8-3. Cam Clay predictions

Here we will have a look at possible outputs from the Cam Clay Model in qualitative ways. At the end of last week, we had a brief discussion on the 3-D paths followed during $K_0$-consolidation and triaxial compression tests in relation to the State Boundary Surfaces. Let us review it in more detail, including the stress-strain relationships. We focus on triaxial compression from normally-consolidated and over-consolidated states, under drained and undrained conditions.

Note the following in the subsequent diagrams:

- Whether under drained or undrained conditions, the ultimate stress is simply determined by the Critical State Line. As far as the strength is concerned, therefore, it is no more complicated than the Mohr-Coulomb Model.

- The ductile nature of normally-consolidated soils and the brittle nature of over-consolidated soils are reproduced by the model.
(i) Drained triaxial compression

\[ q - p' \]

**CSL**

- Normally consolidated
- Over-consolidated

\[ v - p' \]
(ii) Undrained triaxial compression

Normally consolidated

Over-consolidated

CSL: $q - p'$ projection

CSL: $v - p'$ projection

NCL

$\nu$

$p'$

$q$

$p'_0$

$v$

$p'_0$
Stress – strain relationships

(i) Drained conditions

Volume decrease

Volume increase

(ii) Undrained conditions
9. Further Notes on State Boundary Surface and Soil Strength

9-1. Two-dimensional representation of State Boundary Surface

Look at $v=const.$ cross-sections of the State Boundary Surface. Their shape is same; only the size is different. So normalise them!

By normalising with regard to $p_e'$, the State Boundary Surface can be drawn uniquely in 2-D.
If we express the stress paths in terms of relative position to the SBS, drained and undrained stress paths are uniquely expressed.

9-2. Two-dimensional representation of State Boundary Surface: Modified form

Let us now depart from the Cam Clay Model, and study a slightly more realistic view of the State Boundary Surface.

The Cam Clay Model is known to overestimate the strength for shearing from over-consolidated states. In an independent study, Hvorslev (1960) proposed an alternative linear failure line for over-consolidated soils. For the segment of the SBS left of the CSL is often represented by this “Hvorslev” Surface. For the segment right of the CSL, the curved shape is retained, and it is called “Rendulic” Surface or “Roscoe” Surface.
Let us come back to the original $q - p'$ space and see how the strengths defined by Mohr-Coulomb, Cam Clay and Hvorslev+Rendulic differ.

Mohr-Coulomb

Cam Clay

Hvorslev+Rendulic

$\text{Apparent cohesion}$

$\text{Tension cut-off: } q/p' = 3$

“Hvorslev” surface
9-3. Some experimental results

Here are some examples of experimental results:

(i) Reconstituted Bothkenner Clay (Allman and Atkinson, 1992)

Drained tests

Unrained tests

Effective stress paths and State Boundary Surface in normalised stress space
9-3. Some experimental results

Here are some examples of experimental results:

(ii) Dogs Bay Sand (Coop, 1990)

**CSL (Critical State Line) in the** $v - p'$ **space**

**CSL (Critical State Line) in the** $q - p'$ **space**

**Drained tests**

**Unrained tests**

Effective stress paths and State Boundary Surface in normalised stress space
References