2020 Soil Mechanics II and Exercises Midterm Exam

2020/6/10 (Wed.) Test time 8:45-10:15, Submission time via PandA 10:30

Attention:

- Stop writing the answer at 10:15 and submit the answer sheet via PandA by 10:30.
- Your submission will not be accepted after the deadline regardless of any reason. Give yourself ample time to get through Panda for submitting the answer sheet.
- During the examination, you may consult the lecture materials and reference sources, but carefully manage your exam time.
- Answer sharing and copying is academic dishonest. If the similarity in answers are observed among examinees, an extra oral examination may be conducted later for individual investigation.
- Wherever necessary, specify the units in your answers.

[Question 1] Answer all the following questions

(1) In Terzaghi's one-dimensional consolidation theory, the time required for consolidation is influenced by the thickness of consolidation layer H and the distance to the drainage edge (drainage distance). Here, explain the reason why the times for consolidation in the layer of thickness H with single-sided drainage condition and in the layer of thickness $2H$ with both-sided drainage condition become same.

(2) Answer the following questions about the stress generated in an elastic ground

(2-1) Explain why the Boussinesq stress solution obtained for a semi-infinite linear elastic body is useful for estimating the stress in the ground even though the ground is not elastic.

(2-2) As shown in Fig. 1, a square-shaped building with a central courtyard is constructed on the surface of a semi-infinite linear elastic ground, and its weight is 100 kN/m^2. Calculate the vertical stress increment at a depth of 10 m below the center of courtyard (Point A). Here, the vertical stress at the point below the corner increased in an elastic ground by a rectangular uniform load p of dimensions B and L is calculated according to the Eq. (1). You may use the chart shown in Fig. 2 to find the solution.

$$\sigma_z = I_z \cdot p = \frac{1}{2\pi}\left[\frac{mn(2+m^2+n^2)}{(1^2+m^2)(1^2+n^2)\sqrt{1^2+m^2+n^2}} + \sin^{-1}\frac{mn}{\sqrt{1^2+m^2}\sqrt{1^2+n^2}}\right]\cdot p \qquad \text{Eq. (1)}$$

(2-3) As shown in Fig. 3, when the uniformly distributed strip load p acts on the surface of a semi-infinite linear elastic ground, the magnitude of the principal stresses are equal on the circumference passing through both ends of the load, and the direction of the maximum principal stress is the direction of the straight line connecting points D and A. Explain the reason why. Here, the stresses on this circumference can be expressed by Eqs. (2) to (4) as follows.

$$\sigma_x = \frac{p}{\pi}\{(\theta_2 - \theta_1) - \sin(\theta_2 - \theta_1)\cos(\theta_2 + \theta_1)\} = \frac{p}{\pi}(2\beta - \sin 2\beta \cos 2\alpha) \quad \text{Eq. (2)}$$

$$\sigma_z = \frac{p}{\pi}\{(\theta_2 - \theta_1) + \sin(\theta_2 - \theta_1)\cos(\theta_2 + \theta_1)\} = \frac{p}{\pi}(2\beta + \sin 2\beta \cos 2\alpha) \quad \text{Eq. (3)}$$

$$\tau_{xz} = \frac{p}{\pi}\sin(\theta_2 + \theta_1)\sin(\theta_2 - \theta_1) = \frac{p}{\pi}\sin 2\alpha \sin 2\beta \quad \text{Eq. (4)}$$

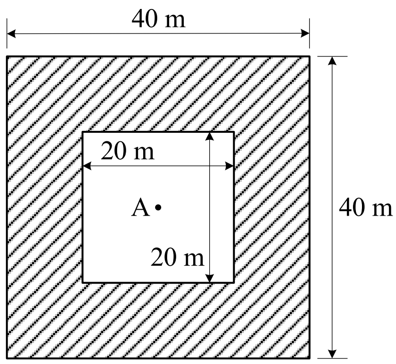

Fig. 1 Square-shaped building with a central courtyard

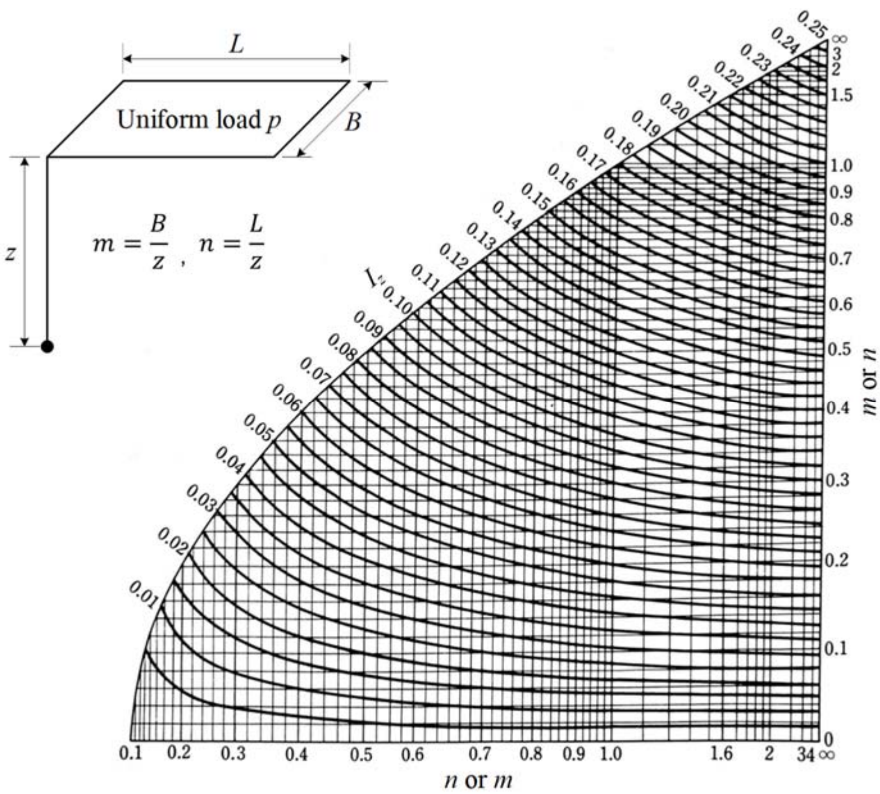

Fig. 2 Influence factor I_z

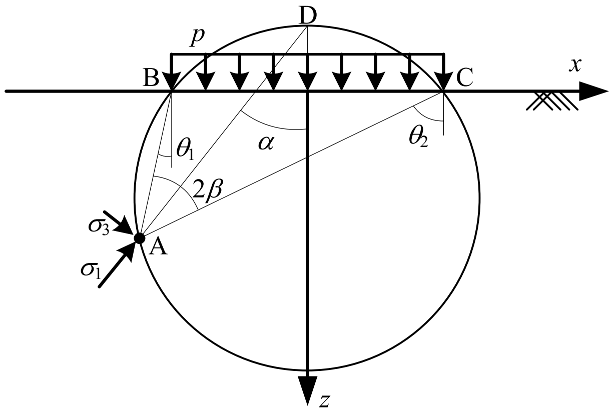

Fig. 3 A circumference having same magnitude of principal stresses

[Question 2] After completing an isotropic consolidation pressure to the mean effective stress p'_o, a consolidated undrained ($\overline{\text{CU}}$) triaxial compression test was conducted with constant confining pressure on a saturated normally consolidated clay (assuming cohesion $c' = 0$). Using experimental data of the two samples tested under the condition, the values of p'_o were 200 kN/m^2 (Test1) and 300 kN/m^2 (Test 2), the effective stress path in the p' - q plane shown in Fig. 4 was obtained. Herein, σ_1 is the major principal stress, σ_3 is the minor principal stress, σ'_1 is the major effective principal stress, σ'_3 is the minor effective principal stress and p_f is the mean total stress at failure.

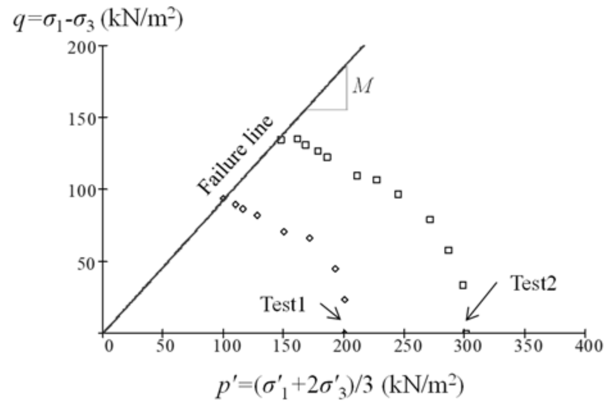

Fig. 4

Table 1 shows the results of the mean effective stress p'_f and the deviator stress q_f obtained at the time of failure in each specimen.

Table 1

Test	p'_o (kN/m^2)	p'_f (kN/m^2)	q_f (kN/m^2)
1	200	99	93
2	300	147	134

Assume that the material properties of the samples used for each test are the same. Answer the following questions.

(1) Calculate the pore water pressure at failure u_f in each test and find the average value of the Skempton's pore pressure coefficient at failure A_f.

(2) Based on the experimental result, find the average of the slope of the failure line (stress ratio at failure), M.

(3) Draw the effective stress Mohr's circle at failure for triaxial compression test and derive the relationship between the slope of the failure line M in the p'-q plane and the angle of internal friction ϕ', and then find the average ϕ' from the tests.

(4) Based on the above results, determine the average shear strength ratio (c_u / p'_o) from the undrained shear strength c_u of this saturated normally consolidated clay.

(5) Regarding the experimental result of the same sample subjected to the isotropic consolidation pressure p'_o = 400 kN/m^2 under the same condition of $\overline{\text{CU}}$ test, draw the relationship among the failure line, the effective stress path and the total stress path in the p - q plane ($q = \sigma_1 - \sigma_3$, $p = (\sigma_1 + 2\sigma_3) / 3$). Specify the estimated values of M, p'_o, p'_f, p_f, q_f and u_f in the figure.

[Question 3] Answer all the following questions

(1) Fig. 5 represents a retaining wall of height H. Let the frictional angle, the cohesion, and the unit weight of the soil behind the wall be ϕ, c, and γ, respectively. Draw a graphic showing the three types of representative earth pressure that act on the retaining wall, taking the displacement of the retaining wall (δ) along the horizontal axis and the earth pressure along the vertical axis. Refer to the figure for the direction of displacement of the retaining wall.

(2) Based on Coulomb's earth pressure theory, determine the earth pressure acting on the retaining wall when it moves towards the soil side (δ - direction). 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. Show the force polygon diagram using the forces that act on the soil wedge shown in the figure. Use appropriate symbols for the forces shown in the force polygon diagram and explain each of those forces. Assume that the ground water table lies far below the retaining wall.

(3) Based on Coulomb's earth pressure theory mentioned in (2), briefly explain the procedure of determining the earth pressure acting on the retaining wall when it moves towards the soil side (δ - direction).

(4) 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 rightward towards the soil (δ + direction). Also, show the earth pressure distribution along the height (H) of the retaining wall. For this, assume that the friction between the retaining wall and the soil behind is zero and that the ground water table lies far below the retaining wall.

(5) Explain the difference in the magnitudes of the active resultant earth pressure (resultant of the earth pressure and the water pressure) when the ground water table behind the retaining wall (i) lies at the bottom surface of the retaining wall and (ii) is rising up 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.

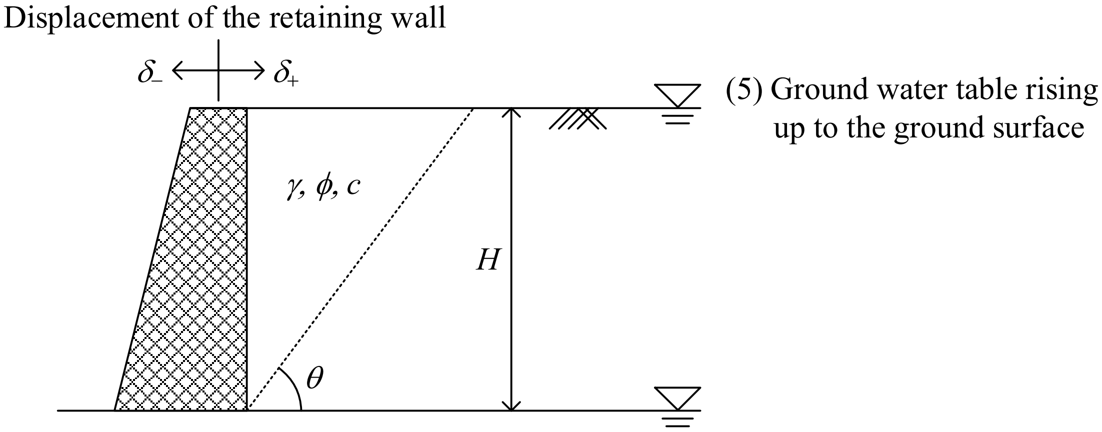

Fig. 5