2018 Soil Mechanics I and Exercises Final Exam

2019/1/29 (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]

1) A soil mass on a mountain side is shown in its original state in Figure 1. Due to a landslide, this mass became the sliding soil mass shown in Figure 2. It is assumed that the soil mass is homogeneous both before and after the landslide. A field survey based on topographic maps and slip surface depth revealed that the original volume of the soil mass was 1000 m^3, which increased to 1200 m^3 after sliding. The water content of soil samples taken from the sliding soil mass immediately after a landslide was measured to be w = 25.0%. In addition, according to the results of a past soil survey, it was found that soil particle density of the original soil mass is ρ_s = 2.50 g/cm^3 (or the specific gravity of soil particles G_s = 2.50) and dry density is ρ_d = 1.50 g/cm^3. Gravitational acceleration is g = 9.81 m/s^2. Under these conditions, determine the following quantities by assuming that the water content remains unchanged before and after a landslide. Show calculation processes and include units whenever necessary.

(1) Wet density of the original soil mass
(2) Void ratio of the original soil mass
(3) Total weight of the sliding soil mass
(4) Wet density of the sliding soil mass
(5) Degree of saturation of the original soil just before a landslide

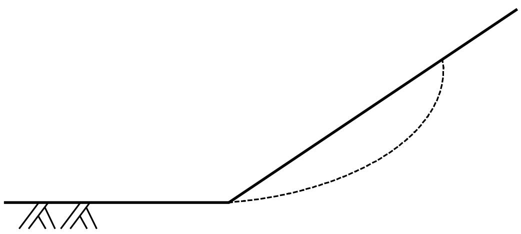


Figure 1 Before landslide

V = 1 000 m^3, ρ_s = 2.50 g/cm^3, ρ_d = 1.50 g/cm^3

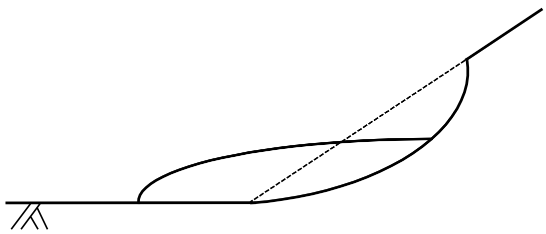


Figure 2 After landslide

V = 1 200 m^3, w = 25.0%

2) Explain the following terms.

(1) Liquid limit
(2) Maximum dry density

[Question 2]

1) A pumping test well was dug all through a homogeneous and uniform permeable layer, reaching the underlain impermeable layer, as shown in Figure 3. This pump withdraws water at a constant rate of Q (volume/unit of time). The figure shows the steady state when the water level measured at the pumping well and observation wells is constant. The Dupuit assumption holds that the groundwater flow is assumed to be radial, towards the test well (axisymmetric problem). Answer the following questions.

(1) The water head at a point located at an arbitrary distance r from the test well, in the radial direction, has a constant value of h regardless of depth. Express the water gradient i, at this point, in differential form.

(2) The flow rate Q, flowing radially at an arbitrary distance r from the test well, can be calculated using Darcy's law ($Q = kiA$). Here, k is the permeability coefficient of the permeable layer (constant), and A is the area of the cylindrical inflow region. Using the expression for i that you found in (1), express Q in terms of r, h, and k.

(3) Integrate (2) by the variable separation method, applying the boundary conditions $h = h_1$ at $r = r_1$, and $h = h_2$ at $r = r_2$, and solve for Q using k, r_1, r_2, h_1, and h_2.

(4) A pumping test well, with a radius of 10 cm, was installed in a soil where the initial groundwater table was located at a height of 8 m from the top of the impermeable layer, reaching a steady state flow of 30 L/min. If the height of the water table at the test well is 5 m from the top of the impermeable layer, and the influence radius is 1000 m, calculate the coefficient of permeability of the permeable layer.

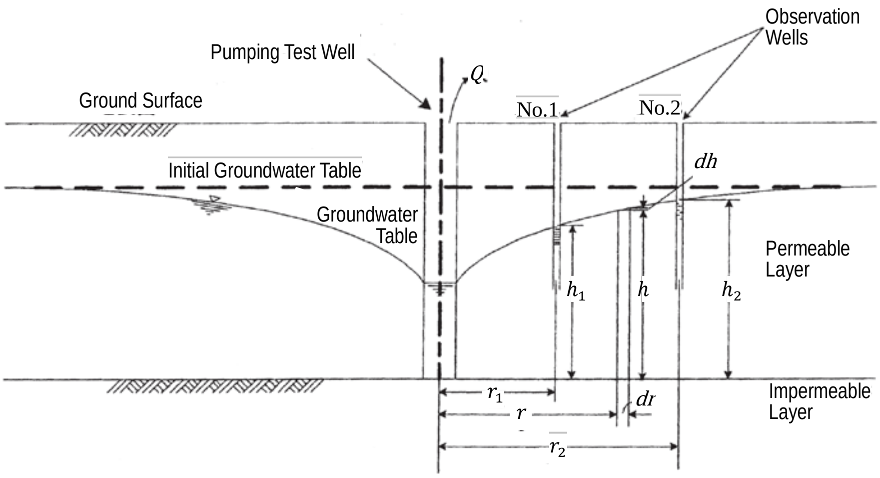


Figure 3

2) Answer the following questions based on Figure 4, which shows three conditions (a, b, and c) for the same soil.

(1) Plot the distribution of the total head, elevation head, and pressure head, for the three cases, along the vertical elevation z = 0 m to 6 m through the soil sample, assuming z = 0 m as the reference datum.

(2) Let $\sigma'_{(a)}$, $\sigma'_{(b)}$, and $\sigma'_{(c)}$ be the values of effective stress at point B (located within the soil sample) for samples (a), (b) and (c), respectively. Order them in descending order, based on their magnitudes, explaining your reasoning.

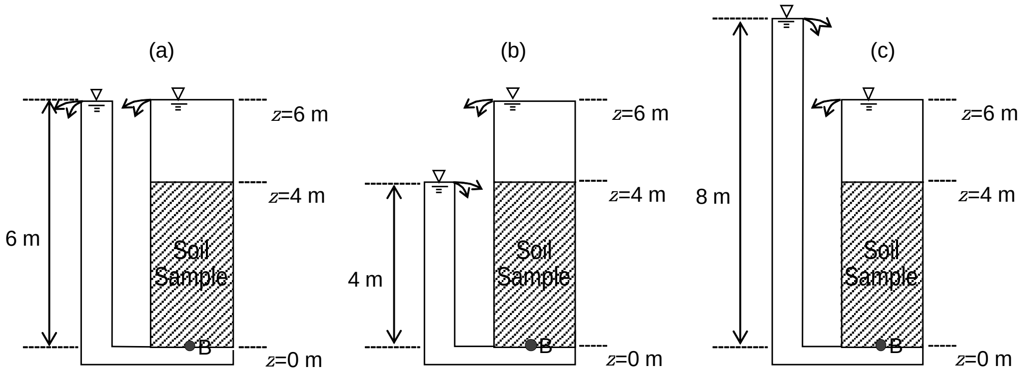
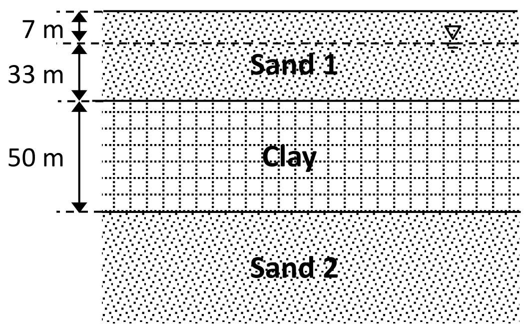


Figure 4

[Question 3]

Due to Japan's rapid development in the 1950s and 1960s, many large cities, including nearby Osaka, increased the amounts of water pumped from the groundwater to satisfy their industrial needs. This overpumping caused an over drawn of the water table, which dropped up to 30 meters in different areas of the city.

After it was recognized that the overpumping was causing subsidence problems, Osaka city expanded its waterworks and groundwater users were required to stop using groundwater, which helped with the recovery of the water table. Although it would be impossible to travel back in time, assume that you somehow managed to get hold of an old, undisturbed, soil sample, taken from the middle of the normally consolidated clay layer described in Figure 5, from an unspecified location in Osaka city. You run a double-drained consolidation test of the cylindrical soil sample (diameter ϕ = 6.00 cm, height h = 2.50 cm) using a laboratory oedometer, and find that it takes 2 minutes and 3 seconds for it to reach 50% average degree of consolidation. The obtained coefficients of compression and swelling were $C_C = 1.20$, and $C_S = \frac{1}{6}C_C$. The initial void ratio was e_0 = 2.00. Unit weight of water is γ_w = 9.81 kN/m^3.



Unsaturated Sand 1:
G_s=2.65, e = 0.70, S_r = 0.15 (= 15%)

Saturated Sand 1:
G_s=2.65, e = 0.70, S_r =1.00 (= 100%)

Clay:
G_s=2.70, e_0 = 2.00

Sand 2:
G_s=2.67, e = 0.70

Figure 5

With this information in mind, answer the following questions:

(1) From the laboratory test, calculate the coefficient of consolidation of the clay layer, c_v.

(2) If, due to the overpumping discussed earlier, the water table dropped 25 m from the original condition shown in Figure 5, calculate the total consolidation settlement of the clay layer. Assume for this problem that the drop of the water table is instantaneous. For calculating consolidation, you may consider the stress and strain at the middle of the clay layer as representative of the full layer.

(3) Assume that the development of the city meant an additional distributed overburden of 100 kN/m^2 over the whole area, in addition to the one you calculated in (2). What would have been the consolidation settlement due to the combined effects of the water table drop and the development of the city? Assume for this problem that the drop of the water table and the application of the additional overburden are simultaneous and instantaneous.

(4) Calculate the average degree of consolidation reached 10 years and 45 years after the beginning of the consolidation process described in (3).

The following assumptions are valid for the whole problem:

i. All soils below the water table are fully saturated

ii. Both sand layers are incompressible and provide full drainage

iii. When using Table 1, average degree of consolidation vs. time factor, if necessary, you may round the values of the time factor to the nearest second decimal position

iv. Terzaghi's theory of one-dimensional consolidation is fully applicable

Table 1

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

[Question 4]

Answer the following questions.

1) The stress tensor for which the state of stress of the soil element in the ground described in Figure 6 can be expressed in matrix form by [①]. The invariants λ (Eigenvalues) obtained from the stress tensor are [②] and [③]. Therefore, the major principal stress is [②] kN/m^2 and the minor principal stress is [③] kN/m^2. As the major and minor principal stresses are known, Mohr's stress circle whose center is at [④] with a radius [⑤] can be drawn. This stress circle implies that the major principal plane on which the major principal stress acts in Figure 6 is rotated [⑥]-wise from plane B by an angle of [⑦] degrees.

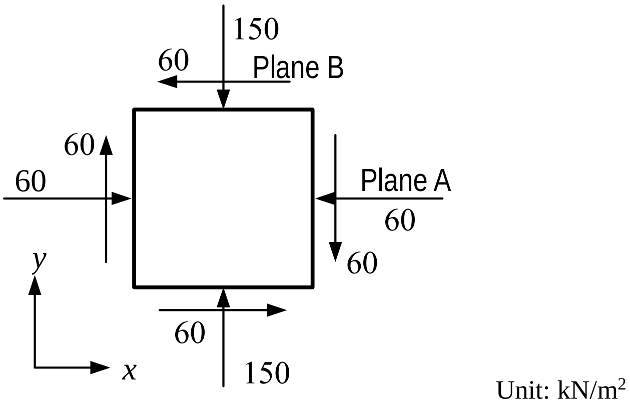


Figure 6

(1) Fill in the blank spaces no.① to no.⑤.

(2) Draw the Mohr's stress circle corresponding to the given state of stress. In Mohr's space, clearly indicate the coordinate of the center, the radius, and the intersecting points between the circle and the axis σ

(3) In regard to the stress circle obtained in (2), describe the state of stress (traction) acting on planes A and B specified in the physical space.

(4) Fill in the blank space no.⑥ by using appropriate terms and determine the angle α for the blank space no.⑦ by imposing it on the Mohr's stress circle obtained in (2).

(5) Use the pole method and explain how to obtain the principal stresses and their principal planes (the planes on which the principal stresses act) by using graphics.

2) A consolidated undrained triaxial test was conducted on a specimen of normally-consolidated clay under saturated condition (regarded as c' = 0). After isotropic consolidation by applying the confining pressure σ_3 equal to 100 kN/m^2, the axial stress was increased in the triaxial test. At failure, the axial stress σ_1 was 200 kN/m^2 and the pore water pressure u was 20 kN/m^2.

(1) Draw the Mohr's stress circle for effective stress at failure (indicate the coordinate of the center, the radius and the intersecting points between a circle and the axis σ) and determine the internal friction angle ϕ'.

(2) By assuming that Mohr-Coulomb failure criterion is valid, determine the state of stress (σ, τ) acting on the failure plane of a specimen as well as the orientation of this failure plane.