Soil Mechanics I and Exercises [Midterm Exam]

November 21, 2023 (Tue.) 13:15–14:15 @W2 Lecture Room

Notes:

- The examination consists of two questions for which you are provided with two answer sheets and one graph.
- Write down your name and student ID number on every 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, continue your answer on the back side of the same sheet of paper, and be careful not to spread the answer to a single question across multiple sheets of paper.
- In addition to personal writing instruments, use of non-programmable calculators and rulers are permitted. However, programmable calculators and calculator functions of mobile phones are prohibited.
- Wherever necessary, specify the units in your answers.
- Any attempt at cheating on the exam will result in failed credit of the course and serious penalties.

[Question 1]

1) Express each of the following indices using the parameters given in Figure 1 and the gravitational acceleration g.
   (1) Soil particle density
   (2) Void ratio
   (3) Degree of saturation
   (4) Gravimetric water content
   (5) Wet unit weight

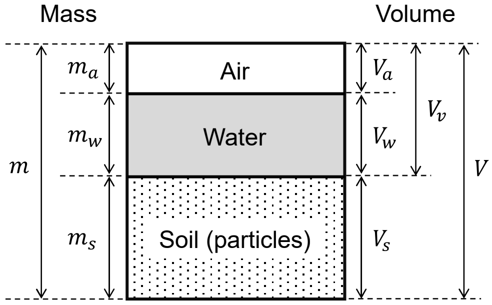

Figure 1

2) Answer the following questions.
   (1) Soil A having a gravimetric water content of 25.0% and Soil B having that of 40.0% are mixed to obtain Soil M having that of 30.0%. Find the mass of Soil B to be mixed for 100 g of Soil A.
   (2) A mold with a volume of 100 cm^3 was filled with Soil M to a wet density ρ_t of 1.70 g/cm^3 while maintaining a water content of 30.0%. Then, the specimen was saturated by water percolation. Find the volume of water required for the saturation. Assume that the soil particle density ρ_s of both soils is 2.60 Mg/m^3 (g/cm^3) and the density of water is 1.00 Mg/m^3 (g/cm^3).
   (3) After (2), the specimen was compressed while maintaining saturation and allowing drainage to achieve the dry density ρ_d of 1.40 g/cm^3. Find the amount of drainage during the compression.

3) Figure 2 shows the results of a sieve analysis conducted on Soil C. Answer the following questions.
   (1) Draw the particle size distribution curve for Soil C on a separate sheet.
   (2) Based on the graph obtained in (1), determine the fines content F_c and the coefficient of uniformity U_c of Soil C.
   (3) Soil D is obtained by mixing fractions of 0.425–2.00 mm of Soil C only. The standard Proctor tests are conducted on Soil C and Soil D. Explain which soil would be expected to have the higher maximum dry density with a brief reason.

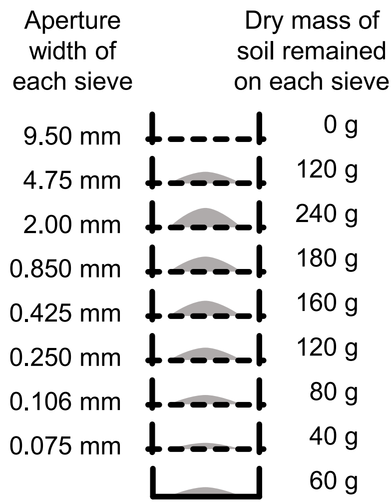

Figure 2

[Question 2]

1) A constant head permeability test for a soil sample is shown in Fig. 3. The cross-sectional area, height and hydraulic conductivity of the soil sample are A, L, and k, respectively. The discharge velocity in the soil sample is v. The difference in water level between the upstream and downstream sides is H.

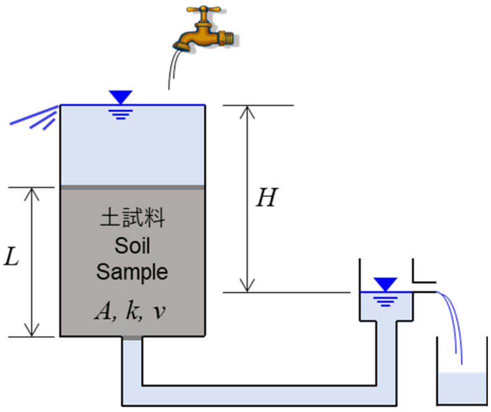

Fig. 3. Constant head permeability test.

(1) Write the equation of Darcy's law using the quantities shown in the figure.

(2) Express the flow rate, q (volume of water flow per unit time), through any horizontal cross section in the soil sample, using the quantities shown in the figure.

(3) After time T, the total volume of water collected in the container on the right side is Q. Express the hydraulic conductivity of the soil sample, k, using the above quantities and the quantities shown in the figure.

2) A geo-engineering company invented a new "Dual-Sample Permeability Testing Device" as shown in Fig. 4. In this device, two soil samples are placed at the left and right sides. A screen is placed at top and bottom of the soil samples to retain the soil while allowing water to flow through. For Sample 1 on the left side, it has permeability, cross-sectional area, and length of k_1, A_1, L_1, respectively. For Sample 2 on the right side, the permeability, cross-sectional area, and length are denoted by k_2, A_2, L_2, respectively. For all questions below, use L_1 = 50 cm, A_1 = 1,000 cm^2, L_2 = 40 cm, A_2 = 1,000 cm^2. The unit weight of water is 9.8 kN/m^3. Assume the flow in the soil samples is one-dimensional flow along the vertical direction.

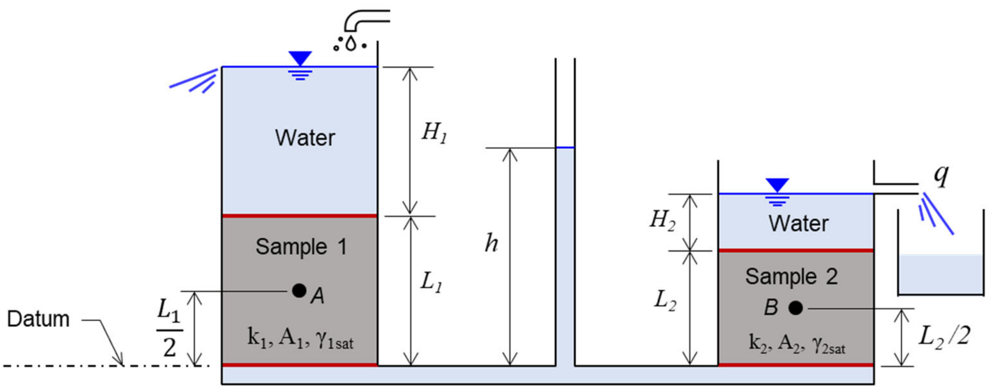

Fig. 4. Setup of the dual-sample permeability test.

(1) Two types of sand are used as soil samples and the saturated unit weights of the two sands are γ_{1sat} = 18 kN/m^3 and γ_{2sat} = 19 kN/m^3, respectively. A constant head test has been conducted with H_1 = 50 cm and H_2 = 25 cm. H_1 and H_2 are kept constant during the test and a steady state flow is maintained. The water level in the tube, h, is also found to be constant during the test at h = 70 cm. The discharge flow rate through Sample 2 (denoted by q) is measured to be q = 1 cm^3/sec. Point A and B in the figure are located at the middle of Sample 1 and Sample 2, respectively. Answer the following questions.

1. Find the hydraulic conductivity of the two samples, k_1 and k_2.
2. Find the elevation head, pressure head, and piezometric head (total head) at Point A.
3. Find the elevation head, pressure head, and piezometric head (total head) at Point B.
4. Find the vertical total stress, σ_A, pore water pressure, u_A, and vertical effective stress, σ'_A, at Point A.
5. Find the vertical total stress, σ_B, pore water pressure, u_B, and vertical effective stress, σ'_B, at Point B.

(2) Briefly explain the condition of quicksand.

(3) For the same soil samples described above, if the water level above Sample 2 (i.e., H_2) does not change but the water level above Sample 1 (i.e., H_1) is gradually raised, determine the value of H_1 when the soil in Sample 2 becomes quicksand.

(4) To confirm the performance of the device, another constant head test is conducted in which the same sand was used for both samples (i.e., $k_1 = k_2$). The values of H_1, and H_2 remained constant as same as previously stated (H_1 = 50 cm, H_2 = 25 cm). The only measured value in this test is h and the discharge flow rate q is not measured. Find the measured value of h.