

Exercise 5 – 31.10.2024

## Modified Cam-clay (MCC) model

### Problem statement

In this exercise, we will use the Modified Cam-clay (MCC) model to predict the behavior of a clay sample.

The clay sample was isotropically compressed to a  $p'_0 = 225 \text{ kPa}$  and then unloaded to  $p'_a = 150 \text{ kPa}$  at which the void ratio was  $e_a = 1.4$ . Starting from  $p'_a$  a drained CTC was then performed.

We want to predict the strains that the sample will undergo during the test when the deviatoric stress  $q$  increases by  $12 \text{ kPa}$  after reaching the initial yield surface.

The clay parameters have previously been determined:

$$\lambda = 0.16, \kappa = 0.05, \varphi'_{cv} = 25.5^\circ, \nu = 0.3$$

The Modified Cam-clay (MCC) model is used to predict the clay sample behavior.

### Question 1 – Initial strains

- Determine the initial yield stresses: the mean effective yield stress  $p'_{y1}$  and the deviatoric yield stress  $q_{y1}$ .
- Plot the ESP, the critical state line, and the initial yield surface in the  $(q - p')$  plane.
- Calculate the elastic volumetric and deviatoric strains increments at initial yield:  $\Delta \varepsilon_{v,i}^e$  and  $\Delta \varepsilon_{d,i}^e$ .

Help for c. → To compute  $\Delta \varepsilon_{d,i}^e$ , we make the approximation of a linear elastic bulk modulus

$$K = \frac{\Delta p'(1+e)}{\kappa} \text{ and we use the shear modulus } G = \frac{3K(1-2\nu)}{2(1+\nu)}.$$

### Question 2 – Strains after initial yield

- Determine the yield stresses after further increasing the deviatoric stress of  $12 \text{ kPa}$  (the mean effective yield stress  $p'_{y2}$  and the deviatoric yield stress  $q_{y2}$ ) and the preconsolidation mean effective stress of the new yield surface  $p'_{02}$ .
- Calculate the total volumetric ( $\varepsilon_v$ ) and deviatoric ( $\varepsilon_d$ ) strain generated by the deviatoric loading.  
We consider an associated flow rule ( $g = F = 0$ ) and the shear modulus  $G$  is assumed constant during the shearing test.
- On the same graph, plot the new yield surface in the  $(q - p')$  plane

## Definitions of interest

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The Modified Cam-clay model yield surface is defined as:

$$F = \frac{q^2}{M^2} + p'(p' - p'_0) = 0 \quad (1)$$

The elastic volumetric strain increment can be written as:

$$\Delta \varepsilon_v^e = \frac{\kappa}{1+e_0} \ln \frac{p'_2}{p'_1} \quad (2)$$

$$\Delta \varepsilon_v^e = \frac{\Delta p'}{K} \quad (3)$$

The elastic deviatoric strain increment can be written as:

$$\Delta \varepsilon_d^e = \frac{\Delta q}{3G} \quad (4)$$

The plastic volumetric strain increment can be written as:

$$d\varepsilon_v^p = \Lambda \frac{\delta g}{\delta p'} \quad (5)$$

$$\Delta \varepsilon_v^p = \frac{\lambda - \kappa}{1+e_0} \ln \left( \frac{p'_{02}}{p'_{01}} \right) \quad (6)$$

The plastic deviatoric strain increment can be written as:

$$d\varepsilon_d^p = \Lambda \frac{\delta g}{\delta q} \quad (7)$$