2015 Soil Mechanics II and Exercises Final Exam

2015/7/29 (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 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

A thick stratum of saturated clay is deposited above an impermeable bedrock. Assume that the groundwater level coincides with the ground surface. After the immediate application of a load over the clay layer, the consolidation process can be analyzed based on Terzaghi's one dimensional consolidation equation. The consolidation equation expressed in terms of excess pore water pressure (= pore water pressure - hydrostatic pressure) u, coefficient of consolidation C_v, time t, and coordinate along the depth direction z is given below.

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

The boundary conditions of this equation are taken at the top surface of the clay layer (ground surface) where z = 0 and at the bottom surface of the clay layer (the top surface of the impermeable bedrock) where $z = H$. At the top surface (z = 0) of the clay layer, it is required that,

$$z = 0: \quad u = 0 \tag{2}$$

Furthermore, at the bottom surface of the clay layer ($z = H$), the impermeable condition is given below as the flow rate becomes zero in Darcy's law,

$$z = H: \quad \frac{\partial u}{\partial z} = 0\,. \tag{3}$$

1) Considering the excess pore water pressure $u = u_0$ immediately after the rapid increase in load as the initial condition, obtain the solution of the consolidation equation (1) using the boundary conditions (2) and (3).

2) Sand drain is a soil improvement method used to accelerate the consolidation of soft ground. Explain the principles to accelerate the consolidation process by this method.

3) When a distributed strip load is applied over a clayey ground as shown in Fig. 1, the vertical stress σ_z with respect to the depth z below the ground surface at point C is given by $I_q\left(\frac{a}{z},\frac{b}{z}\right)$ as a function of the variables a/z and b/z, so that:

$$\sigma_z = I_q\left(\frac{a}{z},\frac{b}{z}\right)\cdot q \tag{4}$$

Similar to Eq.(4), express the vertical stress σ_z with respect to the depth z below the ground surface at points A and B in association with the function I_q. Herein, the behavior of clayey ground is assumed to be linearly elastic.

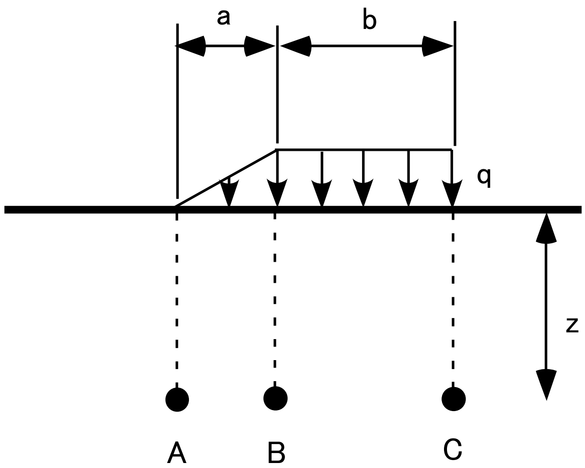

Figure 1

[Question 2] Briefly explain the following concepts. You may use figures and equations if needed.

1) Mohr-Coulomb failure criterion

2) Soil dilatancy

3) Soil sensitivity ratio

4) Soil undrained shear strength ratio

5) Skempton's pore pressure parameter A

[Question 3] Answer the following questions

1) Consider Rankine's theory applied to a smooth wall retaining a dry cohesionless soil with friction angle ϕ. According to Fig. 2, when the soil surface is a horizontal plane, the active pressure σ_3 acts on a vertical plane while the vertical pressure σ_1 acts on a horizontal plane. The mobilized states of stresses for σ_1 and σ_3 are shown on Mohr's stress circle (see Fig. 4) with center at point C touching the failure envelop of the soil at point D. Herein, p = OC is the mean stress and q = CD is the stress deviator. Find the active earth pressure coefficient, which is represented by σ_3/σ_1, in terms of ϕ.

2) According to Fig. 3, when the soil surface slopes at a constant angle i, where $i < \phi$, it is assumed that the active pressure σ_i acts in a direction parallel to the sloping surface while the vertical pressure σ_v acts on a plane inclined at an angle i to the horizontal. Since these mobilized stresses are not normal to their respective planes, they are not principal stresses. The normal and tangential components of σ_v along its applied surface are s_v and t_v, respectively, and are represented by the coordinates of point A while those of σ_i, which are s_i and t_i, are represented by the coordinates of point B′ in Mohr's stress circle (see Fig. 4). This is brought out by tracing a line OA in a direction parallel to the sloping surface. Line OA also intersects the Mohr's stress circle at point B; therefore OB = OB′. Note that Point F divides AB in half. Find the active earth pressure coefficient, which is represented by σ_i/σ_v, in terms of ϕ and i.

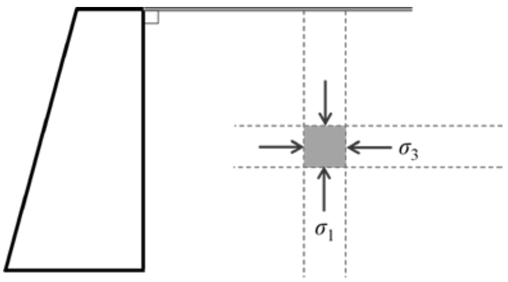

Figure 2

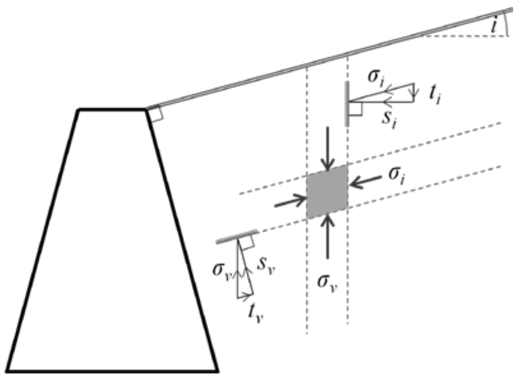

Figure 3

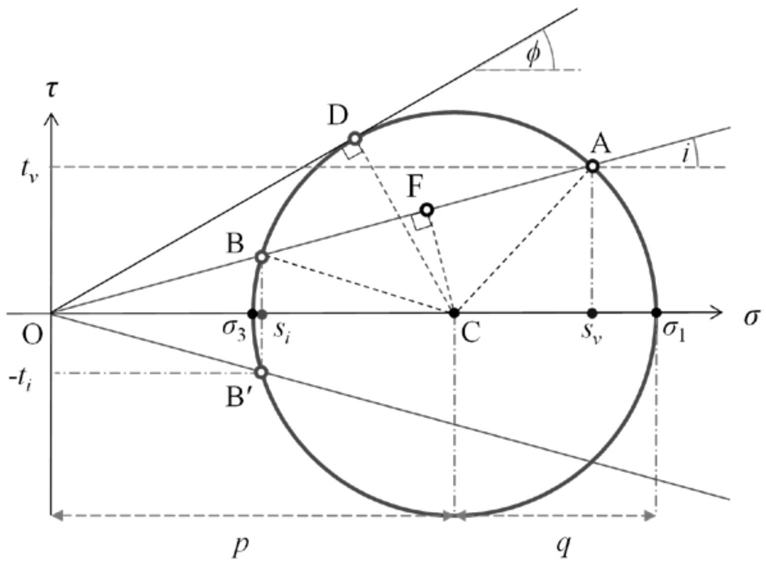

Figure 4

[Question 4] Answer the following questions.

1) The following figure (Fig. 5) depicts the stability problem of a long slope with a sliding surface in a weathered rock layer. The groundwater is present at a depth z_0 in the weathered rock layer by rainfall infiltration to the slope. Herein, it is assumed that the flow line is parallel to the slope surface. Let the vertical depth from the slope surface to the sliding plane be H, the angle of inclination of the slope be β, the unit weight of the soil above the groundwater level be γ_t, the unit weight of the soil below the groundwater level be γ_{sat}, the cohesion of soil be c', the internal friction angle of soil be ϕ', and the unit weight of water be γ_w. Answer the following questions:

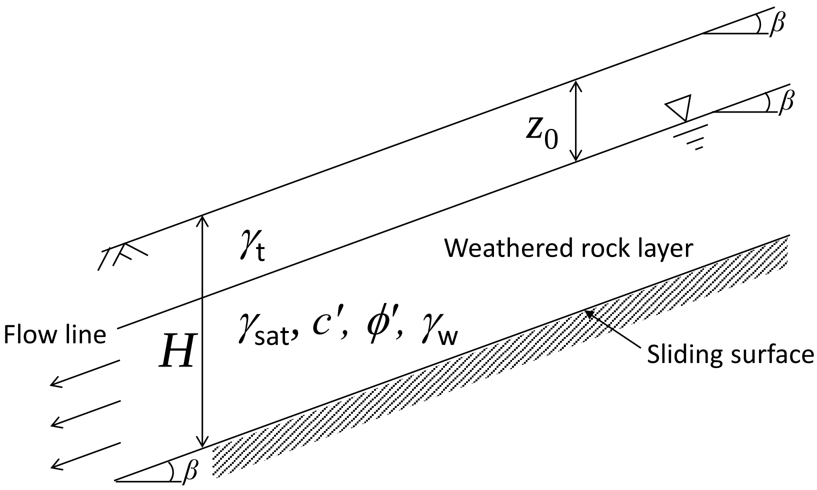

Figure 5

(1) Find the safety factor against sliding of this slope. Clearly express the following elements.

- Normal stress σ and shear stress τ acting on the sliding surface
- Pore water pressure u acting on the sliding surface
- Normal effective stress σ' acting on the sliding surface
- Mohr-Coulomb failure criterion

(2) It is assumed that the slope fails when the groundwater level reaches the slope surface. Find the depth (the critical depth H_c) at which sliding failure occurs.

2) Investigation of topographic maps is undertaken due to construction of a highway embankment. It was found that the site is located exactly on an old river bed. In addition, the area is often stricken by large earthquakes. Prior to the design, the standard penetration tests were conducted and a borehole profile was obtained as shown in Fig. 6.

(1) Explain how to obtain an N-value. In addition, qualitatively describe the relationship between ground density and N-value.

(2) Discuss the possibility of liquefaction at the site under the given conditions, such as the topography, seismic history and also the standard penetration test results shown in Fig. 6.

(3) The definition of factor of safety against liquefaction is described below where R_l is the normalized cyclic resistance ratio (CRR) and L is the normalized cyclic shear stress ratio (CSR). Explain how R_l and L are derived and obtained.

$$\text{Factor of safety against liquefaction : } F_L = \frac{R_l}{L}$$

(4) The result of the investigation indicates that the liquefaction susceptibility is quite high at the site; therefore, engineering countermeasures are employed before constructing the embankment. Explain about the principles of mitigation of the measures against liquefaction that are particularly effective to embankments and list three appropriate techniques based on these principles.

Depth (m)	Soil classification	Relative density	*N*-value
1	Fine sand	Very loose	4
2			8
3			10
4			12
5	Fine sand	Loose	7
6			3
7			5
8			12
9			18
10			7
11			12
12			9
13	Fine sand	Dense to medium	24
14			34
15			35
16			35
17			40
18			34
19	Silty fine sand	Medium	25
20			27
21			29
22			29
23			27
24			34
25			16
26			37
27			11
28	Silt mingled with sand	Loose	6
29			26
30			13

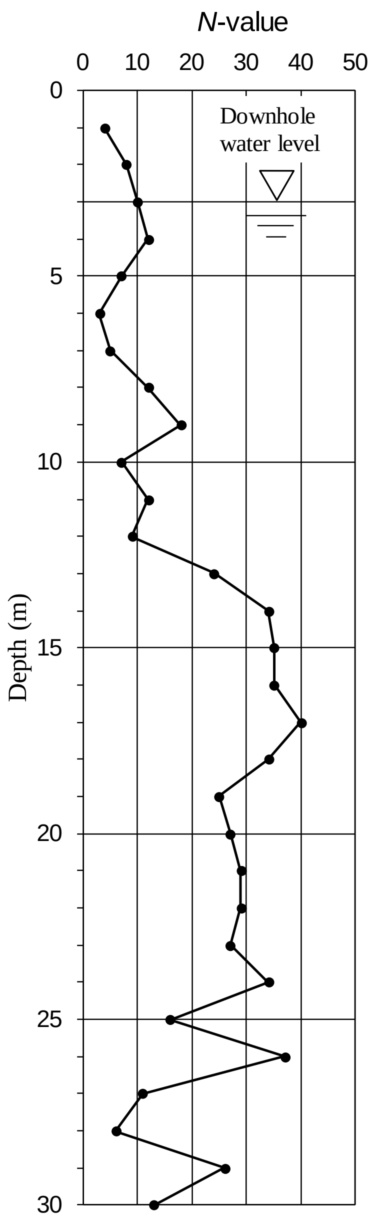

Figure 6

[Question 5]

1) Explain the following concepts with the help of figures.
   - General shear failure and local shear failure
   - Shallow foundation and deep foundation
   - Negative friction

2) To answer the following questions assume that the strip foundation was built in a homogeneous ground, as shown in Fig. 7.

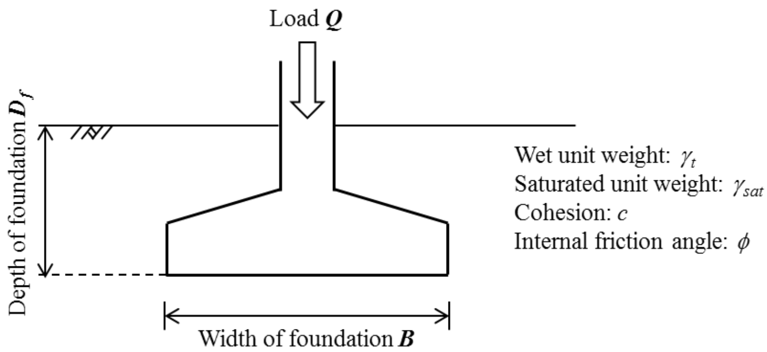

Figure 7

(1) Express the formula to calculate the bearing capacity of the soil, q_d, as a function of Terzaghi's bearing capacity factors (N_q, N_c, and N_γ) and the soil parameters indicated in Fig. 5.1. 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).

3) 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. 8.

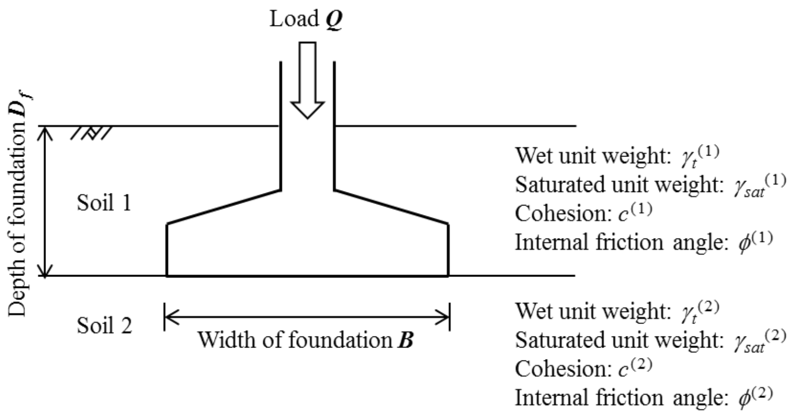

Figure 8

(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. 8. Assume, for this problem, that the groundwater is located deep enough.

(2) From the condition shown in Fig. 8, the groundwater raises until reaching a depth h_w, as indicated in Fig. 9. 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. 9. Use γ_w as the unit weight of water.

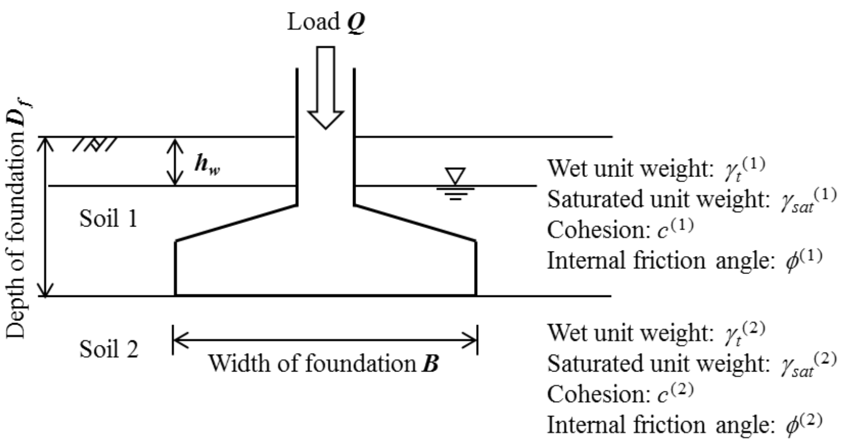

Figure 9