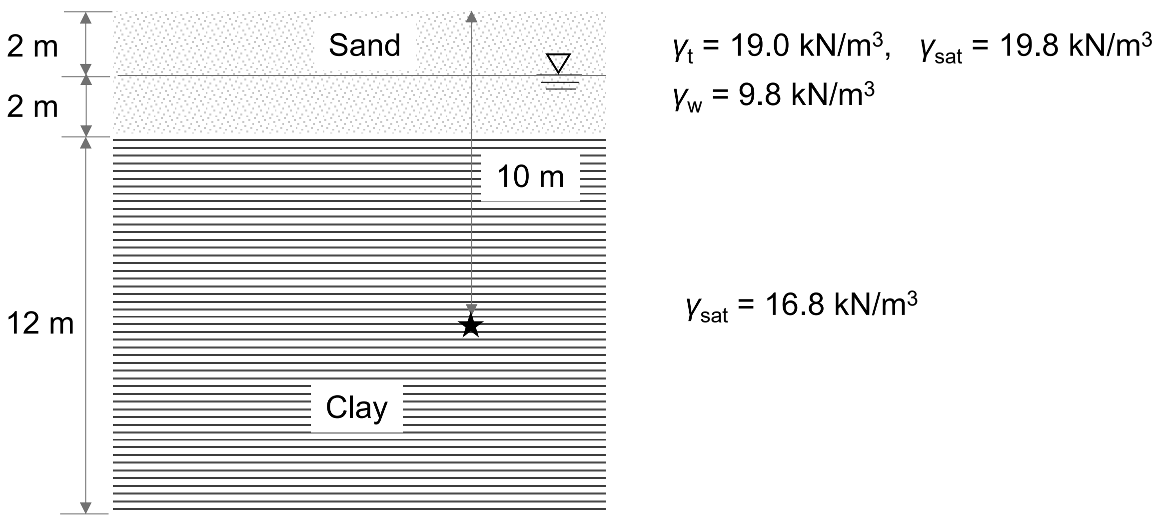

Figure 3

[Question 4]

(1) Answer the appropriate words in the blanks provided below.

In the direct shear test tests, Coulomb's failure criterion can be obtained from the relationship between the various normal stresses and the [①] stress at failure under those normal stresses.
The uniaxial compression test is mainly used for clays to obtain the unconfined compressive strength of the clay. The ratio of the compressive strength of a naturally deposited sample to that of a remolded sample is called the [②]. It is known that the higher the [③] index of the clay, the greater the [②].
The triaxial compression test is carried out in the [④] stress state where the [①] stress is zero. The stress states at failure in tests carried out under various confining pressures are illustrated by Mohr's circles, and Mohr's failure criterion is obtained from the [⑤] of these circles. The Mohr-Coulomb failure criterion is [⑥] of Mohr's failure criterion.
The change in volume due to shear is called [⑦]. In general, dense sands and overconsolidated clays [⑧] in volume due to shear and produce [⑨] pore pressures in consolidation undrained triaxial compression tests.

(2) Stress state at a certain point in soil is as shown in Figure 4.

1) Find the values of the maximum and minimum principal stress, and their directions of the principal plane.
2) Find the stress acting on the A-A plane.

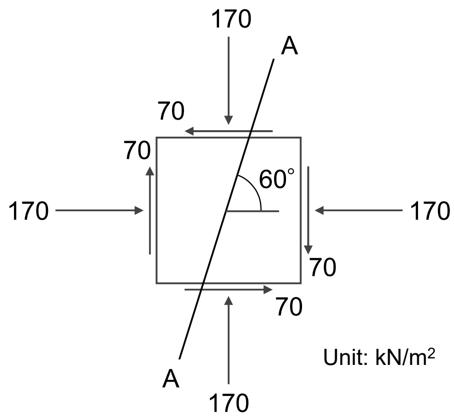

Figure 4

(3) Consolidated-undrained ($\overline{CU}$) triaxial compression test of a normally consolidated clay in saturated condition under the confining pressure σ_3 = 300 kN/m^2 was undertaken. Answer the following questions if the axial stress σ_1 and pore water pressure u_w measured at failure were σ_1 = 500 kN/m^2 and u_w = 180 kN/m^2.

1) Draw the Mohr's stress circles for total stress and effective stress at failure.
2) By assuming that the Mohr-Coulomb failure criterion is satisfied, determine the internal friction angle ϕ' based on the effective stress of this clay. Note that cohesion c' = 0 kN/m^2 can be regarded for normally consolidated clays.
3) Find the orientation of the failure plane.
4) If consolidated-drained (CD) triaxial compression test was carried out using the same clay, find the value of the axial stress σ_1 at failure.