SOIL MECHANICS I
LABORATORY CLASS 5: TRIAXIAL TEST

Aim:

The laboratory class demonstrates the standard triaxial apparatus and the conventional "drained triaxial compression" test. Further some essential features of the strength and behaviour of soil at loading are investigated:

- Peak and post-peak strength, difficulties with critical strength determination in the triaxial device (strain localisation),
- Relation between deviator stress and volume changes in drained tests,
- Dependence of soil stiffness on strains.

Drained triaxial test on water saturated specimen

The triaxial test is a common method to determine the shear strength of soils. The specimen, protected by a rubber membrane, is placed inside the cell filled with water, which enables us to apply all-round cell pressure. The cell pressure is the radial principal stress σ_r acting on the sample. During the shearing stage of the triaxial test so called "deviatoric stress" $q=\sigma_a-\sigma_r$ is applied axially by the loading piston. The deviatoric stress q represents one component of the axial stress σ_a , the other being the cell pressure σ_r.

The sample can be drained through a filter stone at the bottom platen. If the drainage valve is closed the loading is undrained, and the test is called undrained test. In this case the apparatus can be equipped by pore pressure gauge to register the pore pressure. If the valve is open the water can run out/into the sample. At the appropriate loading rate (depending on the permeability of the soil) there are no excess pore pressures (the pore pressure is constant throughout the test).

In the standard test the specimen is subjected to constant rate of axial strain loading by moving the cell upwards against the load frame, while the cell pressure σ_r is kept constant. The force Q in the loading piston ($Q= A\times q=A(\sigma_a-\sigma_r)$, where A is the specimen cross-section) is measured by a force transducer (for example by a steel proving ring).

Procedure

Prepare a water saturated sand specimen and measure its dimensions (height H_0 and diameter D_0). Consolidate the specimen by the required cell pressure (in your case σ_r =………kPa). Calculate the initial dimensions for the shearing phase H_{0cons}, D_{0cons} (from $\varepsilon_V=\varepsilon_a+2\varepsilon_r$ assuming isotropic soil with $\varepsilon_a=\varepsilon_r$ during consolidation).

In your data sheet write down the initial dimensions, initial reading of the proving ring dial gauge, dial gauge registering the specimen height and the initial reading of the burette. After switching on the motor of load frame take the readings at convenient intervals until the test is terminated at about 15 mm of travel (change of specimen height).

During the test observe the shape of sample and the mode of failure. Sketch the shear planes if they develop during the test. After the test determine the dry density of the soil, and the initial porosity prior and after consolidation.

Data evaluation

Calculate all quantities as prescribed in the data sheet. In calculating the axial stress consider the actual cross sectional area of the specimen assuming that the specimen keeps the shape of right cylinder, i.e. $A_i=A_0((1-\varepsilon_V)/(1-\varepsilon_a))$. Be careful to have the signs of ΔH, ΔV, ε_a and ε_V right.

Plot the following:

Graph 1: $q'=\sigma_a'-\sigma_r'=\sigma_a-\sigma_r$ versus axial strain ε_a.
Graph 2: volumetric strain ε_V vs. ε_a.
Draw plots 1 and 2 draw on one sheet, to the same ε_a axis, just shifted vertically to be able to compare them easily.

Identify the peak and critical states (the latter one when the soil is sheared at constant stresses and volume).

From one test you obtain only one Mohr's circle for the failure at the peak state and and one for the critical state. To determine the Mohr-Coulomb envelopes you need further tests, typically three or more. In our case you will exchange results with another group to be able to plot at least two Mohr's circles for each state when processing the results.

Graphs 3 and 4: Mohr's circles for effective stresses at peak and critical states (τ' vs. σ'). Construct graphically a tangent and determine the Mohr-Coulomb strength parameters.

Graph 5: In t vs. s' plot the stresses at the peak and critical states, determine the best fit straight line and the peak and critical state friction angle φ_{cr}'. If the samples at the test had different initial porosities, the peak values will depend on the initial porosity.

Calculate the secant Young‘s modulus relevant to the change of q from 0 to 20%, 0 to 50%, 0 to 100% and from 50% to 100% of the maximum q. Compare the values and explain the difference, if any.

Report

Together with recorded data and above stated plots report should conclude also following analyses comments:

- Plots 1 – 5,
- Parameters of shear strength for each states and densities.
- Young’s modulus
- Evaluation of results with comments to this points:

1. Was the peak strength identified? Can you estimate whether the specimen was dense or loose from the presence/absence of the peak?
2. Was the critical state reached? Why do you think so?
3. Was there any dependence between peak strength and the initial porosity? Does your observation correspond with theory?
4. Was there any dependence between critical strength and the initial porosity? Does your observation correspond with theory?
5. Compare the strength determined by the triaxial test and the angle of repose test (lab class #4).
6. Have you found any cohesion of saturated sand?
7. Have you found any influence of pore-water on the friction angle?
8. What is the relation between deviator stress and volumetric change (see plot 1, 2)?
9. Please comment on the linearity/non-linearity of the Young’s modulus and relevance of Young’s modulus as a parameter of the tested soil.

σ_r [kPa]	Reading of change of height [mm]	Reading of proving ring dial gauge [mm]	Reading of burette [cm^3]	ΔH [mm]	ΔV [mm^3]	ε_a [-]	ε_V [-]	A [mm^2]	Force Q Q [N]=(dial gauge reading in mm)×245 [N]	$Q/A_i = q = \sigma_a - \sigma_r$ [MPa]