# 2019 Soil Mechanics II and Exercises Midterm Exam

2019/6/5 (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) Terzaghi's one-dimensional consolidation equation is derived from the following four assumptions and conditions.

1. Effective stress-strain relationship of soil (constitutive model)
2. Constant total stress
3. Darcy's Law
4. Continuity equation of water (law of mass conservation)

Show the mathematical equations used to express the four listed assumptions and use them to derive Terzaghi's one-dimensional consolidation equation. Use the soil parameters indicated in Table 1.

Table 1

| | | | | | |
|---|---|---|---|---|---|
| $v$ | : Flow velocity of pore water | $k$ | : Hydraulic conductivity | $\gamma_w$ | : Unit weight of water |
| $u$ | : Excess pore water pressure | $\varepsilon$ | : Volumetric strain | $m_v$ | : Coefficient of volume change |
| $\sigma'$ | : Effective stress | $\sigma$ | : Total stress | $c_v$ | : Coefficient of consolidation |
| $t$ | : Time | $z$ | : Vertical coordinate | | |

(2) The vertical stress generated in an elastic ground by a trapezoidal strip load (Figure 1), such as a levee or a road embankment, is calculated by Osterberg according to the following equation.

$$\sigma_v = \frac{p}{\pi}\left[\frac{a+b}{a}(\theta_1+\theta_2) - \frac{b}{a}\theta_2\right] = I_z \cdot p$$

Figure 2 shows one such case, with a trapezoidal strip load acting on an elastic ground. Calculate the vertical stress increment in points A, B, and C. You may use the chart shown in Figure 3 to find the solution.

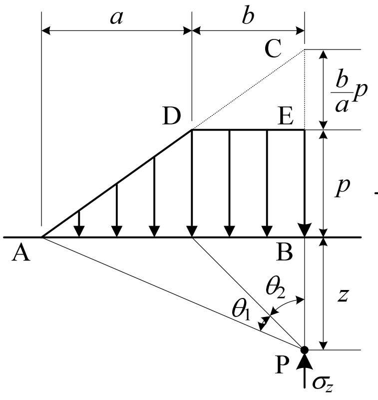


Figure 1

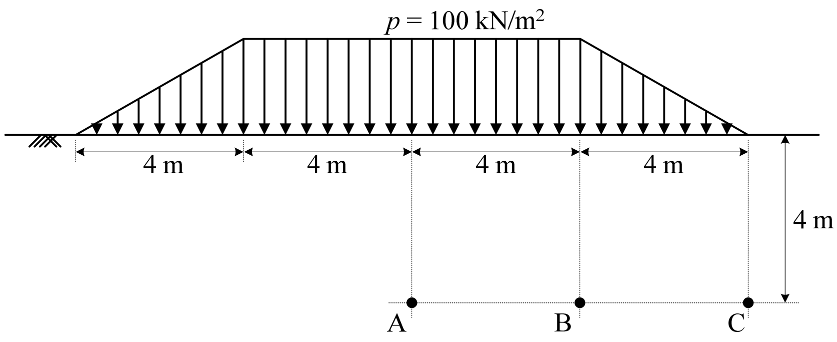


Figure 2

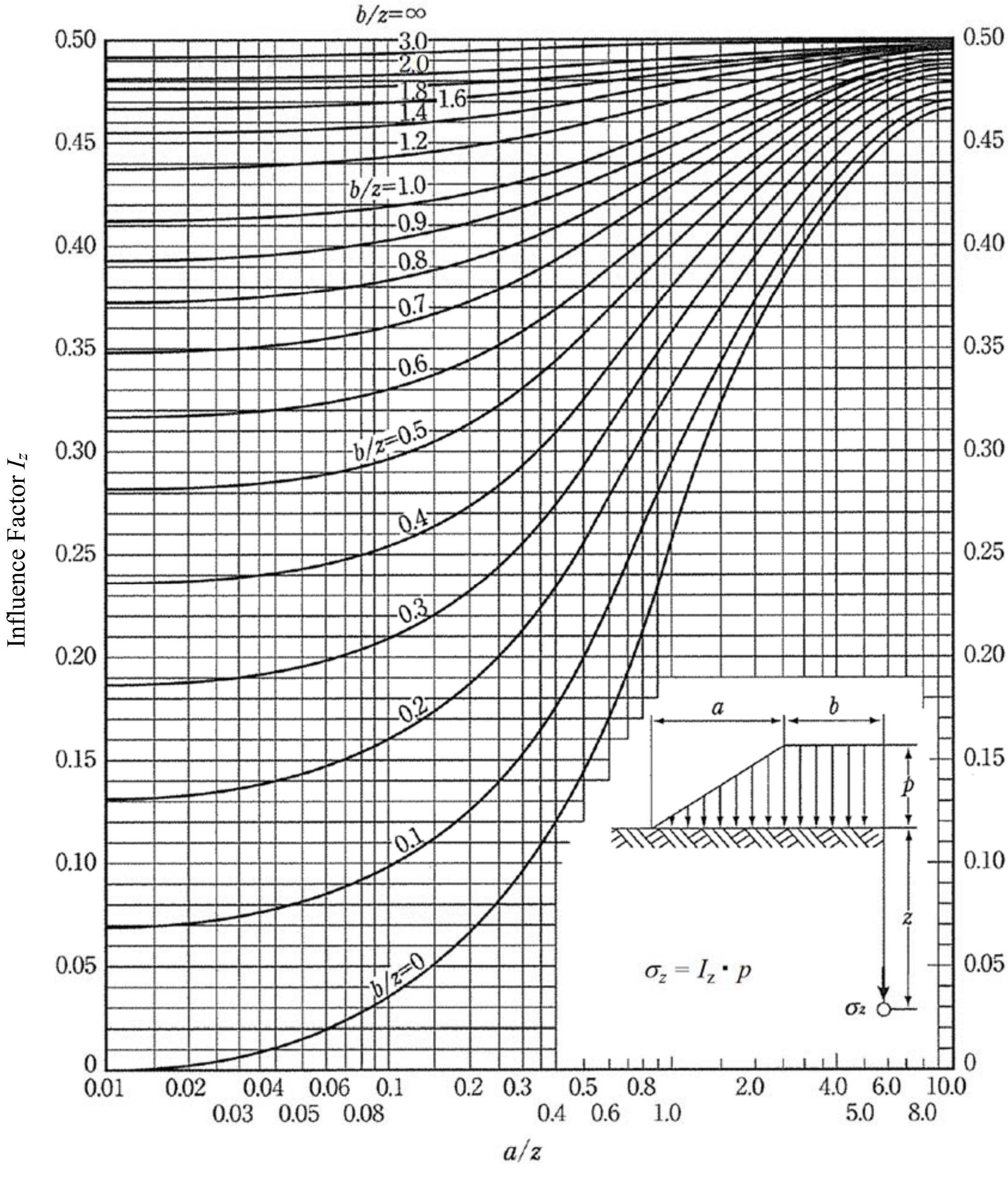


Figure 3

[Question 2] Answer the following questions regarding the theory of soil failure

(1) An unconfined compression test was conducted on a clayey soil sample collected from an in-situ location. Answer the following questions.

(a) At its original location, the overburden pressure on the sample was 100 kPa and its pore water pressure was 50 kPa. Describe how the pore water pressure changes when the sample is retrieved and taken to the ground surface. Assume that the void ratio does not change during this process.

(b) In order to avoid changes in the sample void ratio, a sample taken from an in-situ location is usually wax-sealed and stored undrained. Briefly, explain the reason why.

(2) Answer the following questions about the theory of soil failure and dilatancy.

(a) Explain Coulomb's failure criterion, Mohr's failure criterion, and Mohr-Coulomb's failure criterion. Use figures and formulas so that their differences become clear.

(b) When running a consolidated-drained triaxial test (CD test) and a consolidated-undrained triaxial test ($\overline{\text{CU}}$ test) on a normally consolidated clay under the same confining pressure $\sigma_3$, the deviator stress $q$ $(= \sigma_1 - \sigma_3)$ at failure is found to be larger in the CD test. Explain why, paying attention to dilatancy.

(c) Express the Mohr-Coulomb failure criterion as a mathematical relationship between cohesion $c'$ $(\neq 0)$, angle of internal friction $\phi'$, and principal effective stresses $\sigma_1'$ and $\sigma_3'$.

(3) A normally consolidated clay sample was first isotropically consolidated at 140 kPa, and then it was subject to an undrained triaxial compression test under constant confining pressure $\sigma_3$. As a result, the axial deviator stress $q$ $(= \sigma_1 - \sigma_3)$ at failure was 150 kPa. The failure stress ratio $M_f$ of this clay is 1.25. Here, the failure stress ratio $M_f$ is $q/p'$, where $p'$ is the mean effective stress ($p' = (\sigma_1' + 2\sigma_3')/3$).

(a) Calculate the increase of pore water pressure from before the triaxial compression to the time of failure (excess pore water pressure at the time of failure).

(b) Calculate the value of Skempton's pore pressure parameter at failure $A_f$.

(c) If cohesion $c' = 0$, obtain the angle of internal friction $\phi'$ of this clay.

(d) Plot the total stress path and the calculated effective stress path for this test on the $pq$ and $p'q$ planes, respectively. The values of $p$ $(= (\sigma_1 + 2\sigma_3)/3$, mean total stress), $p'$ (mean effective stress), and $q$ (deviator stress) right after the consolidation process and at failure at the end of the shearing process should be clearly shown.

[Question 3] Answer the following questions

Figure 4 shows the diagram of the section of a model test used to demonstrate a retaining wall rotating about its base. The rigid wall AC (width $b$ and height $h$) turning around hinges at point A, is located between a pair of vertical sides parallel to the section. The box is filled with cohesive soil of unit weight $\gamma$, friction angle $\phi$, and cohesion $c$ to a thickness $t$. The top center of the retaining wall is hooked by a strong cord CE, which runs horizontally and passes over the pulley D, and then runs vertically down to the dead weight given by a mass $m$. The wall can gently rotate either inwards or outwards upon the balance between the earth pressure and the tension of the cord. At the instant of soil yielding, there is an excessive movement of the wall when the dead weight undergoes the extreme values limited by active and passive earth pressure. Assuming that the results are not affected by the length $l$ of the rigid box, the mass of the wall, friction in the hinges as well as friction between the soil and the wall as well as the box, answer the following questions. The displacement of the wall until failure occurs is assumed to be sufficiently small and ignorable.

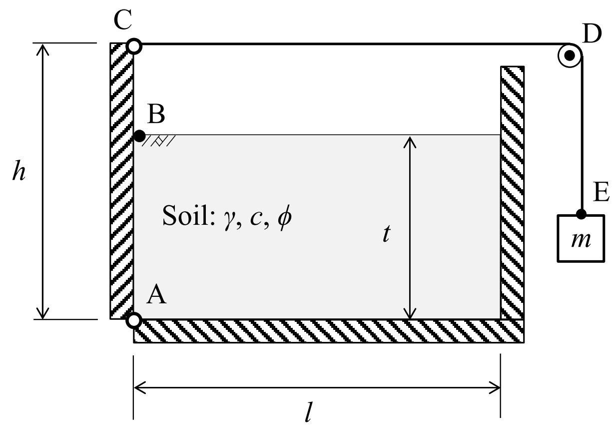


Figure 4 Model test of a rigid retaining wall

(1) According to Rankine's earth pressure theory, draw the active and passive earth pressure diagrams behind the retaining wall. Also show the expressions of the active and passive earth pressure at the top layer of the soil (point B) and point A, and indicate them in each diagram.

(2) It is common practice to ignore negative earth pressure (tensile stress) in the calculation of resultant force. In regard to (1), calculate the minimum and maximum mass $m$ that can stabilize the retaining wall, using the gravitational acceleration $g = 9.8$ m/s$^2$. Herein, $h = 0.30$ m, $t = 0.20$ m, $b = 0.25$ m, $\gamma = 12.5$ kN/m$^3$, $\phi = 34^\circ$ and $c = 0.2$ kPa.