2016 Soil Mechanics II and Exercises Midterm Exam

2016/6/8 (Wed) 8:45-10:15 Kyotsu 4 Lecture room

Attention:

- The exam consists of three questions for which you are provided with three 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.
- 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 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) A saturated clay layer of thickness H lies above an impermeable rock layer. Assume that the groundwater level coincides with the ground surface. After the rapid application of a load over the clay layer, the consolidation process can be analyzed based on Terzaghi's one dimensional consolidation equation. Terzaghi's consolidation equation is given below where u is the excess pore water pressure (= pore water pressure – hydrostatic pore water pressure), C_v is the coefficient of consolidation, t is the time, and z is the coordinate along depth direction.

$$\frac{\partial u}{\partial t} = C_v \frac{\partial^2 u}{\partial z^2} \qquad (1)$$

(a) The ground with high coefficient of permeability will have higher coefficient of consolidation than the ground with low coefficient of permeability; therefore, the period of time needed for consolidation is shorter. Explain whether the ground with high coefficient of volume compressibility will need a shorter or longer consolidation time than the ground with low coefficient of volume compressibility if both grounds have the same value of the coefficient of permeability.

(b) The solution of consolidation equation can be expressed using the time factor T_v. Explain what the time factor is.

(2) If the upper surface of the clay layer (the ground surface) is represented as $z = 0$, and the lower surface of the clay layer (the upper surface of the impermeable rock layer) as $z = H$,

(a) Write down the boundary condition for the upper surface ($z = 0$) of the clay layer.

(b) Write down the boundary condition for the lower surface ($z = H$) of the clay layer (Hint: Think about the condition under which the flow rate becomes zero in Darcy's law)

(3) In order to solve the consolidation equation, the solution of Eq.(1) is written as follows..

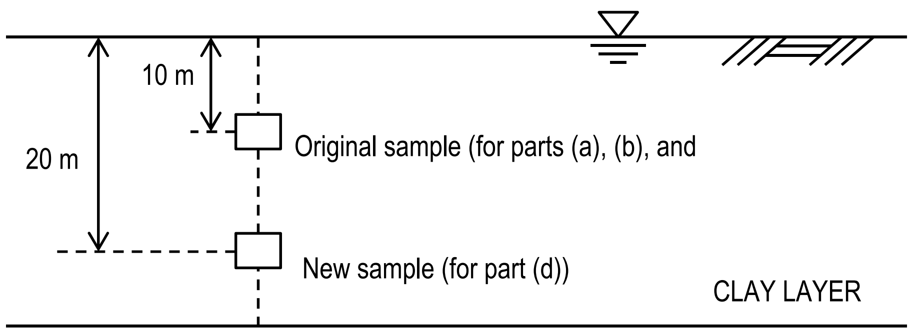
$$u = f(t)g(z) \tag{2}$$

Based on this, find the general solution of the consolidation equation as given in Eq.(1) from the boundary conditions of the upper surface ($z = 0$) and the lower surface ($z = H$) of the clay layer.

[Question 2] Answer the following questions

(1) An undisturbed clay sample with a diameter $\phi = 5$ cm was taken from a depth of 10 m beneath the ground surface, and was subsequently subjected to an unconfined compression test in the laboratory. The sample failed when the applied axial compression force was $F = 196.35$ N. After failure, a new sample of the same size was prepared from the remaining material by remolding it, and this new remolded sample failed when the applied axial compression force reached $F = 130.90$ N. (For this problem, assume that the change in sample diameter due to vertical stress is negligible).

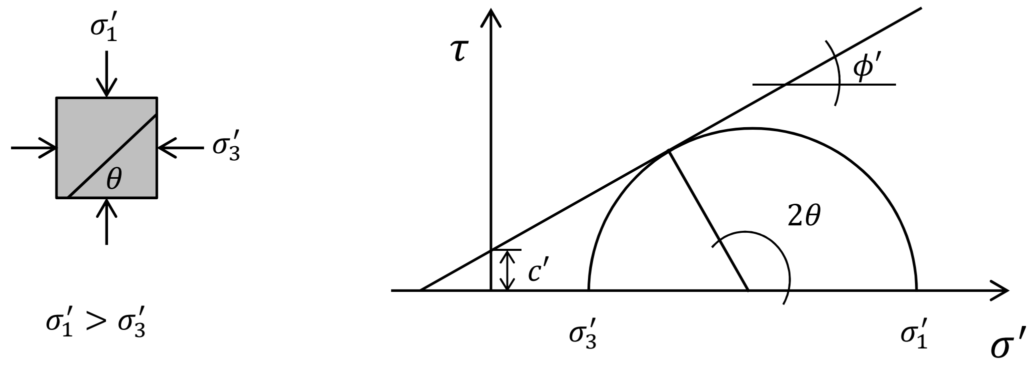
(a) Draw the Mohr circles for both the undisturbed and the remolded samples, and calculate the values of undrained shear strength (c_u and c_{ur}) for both cases.
(b) Calculate the degree of sensitivity for this clay sample
(c) If both samples are subjected to Triaxial UU tests, with a confining pressure of $\sigma_3 = 150$ kPa, calculate the axial compressive stresses that would cause them both to fail
(d) If a new clay sample from the same clay layer was obtained from a depth of 20 m beneath the ground surface, predict the value of undrained shear strength that would be obtained in this case (assume that the clay is normally consolidated, that the clay layer extends from the ground surface to a depth larger than 20 m, and that the water table is located on the surface, as in the figure)



(2) The Mohr-Coulomb failure criterion can be described by the equation $\tau = c' + \sigma \tan \phi'$ that represents the tangent to the Mohr circle in the following figure where σ_1' and σ_3' ($\sigma_1' > \sigma_3'$) are the effective principal stresses, ϕ' is the effective friction angle and c' is the cohesion based on the concept of effective stress. Since the Mohr circle is, by definition, tangent to the aforementioned line, the maximum value of σ_1' at failure can be calculated as a function of σ_3', c', and ϕ'.

(a) Obtain the mentioned function $\sigma_1' = f(\sigma_3', c', \phi')$

(b) For a normally consolidated soil, $c' = 0$. If $\sigma_3' = 300$ kPa and the deviator stress $\sigma_1' - \sigma_3' = 575$ kPa, calculate both the value of the effective friction angle ϕ', as well as the angle of the failure plane θ (as shown in the figure below).



[Question 3] Answer the following questions

(1) The figure below represents a retaining wall of height H. Let the frictional angle, the cohesion, and the unit weight of the backfill soil be ϕ, c, and γ, respectively. Draw a diagram showing the three types of representative earth pressure that act on the retaining wall, taking the displacement of the retaining wall (δ) along the horizontal axis and the earth pressure along the vertical axis. Refer to the figure below for the direction of displacement of the retaining wall.

(2) Based on Coulomb's earth pressure theory, determine the earth pressure acting on the retaining wall when it moves leftward (δ_- direction). Assume that the cohesion, c, of the backfill soil is zero. Also, assume that the surface of the retaining wall is not smooth; hence, there is friction between the retaining wall and the backfill soil (interface friction angle α). Show the force polygon diagram using the forces that act on the soil wedge shown in the figure. Use appropriate symbols for the forces shown in the force polygon diagram and clearly describe each of those forces.

(3) While reassessing the conditions of the backfill soil, it was found that the cohesion was not zero. Under this new condition, and based on Rankine's earth pressure theory, draw the earth pressure distribution diagram exerting on the retaining wall of height H when it moves leftward (δ_- direction). For this, assume that the friction between the retaining wall and the backfill soil can be ignored and that the groundwater table lies deep below the retaining wall.

(4) Explain the difference in the magnitudes of the resultant active force (a sum of the forces due to earth pressure and the water pressure) when the groundwater table behind the retaining wall rises up the ground surface and lies at the bottom surface of the retaining wall. Focus your answer on the difference in the earth pressure and the water pressure under those two conditions. Assume that the cohesion of the backfill soil is zero and the unit weight of water is γ_w. When the groundwater table lies at the bottom surface of the retaining wall, the active earth pressure p at depth z can be written as $p = K_A \gamma z$, where K_A is the coefficient of active earth pressure.