2019 Soil Mechanics I and Exercises Final Exam

January 28, 2020 (Tue.) 13:00-15:00 Kyotsu (Joint) 2 Lecture room

Attention:

- **This exam consists of four questions for which you are provided with four 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 (for example, "continues on the back").**
- **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 the following questions.

(1) An embankment was constructed from the soil excavated from an excavation site. After completion, the total volume of this embankment is 50,000 m^3. The soil taken from the excavation site was investigated under its natural conditions and the following results were obtained:

Bulk density: 1.80 t/m^3 (g/cm^3) Water content: 13.0 % Specific gravity of soil grains: 2.70

In addition, the following results were obtained from the compaction tests conducted for the excavated soil:

Maximum dry density：1.90 t/m^3 (g/cm^3) Optimum water content: 15.0 %

From the results of the compaction tests, water is sprayed to reach the optimum water content condition and the dry density of the embankment is set to be 90.0 % of the maximum dry density (i.e., degree of compaction = 90.0%) during the construction of the embankment.

Answer the following questions considering the density of water as 1.00 t/m^3 (g/cm^3).

1) Calculate the void ratio, degree of saturation, and dry density of the soil at the excavation site in its natural condition.

2) Calculate the mass and volume and of the soil to be excavated from the excavation site in its natural condition.

3) Calculate the mass of water necessary to be sprayed on 1 m^3 of soil in natural condition at the excavation site.

4) Calculate the degree of saturation of the embankment after the completion of compaction.

(2) Briefly explain the following terms using the figures.

1) Particle size distribution curve

2) Plasticity chart

3) Compaction curve

[Question 2] Answer the following questions on the water flow in saturated soils. Assume that the water flow is governed by Darcy's law and steady state condition is established for all cases below.

(1) Determine the flow rate, Q_1, when the constant head permeability test is conducted on Soil 1 as shown in Figure 1. The hydraulic conductivity of Soil 1, $k_1 = 3.0\times10^{-4}$ m/s, was obtained prior to this permeability test. The cross-sectional area of the specimen is 1.0×10^{-2} m^2, and the specimen is supported by mesh at the bottom.

(2) Plot the variations of total, potential and pressure heads along the horizontal axis of a graph and label the vertical axis with elevations, under the constant-flow condition shown in Question (1). Assume that the bottom level of Soil 1 is the datum.

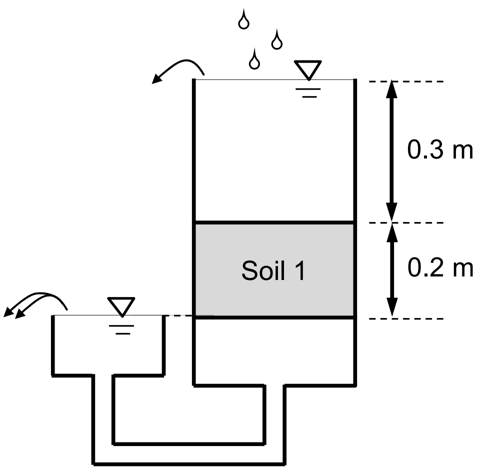

Figure 1

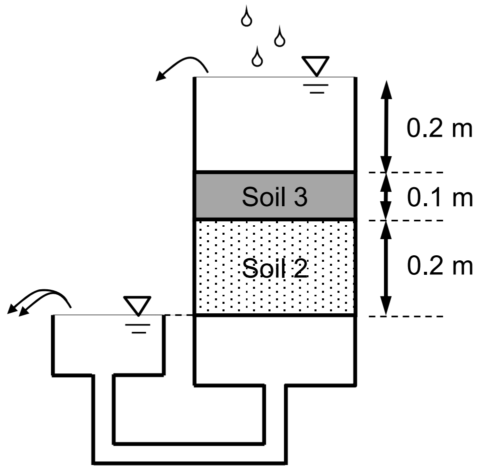

Figure 2

A second constant head permeability test, with Soil 2 and Soil 3 placed as shown in Figure 2 using the same permeameter, gives the flow rate, Q_2, which is found to be equal to the flow rate, Q_1, shown in Question (1). The hydraulic conductivity of Soil 2, k_2, is known, ($k_2 = 6.0\times10^{-4}$ m/s), while the hydraulic conductivity of Soil 3, k_3, is unknown. The cross-sectional area of the specimen is 1.0×10^{-2} m^2.

(3) Determine the equivalent hydraulic conductivity in the vertical direction, k_V, when Soil 2 and Soil 3 shown in Figure 2 are regarded as one unit layer.

(4) Determine the hydraulic conductivity of Soil 3, k_3.

(5) Determine the pressure head at the boundary between Soil 2 and Soil 3.

[Question 3] Answer the following questions.

Figure 3 shows the cross-section of a ground consisting of an impermeable rock mass overlain by a clay layer and a sand layer, where the groundwater table is located at 3 m below the surface. The thickness of the sand layer and the clay layer are 6 m and 10 m, respectively. Take the z-axis along the vertical depth for one-dimensional problem. The distribution of total stress σ at a depth z ($3 \leq z \leq 6$) in the sand layer is given as

Sand layer : $\sigma = \boxed{\text{(a)}}\ z + \boxed{\text{(b)}}$ $\qquad (3 \leq z \leq 6)$

and the total stress σ due to the overlying layers in the clay layer becomes,

Clay layer : $\sigma = \boxed{\text{(c)}}\ z + \boxed{\text{(d)}}$ $\qquad (6 \leq z \leq 16)$

As the pore water pressure distribution, u, follows a $\boxed{\text{(e)}}$ relationship, it can be expressed as

Pore water pressure : $u = \boxed{\text{(f)}}\ z + \boxed{\text{(g)}}$ $\qquad (3 \leq z \leq 16)$

Therefore, the effective stress σ' of each soil layer can be obtained as follows.

Sand layer : $\sigma' = \boxed{\text{(h)}}\ z + \boxed{\text{(i)}}$ $\qquad (3 \leq z \leq 6)$

Clay layer : $\sigma' = \boxed{\text{(j)}}\ z + \boxed{\text{(k)}}$ $\qquad (6 \leq z \leq 16)$

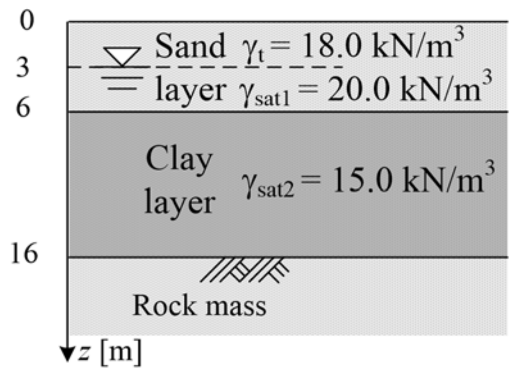

Figure 3

Assuming that a 4-m high embankment with a total unit weight of soil $\gamma_t = 18.0$ kN/m^3 is constructed instantaneously on this ground, answer the following questions.

(1) In the above sentences, fill in the blanks $\boxed{\text{(a)}}$ ～ $\boxed{\text{(k)}}$ using γ_t, γ_{sat1}, γ_{sat2}, γ_w while describing $\boxed{\text{(e)}}$ using suitable terms.

(2) Using $\gamma_{sat1} = 20.0$ kN/m^3, $\gamma_{sat2} = 15.0$ kN/m^3, $\gamma_w = 9.81$ kN/m^3, find the distributions of effective stress in terms of z in both sand and clay layers at the time immediately after construction of the embankment.

(3) Using the conditions described in (2), show the profiles of total stress, pore water pressure, and effective stress distribution from the ground surface to the rock mass ($0 \leq z \leq 16$) when sufficient time has elapsed (consolidation is completed) after embankment construction. In the profiles, indicate the values of total stress, pore water pressure, and effective stress at the ground surface and at the boundary between the sand and clay layers, as well as between the clay layer and the rock mass.

(4) The coefficient of consolidation, C_v, of the clay layer is obtained to be 1.55×10^{-3} cm^2/s. Using Table 1, estimate the degree of consolidation of this clay layer after 1 year of the construction of the embankment without taking into account the construction process.

Table 1 The degree of consolidation and time factor, T_v, relation

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	∞

(5) Before construction of the embankment, oedometer tests on sampling clay were carried out. Then, the following results were obtained: the consolidation yield stress p_c is 1.40×10^2 kN/m^2, the compression index C_c is 2.00×10^{-1} and the swelling index C_s is 2.00×10^{-2}, respectively. When sufficient time has elapsed (consolidation is completed) after embankment construction, calculate the amount of consolidation settlement of the clay layer. Here, before embankment construction, the initial void ratio of the clay layer is 0.80 regardless of the depth.

[Question 4] Answer the following questions.

(1) A consolidated drained triaxial compression test was conducted on the silty soil specimen under the condition of the constant confining pressure, σ_3 = 100 kN/m^2 after an isotropic consolidation. When the axial stress reached σ_1 = 500 kN/m^2, a failure occurred with a 60° failure surface measured counterclockwise from the maximum principal stress plane as shown in Fig. 4. Answer the following questions.

1) Draw the Mohr's stress circle at failure and find the normal stress, σ_f and shear stress, τ_f acting on the failure surface.

2) Assuming the Mohr-Coulomb's failure criterion holds for a failure of the soil, find the cohesion, c' and the angle of shear resistance, ϕ' of this silty soil. (A failure line should be drawn in the figure for question (1) together with c' and ϕ').

3) Obtain the maximum stress, τ_{max} and the maximum stress plane (the angle measured from the maximum principal stress plane) of this silty soil.

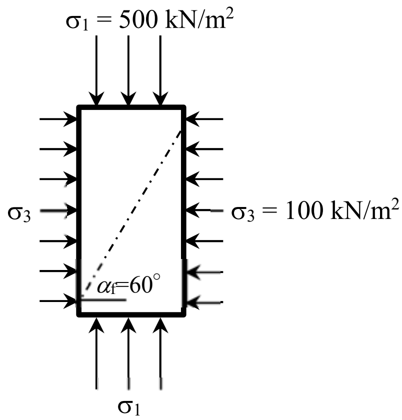

Figure 4

(2) Explain the following terms. (You may use schematic figures.)

1) Dilatancy

2) Sensitivity