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A CONSTITUTIVE MODEL FOR UNSATURATED SOILS WITH STRUCTURE DEGRADATION

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ABSTRACT

The mechanical behaviour of natural clays is significantly affected by their in situ or initial structure in the form of cementation or interparticle bonding. This behaviour can differ substantially from the behaviour of reconstituted clays. Models which explicitly account for structure, and damage to structure, within a single yield locus elastic-plastic framework are provided by Gens & Nova (1993). Further advances have been made using the framework of kinematic hardening bounding surface plasticity. Within this framework, a model has been developed by Rouainia & Muir Wood (1999) in which the kinematic hardening extension of Cam clay is combined with a simple measure of structure which gradually degrades as plastic deformation occurs. The next stage in the development of this model is to include the suction in order to describe the the weathering effects induced by drying-wetting cycles.

Suction as well as plastic volumetric strains drive isotropic hardening/softening as this is a simple way to account for the phenomenon of volumetric collapse upon wetting (Pereira & al. (2006)) and the stiffening effect that suction has on the soil skeletal response. The definition of the suction hardening component is sufficiently general such that it may describe the behaviour observed for a range of soil types.

Following the general framework proposed by Pereira *et al.* (2005), an extension to account for unsaturated states of the basis constitutive model for structured soils has been carried out. The stress state of the soil is described by an effective stress as proposed by Coussy and Dangla (2002) as follows:

$$\boldsymbol{\sigma}' = \boldsymbol{\sigma} - p_g \mathbf{1} - \frac{2}{3}\int_{S_r}^{1} s(S_r)dS_r \mathbf{1} \qquad (1)$$

where $\boldsymbol{\sigma}'$, $\boldsymbol{\sigma}$, p_g and $s = p_g - p_l$ respectively are the effective stress tensor, the total stress tensor, the gas pressure and suction (difference between gas and liquid pressures). Concerning the evolution of the preconsolidation pressure p_0' with respect to suction, the LC curve giving the net preconsolidation pressure evolution as a function of suction $p_0(s)$ of the Barcelona Basic Model (BBM) from Alonso

et al. (1990) has been used. Since the BBM model is defined in net stress-suction space, the following identification is used:

$$p_0' = p_g + \pi + p_0 \qquad \text{with} \qquad \frac{p_0}{p^c} = \left(\frac{p_0^*}{p^c}\right)^{\frac{\lambda(0)-\kappa}{\lambda(s)-\kappa}} \tag{2}$$

where $\lambda(s) = \lambda(0)((1-r)\exp(-\beta(s-s_e)) + r)$. The water retention curve, needed to fully define the effective stress, is modeled using Brooks and Corey's model:

$$S_r(s) = \left(\frac{s_e}{s}\right)^{1/\alpha} \tag{3}$$

The constitutive model has been implemented into a numerical procedure using an explicit algorithm and the modified Newton-Raphson method. Oedometer simulations under controlled suction have been performed and are presented in the following figures. The respective influences of the degree of structure and suction are investigated. A serie of collapse tests are also illustrated.

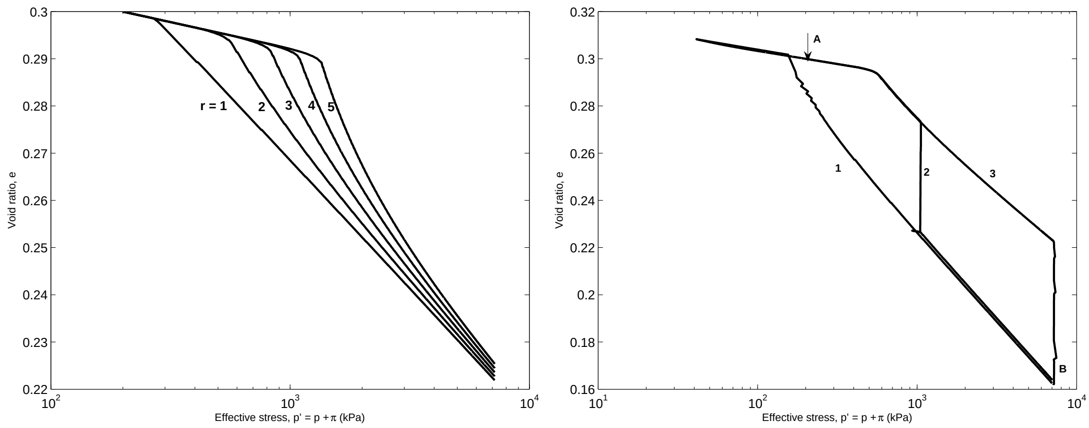

Figure 1: Effect of different values of intial structure and simulation of collapse tests.

In conclusion, a model that combine unsaturated and structured behaviour is used to simulate stress strain behaviour observed for an unsaturated clay subjected to oedometric test load paths, as well as volumetric collapse, using typical soil properties.

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