

Exercise 4 – 16.10.2025

Critical state concept

Problem statement

The exercise deals with the characterization of the critical state reached in drained and undrained CTC tests, samples are normally consolidated.

The following information is given:

- (i) the initial condition of a clay specimen in terms of initial mean effective stress (p'_0) and initial specific volume (v_0)
- (ii) the parameters of the normal compression line (NCL) and of the critical state line (CSL)
- (iii) the condition in which the triaxial test is performed (i.e. drained or undrained)

The normal compression line and the critical state line of the considered clay are characterized by the following parameters:

$$N = 2.95, \lambda = 0.15, \Gamma = 2.75, M = 0.85$$

The clay specimen is isotropically compressed in drained condition (isotropic compression stage) up to $p'_0 = 300 \text{ kPa}$, the specific volume at the end of the isotropic compression is $v_0 = 2.09$. The initial pore water pressure ($p_{w,0}$) is approximately equal to 0. Then, the specimen is subjected to the shearing phase. Consider the shearing phase performed in drained condition for Question 1 and undrained condition for Question 2.

Question 1 – Drained CTC test

- Sketch the critical state line and the stress path followed during the shearing stage of a CTC **drained** test in the planes $(q - p')$ and $(v - \ln(p'))$.
- Calculate the corresponding values of deviatoric stress (q), mean total stress (p), mean effective stress (p'), specific volume (v), volumetric strain (ϵ_{vol}) at the critical state.
- How does the specific volume at the critical state (v_{cs}) change with respect to the specific volume at the end of the isotropic compression (v_0) for an overconsolidated (OC) clay during the shearing stage of a CTC **drained test**. What is the physical meaning of this behaviour?

Question 2 – Undrained CTC test

- Sketch the critical state line and the stress path followed during the shearing stage of a CTC **undrained** test in the planes $(q - p')$ and $(v - p')$.
- Comment on the difference between the total stress paths and the effective stress path during the shearing stage of a CTC **undrained** test. How is it different from the **drained** case?
- Calculate the corresponding values of deviatoric stress (q), mean total stress (p), mean effective stress (p'), specific volume (v), volumetric strain (ϵ_{vol}), pore water pressure (p_w) at the critical state. Which is the constant volume/critical state shear strength angle ϕ'_{cv} of the analysed soil?
- Does the critical state line depend on the initial void ratio?

Question 3 – Overconsolidation

- Consider that samples in questions 1 and 2 are overconsolidated. Draw schematically $(q - p')$, $(q - p)$ and $(q - \varepsilon_a)$ graphs.
- Will the critical state line change if the soil is overconsolidated? Explain why.