2018 Soil Mechanics II and Exercises Final Exam

2018/8/1 (Wed) 10:00-12:00 Kyotsu 2 Lecture room

Attention:

- This exam consists of five questions for which you are provided with five answer sheets. 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 any answer sheet is insufficient to complete your answer, use the back page of the same answer sheet after clearly indicating your intent.
- Scores of all questions are weighted evenly.
- In addition to personal writing instruments, non-programmable calculators are permitted. However, programmable calculators and calculator functions of mobile phones are prohibited. Any attempts at cheating on the exam will result in failed credit of the course and serious penalties.
- Wherever necessary, specify the units in your answers.

[Question 1]

The ground shown in Figure 1 consists of a 10 m-thick layer of soft clay deposited over an impermeable bedrock. Samples were taken from this clay layer and tested at the laboratory. For a certain set of load conditions, the following properties that represent this ground were obtained: coefficient of volumetric change $m_v = 3.00 \times 10^{-3}$ m^2/kN, and coefficient of permeability $k = 1.55 \times 10^{-4}$ m/day. To answer the following questions, assume that load conditions at the field are similar to the laboratory ones and also that the clay layer is completely saturated and deformed only by one-dimensional consolidation.

The groundwater table coincides with the ground surface, and the unit weight of water is 9.8 kN/m^3.

(1) Calculate the vertical coefficient of consolidation c_v (m^2/day) of the clayey soil.

(2) Calculate the time (days) for this soil to reach 90% degree of consolidation ($T_v = 0.848$) due to vertical loading.

(3) Calculate the settlement (consolidation at the time described in point (2)) when the soil is subject to the surcharge load $\Delta p = 60$ kN/m^2.

(4) The sand drain method was adopted to shorten the time required for consolidation. As shown in Figure 2, a hexagonal pattern was chosen, with sand pile diameter $d_w = 0.35$ m and distance between sand pile cores $d = 2.0$ m. Calculate the equivalent sand drain diameter d_e.

(5) Using Figure 3, find the time required for this clay layer to reach 90% consolidation. For simplicity, assume the mechanical properties to be the same in both the vertical and horizontal directions ($c_v = c_h$).

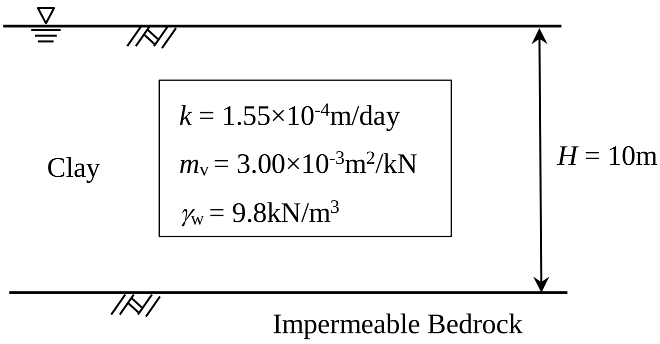

Figure 1

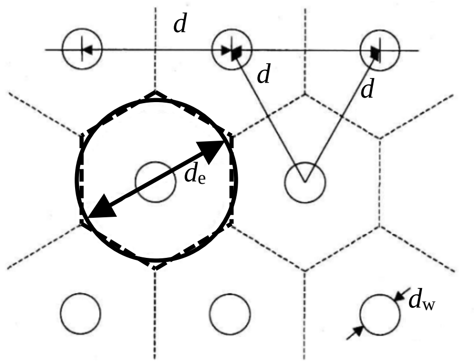

Figure 2

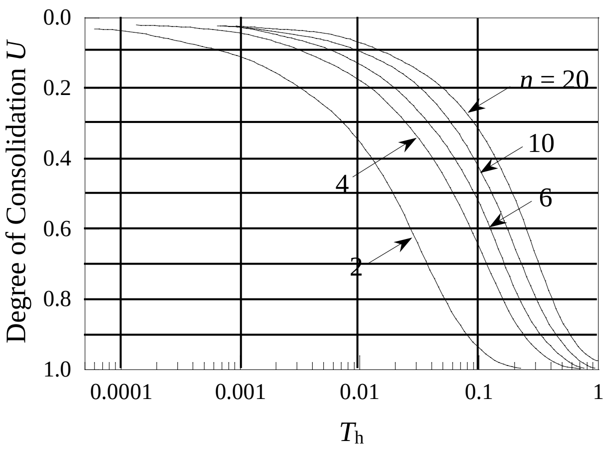

Figure 3

[Question 2]

Answer the following questions regarding shear strength of soils.

(1) A consolidated undrained triaxial compression test was conducted on a saturated, normally consolidated clay. The confining pressure, used until the end of consolidation and kept constant during shearing, was 100 kN/m^2. The deviator stress measured at failure was 72 kN/m^2. The pore water pressure increment obtained from the beginning of shearing was 64 kN/m^2. Answer the following questions, assuming that the cohesion c' is zero.

(a) Draw Mohr's circles for total stress and effective stress at failure along with the values of the maximum and minimum principal stresses.

(b) Find the internal friction angle ϕ' of the clay

(c) Draw the total stress path and the expected effective stress path in $p - q$ and $p' - q$ planes, respectively. Include the values of p', p, q at the beginning of shearing and at failure in the figure. Herein, p is the mean total stress, p' is the mean effective stress, and q is the deviator stress.

(d) Find the value of Skempton's pore pressure coefficient at failure A_f.

(e) Find the slope of the critical state line M of the clay.

(2) The three types of triaxial compression tests for soils generally depend on the consolidation process and the drainage conditions during the shearing process.

(a) Apart from consolidated-undrained triaxial compression test, list the other two test methods.

(b) For each of the test methods answered in (a), schematically draw Mohr's circles of the total stress and effective stress at failure for experiments conducted with two different confining pressures.

(c) Describe the characteristics of cohesion and internal friction angle obtained for each test answered in (a).

[Question 3]

Consider the retaining wall of height H shown in Figure 4. Let the frictional angle, the cohesion, and the unit weight of the backfill soil be ϕ, c, and γ, respectively. Answer the following questions.

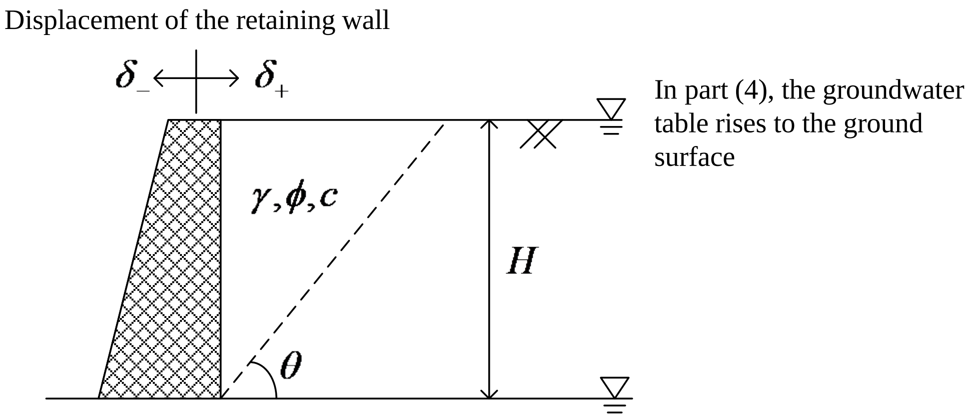

Figure 4

(1) Based on Coulomb's earth pressure theory, determine the earth pressure acting on the retaining wall when it moves leftward (δ_-) as indicated in the figure. Assume that the cohesion c of the backfill soil is zero and that the surface of the retaining wall is smooth; hence, there is no friction between the retaining wall and the backfill soil. Draw the force diagram composing of the forces that act on the soil wedge shown in the figure. Use appropriate symbols for the forces that appear in the force diagram and clearly explain each one of those forces.

(2) Under the concept of Coulomb's earth pressure described in (1), briefly explain the procedure by which the earth pressure acting on the retaining wall is determined when it displaces in the direction to the left (δ_-) of the figure.

(3) While reassessing the conditions of the backfill soil, it was found that the cohesion was not zero. Under the concept of Rankine's earth pressure, obtain the earth pressure that acts on the retaining wall when it moves in the direction to the left (δ_-) of the figure and draw the earth pressure distribution diagram exerting on the retaining wall of height H. It is assumed that the friction between the retaining wall and the backfill soil is zero and that the groundwater table lies sufficiently deep below the retaining wall.

(4) Focusing on the difference in the earth pressure and water pressure, explain the difference in the magnitudes of the resultant active force (a sum of the forces due to earth pressure and the water pressure) when the groundwater table behind the retaining wall rises up to the ground surface and lies at the bottom of the retaining wall. Herein, the unit weight of water is γ_w.

[Question 4]

Answer the following questions about bearing capacity of soils.

(1) Draw the failure patterns for the cases of local shear failure and general shear failure for a strip foundation. Clearly indicate which of the plotted regions are under passive or active condition. Assume that the water table is located deep enough and does not affect these patterns.

(2) Terzaghi developed the following equation to calculate the bearing capacity of soils, q_u. The constants k_1, k_2, and k_3 are different for strip, square, and circular foundations, but the expressions (*I*), (*II*), and (*III*) are similar in all three cases.

$$q_u = k_1 \boxed{\quad (I) \quad} + k_2 \boxed{\quad (II) \quad} + k_3 \boxed{\quad (III) \quad}$$

Type of Foundation	Constant for contribution of cohesion, k_1	Constant for contribution of surcharge, k_2	Constant for contribution of unit weight of soil, k_3
Strip	1.0	1.0	1.0
Square	1.3	1.0	0.8
Circular	1.3	1.0	0.6

Complete down Terzaghi's equation by indicating the expressions that should replace the terms (*I*), (*II*), and (*III*). Assume that the foundation has a width *B* and a depth *D*, and that the characteristics of the soil are: unit weight γ, cohesion *c*, and angle of friction ϕ.

(3) The base of a circular footing of diameter $B = 2$ m rests at a depth $D = 1.7$ m in a soil with parameters $\gamma = 19$ kN/m^3, $\gamma_{sat} = 21$ kN/m^3, $c = 26$ kPa, $\phi = 22.5°$. Assume that the water table is located deep enough and does not affect the bearing capacity of the soil. Determine the ultimate bearing capacity of the soil under these conditions.

For your analysis you can use the following equations for the bearing capacity factors, where ϕ is in radians:

$$N_q = \frac{1}{1-\sin\phi} \exp\left[\left(\frac{3\pi}{2} - \phi\right)\tan\phi\right]$$

$$N_c = \left(N_q - 1\right)\cot\phi$$

$$N_\gamma = \left(N_q - 1\right)\tan(1.4\phi)$$

(4) If the water table rises and stays at the base of the foundation, calculate the new bearing capacity of this soil. Use a unit weight of water: $\gamma_w = 9.8$ kN/m^3.

(5) If we replace the circular footing with a square one of sides $B = 2$ m, calculate the new bearing capacity of the soil under the same conditions described in (4). Comment on the difference.

【Question 5】

Answer the following questions.

(1) According to the Fellenius method of stability analysis, a sliding soil mass is divided into n slices as show in Figure 5. For any i^{th} slice counted from the right of a circular arc with radius r and center at point O, let the width be b_i, the height be h_i, the length of the base be l_i, the angle of inclination be α_i, the angle of internal friction be ϕ_i and the cohesion be c_i. Also, the weight of slide is W_i, the forces acting on the right and left sides of the slice are E_i (the resultant of the horizontal force H_i and the vertical force V_i) and E_{i+1} (the resultant of the horizontal force H_{i+1} and the vertical force V_{i+1}). Along the base of slide, P_i denotes the normal force and S_i denotes the shearing force.

(a) Show the equilibrium equation of force in the direction perpendicular to the base of the i^{th} slice.

(b) In the Fellenius method, the resultant forces acting on the left and right sides of the slice are assumed to be parallel to the sliding plane; thus $(V_{i+1} - V_i)/(H_{i+1} - H_i) = \sin\alpha_i / \cos\alpha_i$. Rewrite the equation obtained in (a) by using this expression.

(c) In regard to the factor of safety F, show the equation by which the failure criterion (sliding condition) of the i^{th} slice is described .

(d) Show the equation of equilibrium for which the balance of moments on the whole sliding soil mass about point O is taken.

(e) Use (b), (c) and (d) to determine the factor of safety F for the soil mass against sliding along the circular slip surface.

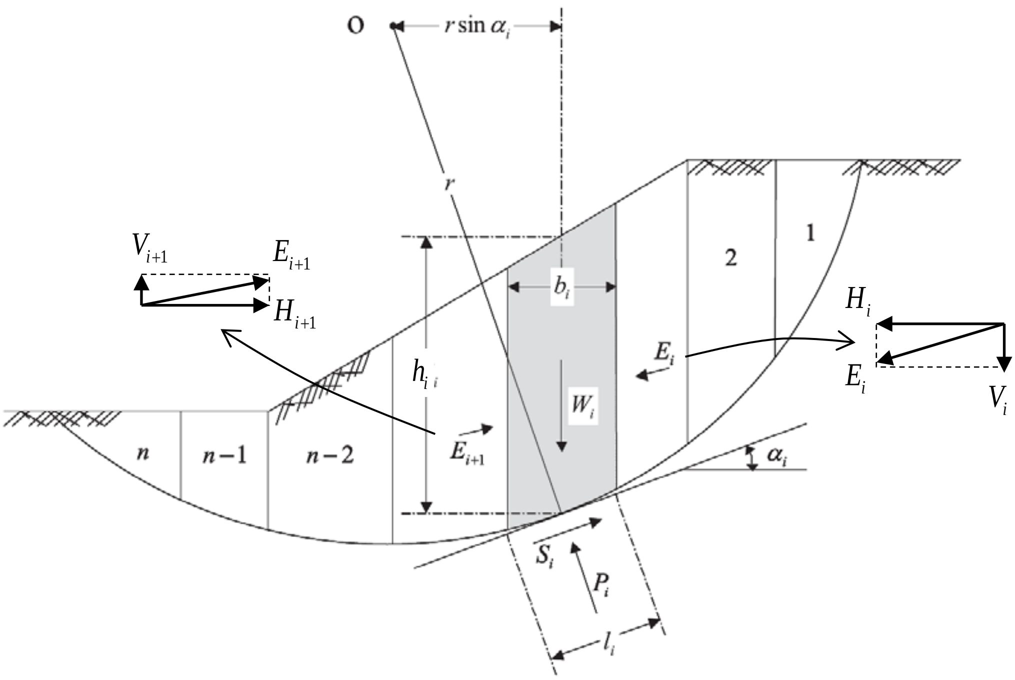

Figure 5 Sliding soil mass

(2) The onset mechanisms of liquefaction can be explained as follows.

A loosely deposited sandy ground such as reclaimed land lying deeper than the groundwater level is under （ ① ）condition. When this ground is subjected to （ ② ）due to an earthquake,（ ③ ）of the sandy ground with respect to the duration time of the earthquake ground motions is small, so the soil element in the ground becomes almost （ ④ ） condition. At that time when the mean effective stress decreased by the negative （ ⑤ ） is nearly zero, liquefaction eventually occurs.

(a) Fill in the blanks ① to ⑤ with the appropriate expressions.

(b) Choose any three of ① ~ ⑤ and present the underlying principle of liquefaction countermeasure associated with each of which (also show the number ① ~ ⑤).