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A MACROSCOPIC FRAMEWORK TO MODEL MATERIALS WITH EVOLVING PORE SIZE DISTRIBUTION

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Summary. A macroscopic modelling framework is presented to account for the change in microstructure that occurs in many geomaterials when loaded or subjected to environmental actions. The framework is based on recent concepts developed in unsaturated Soil Mechanics although it may be also used for saturated conditions. The Pore Size Distribution (PSD) of the material, which has a strong parallelism with the Water Retention Curve in unsaturated soils, is included in a strain-hardening elastoplastic framework, leading to the definition of a multi-surface model able to predict and capture the PSD evolution under straining and its effect on the mechanical response of the material. Model is further extended for different configurations of pore filling: liquid, liquid and gas, solid and liquid (for ex. ice), or solid, liquid and gas by defining a multi-phase effective stress concept on the basis of energy considerations. Performance of the model is analyzed by modelling different hydro-mechanical tests carried out on materials with marked microstructural changes under load and water content changes and validated on experimental results.

1 MODELLING FRAMEWORK

According to the framework of Critical State Mechanics, the hardening law is generally controlled by the volumetric plastic strain, leading to yield surfaces dependent on the global void ratio. This framework is here extended by considering voids distributed across families with different pore radii that may evolve with the load.

Fig.1 shows the PSD and the Cumulated PSD of silt samples compacted at three void ratios. By analogy with the Water Retention Curve ([1]), CPSDs are expressed as a combination of several single family modes of pore size distribution, each one expressed by simplified, integrable, van-Genuchten-like expressions:

$$e_r = \sum_{i=1}^{f} \omega_i e_{r_i} = \sum_{i=1}^{f} \omega_i \left(1 + \frac{r_{0_i}}{r}\right)^{-m_i} \qquad (1)$$

where e_r is the volume of void in all the families with radius higher than r, e_{r_i} is the volume of void in i-family with radius higher than r, ω_i is the weighting factor for family i and f is the total number of families. Both m_i and r_i are dependent of void ratio.

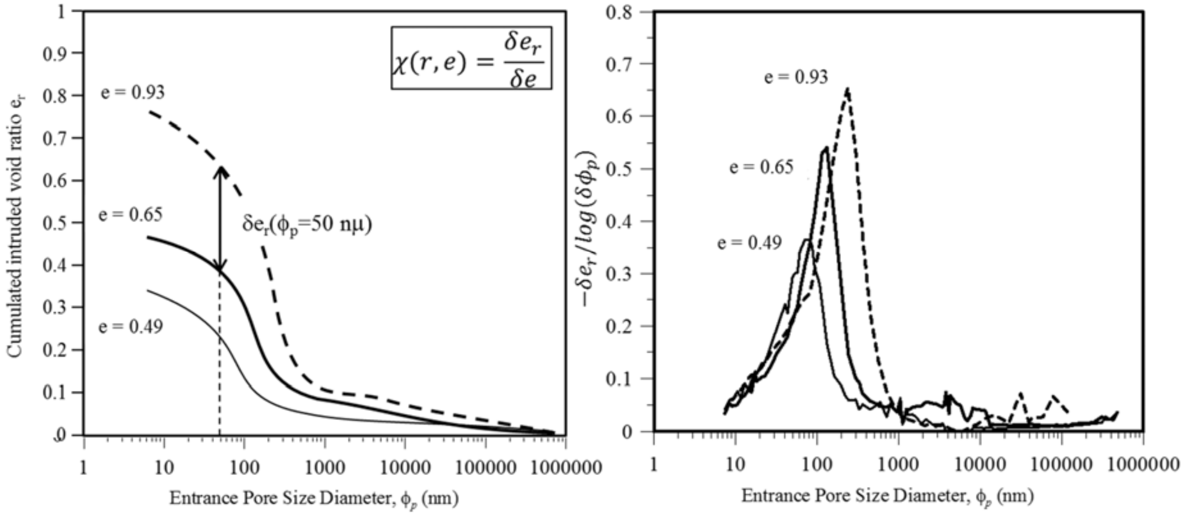

Fig. 1 – Graphical definition of χ coefficient from cumulated PSDs for the case of a clayey material at three densities.

Changes in PSD is introduced in the elastoplastic framework by considering a volumetric strain associated to the change in e_r and introducing *r* as a new variable.

$$\delta\varepsilon_{vr} = -\frac{\delta e_r}{1+e} = -\frac{\chi\delta e}{1+e} = \chi\delta\varepsilon_v \tag{2}$$

where χ is defined in Fig. 1. It depends generally on *r* and e values according to a variation law obtained by derivation of Equation 1 and the dependencies of m_i and r_{0_i} on void ratio. Once removed the elastic strains, Equation (2) appears to establish a rule between $\delta\varepsilon_{vr}^p$ and $\delta\varepsilon_v^p$, whose integration allows to define a yield surface and a flow rule in the stress-*r* plane. It states the onset of plastic changes in the PSD and its evolution under load.

Model is further extended to account for mechanical effects due to pore intruded multi-phase species in local thermomechanical equilibrium: liquid, liquid and solid (ice), liquid and gas (vapour) or solid, liquid and gas. A generalized effective stress is defined by considering interfacial energies and thermodynamics restrictions and dependencies of the hardening parameters on phase fraction and properties adequately introduced.

2. NUMERICAL SIMULATIONS

The model is applied to the modelling of a compacted materials with one-mode and two modes Pore Size distribution. PSD changes are followed for different hydro-mechanical paths and results validated on experimental data.

REFERENCES

[1] Casini, F., Vaunat, J., Romero, E. & Desideri, A. Consequences on water retention properties of double-porosity features in a compacted silt. *Acta Geotechnica*, 7(2):139-150, 2012. DOI 10.1007/s11440-012-0159-6.