2017 Soil Mechanics I and Exercises Final Exam

2018/1/30 (Tue.) 13:00-15:00 Kyotsu 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 space provided in any answer sheet is insufficient, use the back of the page after clearly mentioning so (for example, "continues on the back").
- In addition to personal writing instruments, rulers and non-programmable calculators are permitted, but programmable calculators and all types of mobile phones are prohibited. Any attempts 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) In constructing highway embankments, the test embankment shown in the figure below is built using soil excavated from a collecting site. The test embankment requires compacted soil with a dry density ρ_d = 1.8 g/cm^3. The rectangular planes forming the base and the top of the embankment are flat, horizontal, and have dimensions of A = 16.0 m, B = 20.0 m, and a = 4.0 m, b = 8.0 m, respectively. The height of the embankment is h = 3.0 m. The soil in the collecting site has soil particle density ρ_s = 2.7 g/cm^3 (specific gravity of soil particles G_s = 2.7), water content w = 15%, and bulk density ρ_t = 2.0 g/cm^3. Under these conditions, obtain the following values, assuming unit weight of water ρ_w = 1.0 g/cm^3.

1) Dry density of the soil in the collecting site
2) Void ratio of the soil in the test embankment
3) Degree of saturation of the soil in the test embankment
4) Dry mass of the test embankment
5) Total mass of soil taken from the collecting site

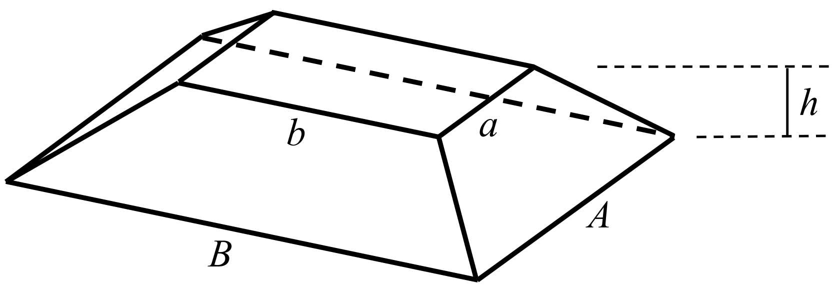

Figure 1

(2) Explain the following technical terms defined in soil mechanics

1) Optimum water content
2) Consistency

[Question 2]

Figure 2 (not to scale) represents the cross section of an infinite sloped ground, showing a permeable sand layer with a density of 1730 kg/m^3 and a hydraulic conductivity of 5.3×10^{-5} m/s overlaying an impermeable rock layer.

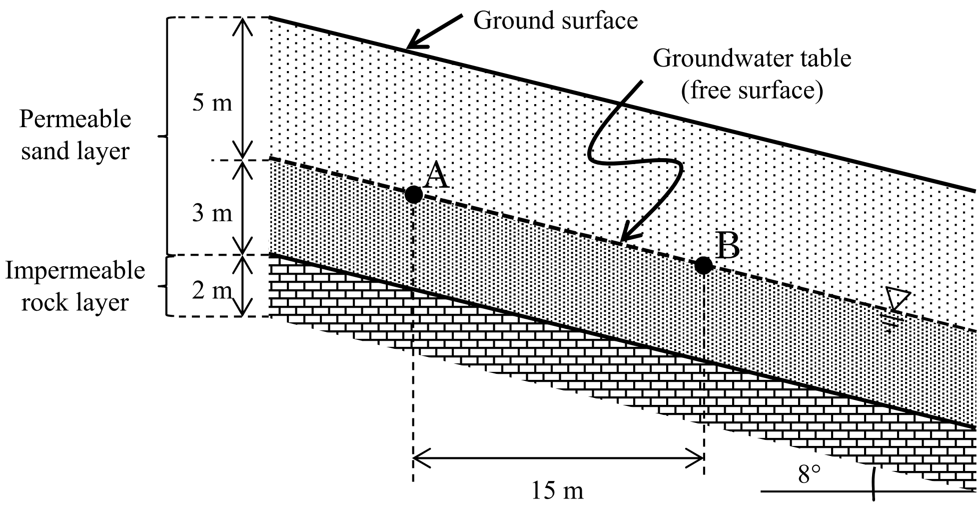

Figure 2 Cross section of the studied sloped ground

(1) Draw a rough flow-net of the water seepage through this system.

(2) Points A and B are located on the groundwater table and separated 15 m horizontally. Calculate the head difference between these two points.

(3) Calculate the flow rate through the permeable soil per day, per unit of width in a section perpendicular to the figure.

(4) Some weeks after finishing your analysis, it was found that the total flow rate was not the one calculated in (3), but just 1.20 m^3/day (per unit of width in a section perpendicular to the figure), instead. Because of this, you were asked to drill some vertical boreholes to analyze the sand layer, and it was only then that you found that the previously thought as a single sand layer was actually composed of two parallel sand layers. Both layers have the same dip (8°) as that of the impermeable rock layer and the ground surface, but the top sand layer (the one closest to the ground surface) is three times thicker than the bottom one (i.e., you found in your vertical borehole that the top layer continued down to a depth of 6 m, while the bottom one continued for the remaining 2 m). You immediately realized that the hydraulic conductivity originally reported (5.3×10^{-5} m/s) corresponded only to the top layer.

If the groundwater table depth is the same as that shown in Figure 2, calculate the hydraulic conductivity of the bottom sand layer (the one closest to the impermeable rock layer) under these circumstances.

[Question 3]

The figure below 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 the ground surface. The thickness of the sand layer and the clay layer are 4 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 in the sand layer is given by its saturated unit weight γ_{sat1},

Sand layer : $\sigma =$ [①] $(0 \le z \le 4)$

and the total stress σ due to the overlying layers in the clay layer with saturated unit weight γ_{sat2} becomes,

Clay layer : $\sigma =$ [②] $(4 \le z \le 14)$

As the pore water pressure distribution u follows a [③] relationship; it can be expressed in terms of the density of water ρ_w and the gravitational acceleration g, as

Pore water pressure : $u =$ [④] $(0 \le z \le 14)$

Therefore, the effective stress σ' of each soil layer can be obtained:

Sand layer : $\sigma' =$ [⑤] $(0 \le z \le 4)$

Clay layer : $\sigma' =$ [⑥] $(4 \le z \le 14)$

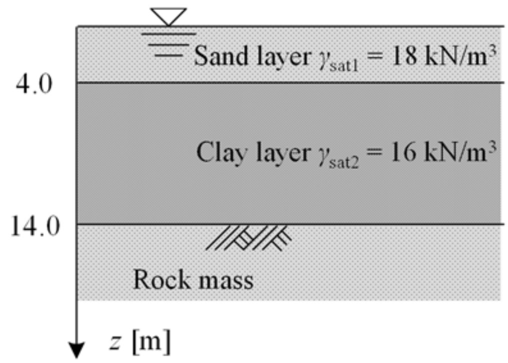

Figure 3

Assuming that a 5 m high embankment with a total unit weight of soil γ_t = 16.0 kN/m^3 is constructed instantaneously on this ground, answer the following questions.

(1) In the above sentences, fill in [①] ~ [⑥] using z, γ_{sat1}, γ_{sat2}, ρ_w, g while describing [③] using suitable terms.

(2) Using γ_{sat1} = 18.0 kN/m^3, γ_{sat2} = 16.0 kN/m^3, ρ_w = 1.0 g/cm^3, g = 9.8 m/s^2, 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), plot the profiles of total stress, pore water pressure, and effective stress distribution from the ground surface to the rock mass $(0 \le z \le 14)$ when sufficient time has elapsed (consolidation has 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) Obtain the increment of effective stress $\Delta\sigma'$ in the clay layer when sufficient time has elapsed after embankment construction, and calculate the compressive deformation after completion of consolidation in the clay layer. Herein, the coefficient of volume change m_v of the clay layer is assumed to be 1.0×10^{-4} m^2/kN.

(5) The coefficient of permeability k of the clay layer is 1.0×10^{-7} m/s. If the amount of compressive deformation when a time t has elapsed after embankment construction was 4.8×10^{-2} m, calculate the time t [days] required to reach such amount of compressive deformation. Refer to the table below showing the variation of degree of consolidation with time factor.

Degree of consolidation %	40	50	60	70	80	90
Time factor	0.126	0.197	0.287	0.403	0.567	0.848

[Question 4]

Answer the following questions. Assume that soil failure occurs following the Mohr-Coulomb failure criterion.

(1) The consolidated-drained triaxial test (CD test) was performed on a dense, saturated silty sand, at a confining stress of σ_3. Failure occurred when the axial stress reached σ_1.

1) Express the values of the normal stress σ_f and shear stress τ_f in the direction of the surface of failure, in terms of the principal stresses σ_1 and σ_3, and of the silty sand strength parameters (cohesion c and angle of internal friction ϕ).

2) Using the fact that $(\sigma_f,\ \tau_f)$ is a point on the failure criterion line, express the Mohr-Coulomb failure criterion as a function of the principal stresses σ_1, σ_3, and of the soil strength parameters c and ϕ.

3) The following results were obtained in the laboratory. Calculate c and ϕ for this silty sand:

Case	A	B	C
σ_3 (kN/m^2)	50	100	150
σ_1 (kN/m^2)	172	344	516

4) Describe the points to pay attention to when setting the experimental conditions for a CD test on a soil with relatively low water permeability such as silty sands.

(2) When the consolidated-undrained triaxial test ($\overline{\text{CU}}$ test) was performed on a saturated, normally consolidated clay at a confining stress of σ_3, the maximum value of the principal stress difference (deviator stress) was $(\sigma_1 - \sigma_3)_{\max}$.

1) Plot the "strain-deviator stress", and the "excess pore pressure-axial strain" diagrams for this test. In the latter diagram, you must clearly specify the sign of the excess pore pressure.

2) From the $(\sigma_3 - \sigma_1)_{\max}$ values obtained for several values of σ_3, the strength parameters for total and effective stress are found to be related as $c > c'$ and $\phi < \phi'$. Explain why.