2020 Soil Mechanics II and Exercises Final Exam

2020/7/29 (Wed.) Test time 10:00-12:00, Submission time via PandA 12:15

Attention:

- The exam consists of five questions. Separate answer sheet for each major question. Write your name and the question number on all pages. You may answer a major question over multiple answer sheets but do not answer multiple major questions on the same answer sheet.
- Stop writing the answer at 12:00 and submit the answer sheet via PandA by 12:15.
- 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]

A road embankment passing through a homogeneous and uniform 8-m-thick layer of normally consolidated clay underlain by a very stiff layer of sand as shown in Figure 1 is considered. The bulk unit weight of embankment γ_t is 15.8 kN/m^3 and the saturated unit weight of clay γ_{sat} is 18.3 kN/m^3. For the clay layer, the initial void ratio e_o is 0.9, the compression index C_c is 0.2, the coefficient of consolidation c_v is 0.02 m^2/day. Groundwater is at the surface of clay and the pore water is drained on the upper and lower boundaries of the clay layer. The unit weight of water γ_w is 9.8 kN/m^3.

Two stages of embankment construction are proposed. First, the clay layer is preloaded by constructing the embankment of height H_1 = 4.0 m, bottom width W = 20.0 m and embankment slope of 1:2. The embankment remains on the clay layer over a number of days Δt to drain the excess pore water and to cause the consolidation settlement S_2 where $S_2 < S_1$ where S_1 represents the final consolidation settlement of the clay layer due to the embankment of height H_1 as depicted in Figure 2. Next, the part of the embankment regarded as preload is removed; therefore the height of the road embankment becomes H_2 = 2.0 m with the same bottom width and embankment slope.

Assume that stress state at the middle of the layer can be used as the representative stress state of the clay layer. Let the stress increase in the clay layer due to the embankment loading follow the elastic solution of the vertical stress in ground beneath the center of an embankment. Ignore immediate settlement, deformation of embankment and ground rebound after removal of preload. Construction and removal periods of embankment are not accounted for calculation. In order to obtain the solutions, Table 1 and Figure 3 may be used. Provided that the clay layer is deformed only by one-dimensional consolidation, answer the following questions.

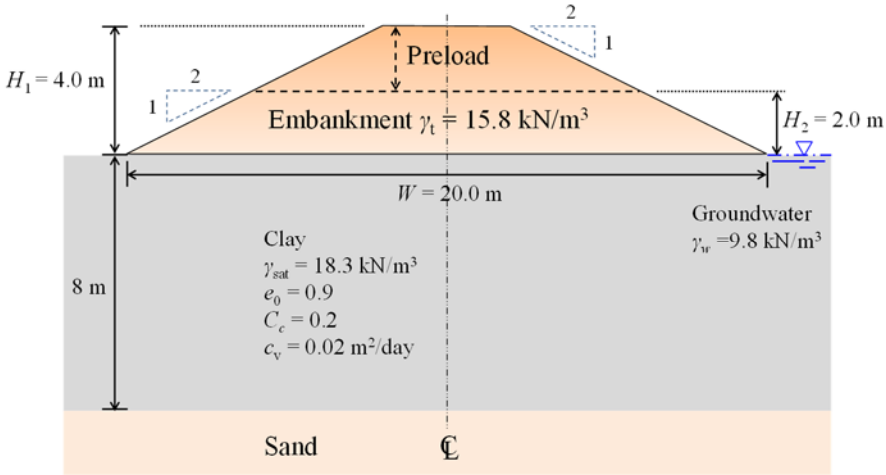

Figure 1: Ground profile and outline of embankment

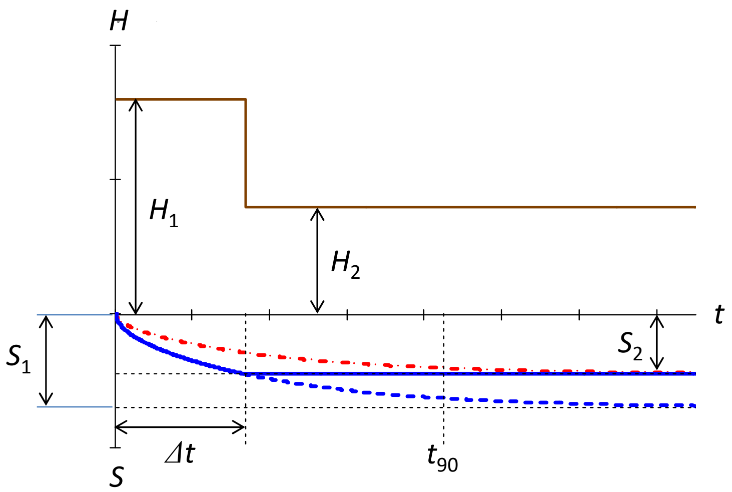

Figure 2: Effects of preload (H_1-H_2) on consolidation time (t) and consolidation settlement (S)

(1) Calculate the effective vertical stress σ'_{zo} at the middle depth of the clay layer before the construction of embankment.

(2) Estimate the vertical stress increase $\Delta\sigma_1$ applied at the middle depth of the clay layer beneath the center of the embankment of height H_1.

(3) Find the final settlement S_1 induced by $\Delta\sigma_1$ using σ'_{zo} at the middle depth of the clay layer.

(4) Estimate the vertical stress increase $\Delta\sigma_2$ applied at the middle depth of the clay layer beneath the center of the embankment of height H_2.

(5) Find the final settlement S_2 induced by $\Delta\sigma_2$ using σ'_{zo} at the middle depth of the clay layer.

(6) Determine the number of days (t_{90}) when the clay layer reaches an average of 90% degree of consolidation.

(7) In order to allow the embankment of height H_1 to settle to S_2 by consolidation, how many days (Δt) is required to hold the embankment before the removal of preload?

(8) Explain the benefits and limitations of preloading method.

Table 1: Relation between average degree of consolidation U and time factor T_v

U (%)	T_v	U (%)	T_v	U (%)	T_v	U (%)	T_v
0	0.000	25	0.049	50	0.197	75	0.477
5	0.002	30	0.071	55	0.239	80	0.567
10	0.008	35	0.096	60	0.286	85	0.684
15	0.018	40	0.126	65	0.340	90	0.848
20	0.031	45	0.159	70	0.403	95	1.129
						100	∞

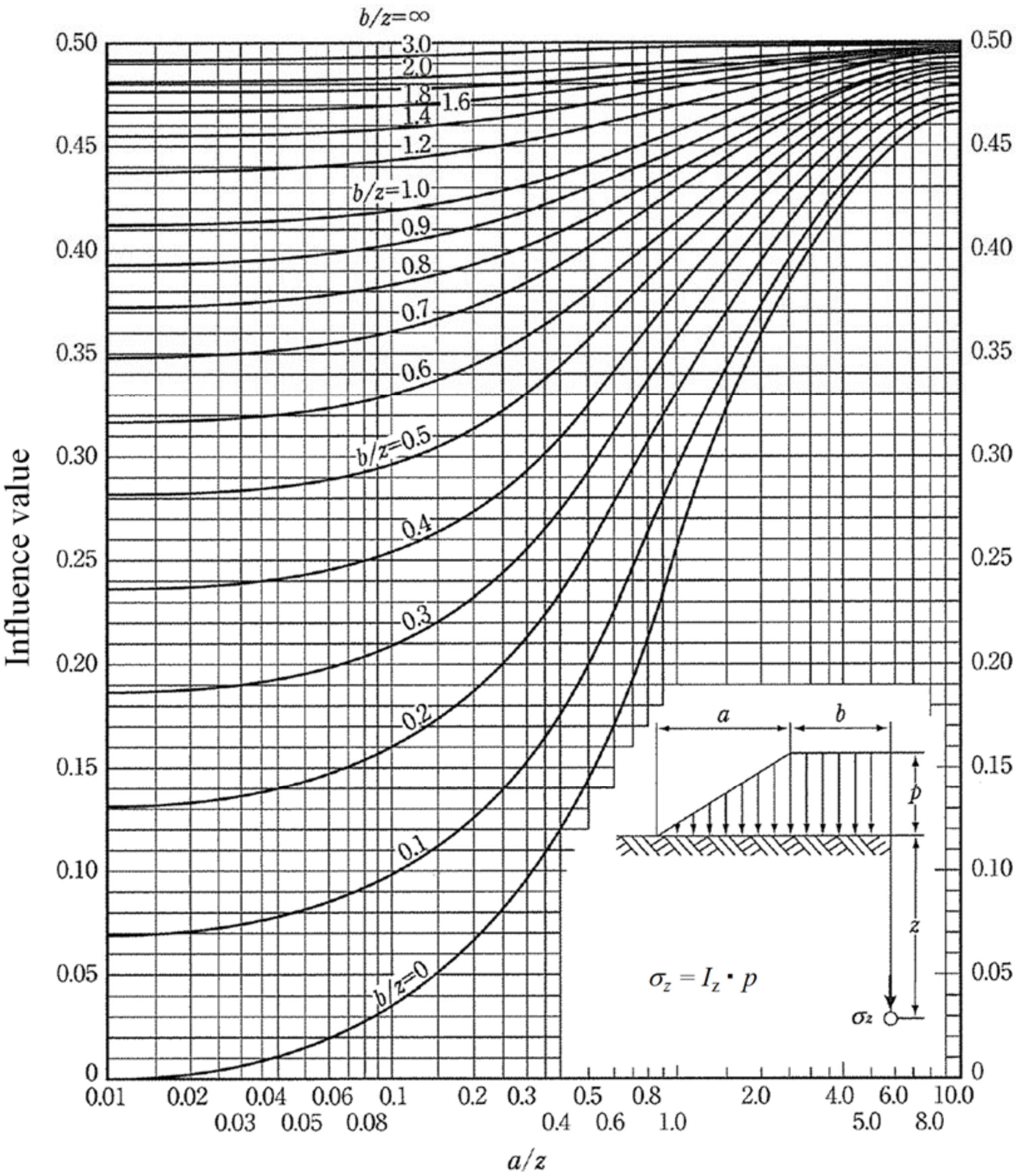

Figure 3: Influence value for vertical stress determination in ground due to a half-width embankment loading

[Question 2]

(1) It is difficult to walk over water, but can walk the top of the soil. Explain this reason.

(2) For soil and steel, explain the difference in volume change when they receive any external force.

[Question 3]

As shown in the Figure 4, an earth retaining wall is installed on the ground composed of a clay layer and a sand layer. It is planned to excavate the ground on the left side of the earth retaining wall up to 5 m in depth. The water table at the end of excavation is located at the top of the clay layer.

It is assumed that there is no frictional force between the earth retaining wall and the ground. The clay layer is considered to be failed in the undrained condition because the construction period is short. The unit weight of water is assumed to be 10 kN/m^3 for simplicity.

(1) Cohesion of the sand layer c and the internal friction angle ϕ are 0 kN/m^2 and 30°, respectively. Find the coefficient of active earth pressure of the sand layer.

(2) Undrained shear strength of the clay layer c_u is 35 kN/m^2 regardless of depth. Vertical effective stress σ'_v applying at the point of the clay layer is 90 kN/m^2. Draw two Mohr's stress circles corresponding to the active and passive failure states of the clay. Indicate the stress values at the intersection of the Mohr's stress circle and the axis of the diagram.

(3) Draw the lateral pressure profile per unit width through the depth (sum of water pressure and soil pressure) acting on the back side of the retaining wall (right side of the retaining wall in the figure) at which the active failure state is reached. In addition, find the resultant force of the lateral pressure per unit width and indicate the position of resultant force measured from the bottom of the earth retaining wall.

(4) Draw the lateral pressure profile per unit width through the depth (sum of water pressure and soil pressure) acting on the front side of the retaining wall (left side of the retaining wall in the figure) at which the passive failure state is reached. In addition, find the resultant force of the lateral pressure per unit width and indicate the position of resultant force measured from the bottom of the earth retaining wall.

(5) Investigate the stability of the retaining wall, considering the bottom of the retaining wall as the center of rotation.

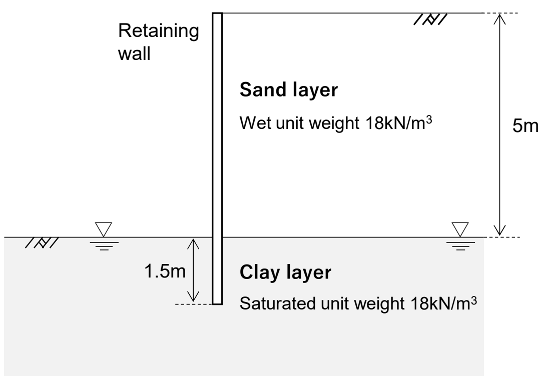

Figure 4

[Question 4]

(1) Figure 5 shows a cross-sectional view of the right half of the symmetry plane of the strip foundation. The ultimate bearing capacity of the 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. Note that γ is the unit weight, c is the cohesion, B is the width of the foundation and D_f is the embedded depth of the foundation.

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

1) Draw the failure slip lines assumed by Terzaghi to derive the ultimate bearing capacity. First, draw the Figure 5 (no symbol is required) on your answer sheet, then draw the failure slip lines there. Also, indicate the angles between the slip lines and the ground surface.
2) Add the directions of slip on the slip lines in the figure shown in 1)
3) Each bearing coefficient is a function of the internal friction angle ϕ. Explain the reason.
4) Explain the reason why the bearing capacity coefficients of other bearing capacity formulas are different from that of Terzaghi.
5) Let the safety factor be F and derive the allowable bearing capacity q_a. In the derivation process, not only formulate equations, but also state its assumptions.
6) In Figure 5, the groundwater level is much lower than the foundation base. Suppose that the groundwater level gradually rises and reaches the ground surface. Explain how the ultimate bearing capacity changes during this process, provided that the cohesion c and internal friction angle ϕ do not change.

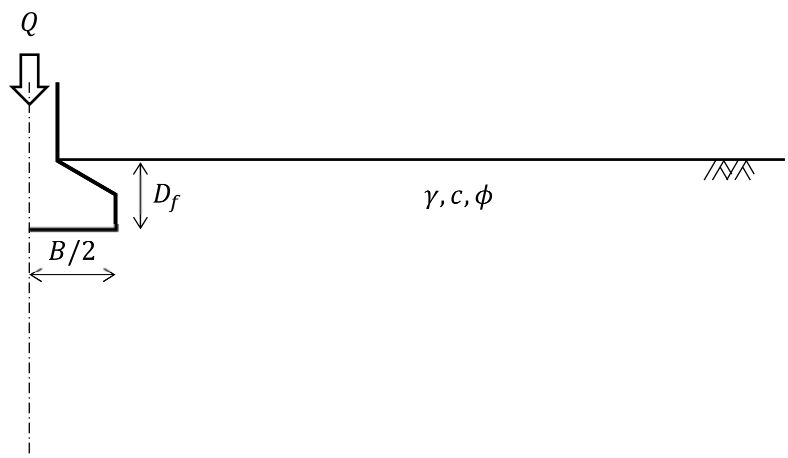

Figure 5

(2) Ultimate bearing capacity for local shear failure is usually smaller than that for general shear failure. Explain the reason.

(3) Describe the principle of countermeasures against negative friction of pile foundation.

[Question 5]

(1) Answer the following questions regarding the slope stability.

Figure 6 shows an infinite slope. Consider a sliding surface at depth H_f as shown in Figure 6 that is parallel to the slope surface. From the balance of the forces acting on the soil area abcd between the ground surface and the sliding surface, find the safety factor, F for the sliding failure under the conditions 1) to 3) shown below. Derivation processes of the safety factor must be described. Here, N and S are the normal and tangential forces acting on the base of the area abcd, respectively. Neglect the balanced forces, E acting on the right and left sides of this area abcd.

1) Assume that the groundwater table is well below the sliding surface (Figure 6 (a)). If the shear strength acting on the sliding surface is governed by the Mohr-Coulomb fracture criterion ($\tau = c + \sigma \tan\phi$), then find the safety factor, F for the assumed failure.
2) Due to the rainfall, the groundwater table rose and reached the ground surface (Figure 6 (a)). If the seepage flow exists and it flows parallel to the slope surface, find the safety factor, F. Here, the effective shear strength, τ of the soil is $\tau = c' + \sigma' \tan\phi'$.
3) The area including the slope was selected for the dam construction site, and the slope was submerged in the dam lake (Figure 6 (c)). The water surface of the dam lake is at a very high level so that there is no water flow in the dam lake, and the difference in water pressures acting on the left and right sides of the region abcd is negligible. Find the safety factor, F. Then, mention how the slope stability changes in the presence of the seepage flow and in the hydrostatic condition by comparing the results of 2) and 3), assuming that the cohesion $c' = 0$.

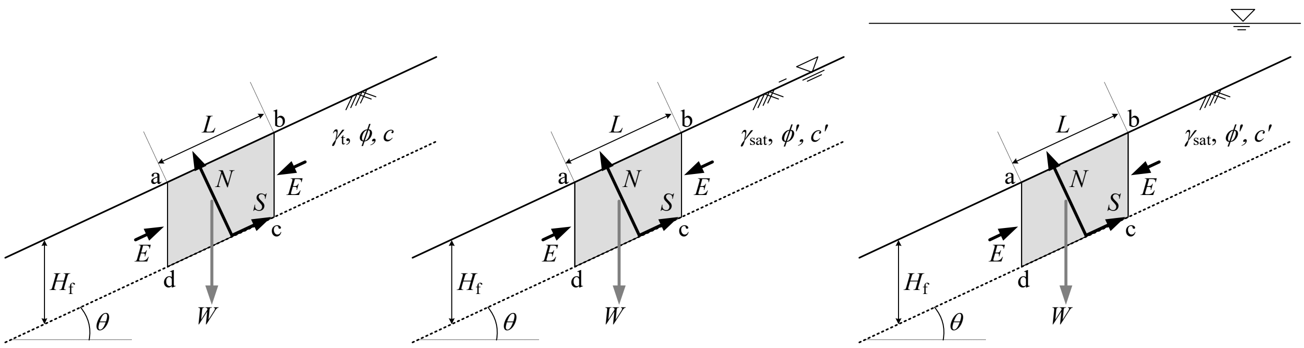

Figure 6 (a) Figure 6 (b) Figure 6 (c)

(2) Answer the following questions regarding the wave propagation and liquefaction.

1) As a laboratory test for examining the liquefaction strength of the ground, the cyclic triaxial test under undrained conditions is often used. How the stress ratio under this experimental condition is expressed by cyclic loads for which an axial stress σ_d is repeatedly applied to an isotropic stress state subjected to a confining pressure σ_3? In addition, explain what kind of plane would the shear forces produced during earthquakes be reproduced in this experiment by using Mohr's stress circles.
2) Explain about the cyclic mobility of soil
3) It is well known that the liquefaction of ground occur easily in loosely deposited sandy ground. Explain reasons why liquefaction is less likely to occur in (1) clay ground and (2) gravel ground.