2022 Soil Mechanics II and Exercises Final Exam

July 27, 2022 (Wed.) 10:00–12:00   Kyotsu 4 Lecture room

Attention:

- **The 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 an answer sheet is insufficient to complete your answer, use the back page of the same answer sheet after clearly indicating your intent.**
- **In addition to personal writing instruments, non-programmable calculators are permitted. However, programmable calculators and calculator functions of mobile phones are prohibited. Any attempt 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] Answer all the following questions.

(1) The ground shown in Fig. 1 consists of a 10 m-thick layer of soft clay deposited over an impermeable bedrock. Coefficient of volume compressibility (m_v) and coefficient of consolidation (c_v) of this clay layer are 3.0×10^{-4} m^2/kN and 2.0×10^{-2} m^2/day, respectively. Consider the construction of a structure on the ground surface with a rectangular spread foundation of 20 m long and 10 m wide. The rectangular foundation will exert a uniform pressure q = 100 kN/m^2 on the ground surface. Assume that the representative value of the stress in the ground can be taken at the center of the clay layer (i.e., at a depth of 5 m). Also, the stress increment in the clay layer due to the construction of the structure can be determined by the elasticity theory, using the stress increment in the ground below the center of the structure.

(1-1) Find the stress increment at the depth of 5 m below the center of the structure after its construction. Fig. 2 may be used.

(1-2) Find the consolidation settlement of the structure.

(1-3) Find the time required for the clay layer to reach 90% degree of consolidation (time factor T_v = 0.848).

(1-4) The sand drain method was adopted to shorten the time required for consolidation. As shown in Fig. 3, a square-shaped pattern was chosen for a sand pile diameter of d_w = 0.4 m with an interval between sand piles of d = 2.13 m. Calculate the effective diameter d_e of a circle whose cross-sectional area equals the area of the square in which water is collected.

(1-5) Find the time required for the clay layer with sand drains to reach an average of 90% degree of consolidation from the diagram representing the theoretical solution of Barron (Fig. 4). It is assumed that coefficients of consolidation for vertical and horizontal drainages are same ($c_v = c_h$).

(2) Fig. 5 shows schematically the Boussinesq's and Strohschneider's theories for determining the vertical stress increment in the ground when a concentrated load Q acts on the ground surface. In Boussinesq's theory, which assumes that the ground is a semi-infinite elastic body, the stresses near the ground surface spread out infinitely along the lateral directions. In reality, however, as in Strohschneider's theory, the stress distribution in the ground is limited within a certain closed region, and no stresses occur outside of it. Explain why Boussinesq's theory differs from the actual stress distribution.

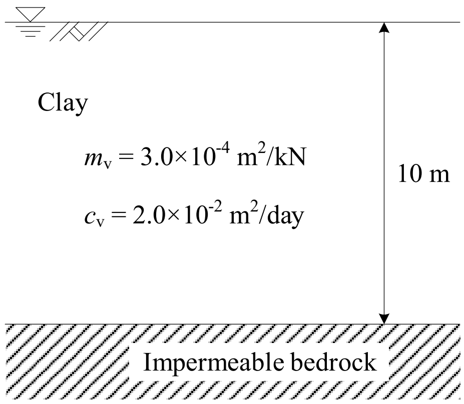

Fig. 1

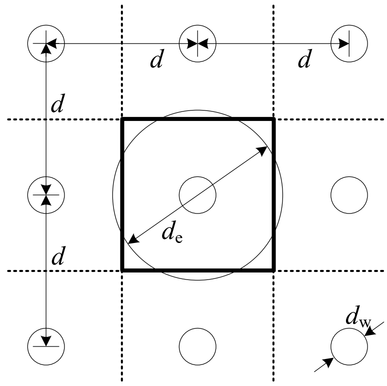

Fig. 3

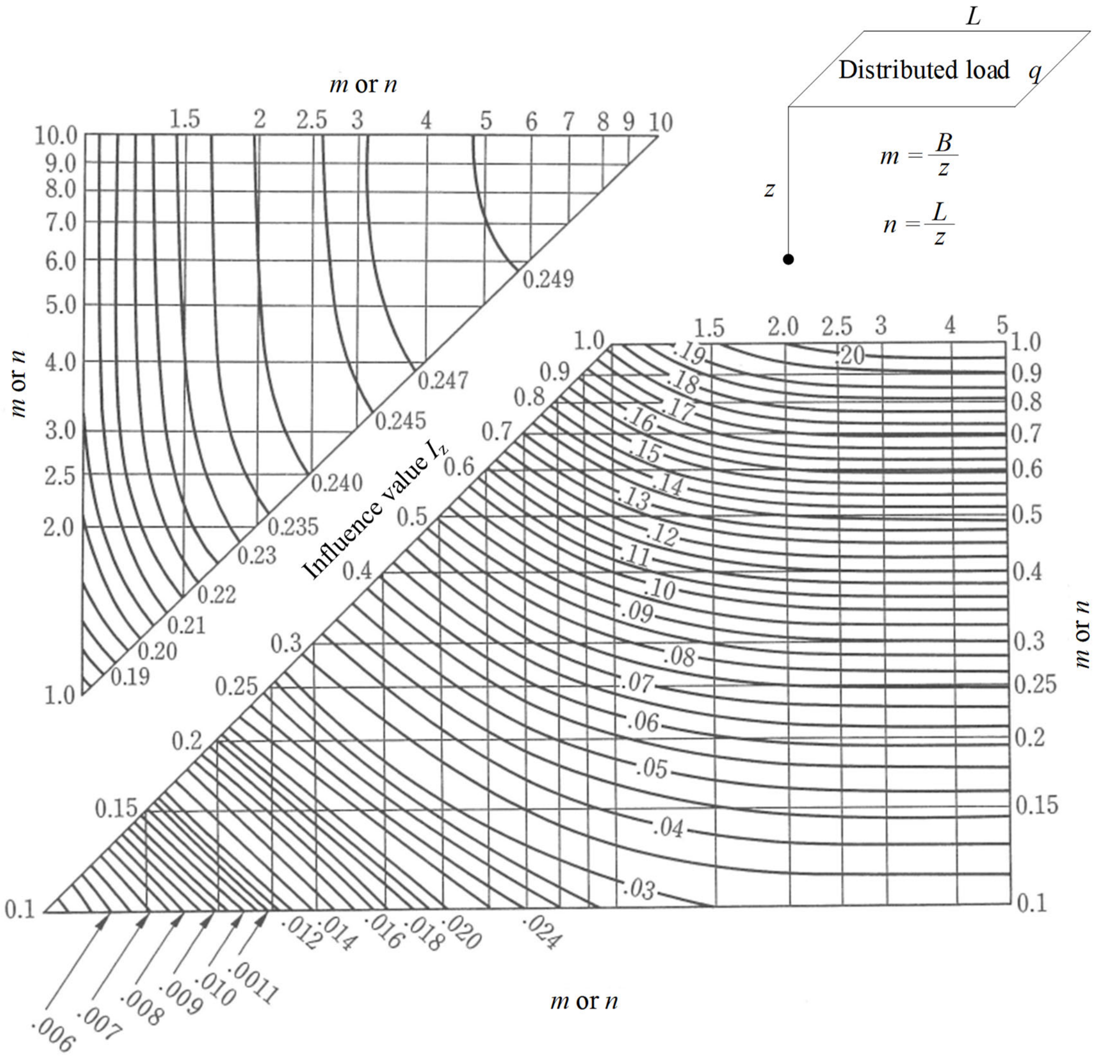

Fig. 2

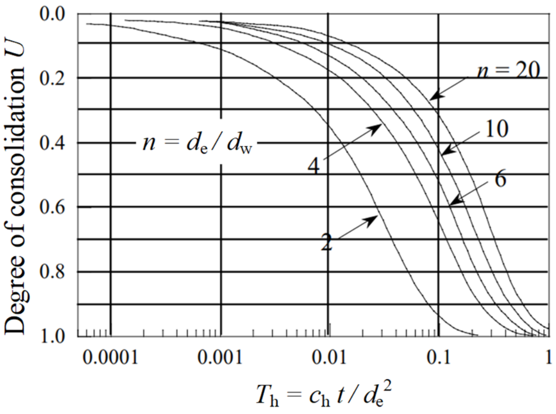

Fig. 4

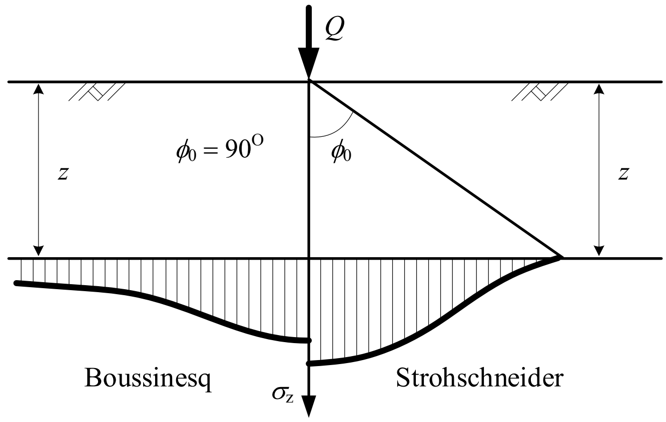

Fig. 5

[Question 2] Answer all the following questions.

A $\overline{\text{CU}}$ triaxial compression test was conducted on a saturated clay under normal consolidation state. The cohesion c' of the normally consolidated clay can be considered as zero. The specimen was first isotopically consolidated at 200 kN/m^2 and the confining pressure was kept constant during the test. At failure, the axial stress σ_a was 400 kN/m^2 with pore water pressure u_w of 100 kN/m^2. Two additional tests were conducted on the same clay. These extra tests were CD direct shear and the clay was in an over-consolidated state. At failure, the applied normal stress in the first test was 10 kN/m^2 and the measured shear stress was 22.7 kN/m^2; in the second test the applied normal stress was 50 kN/m^2 and the measured shear stress was 33.4 kN/m^2.

(1) Find the effective shear strength parameters (cohesion c' and internal friction angle ϕ') of the clay from the $\overline{\text{CU}}$ triaxial compression test and CD direct shear tests, respectively.
(2) Find the pre-consolidation pressure of the clay.
(3) Calculate the Skempton's pore pressure coefficient A_f in the $\overline{\text{CU}}$ triaxial compression test.
(4) Another CD triaxial compression test on the same clay was conducted by keeping the effective mean stress (p') to be constant during the test. The p' is the average of all the three effective principal stresses and the clay was in a normally-consolidated state. The test started with an isotropic confining pressure of 200 kN/m^2. In order to keep p' constant, the axial stress was increased while the radial stress was reduced during the test. Calculate the axial stress and radial stress at failure for the test, then draw the effective stress path in p'-q plane.

Note: you may solve (1) and (2) either analytically or graphically. However, if you use graphical approach, please ensure the accuracy. Points may be deducted for inaccurate solution.

[Question 3] Answer all the following questions.

(1) Describe the significance and/or the purpose of studying earth pressure within 30 words.

(2) Fig. 6 represents a retaining wall of height H where the groundwater level lies at its bottom. Let the frictional angle, the cohesion, and the unit weight of the soil behind the wall be ϕ, c, and γ, respectively. Based on Coulomb's earth pressure theory, determine the earth pressures acting on the retaining wall when it moves rightward and leftward. Show the force polygon diagrams using the forces that act on the soil wedge shown in the figure. Use appropriate symbols for the forces shown in the force polygon diagrams and explain each of those forces. Assume that the cohesion, c, of the soil behind the retaining wall is zero. Also, assume that the surface of the wall is smooth and, hence, there is no friction between the retaining wall and the soil.

(3) While reassessing the conditions of the soil behind the retaining wall, it was found that the cohesion of the soil, c, was not equal to zero. Under this new condition, and based on Rankine's earth pressure theory, obtain the earth pressure that acts on the retaining wall when it moves leftward. Use Mohr's stress circle for the calculation of the earth pressure. Also, show the earth pressure distribution along the height (H) of the retaining wall.

(4) Explain the difference in the magnitudes of the active resultant earth pressure (resultant of the earth pressure and the water pressure) when the groundwater level behind the retaining wall (i) lies at the bottom surface of the retaining wall and (ii) rises to the ground surface. Focus your answer on the difference in the earth pressure and the water pressure under those two conditions. Assume the unit weight of water as γ_w and the cohesion, c, of the soil behind the retaining wall is zero. Also, assume that the active earth pressure p at the depth of z can be expressed as $p = K_a \gamma z$ when the groundwater level lies at the bottom surface of the retaining wall.

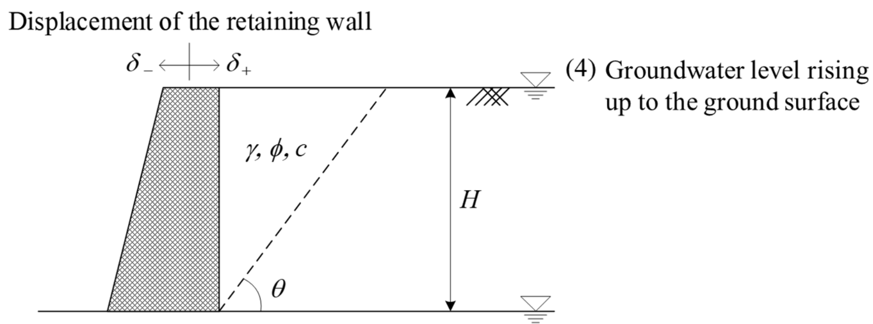

Fig. 6

[Question 4] A strip footing with a width B is constructed on the ground with the surcharge load q. According to Terzaghi, when the ground reaches the ultimate bearing capacity, the slip line will develop, which divides the ground into regions I, II and III as shown in Fig. 7. Let the region bounded by the ground surface and the slip line be defined by the maximum width W and the maximum depth H. Herein, the shape of region II is expressed by the logarithmic spiral $r = \frac{1}{2}B\exp(\theta\tan\phi)/\cos\phi$ using the internal friction angle ϕ of the ground and the angle θ. The ground possesses cohesion c of 80 kN/m^2, internal friction angle ϕ of 30º and bulk unit weight γ_t of 17 kN/m^3. The width B of the strip foundation is 1 m and the surface load q is 10 kN/m^2. Assume that the effects of groundwater are negligible, answer the following questions.

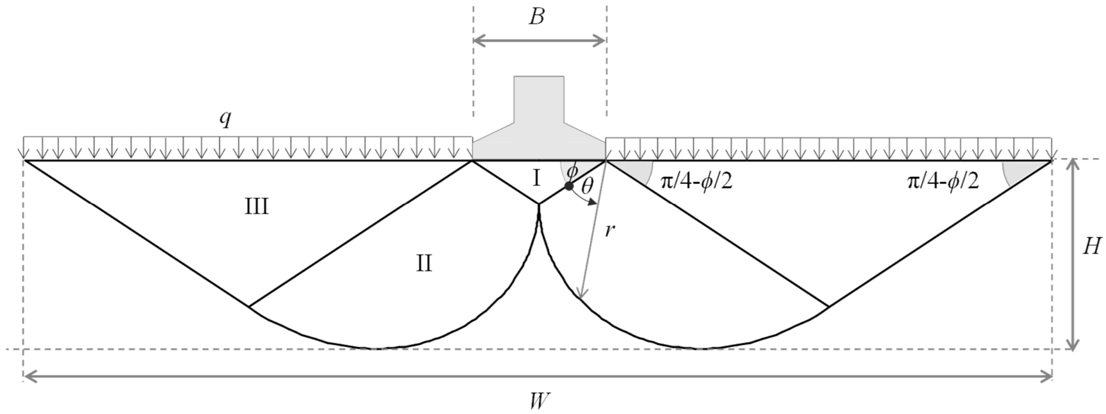

Fig. 7

(1) Find W/B

(2) Find H/B

(3) Explain the benefit of knowing W and H in design and construction of foundation

(4) Calculate the ultimate bearing capacity using the bearing capacity factors showing on Fig. 8

(5) Find the allowable bearing capacity with a safety factor of 3

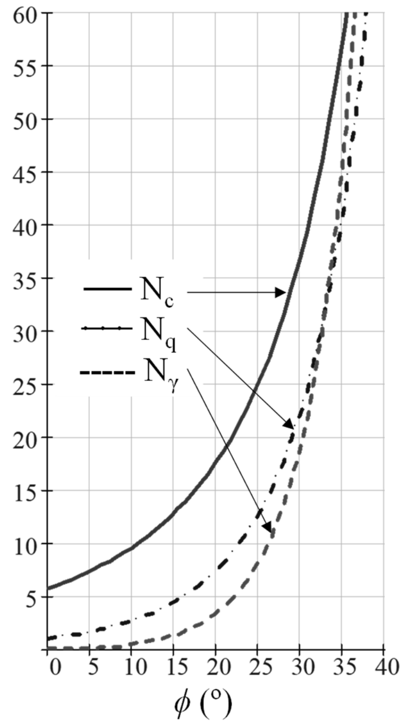

Fig. 8

[Question 5] Answer the following questions.

(1) According to the Fellenius method of stability analysis, a sliding soil mass with underground water is divided into n slices as show in Fig. 9. For any ith 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 effective cohesion be c'_i, and effective angle of internal friction be ϕ'_i. Also, the weight of slide is W_i, the forces acting on the right and left sides of the slice are E_i and E_{i+1}. Along the base of slice, P_i (sum of effective normal force P'_i and force $u_i l_i$ with pore water pressure u_i) denotes the normal force and S_i denotes the shear force. 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.

(1-1) Show the equilibrium equation of force in the direction perpendicular to the base of the ith slice.

(1-2) In regard to the factor of safety F, show the equation by which the failure criterion (sliding condition) of the ith slice is described.

(1-3) Show the equation of equilibrium for which the balance of moments on the whole sliding soil mass about point O is taken.

(1-4) Determine the factor of safety F for the soil mass against sliding along the circular slip surface using the above equations.

(1-5) Explain the stability of slope when the ground water level rises due to rainfall using F in (1-4).

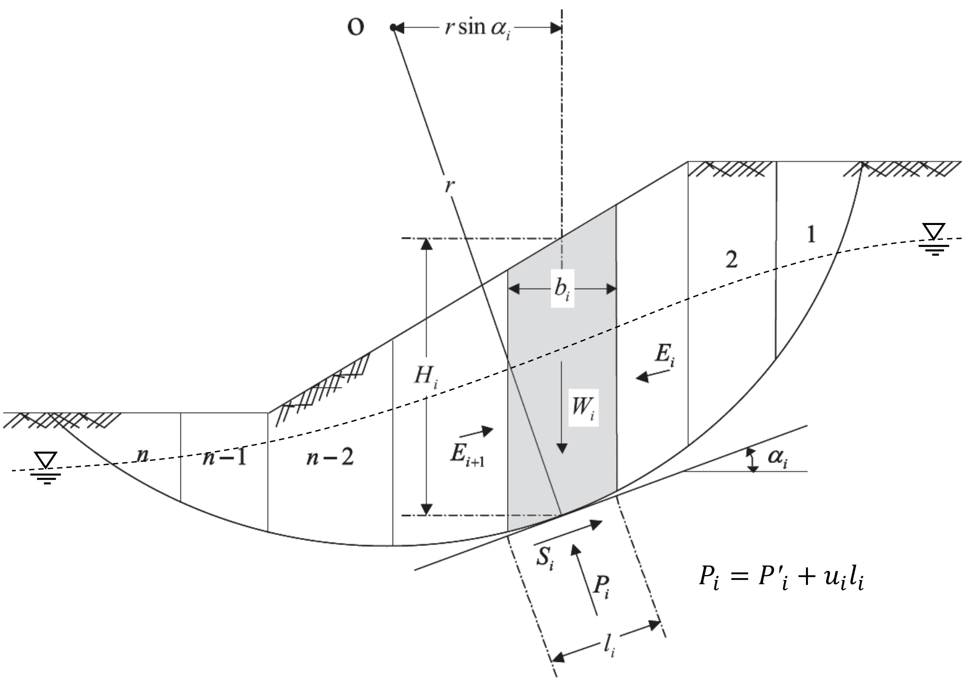

Fig. 9 Sliding soil mass

(2) Answer the following questions regarding soil dynamics and liquefaction.

(2-1) Show two geotechnical conditions that affect the amplification of earthquake ground motion and explain the effect of the geotechnical conditions on the amplification respectively.

(2-2) Show three principles of liquefaction countermeasure and explain the liquefaction-triggering factor that the countermeasure targets respectively.