2018 Soil Mechanics II and Exercises Midterm Exam

2018/5/30 (Wed.) 8:45-10:15 Kyotsu 4 and Kyotsu 155 lecture rooms

Attention:

- The exam consists of three questions for which you are provided with three 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.
- Scores for each question are equally weighted.
- 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) A saturated clay layer of thickness H lies above an impermeable rock layer. Assume that the groundwater 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, given below. Here, u is the excess pore water pressure (= pore water pressure – hydrostatic pore water pressure), C_v is the coefficient of consolidation, t is time, and z is the coordinate along the vertical direction.

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

(a) Derive equation (1) from the following assumptions and conditions:

①	Darcy's law	$v = ki = -\frac{k}{\gamma_w}\frac{\partial u}{\partial z}$	v: flow velocity k: coefficient of permeability γ_w: unit weight of water
②	Continuity equation for water	$\frac{\partial v}{\partial z} = \frac{\partial \varepsilon}{\partial t}$	ε: soil strain
③	Relation between effective stress and strain	$d\varepsilon = m_v d\sigma'$	m_v: coefficient of volumetric compression σ': effective stress
④	Constant total stress condition	$\frac{\partial \sigma}{\partial t} = \frac{\partial \sigma'}{\partial t} + \frac{\partial u}{\partial t} = 0$	σ: total stress

(b) Write down the boundary condition for the upper surface of the clay layer (ground surface, $z = 0$).

(c) Write down the boundary condition for the lower surface of the clay layer (in contact with the impermeable rock layer, $z = H$).

(d) Assuming that the initial pore water pressure u_o is constant regardless of depth, the solution of the consolidation equation is given by the following equation. Explain the changes in the pore water distribution with time by drawing a schematic diagram of the following equation. Make the horizontal axis represent the excess pore water pressure u, and the vertical one the depth z.

$$u=\sum_{m=0}^{\infty}\left[\frac{2u_0}{M}\sin\left(\frac{M}{H}z\right)\exp\left(-M^2T_v\right)\right] \quad M=\frac{2m+1}{2}\pi, \quad T_v=\frac{C_v t}{H^2} \tag{2}$$

(2) A uniformly distributed load of 100 kN/m^2 is acting on a rectangular foundation of dimensions 8 m × 4 m. Assuming the ground as a linear elastic body, find the vertical stress at a depth of 2 m just under the center of the foundation. The vertical stress under the corner of a rectangular distributed load q can be obtained by the following equation. In addition, the value of the influence factor I_q may be obtained from Figure 1.

$$\sigma_z=qI_q(m,n)=\frac{q}{2\pi}\left[\frac{mn\left(m^2+n^2+2\right)}{\left(m^2+1\right)\left(n^2+1\right)\sqrt{m^2+n^2+1}}+\sin^{-1}\left(\frac{mn}{\sqrt{m^2+1}\sqrt{n^2+1}}\right)\right] \quad m=\frac{a}{z} \quad n=\frac{b}{z} \tag{3}$$

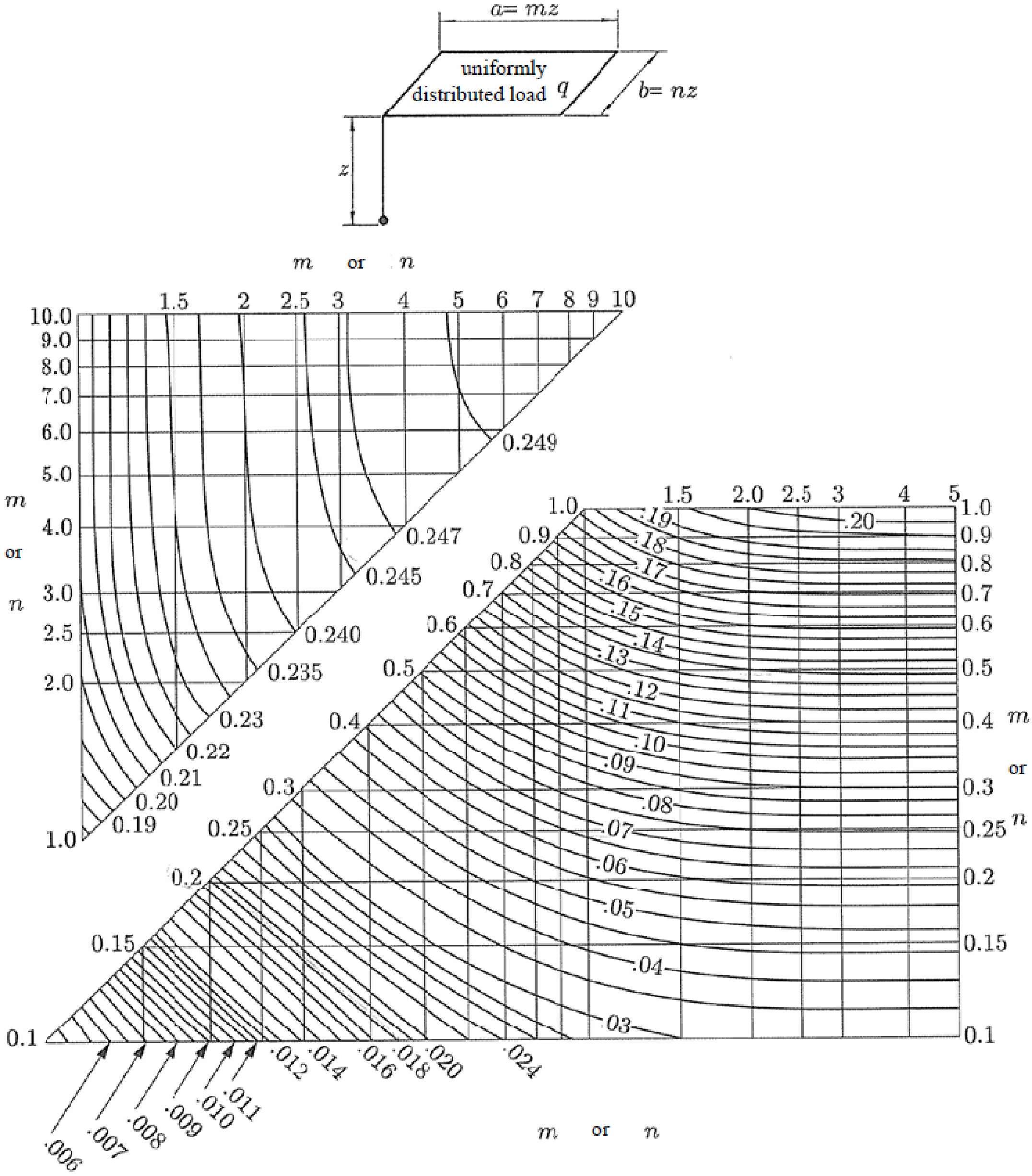

Figure 1. Influence Factor I_q

[Question 2]

Unconfined compression test of a saturated normally consolidated clay sample taken from the ground layer was carried out. The states of stress (total and effective stress) and pore water pressure at the time of failure are exhibited in Figure 2 by Mohr's stress circles. The symbols used in this figure are defined as follows:

τ	Shear stress
σ, σ'	Normal stress (total, effective)
σ'_f, τ_f	Normal effective stress and shear stress acting on the failure plane
σ_{1f}, σ'_{1f}	Major principal stress at failure (total, effective)
σ_{3f}, σ'_{3f}	Minor principal stress at failure (total, effective)
ϕ', c'	Internal friction angle, cohesion
q_u	Unconfined compressive strength
u_f, Δu_f	Total pore water pressure, excess pore water pressure at failure
u_o	Pore water pressure before shearing

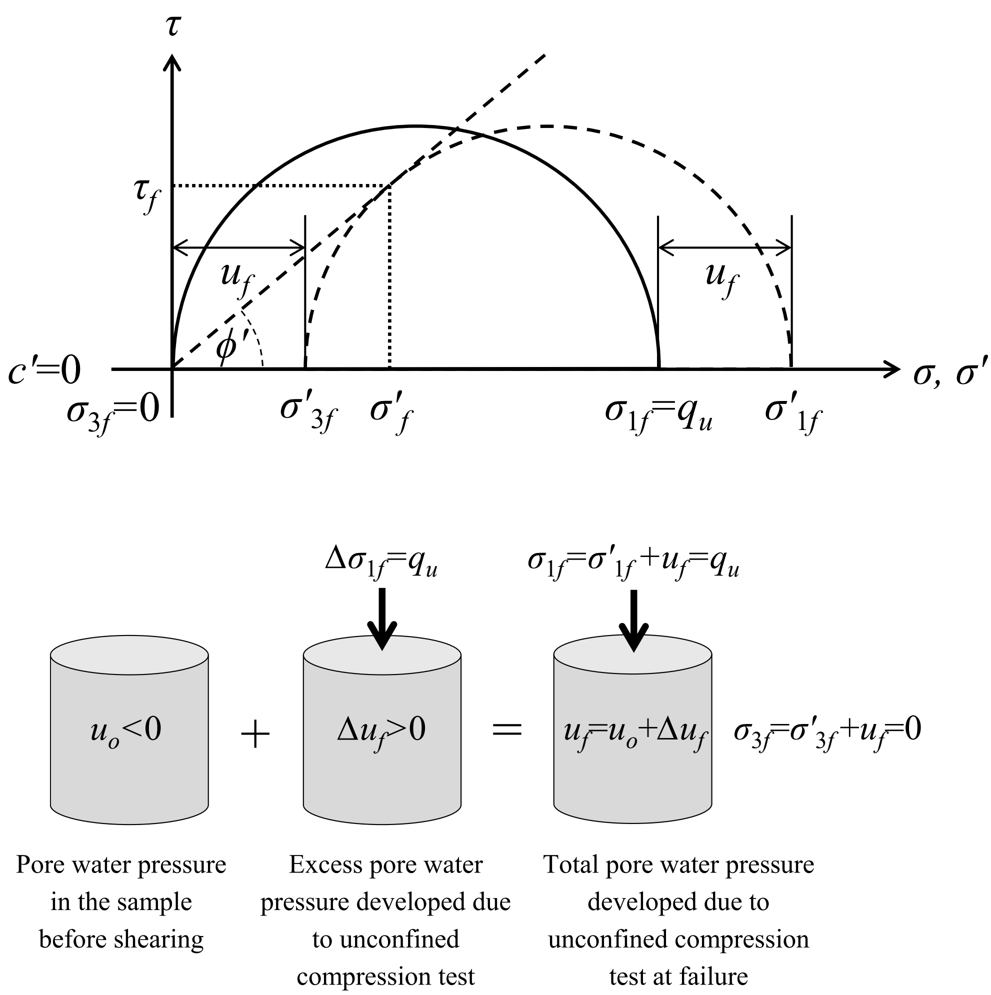

Figure 2

The change in pore water pressure, which cannot be regularly measured in an unconfined compression test, is considered in this problem. Assuming that the Mohr-Coulomb failure criterion is valid, answer the following questions.

(1) The unconfined compressive strength q_u = 160 kPa was obtained. Calculate the total pore water pressure at failure, u_f, provided that c' = 0, ϕ' = 30º were obtained from a sample.

(2) Find normal effective stress, σ'_f, normal total stress, σ_f, and shear stress, τ_f, acting on the failure plane at that time.

(3) Total pore water pressure u_f is considered to be a combination of pore water pressure u_o before shearing and excess pore water pressure Δu_f at failure, i.e., $u_f = u_o + \Delta u_f$. Calculate u_o when Skempton's pore pressure parameter $A_f = \Delta u_f / (\sigma_{1f} - \sigma_{3f}) = 0.7$ at the time of failure.

(4) To avoid negative pore water pressure, u_o, before shearing, unconsolidated undrained (UU) triaxial compression was conducted on the same sample under a constant confining pressure of 200 kPa. Determine the undrained shear strength, c_u.

(5) Explain why the pore water pressure before shearing, u_o, is negative in the initial state of (1).

[Question 3]

Consider the retaining wall shown in Figure 3. Let the cohesion c' of the backfill soil be zero. Assume that the retaining wall is smooth without friction, and that the groundwater level is sufficiently deep so that pore water pressure in the backfill soil is assumed to be zero. Answer the following questions.

(1) Briefly describe:
  (a) An empirical relationship between the coefficient of earth pressure at-rest and the internal friction angle ϕ'.
  (b) Three criteria taken into account when considering stability of a retaining wall

(2) Graphically show the three representative coefficients of earth pressure acting on the retaining wall. Use the displacement δ of the retaining wall as the horizontal axis, and the coefficient of earth pressure as the vertical axis. Use as reference the direction of displacement from Figure 3.

(3) Determine the earth pressure acting on the retaining wall based on Coulomb's earth pressure theory. In

Figure 3, the weight of the soil wedge is W, the resultant force acting against the retaining wall is P, the reaction force normal to the assumed failure plane is N, and the frictional resistance tangent to the same assumed failure plane is T. Show the force polygon diagram consisting of the forces that act on the soil wedge under the following two cases as well as describing the expression of the resultant force P in terms of W, θ, and ϕ'.

(a) When the retaining wall displaces to the left side (δ_-) direction of the figure

(b) When the retaining wall displaces to the right (δ_+) direction of the figure

(4) Briefly explain the procedure of determining the earth thrust acting on the retaining wall from the value of P obtained in (3), for each case (a) and (b).

(5) After experimentally confirming the ground conditions of the backfill, it was found that the cohesion, c', was not zero. Based on Rankine's earth pressure theory, obtain the earth pressure that acts on the retaining wall when it moves to the left (δ_-) direction of the figure under this new condition.

(a) Obtain the earth pressure acting on the wall at the depth z from the surface of the backfill soil.

(b) Find the direction of the failure plane

(c) Clearly show the distribution of earth pressure acting on the wall

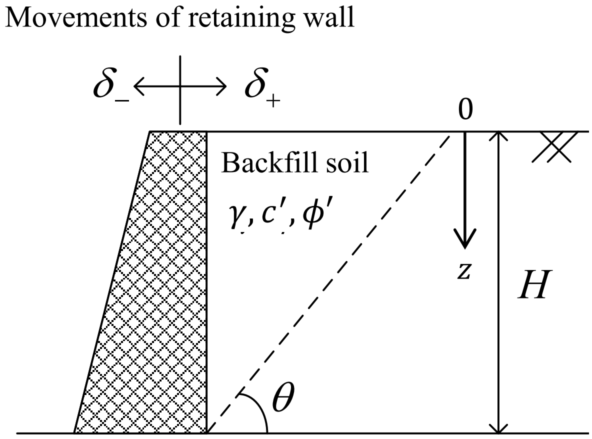

Figure 3