2022 Soil Mechanics II and Exercises Midterm Exam

2022/6/8 (Wed.) 8:45-10:15 Kyotsu 4 lecture room

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.

(1-1) Derive Terzaghi's one dimensional consolidation equation from the following four equations, and answer the relationship between coefficient of consolidation c_v and other parameters:

Relation between effective stress and strain: $d\varepsilon = m_v d\sigma'$ Eq. (1)

Constant total stress condition: $\frac{\partial \sigma}{\partial t} = \frac{\partial \sigma'}{\partial t} + \frac{\partial u}{\partial t} = 0$ Eq. (2)

Darcy's law: $v = -k\frac{\partial h}{\partial z} = -\frac{k}{\gamma_w}\frac{\partial u}{\partial z}$ Eq. (3)

Continuity equation for water: $\frac{\partial v}{\partial z} = \frac{\partial \varepsilon}{\partial t}$ Eq. (4)

where, ε is soil strain, m_v is coefficient of volume compressibility, σ' is effective stress, σ is total stress, u is excess pore water pressure, t is time, v is flow velocity, k is coefficient of permeability, h is total head, z is the position coordinate and γ_w is unit weight of water.

(1-2) Write down the boundary condition for the upper surface of the clay layer (ground surface, $z = 0$).

(1-3) Write down the boundary condition for the lower surface of the clay layer (in contact with the impermeable rock layer, $z = H$).

(1-4) The solution of the consolidation equation can be expressed using the time factor T_v. Assuming that the initial pore water pressure u_0 is constant regardless of depth, explain the changes in the pore water pressure distribution with the time factor T_v by drawing a schematic diagram of the solution of consolidation equation. Make the horizontal axis represent the ratio of the excess pore water pressure u to u_0 (u/u_0), and the vertical one the ratio of the depth z to the thickness of clay layer H (z/H).

(2) The thickness of the clay layer in (1) is H = 3 m. When a soil sample was taken from this clay layer and a consolidation test was conducted, it took 20 minutes for the 2-cm-thick specimen to reach 90% consolidation. Find the time required for this clay layer to reach 90% consolidation.

(3) When a uniformly distributed rectangular (length of each side: a and b) load of q shown in Figure 1 is applied on the surface of a clayey ground, the vertical stress σ_z at a depth of z under the corner of the rectangular can be given by the Eq. (5) in terms of the arguments a/z and b/z of the function I_q. By using this function, describe the vertical stress σ_z at point A shown in Figure 2. Herein, the ground behavior is assumed to be linearly elastic.

$$\sigma_z = I_q\left(\frac{a}{z}, \frac{b}{z}\right) \cdot q \qquad \text{Eq. (5)}$$

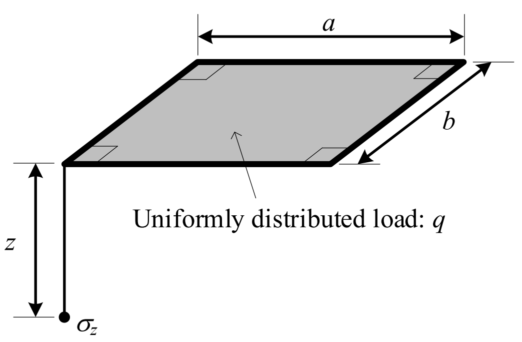


Figure 1

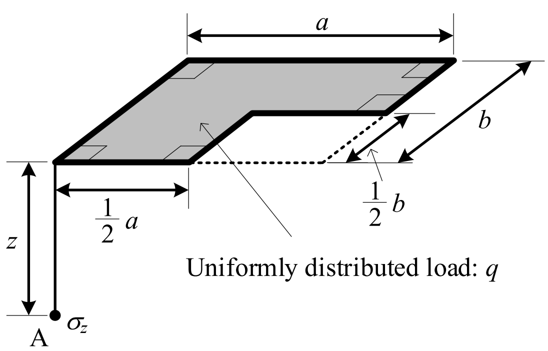


Figure 2

[Question 2] Answer the following questions.

(1) An unconfined compression test using a clay sample was conducted. The unconfined compressive strength q_u was 120 kN/m^2. An undrained triaxial compression test was also conducted using the same clay sample at a confining pressure of 150 kN/m^2.

(1-1) In the unconfined compression test, the effective stress at the sampled depth was maintained. Give the reason why the effective stress is maintained.

(1-2) Find the undrained shear strength c_u of this clay.

(1-3) Draw Mohr's circles at failure for the above unconfined compression test and undrained triaxial compression test, respectively.

(2) A clay sample was isotropically consolidated with a confining pressure of 150 kN/m^2 and then subjected to a consolidated undrained triaxial compression test. The deviator stress q was 126 kN/m^2 and the excess pore pressure u was 72 kN/m^2 at failure.

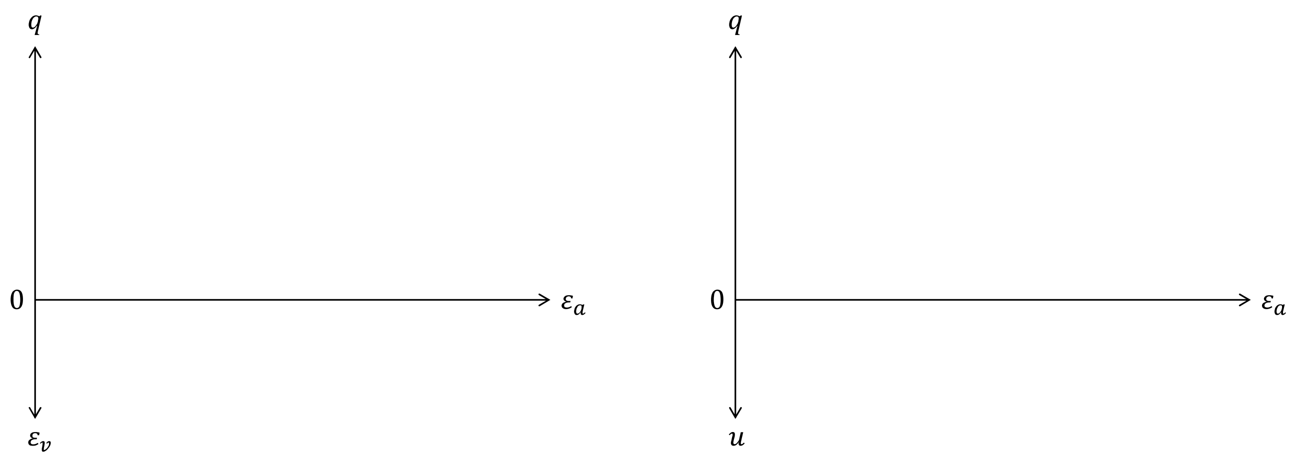
(2-1) Find the mean effective stress p' at failure, Skempton's pore pressure coefficient A_f, and the failure stress ratio M_f.

(2-2) Find the internal friction angle ϕ' when the cohesion c' can be assumed to be zero.

(2-3) Draw the total stress path in the $p - q$ plane and the expected effective stress path in the $p' - q$ plane for this test.

(2-4) If this specimen is isotropically consolidated with a confining pressure of 150 kN/m^2, followed by a consolidated-drained triaxial compression test, determine the deviator stress q and the effective mean p' at failure.

(3) Copy Figure 3 in your answer sheet and sketch the expected experimental results for: (a) the consolidated-drained (CD) triaxial compression tests of dense and loose sands; and (b) the consolidated undrained (CU) triaxial compression tests on dense and loose sand samples. Assume that compression is positive. Herein, ε_a is the axial strain and ε_v is the volumetric strain.

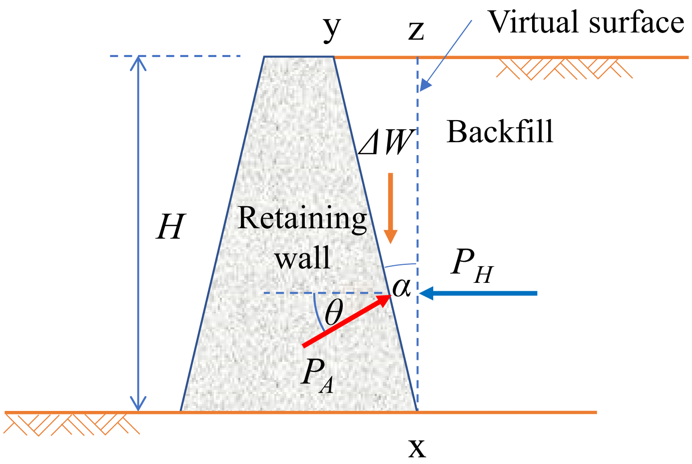


(a) CD test

(b) CU test

Figure 3

[Question 3] The back surface of a retaining wall is not necessarily vertical, but may be inclined. For a horizontal cohesionless backfill (c = 0 kPa), answer the following questions regarding the active earth pressure on an inclined retaining wall ($\alpha > 0°$) as shown in Figure 4, where point x is the base of the wall, point y is the top of the wall and point z is the intersection of the vertical line through x and the surface of the backfill.



Horizontal cohesionless backfill
Unit weight γ = 16 kN/m^3
Friction angle ϕ = 30°
Cohesion c = 0 kPa

Retaining wall
Height of wall H = 5 m
Inclined angle of wall α = 15°
Wall friction angle δ = 20 °

Figure 4

(1) Explain why Rankine's earth pressure theory cannot take the inclination of the back surface of retaining wall into account but Coulomb's earth pressure theory can.

(2) If the vertical plane xz through the heel is taken to be the virtual surface where no shear stresses act on this surface, the active Rankine's earth pressure theory can be applied. Determine the horizontal active force per unit width (P_H) on the virtual surface in the backfill of height H = 5 m having the unit weight γ = 16 kN/m^3 and the friction angle ϕ = 30°.

(3) Calculate the weight per unit width of triangle xyz (ΔW) for which α = 15°. There must be equilibrium among weight ΔW and the forces across the virtual plane and the back of the wall. Obtain the magnitude of the active resultant force on the wall (P_A) and its tilt angle (θ) from the horizontal plane by finding the sum of force vectors P_H and ΔW.

(4) According to Coulomb's earth pressure theory, the resultant force P_A on a retaining wall is designated by the following equations. Herein, the wall friction angle δ is 20°.

$$P_A = \frac{1}{2}\gamma H^2 K_A \quad \text{where} \quad K_A = \frac{\cos^2(\phi-\alpha)}{\cos^2\alpha\cos(\alpha+\delta)\left[1+\sqrt{\dfrac{\sin\phi\sin(\phi+\delta)}{\cos\alpha\cos(\alpha+\delta)}}\right]^2}$$

Based on Coulomb's earth pressure theory, determine θ and P_A on an inclined retaining wall using the parameters listed in Figure 4.

(5) Compare P_A and θ obtained from (3) and (4), and discuss about the benefit and limitation of the assumption of the virtual surface.