2017 Soil Mechanics II and Exercises Final Exam

2017/7/26 (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 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] Answer the following questions regarding consolidation and stress in clayey ground

(1) Consider a saturated clay layer of thickness H deposited above an impermeable rock layer, and assume that the ground water level coincides with the ground surface. After the rapid application of a load over the clay layer, the consolidation process can be analyzed based on Terzaghi's one dimensional consolidation equation. The governing equation of consolidation, where u is the excess pore water pressure (= pore water pressure - hydrostatic pore water pressure), C_v is the coefficient of consolidation, t is the elapsed time, and z is the coordinate along the depth direction, is given below.

$$\frac{\partial u}{\partial t} = C_v \frac{\partial^2 u}{\partial z^2} \tag{1}$$

1) Formulate the governing equation of consolidation, Eq.(1), in terms of a time factor $T = \frac{C_v t}{H^2}$ and a dimensionless depth $Z = \frac{z}{H}$.

2) Express the boundary condition for the upper surface of the clay layer (the ground surface where $z = 0$)

3) Express the boundary condition for the lower surface of the clay layer (the surface above the impermeable rock layer where $z = H$)

4) The solution of the consolidation equation considered in 1) can be given in the following form of separation of variables. In regard to this, find the general solution to the consolidation equation shown in Eq. (1) from

the boundary conditions for the upper and lower surfaces of the clay layer. As the initial condition is not provided, it is acceptable to leave some coefficients undetermined.

$$u(Z,T)=S(Z)W(T) \tag{2}$$

(2) When the triangular distributed load shown in Figure 1 is applied on the surface of a clayey ground, the corresponding vertical stress σ_z at point A located at a depth z below the ground surface is given by the following equation in terms of the argument a/z of the function I_q.

$$\sigma_z = I_q\left(\frac{a}{z}\right)q \tag{3}$$

By using this function, describe the vertical stress σ_z at point B located at a depth z below the ground surface when the trapezoidal distributed load shown in Figure 2 is applied on the ground surface. Herein, the ground behavior is assumed to be linearly elastic.

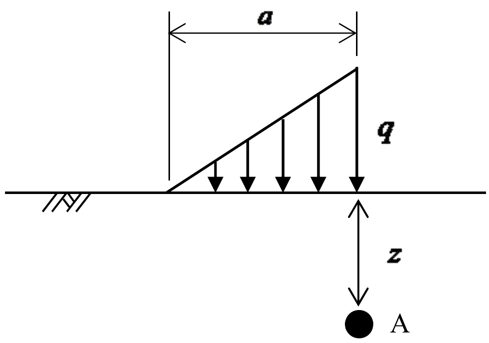

Figure 1

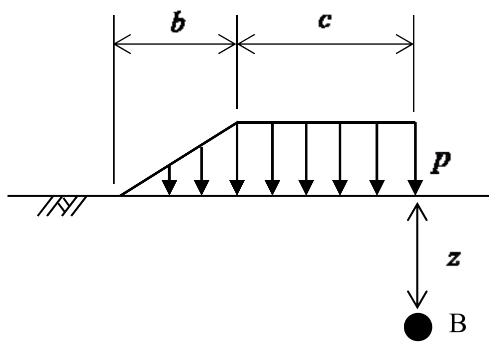

Figure 2

[Question 2] Answer the following questions regarding shear strength of soils. Show all mathematical steps required to reach your answer:

(1) In a series of unconsolidated-undrained triaxial compression tests on specimens of a fully saturated clay, the following results were obtained at failure. Draw the Mohr circles for the three tests, clearly show the Mohr-Coulomb failure envelope, and determine the values of the shear strength parameters c_u and ϕ_u.

Confining pressure (kPa)	200	400	600
Deviator stress (kPa)	220	220	220

(2) Assuming that the Mohr-Coulomb failure criterion is valid, derive the expression that can be used to predict the value of the deviator stress q that, for a given value of effective confining pressure σ_3', would produce failure on a studied soil sample in triaxial compression tests. Show all steps needed to calculate the aforementioned equation $q = f(\sigma_3', c', \phi')$.

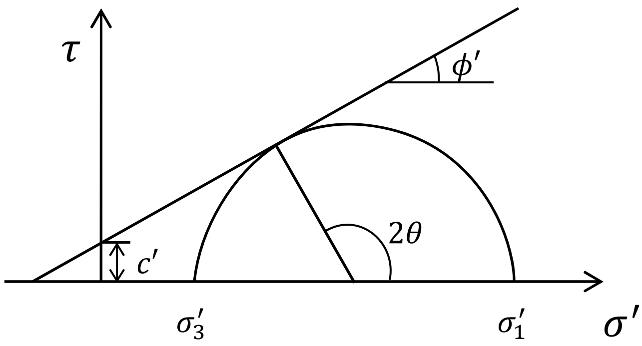

Figure 3

(3) The parameters obtained by the different triaxial tests represent different conditions of stability problem. Which triaxial test would you carry out when asked to perform short-term stability analysis? Briefly explain why.

[Question 3] Figure 4 shows a diagram of a model test in section used to demonstrate a retaining wall rotating about its base. The rigid wall AB turning around hinges at point A was placed between a pair of vertical sides parallel to the section, forming a rigid box as shown in the figure. The inner faces of the wall and the box were coated with smooth films.

The box has been filled with dry soil of unit weight γ and friction angle ϕ to a thickness t while keeping the wall AB upright. Later, the middle of the top of the wall was hooked by a strong cord BF, which ran horizontally and passed over the pulley E, and then ran vertically down to the dead weight given by a mass m. The wall was gently rotated either inward or outward upon the balance between the earth pressure and the tension of the cord. At the instant of soil yielding, there was an excessive movement of the wall when the dead weight underwent the extreme values limited by active and passive lateral earth pressure.

Assuming that the results were not affected by a mass of the wall, friction in hinges as well as friction between the soil and the wall as well as the box, answer the following questions.

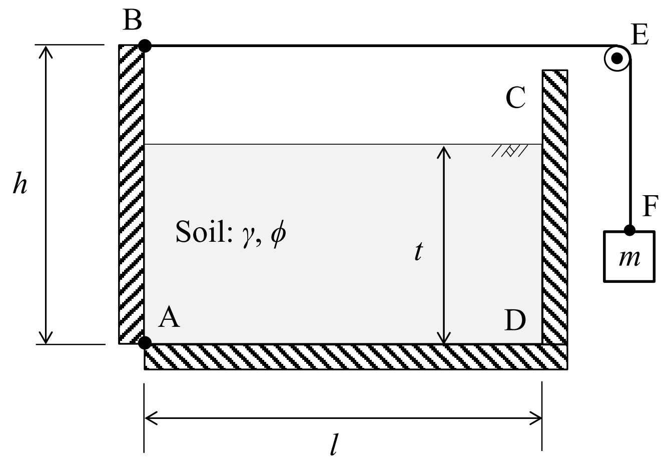

Figure 4

1) In order to avoid the boundary effect of the side CD on the wall AB, the base AD with inner length l must be sufficiently long. Based on Coulomb's earth pressure theory, express the required minimum length l, in terms of t and ϕ, by which the rupture plane of any wedge failure in cohesionless soil does not reach the side CD.
2) Experiments using cohesionless soil with unknown unit weight γ and friction angle ϕ were undertaken to obtain the extreme values of mass m capable of sustaining the wall AB in stability at the time of yielding. Herein, the height h of the wall AB was 0.30 m, the thickness t of the soil was 0.20 m, and the inner breadth b of the box perpendicular to the section was 0.25 m. The lowest mass m was 0.4 kg and the highest mass m was 5.0 kg. According to Rankine's earth pressure theory, find two unknown parameters γ and ϕ, using the gravitational acceleration $g = 9.8$ m/s^2.

[Question 4] Answer the following questions:

(1) To answer the following questions, assume that the strip foundation was built in a ground composed of two different soil layers, as shown in Fig. 5.

1) Express the formula to calculate the bearing capacity of the soil, q_d, making use of Terzaghi's bearing capacity equation, Terzaghi's bearing capacity factors (N_q, N_c, and N_γ), and the soil parameters indicated in Fig. 5. Assume, for this problem, that the groundwater is located deep enough.

2) Derive the formula of the allowable bearing capacity of the soil, q_a, by introducing safety factor, SF, to the formula for the bearing capacity of the soil, q_d, as described in 1).

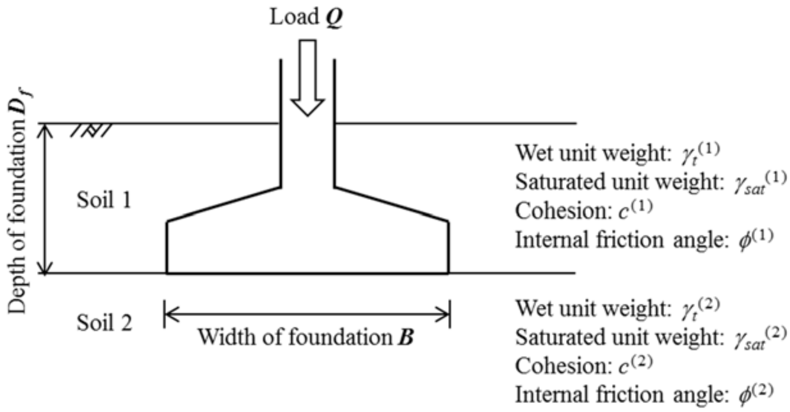

Figure 5

3) From the condition shown in Fig. 5, the groundwater raises until reaching a depth h_w, as indicated in Fig. 6. Express the formula to calculate the bearing capacity of the soil, q_d, making use of Terzaghi's bearing capacity factors (N_q, N_c, and N_γ), and the soil parameters indicated in Fig. 6. Use γ_w as the unit weight of water.

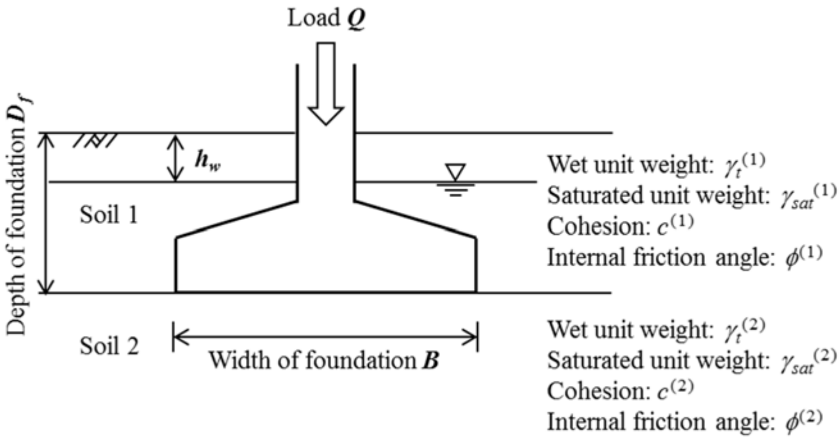

Figure 6

(2) Explain the following concepts with the help of figures:

1) General shear failure and local shear failure

2) Shallow foundation and deep foundation

3) Negative friction

[Question 5] Answer the following questions.

(1) It was decided to investigate the stability of a steep slope making an angle of 60º with the horizontal. The height of the crest of the slope was 4.8 m, measured by survey work. Next, undisturbed soil samples were taken from the slope and subjected to geotechnical laboratory testing, revealing that the total unit weight γ_t = 15.0 kN/m^3, the cohesion c = 18 kN/m^2, and the angle of shearing resistance ϕ = 0º. The stability of slope is assessed using the chart of stability factor shown in Fig. 7.

1) Determine the critical height H_c of this slope with the depth factor n_d = 1.

2) Using 1), calculate the factor of safety F against the collapse of slope.

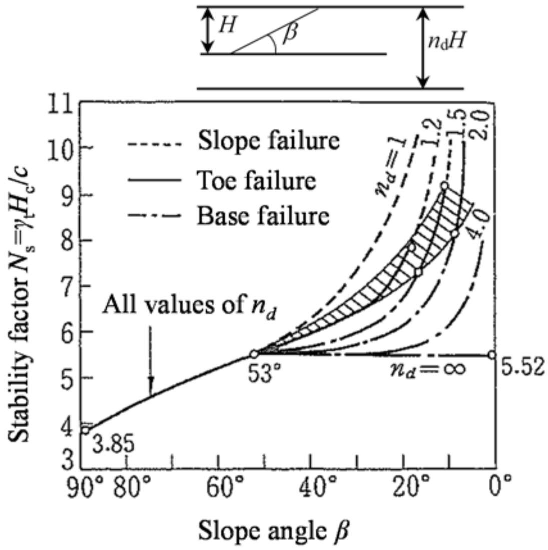

Figure 7

(2) Liquefaction potential in a sandy ground is evaluated. It was found that a continuous sandy soil exists in the ground up to the surface and the groundwater level lies 1 m below the ground surface. As a result of the investigation, γ_t = 17.6 kN/m^3 and γ_{sat} = 19.3 kN/m^3 was reported. Assuming that a liquefaction resistance ratio R_L = (τ/σ'_v) = 0.30 is obtained by conducting undrained repetitive triaxial test on an undisturbed sample collected from this sandy ground, answer the following questions, using the gravitational acceleration g = 9.8 m/s^2 and the unit weight of water γ_w = 9.8 kN/m^3.

1) Calculate the vertical total stress and the vertical effective stress at a depth of 5 m below the ground surface.

2) When the maximum acceleration at the ground surface that occurred during earthquake α_{max} = 1.96 m/s^2, point out whether liquefaction occurs at a depth of 5 m or not based on the F_L method. In determining the maximum shear stress ratio L, consider the reduction factor r_d = 1 - 0.015z (where z is the depth from the ground surface).

3) The groundwater level has reached 2 m below the ground surface due to a 1 m drop after an operation of groundwater level lowering. At this time, calculate the maximum acceleration at the ground surface α_{max} for which liquefaction is required to trigger at a depth of 5 m.

4) A method of lowering of groundwater level is one of countermeasures against liquefaction, list two other countermeasures against liquefaction and briefly explain about them.