The Different Predictions of DEM and Soil Constitutive Models for Soil Behavior Under Various Loading Paths

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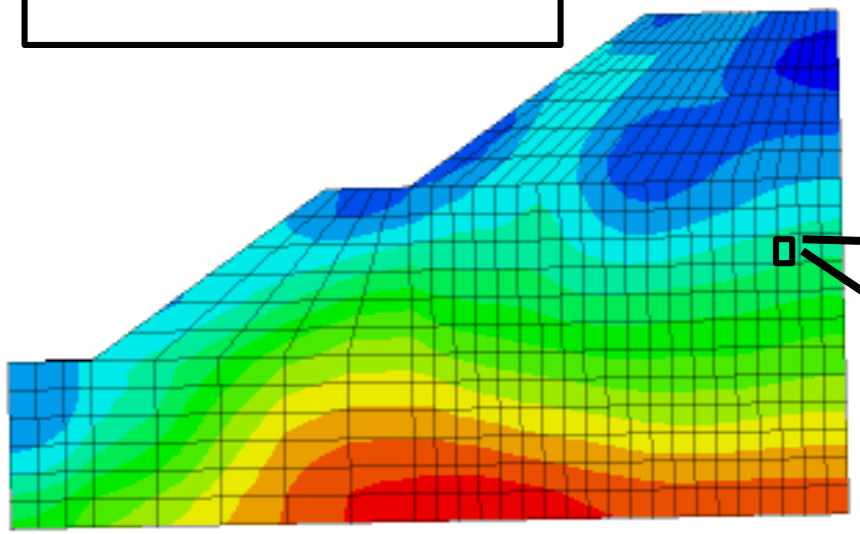
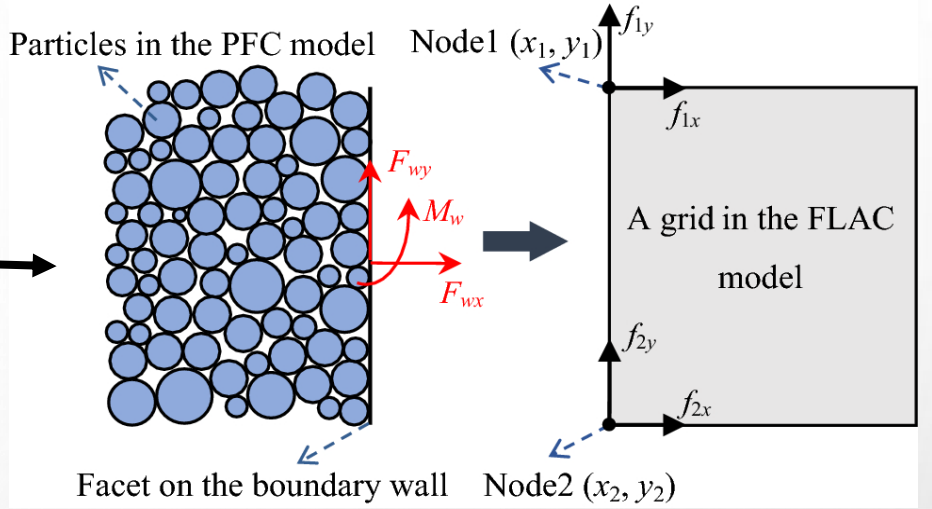
Introduction

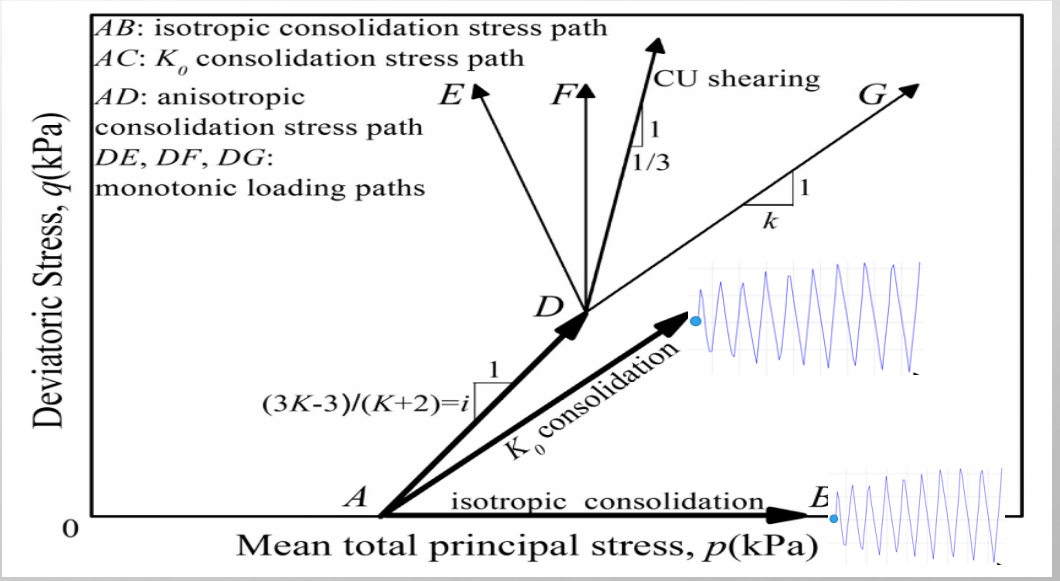


Representative volume of soil DEM



Mathematical formulation according to a theory of plasticity

- Soils are exposed to different stress paths during their life.
- The comprehensive predictions for these stress paths are not an easy issue and need e.g. a sophisticated soil model (with a lot of non physical parameters).
- DEM is a promising approach, since it deals with physics.

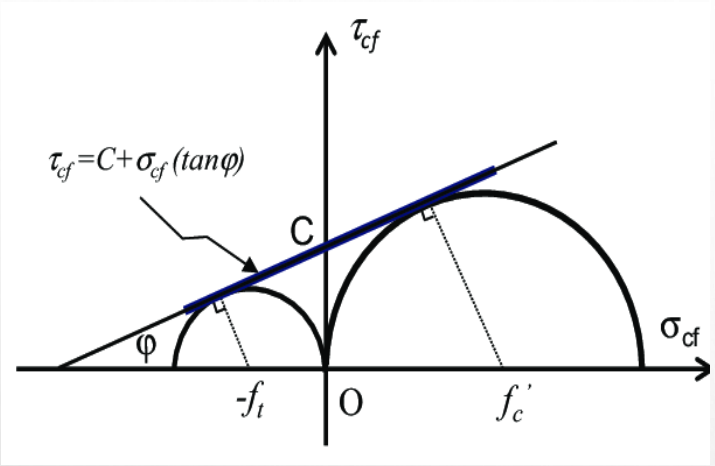


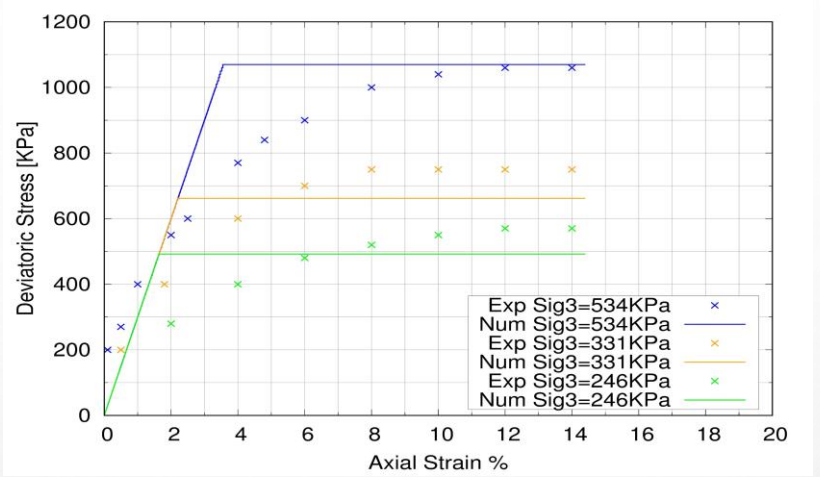
Yuanqiang et al 2018

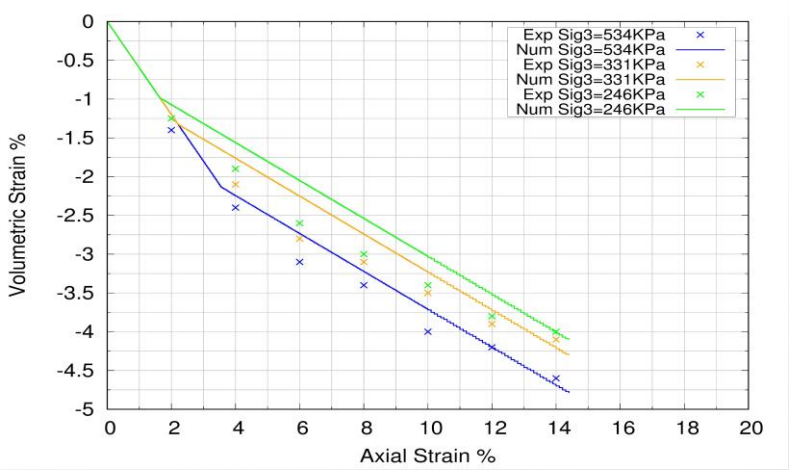
Outlines

- Introduction.
- Drained triaxial stress path (Soil Models).
- Undrained triaxial stress path (Soil Models).
- Ko Stress path (Soil Models).
- Drained biaxial stress path (DEM).
- Drained cyclic simple shear test stress path (DEM).
- Conclusions.

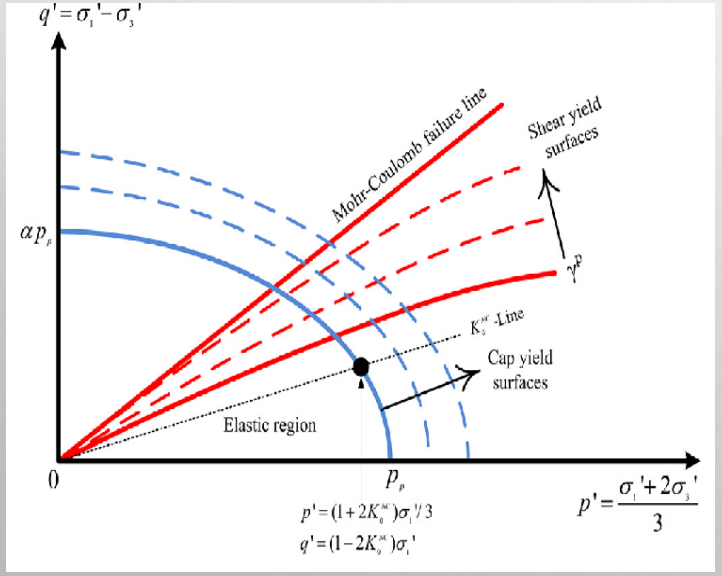
Calibration/Validation of Mohr-Coulomb and Cap-Yield Model Model Criterion on Tropical Soils
Drained triaxial Experimental data (Mouali et al 2018)

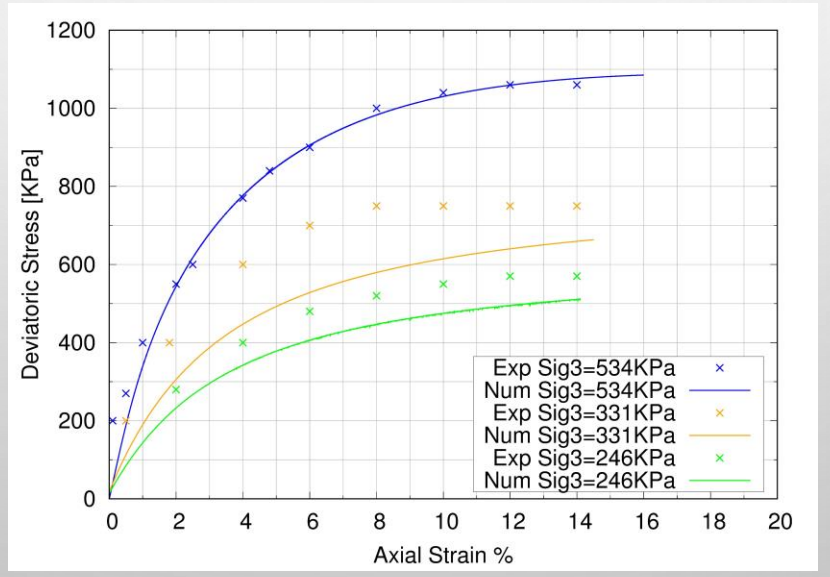


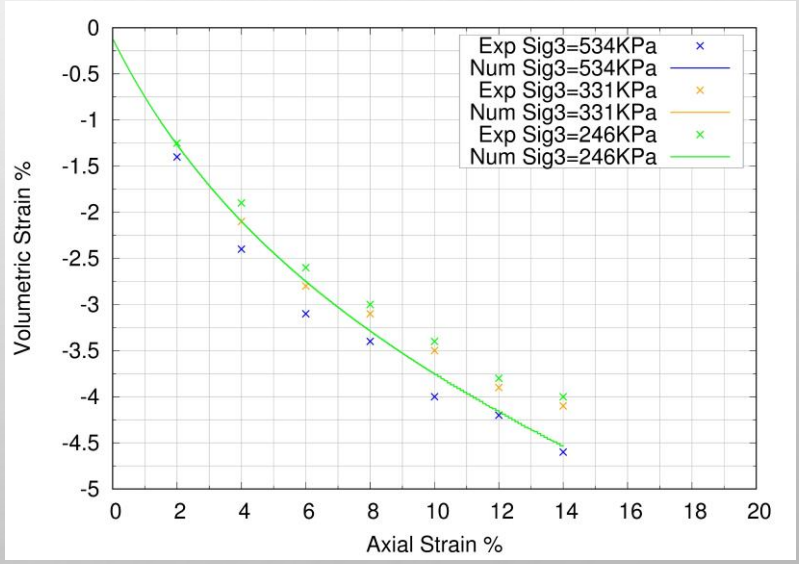




Mohr-Coulomb Model Parameters 5



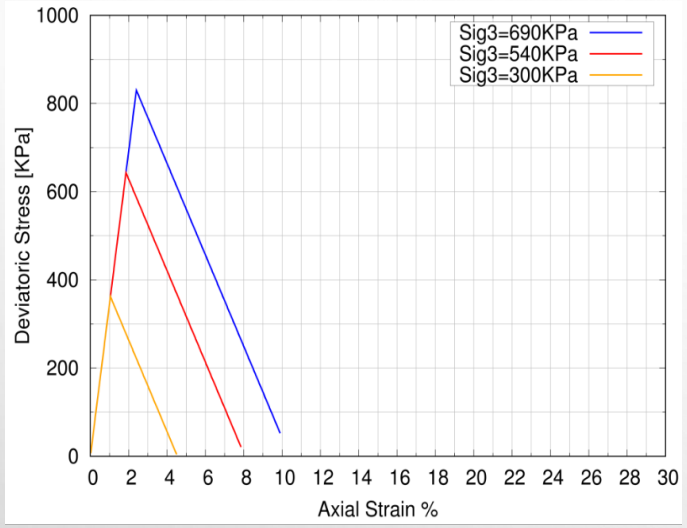




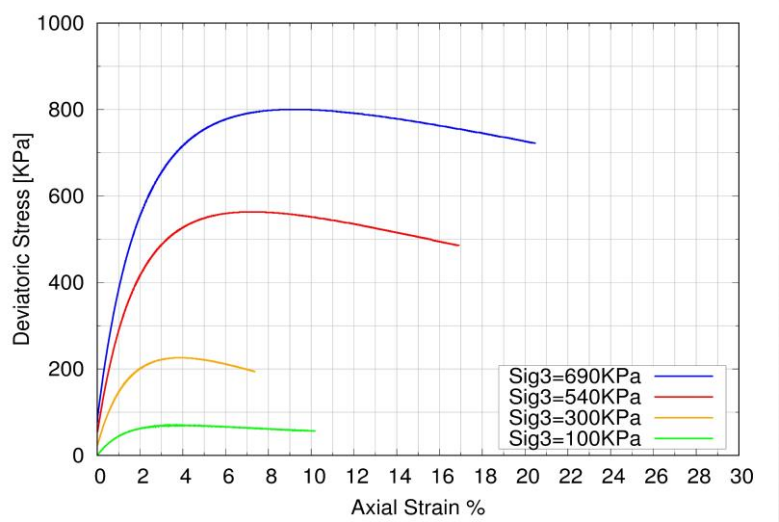
Cap-Yield Model Parameters 14

Validation of Mohr-Coulomb and Cap-Yield Model Criterion on Tropical Soils Undrained Triaxial Experimental Data (Futai et Al 2004)

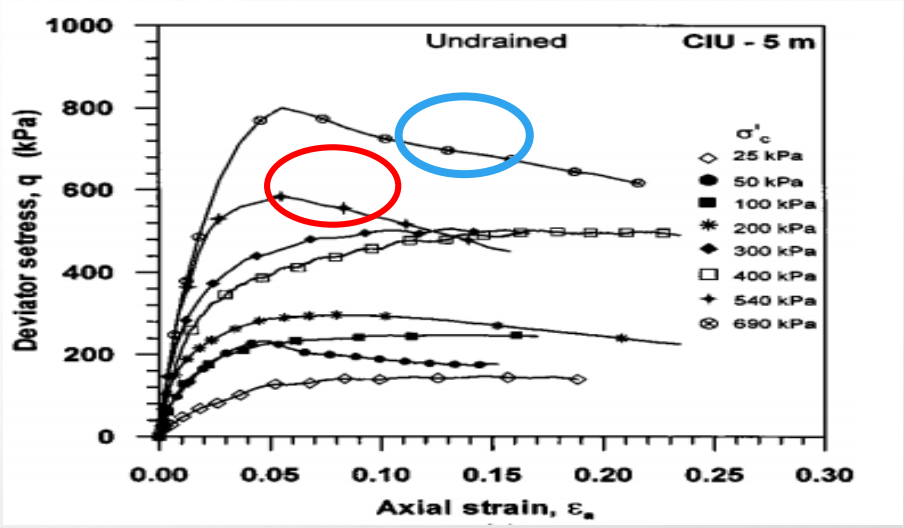
Mohr-Coulombl Numerical

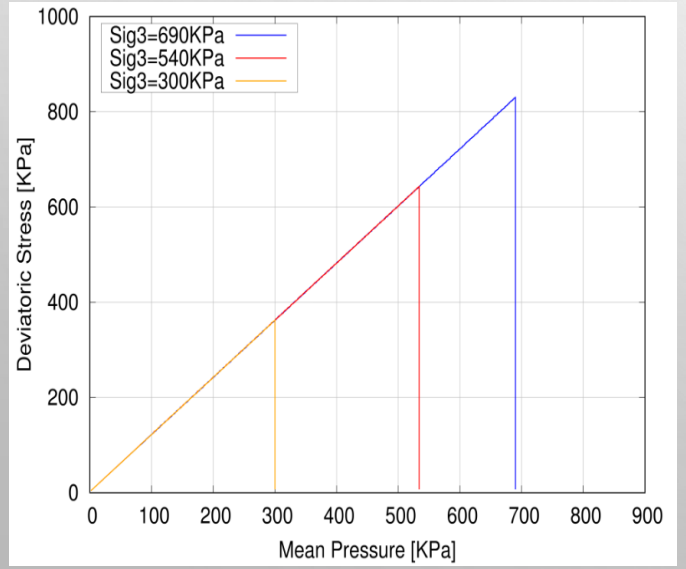


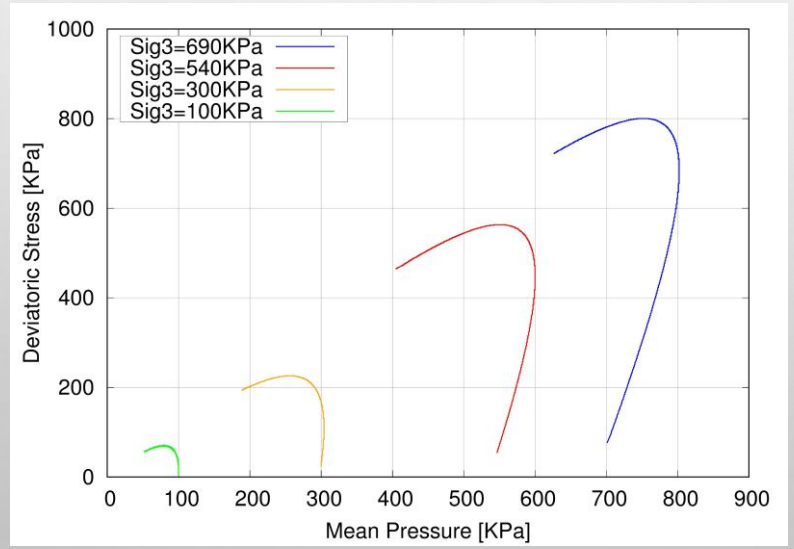
CY-Model Numerical

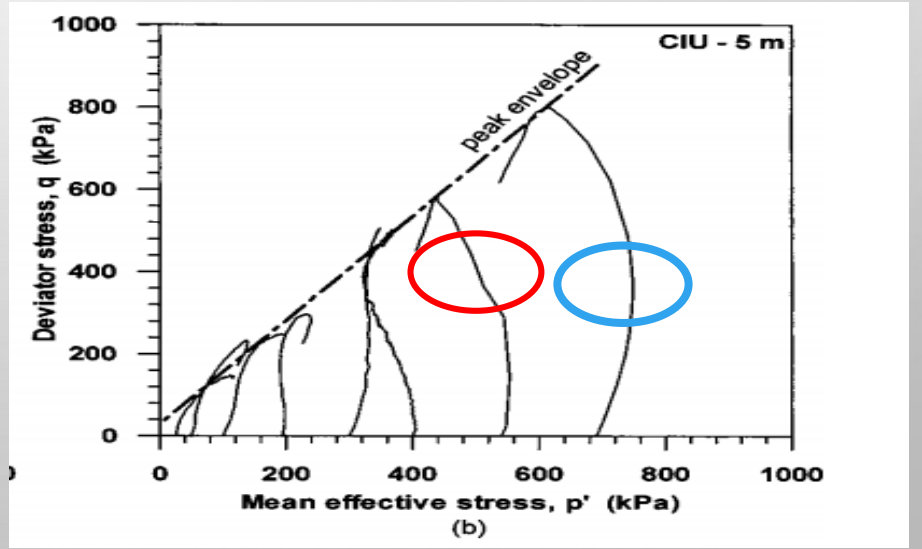


Experimental



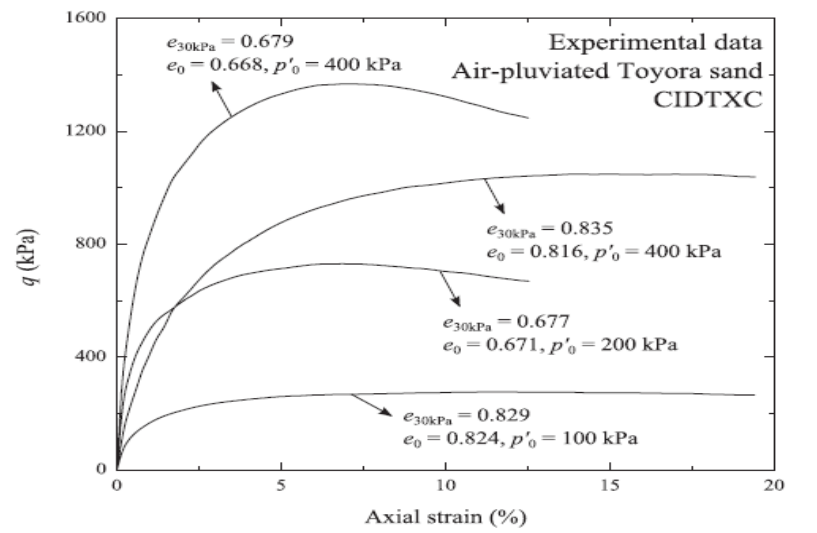


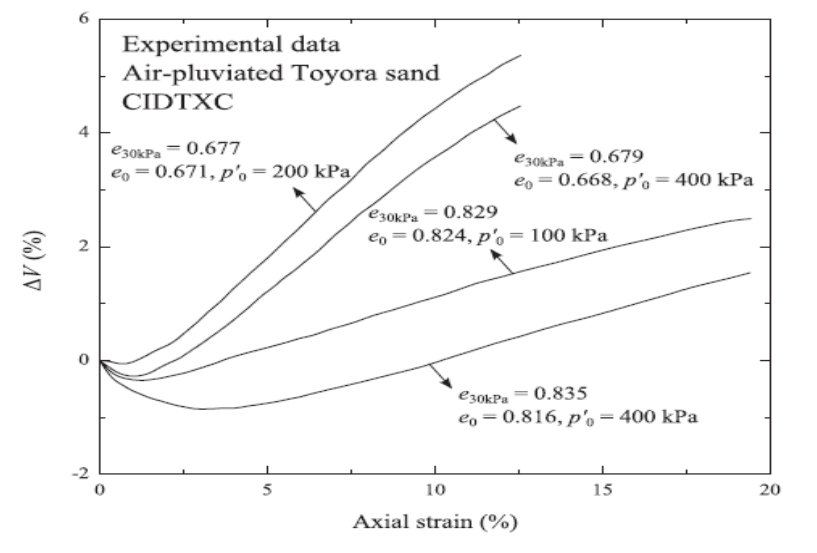




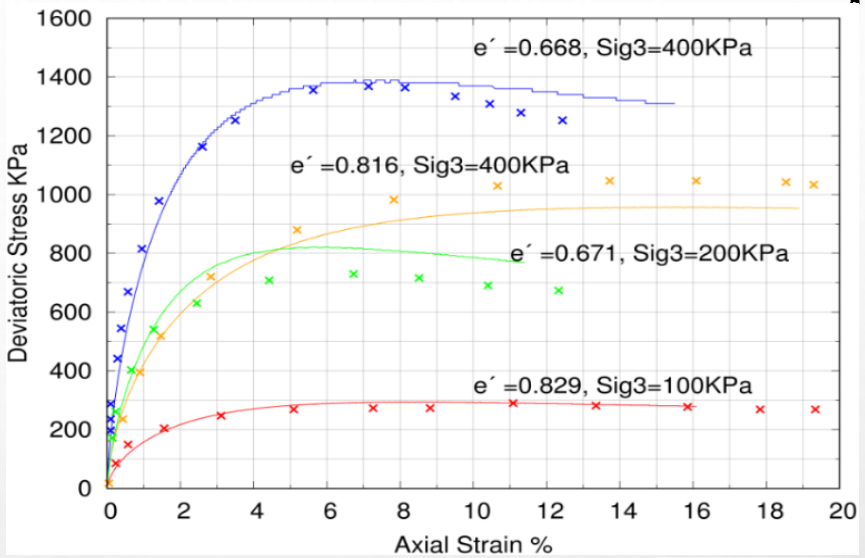
P2PSand Criterion 17 Parameters Calidation on Toyora sand, Experimental Data (Fukushima et al, 1984)

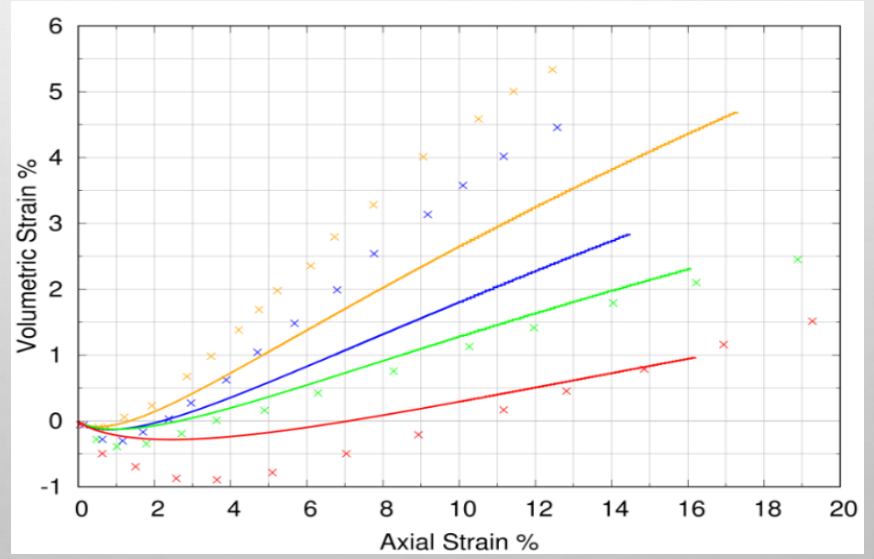
Experimental





Numerical





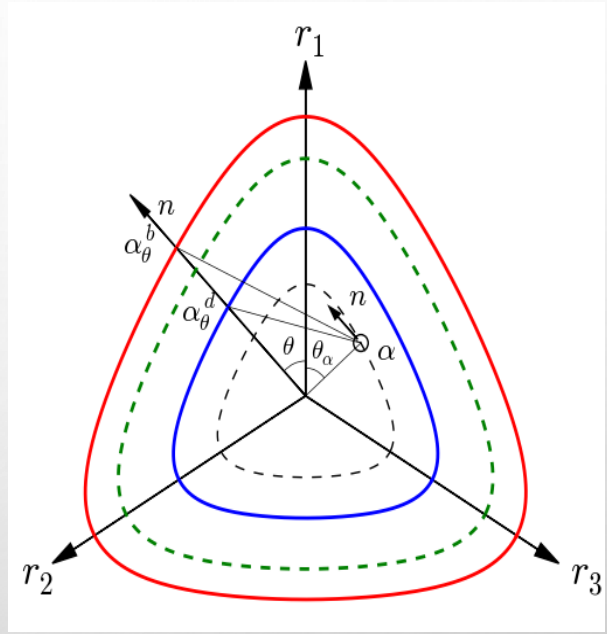
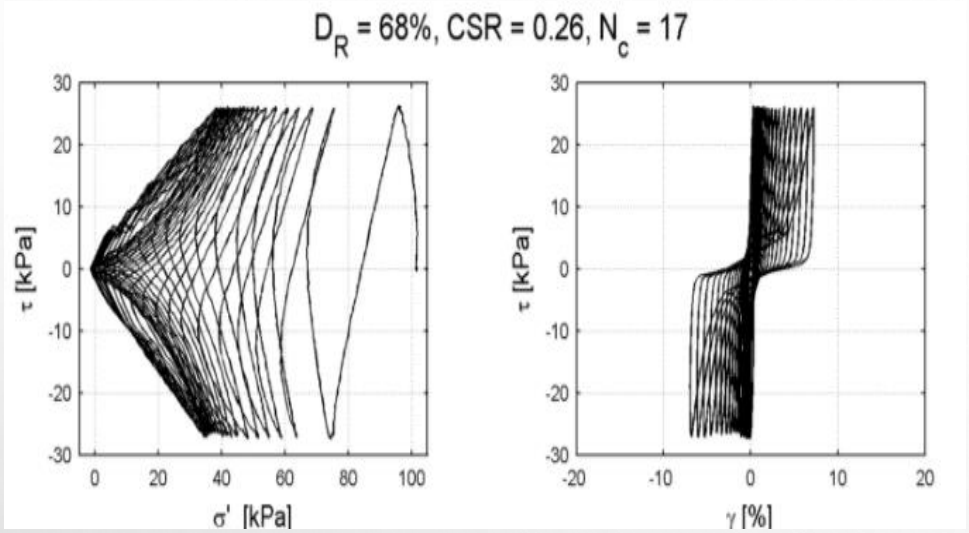
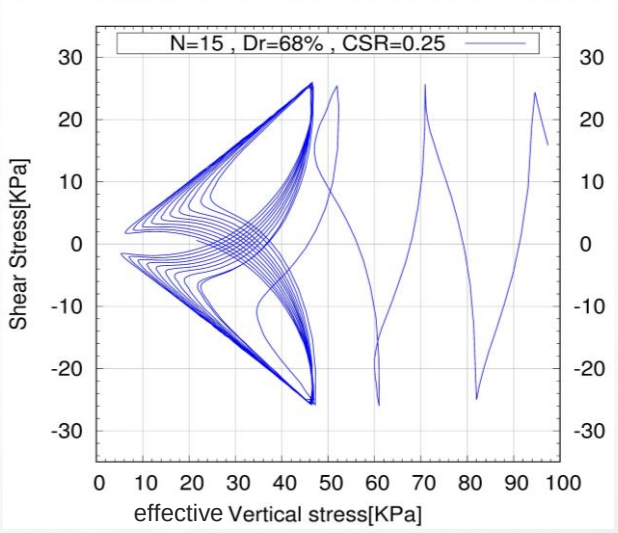


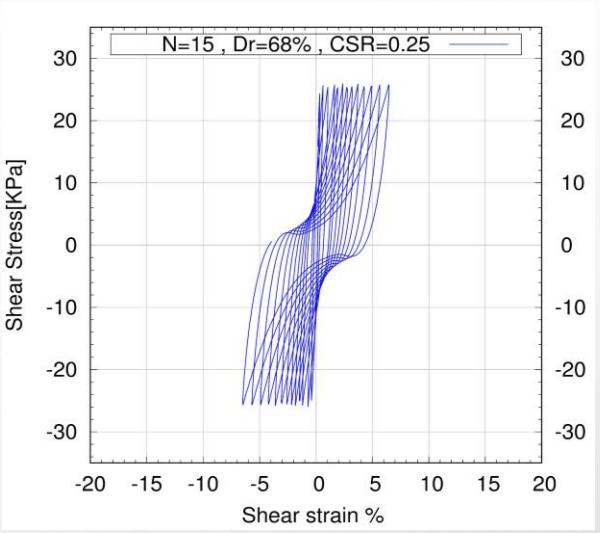
Figure 1: Schematic of surfaces in the π plane: bounding surface (red); dilatancy surface (blue); critical-state surface (green dash), maximum stress-ratio surface (black dash), and the yield surface (black circle).

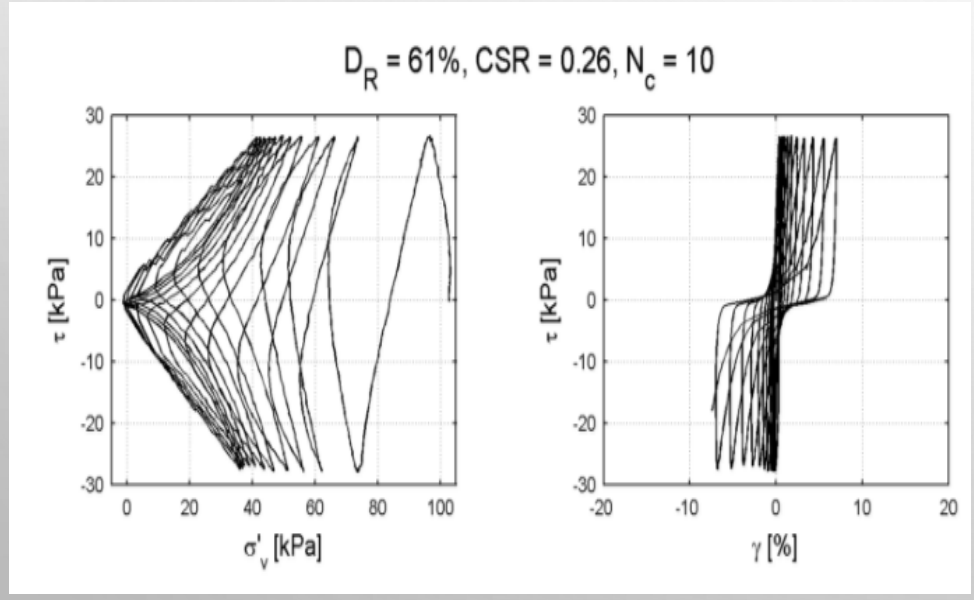
Stiffness depends on the distance from the current stress state to the bounding surface.

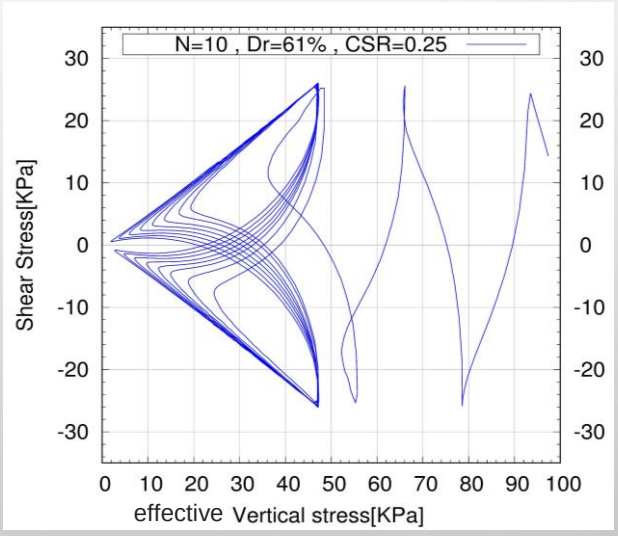
P2PSand Model Prediction of Liquefaction Phenomena Christchurch Sand Undrained Cyclic Simple Shear Test

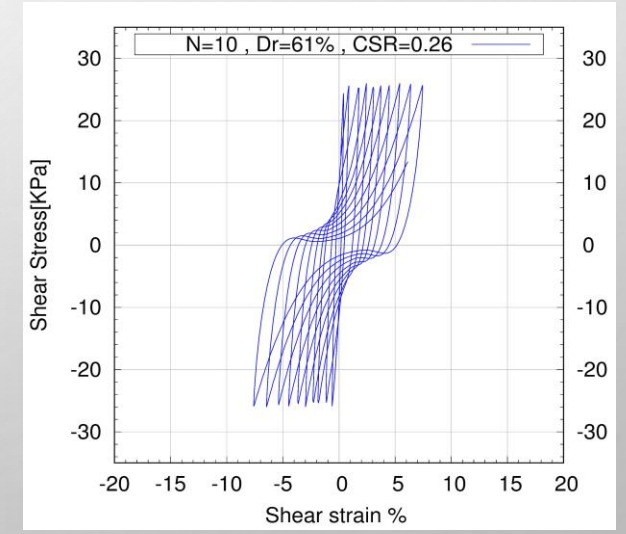








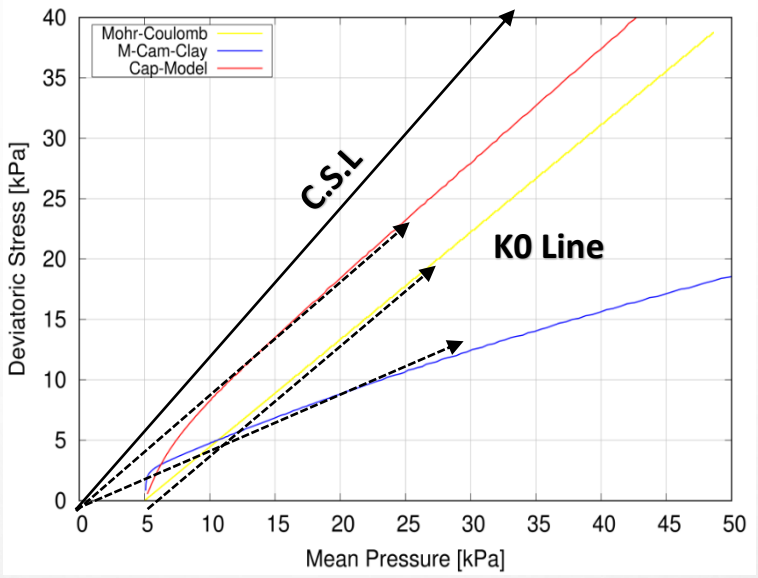


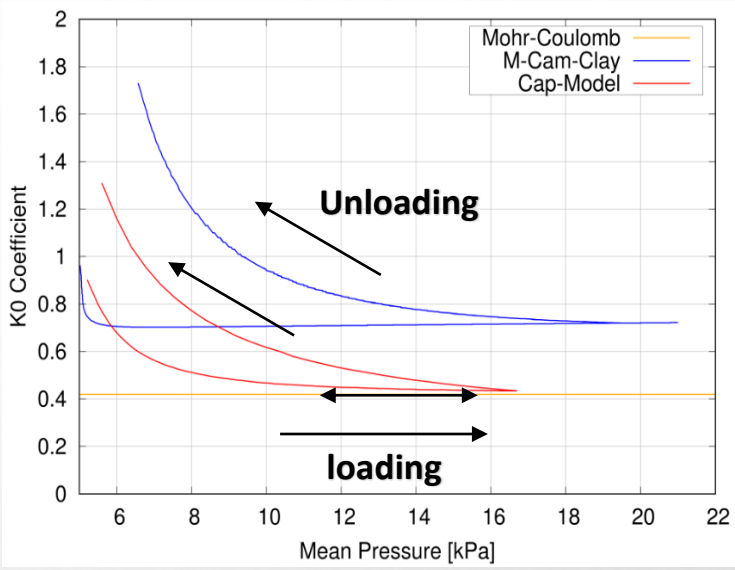


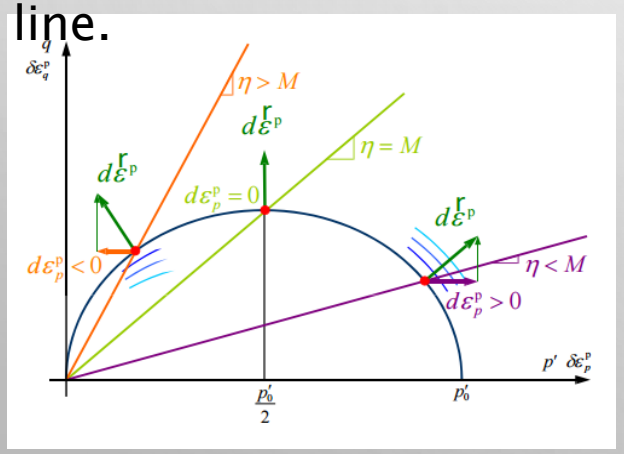
Experimental *Numerical*

Models Prediction for the Coefficient of Earth Pressure at Rest K0 Value

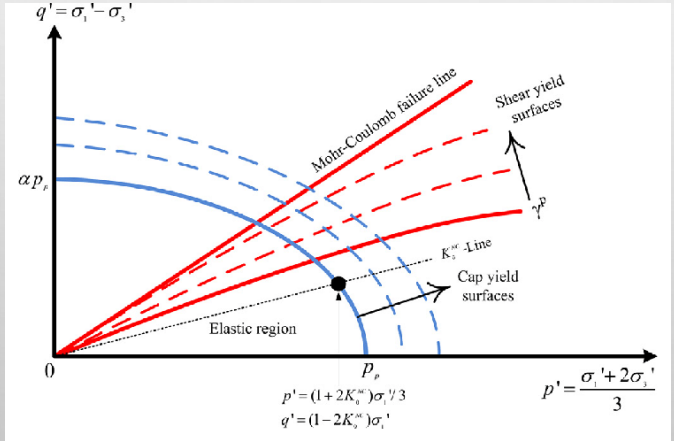
- K0 = σ_h/σ_v, coefficient is useful to initialize the initial stress state of the soil.
- MCC model predicts unrealistically high K0 values in normally consolidated state.
- The Mohr-Coulomb model predicts a constant Ko value for loading and unloading.
- This has been fixed in the Cap-Yield model by de-coupling the volumetric yield surface (cap) from the failure line.



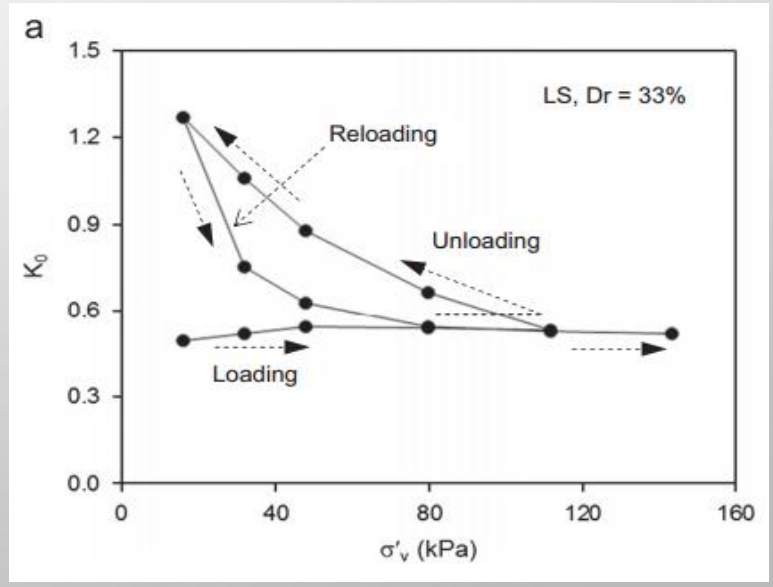




Modified Cam-Clay

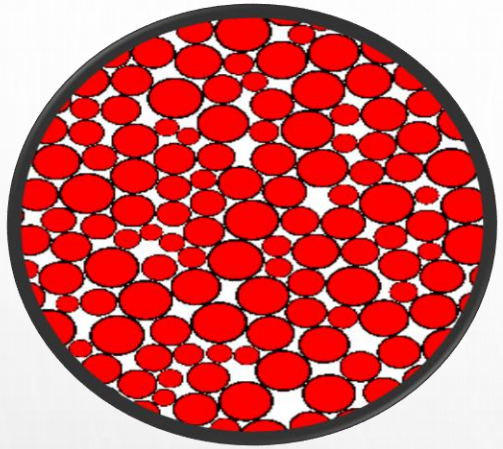


Cap-Yield Model

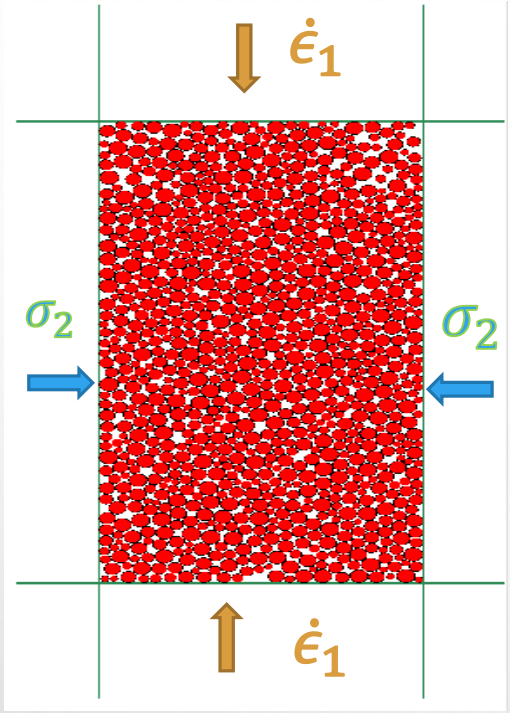


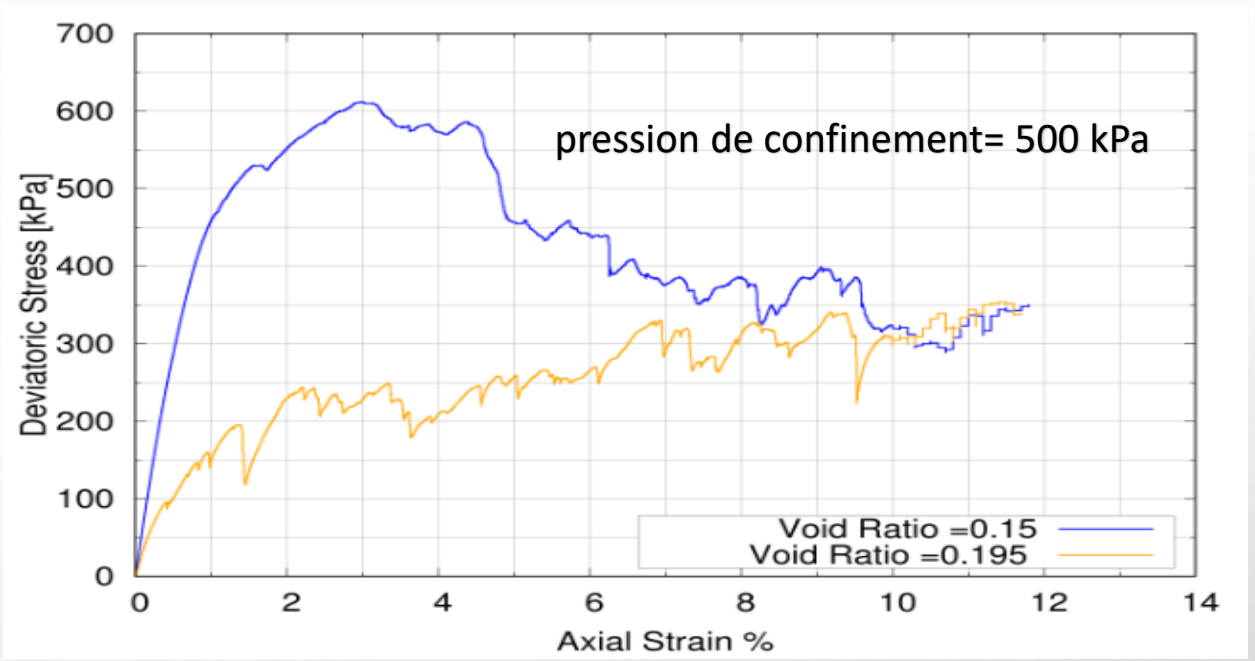
J. Lee et al, 2013

Essai Biaxial sur matériau granulaire (indice de vide)



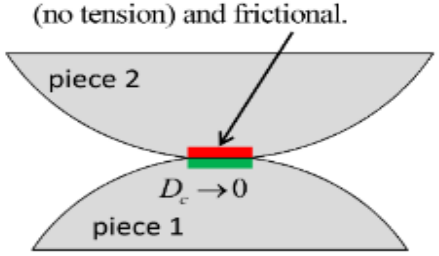
Dimension:
5*10 cm

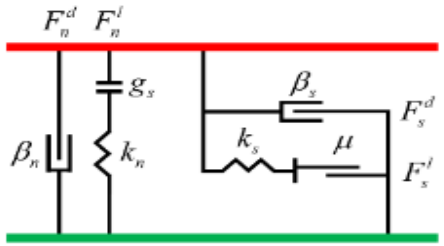




Dashpot force $(\mathbf{F}^d)$, viscous.

Linear force $(\mathbf{F}^l)$, linear elastic (no tension) and frictional.

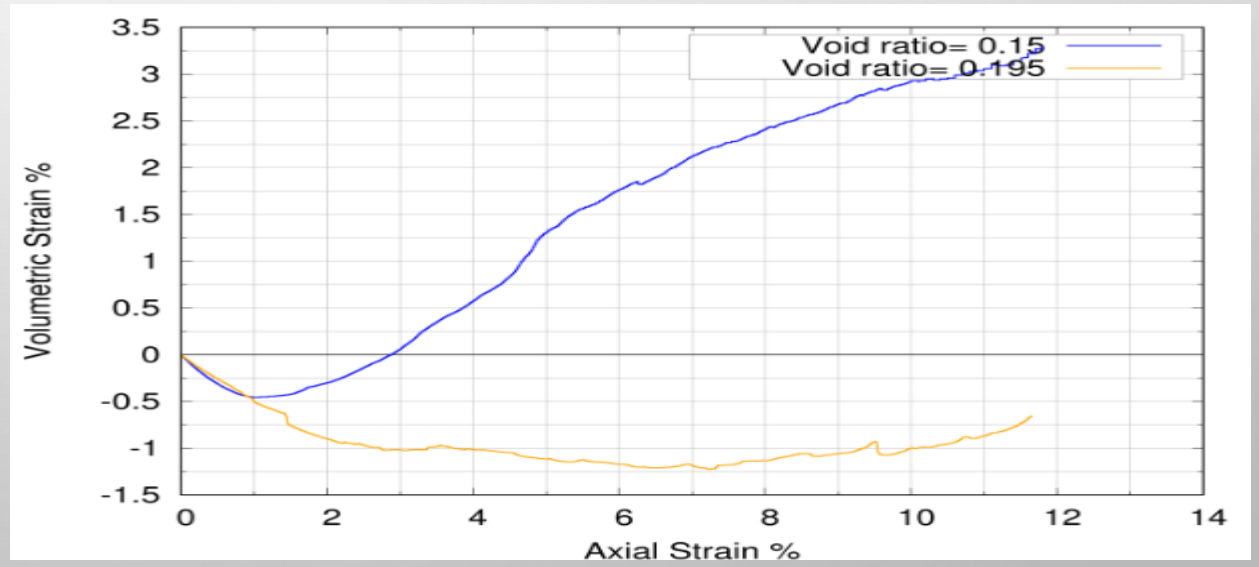




$\mathbf{F}_c = \mathbf{F}^l + \mathbf{F}^d, \ \mathbf{M}_c \equiv \mathbf{0}$

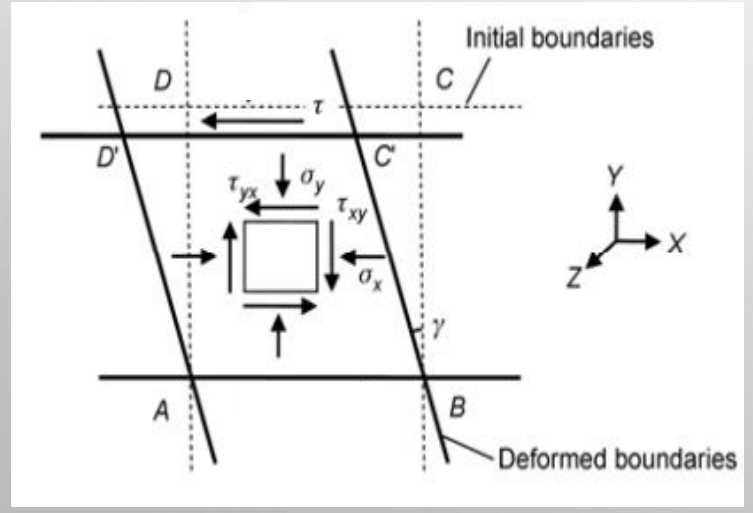
$F_n^l \leftarrow M_l, \ \mathbf{F}^d \leftarrow M_d$

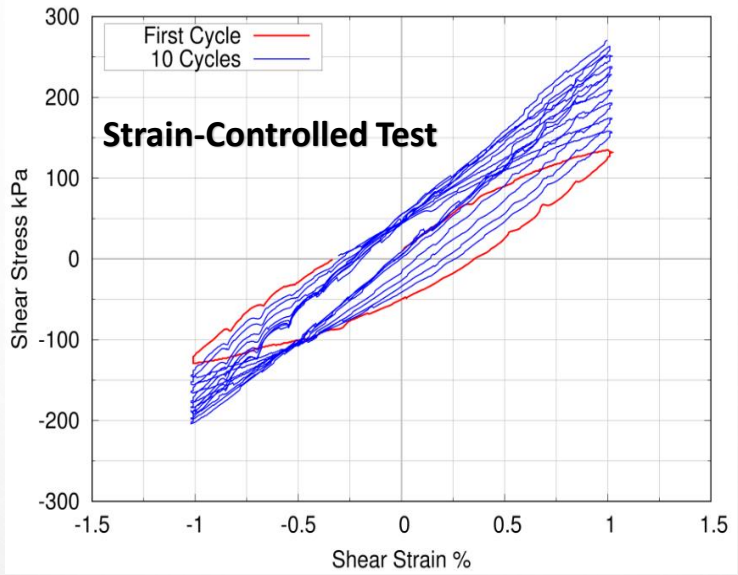
Figure 1: Behavior and rheological components of the linear model.

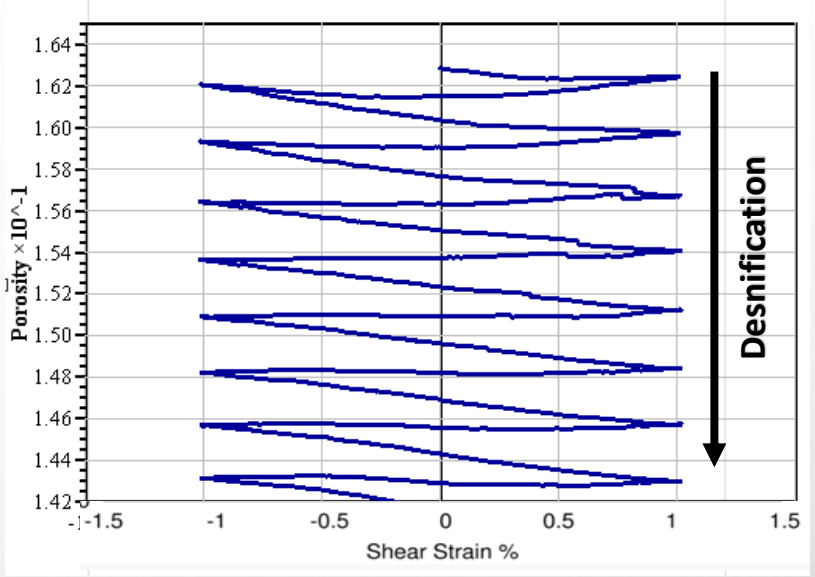


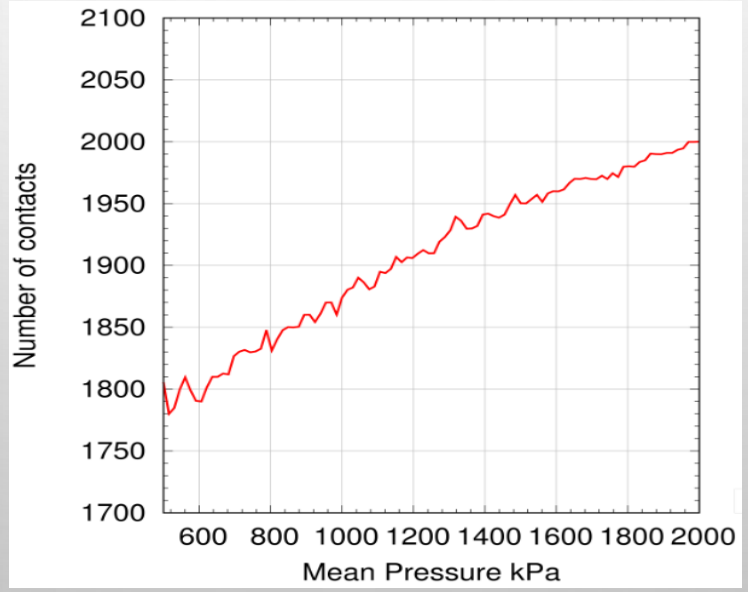
Prediction of DEM for Drained Cyclic Simple Shear Test

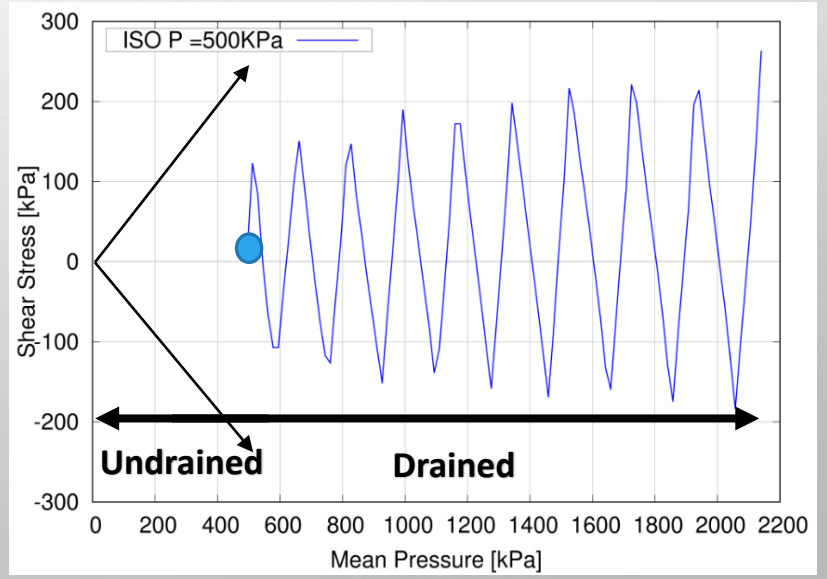
- The loading procedure includes two distinct stages, consolidation and shearing.
- The consolidation stage starts with an isotropic pressure which is applied on the sample.
- During the shearing, only shear stress is applied along the top surface.





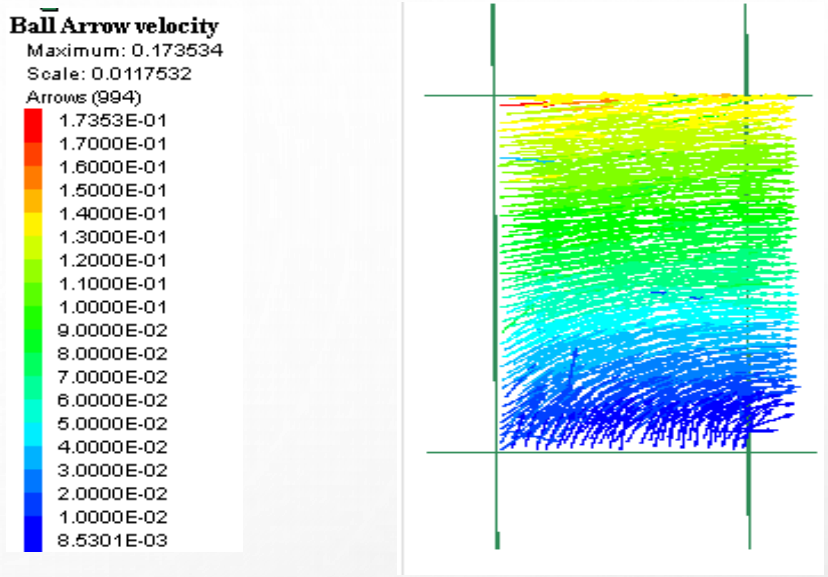






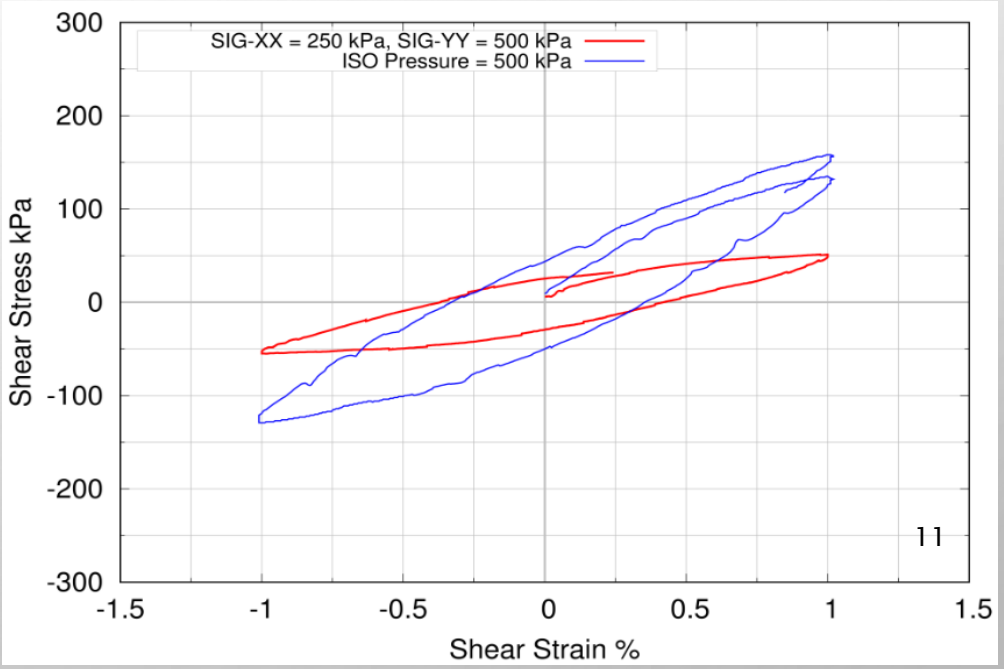
Remarks on Cyclic Simple Shear Test

- With three physical parameters, a complex behavior of soil can be described.
- The material response is shown, through the velocity vector of balls.
- The stress path of constant volume needs to be assessed (undrained condition).



Effect of Anisotropic Consolidation Stress Paths

- The change in the consolidation stress path leads to a decrease in the shear strength of the material for the same shear strain level.



Conclusions:

- A good prediction of k0 is a must to initialize the stress state of the model.
- The more the model is advanced/complex, the more the phenomena that could be described by the model.
- The most of the constitutive models are developed depending on ideal types of soil and on the classical stress paths.
- The more the model is complex, the more is the calibration effort (number of parameters).
- The discrete element method could be a good approach to simulate the behavior of the granular material.
- The computational time of the DEM is much higher than that of the soil models.

Thank You For Your Attention