

2019 Soil Mechanics II and Exercises Final Exam

July 24, 2019 (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.
- 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 is considered. Terzaghi's one dimensional consolidation equation is 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.

$$\frac{\partial u}{\partial t} = c_v \frac{\partial^2 u}{\partial z^2} \quad (1)$$

- (a) Write down the boundary condition for the upper surface of the clay layer (ground surface, $z = 0$).
- (b) Write down the boundary condition for the lower surface of the clay layer (in contact with the impermeable rock layer, $z = H$).
- (c) Assuming that the initial pore water pressure u_0 is constant regardless of depth, the solution of the consolidation equation is given by the following equation. Let the horizontal axis represent the excess pore water pressure u , and the vertical one be the depth z . Draw schematic diagrams of excess pore water pressure for the initial value, during consolidation and at the end of consolidation, respectively.

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

- (d) Sand drain is a soil improvement method for soft ground. Explain the change in consolidation behavior by using this method.

(2) A uniformly distributed load of q is acting on a rectangular foundation of dimensions $a \times b$ as shown in Figure 1.

(a) Assuming the ground as a linear elastic body, find the vertical stress at a depth of z just under the center of the foundation. The vertical stress σ_z at a depth of z under the corner of a rectangular ($a \times b$) distributed load q can be obtained by the following equation.

$$\sigma_z = qI_q(m, n) \quad m = \frac{a}{z} \quad n = \frac{b}{z} \quad (3)$$

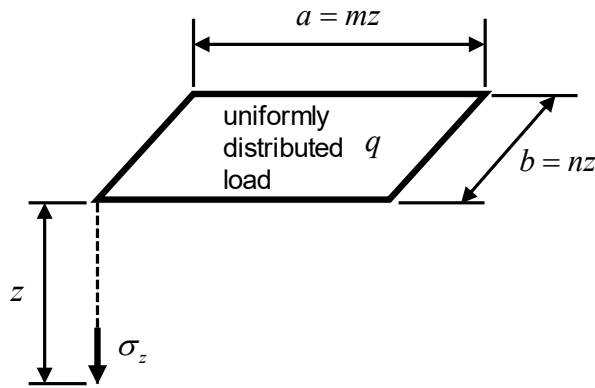


Figure 1

(b) Real soil ground is not elastic. Explain the reason why the solution given in (a) assuming that soil is a linear elastic body is useful for calculation of stress in soil ground.

[Question 2]

Answer the following questions regarding failure of soil.

- (1) Using Mohr's stress circle, derive the Mohr-Coulomb failure criterion in terms of the principal stresses.
- (2) Drained triaxial tests under constant confining pressure were carried out for two samples of the same sand that were prepared at different densities. Plot the relationship between volume change and axial strain for the loose and dense samples, respectively.
- (3) Briefly explain the following terminology.
 - 1) Skempton's pore pressure parameter
 - 2) Soil sensitivity ratio

[Question 3]

Answer the following questions based on the theory of retaining walls.

- (1) Using a X-Y figure, with horizontal displacement shown in the X axis and earth pressure in the Y axis, show the different behaviors between active and passive earth pressure acting on a retaining wall.
- (2) After applying for all corresponding permits with the local government, a neighborhood association built an artificial pond so the neighbors could enjoy swimming and sailing during the scorching summer months. If the unit weight of the reinforced concrete used to build the vertical retaining wall is $\gamma = 24 \text{ kN/m}^3$, calculate the factor of safety against overturning moment, for the chosen design, at point A. Assume that the friction on the bottom surface of the retaining wall prevents sliding. A smooth plastering was applied on the vertical wall to create an impermeable barrier against the filtration of water. Note that the water level of the pond does not reach the top of the retaining wall due to the installation of an overflow drainage system.

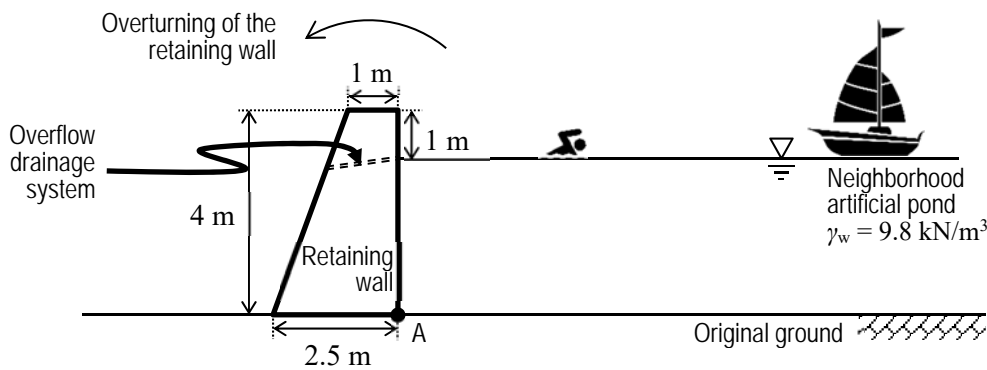


Figure 2

- (3) After several years of summer fun, and with the corresponding government licenses, the association filled the pond with a horizontal compacted cohesionless backfill so that new houses could be built on the newly developed area. Assume that the original smooth vertical surface of the retaining wall and the drainage system were kept the same, so that no friction occurs between the wall and the backfill, and the water table can only rise up to the original water level of the pond. Calculate the factor of safety against overturning moment around point A during both, (i) dry and (ii) rainy seasons. For dry season, assume that the water table drops far below the base of the wall.

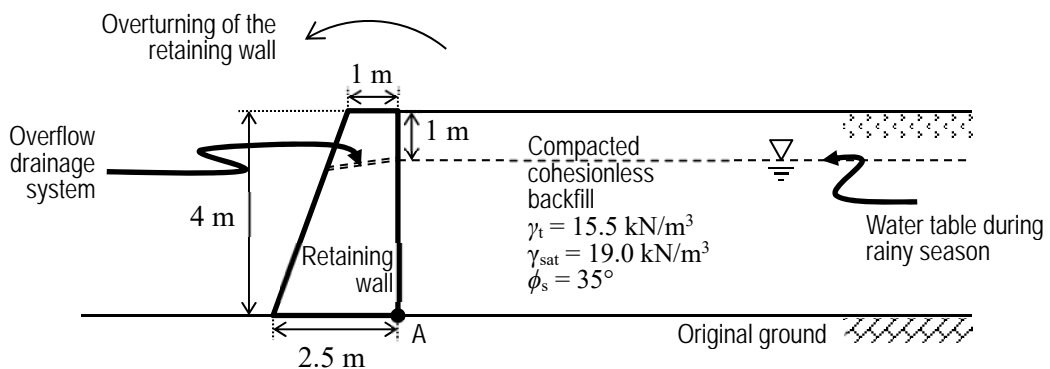


Figure 3

[Question 4]

Answer the following questions.

(1) Explain the following two concepts about pile foundations, using figures if necessary.

- 1) Bearing mechanism of pile foundations
- 2) Negative friction

(2) The ultimate bearing capacity of strip foundations q_u proposed by Terzaghi can be given by the following equation using the bearing capacity factors N_c , N_γ , and N_q :

$$q_u = cN_c + \frac{1}{2}\gamma B N_\gamma + \gamma D_f N_q$$

where c is the cohesion, γ is the unit weight, B is the width of the foundation and D_f is the embedded length of the foundation.

- 1) Draw the failure slip lines and explain the failure mechanism used by Terzaghi to derive the ultimate bearing capacity.
- 2) Derive allowable bearing capacity q_a considering the safety factor F_s .

(3) A strip foundation is installed in the two-layer base ground shown in Figure 4. The ground water table is located at a depth h_w from the ground surface.

- 1) Describe the ultimate bearing capacity of this foundation using the bearing capacity factors N_c , N_γ , and N_q , and the parameters listed in the table. The unit weight of water is γ_w .
- 2) Select the parameters needed to calculate the bearing capacity factors N_c , N_γ , and N_q from the following table.

Table				
	Bulk unit weight	Saturated unit weight	Cohesion	Internal friction angle
Soil layer 1	$\gamma_t^{(1)}$	$\gamma_{sat}^{(1)}$	$c^{(1)}$	$\phi^{(1)}$
Soil layer 2	$\gamma_t^{(2)}$	$\gamma_{sat}^{(2)}$	$c^{(2)}$	$\phi^{(2)}$

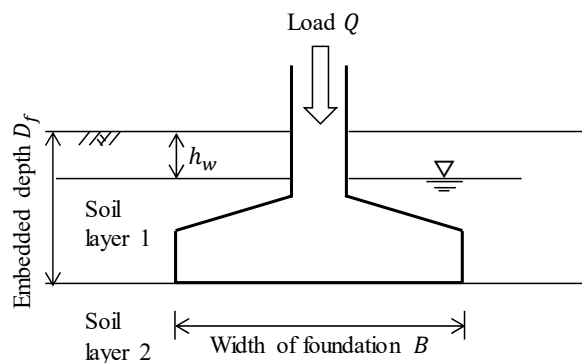


Figure. 4

[Question 5]

Answer the following questions.

(1) Answer the following questions about slope stability using the method of slices. Assume that the water table is located deep enough and does not affect the slope stability.

1) According to the Fellenius method of stability analysis, a sliding soil mass is divided into n slices as shown in Figure 5. For any i^{th} slice counted from the left of a circular arc with radius R and center at point O , let the angle of internal friction be ϕ_i , the cohesion be c_i , the length of the base be L_i , the angle of inclination be θ_i . Also, the weight of slide is W_i , the horizontal forces acting on the right and left sides of the slice are H_i and H_{i+1} , the vertical forces acting on the right and left sides of the slice are V_i and V_{i+1} , respectively. Along the base of slide, N_i denotes the normal force and S_i denotes the shearing force.

In the Fellenius method, the factor of safety F_s for the soil mass against sliding along the circular slip surface is derived as follows by assuming the forces acting on the both sides of the slice are in equilibrium (the resultant forces acting on the left and right sides of the slice are parallel to the sliding plane)

$$F_s = \frac{\sum_{i=1}^n (c_i L_i + W_i \cos \theta_i \tan \phi_i)}{\sum_{i=1}^n W_i \sin \theta_i} \quad \text{Eq. (1)}$$

Derive Eq. (1) and show the following three equations.

- a) Equilibrium equation of force in the direction perpendicular to the base of the i^{th} slice
- b) Equation of failure criterion (sliding condition) of the i^{th} slice
- c) Equation of equilibrium for which the balance of moments on the whole sliding soil mass about point O

2) Consider the slope stability during an earthquake using the seismic coefficient method. In this method, the ground is assumed to be a rigid body, and the inertial force which is calculated by the acceleration acting on the ground multiplied by the mass of ground is considered in the static balance equation. Here, only horizontal earthquake motion is considered because the influence of vertical motion is negligible. Let the acceleration of gravity, the acceleration acting on the ground, the horizontal seismic coefficient be g , α , and $k_h (= \alpha/g)$, respectively. When the horizontal seismic force $k_h \cdot W_i$ acts on the i^{th} slice, show the factor of safety F_s for the soil mass against sliding along the circular slip surface.

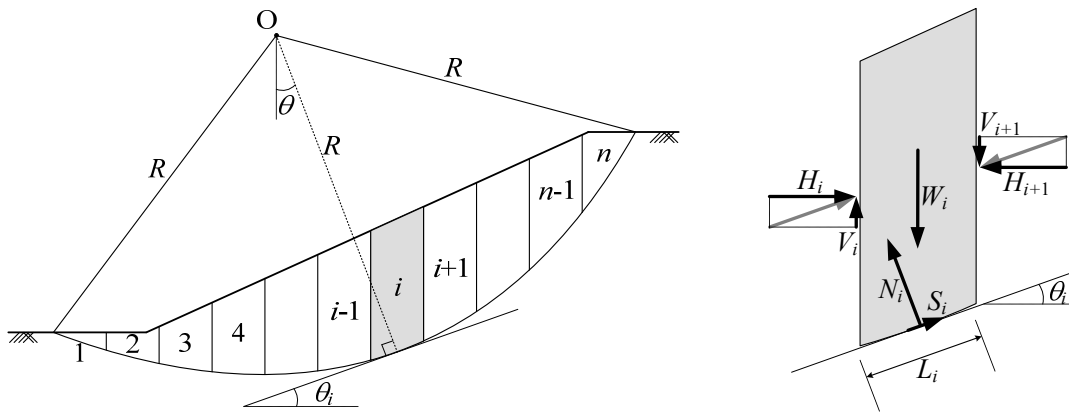


Figure 5

- (2) Answer the following questions about soil liquefaction.
- 1) Explain the mechanism of soil liquefaction at the time of earthquake in the context of the dilatancy of soils. If necessary, you may explain using a figure.
 - 2) Explain the following terms about soil liquefaction. If necessary, you may explain using a figure.
 - a) Liquefaction strength curve
 - b) Factor of safety against liquefaction