2015 Soil Mechanics I and Exercises Final Exam

2016/1/26 (Tue.) 13:00-15:00 W2 Lecture room

Attention:

- The exam consists of four questions for which you are provided with five answer sheets. Write down your name and ID number on every answer sheet. Use the first answer sheet to answer [Question 1], the second and third to answer [Question 2], the fourth one to answer [Question 3], and the fifth answer sheet for [Question 4]. If the space provided in any answer sheet is insufficient, use the back page after clearly mentioning so (for example, "continued on back page").
- In addition to personal writing instruments, 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 regarding the index properties of soils

(1) A cylindrical specimen of clay sampled from the ground has the following dimensions: 5 cm in diameter and 10 cm in height. The mass of the specimen before and after completely removing all soil moisture using an oven dry is 323.85 g and 235.55 g, respectively. The result of the specific gravity test reports the density of soil particle ρ_s = 2.68 g/cm^3. Use ρ_w = 1.00 g/cm^3 as water density and determine the following values.

1. Bulk density ρ_t
2. Water content w (%)
3. Dry density ρ_d
4. Void ratio e
5. Degree of saturation S_r (%)

(2) The dry density of a sandy soil measured in the field was ρ_d = 1.58 g/cm^3. This sand was taken to the laboratory where the maximum dry density ρ_{dmax} = 1.72 g/cm^3 and the minimum dry density ρ_{dmin} = 1.43 g/cm^3 were obtained. Determine the relative density D_r (%) of the sand at the field.

(3) Explain each technical term listed below using approximately 3 lines for each one. Figures may be used if necessary.

1. Particle size distribution curve 2. Plasticity index 3. Optimum water content

[Question 2] Answer the following questions for the concrete dam built on top of a sandy soil shown in Figure 2-1. The hydraulic conductivity of the sand is 4.0×10^{-4} m/s and the unit weight of water is $\gamma_w = 9.81$ kN/m^3. Use the second page of the answer sheets to answer parts (1) and (4), but use the third page of the answer sheets to answer parts (2) and (3).

(1) Explain the following concepts:
 1) Darcy's Law 2) Quicksand phenomenon 3) Critical hydraulic gradient

(2) Draw the flow net that represents the flow of water under the dam. Use Figure 2-2 in the third page of the answer sheets for this. Calculate the flow rate of the water leakage under the dam, per unit of width (perpendicular to the paper).

(3) Find the hydrostatic pressure head acting on point A, located on the upstream side of the base of the dam. Also, plot the distribution diagram of the uplift pressure acting on the base of the dam (a schematic diagram is fine). Use Figure 2-3 in the third page of the answer sheets for this.

(4) From your analysis, explain the effects due to the construction of the sheet pile.

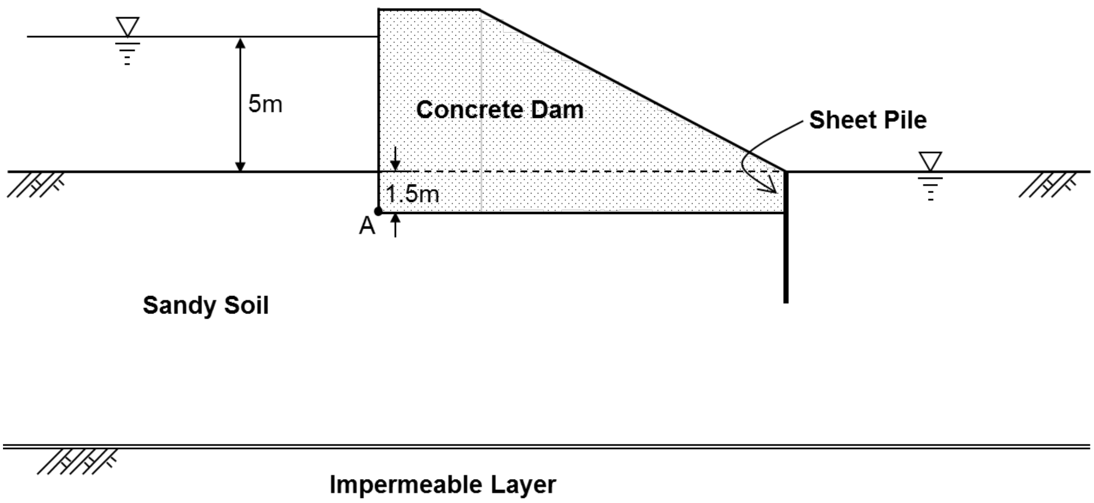


Figure 2-1. Concrete dam built on top of a sandy soil

[Question 3] A certain structure was designed to be constructed on top of an inactive vertical fault, with one half of said structure resting on top of each side of the fault. By design, a 40 m gap was considered so the structure would not produce any stress in the middle of the fault zone (Figure 3-1).

As the engineer in charge, you have been tasked with predicting two important parameters for this structure: the total consolidation settlement, and the differential settlement after 5 years.

To do so, you need to work under the following assumptions:

i. The clay on both sides of the fault is the same, fully saturated, and normally consolidated (Unit weight of the saturated clay, γ_{sat} = 16.2 kN/m^3)

ii. The sand that overlays the clay is incompressible, fully saturated, provides full drainage, and the water table lays on its surface (Unit weight of the saturated sand, γ_{sat} = 19.0 kN/m^3; Unit weight of water, γ_w = 9.81 kN/m^3)

iii. The bedrock is incompressible and impermeable

iv. The structure can be represented by a distributed load p = 350 kN/m^2 on both sides of the fault (Figure 3-2)

v. The settlement on both sides of the fault is different and can be calculated independently

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

To better understand the clay, you took samples at the middle of the clay layers, and run a consolidation test in the laboratory. The samples were 2.5 cm tall, drained on both ends, and took 142 seconds to reach 50% of consolidation. The obtained coefficient of compression was C_c = 0.55. The initial void ratios were e = 2.0 (for the sample taken at the middle of the h = 33.0 clay layer), and e = 2.2 (for the sample taken at the middle of the 14.7 m clay layer).

With this information in mind, answer the following questions:

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

(2) Calculate the total consolidation of the clay layer located left to the fault (h = 33.0 m) and also of the clay layer located right to the fault (h = 14.7 m)

(3) Calculate the settlement that will occur, on each side of the fault, five years after the structure is constructed

(4) The difference between the two settlement values that you obtained in (3), divided over the gap distance (L = 40.0 m) is called *differential settlement*. This value should be less than 1/500. Calculate the differential settlement for this particular case, and conclude if it's acceptable or not.

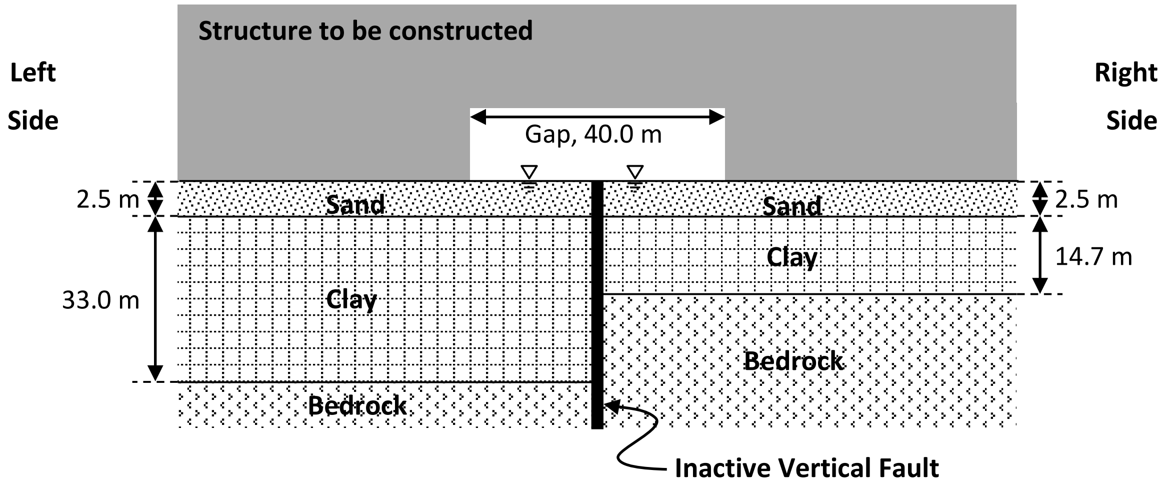


Figure 3-1. Structure to be constructed on top of an inactive vertical fault

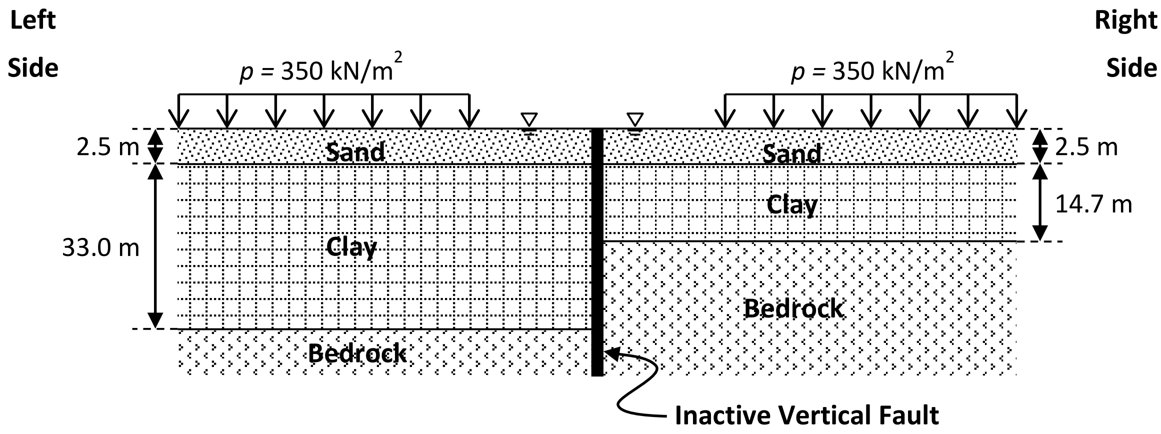


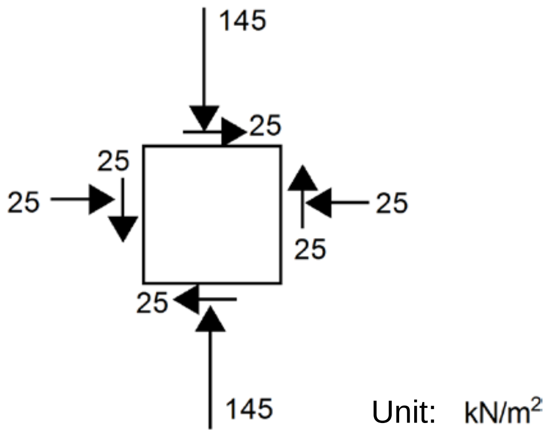
Figure 3-2. Load diagram

Average degree of consolidation vs. time factor (for this problem, assume $T_v \pm 0.001$):

U (%)	0	10	20	25	30	35	40	45	50	60	70	80	90
T_v	0.000	0.008	0.031	0.049	0.071	0.096	0.126	0.159	0.197	0.286	0.403	0.567	0.848

[Question 4] Answer the following questions

(1) The state of stress of a soil element in the ground is given in the figure below. Draw the corresponding Mohr's stress circle (show the coordinate of the center and radius of the Mohr's stress circle). Also, find the maximum principal stress, the minimum principal stress as well as the direction of each principal plane.



(2) Consolidated-undrained ($\overline{\mathrm{CU}}$) triaxial compression test of a normally consolidated clay in saturated condition under the confining pressure σ_3 = 300 kN/m^2 was undertaken. Answer the following questions if the axial stress σ_1 and pore water pressure u_w measured at failure were σ_1 = 900 kN/m^2, u_w = 100 kN/m^2.

1. Draw the Mohr's stress circles for total stress and effective stress at failure.
2. By assuming that the Mohr-Coulomb failure criterion is satisfied, determine the internal friction angle ϕ' based on the effective stress of this clay. Note that cohesion c'= 0 can be regarded for normally consolidated clays.
3. Find the orientation of the failure plane measured from the maximum principal plane as well as the normal stress and shear stress acting on the failure plane.

(3) Explain the reason why the shear strength of a densely compacted and saturated sand obtained from the consolidated-undrained (CU) triaxial compression test is greater than that obtained from the consolidated-drained (CD) test.