SOIL STRUCTURE CONSIDERATIONS
IN DESCRIPTION OF COMPACTED
AND NATURAL CLAY BEHAVIOUR

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INTRODUCTION
The term soil structure is usually referred to the combination of soil fabric, namely arrangement of particles, and inter-particle bonding. Soil structure properties are of great importance in geotechnical and geoenvironmental engineering as they influence many soil characteristics, such as compressibility (Labine 1958), hydraulic conductivity (Tamari 1984) or the soil-water characteristic curve (Brusart 1968) of both the compacted and natural soils. Structure of these materials might be strongly altered during the construction of the underground disposal including excavation or closure stages. Meanwhile, changes in soil structure could influence, through a coupled process, the soil behaviour in the phenomenon under study. Materials involved in such problems exhibit, in contrast to reconstituted homogenous soils, a bi-modal pore size distribution. It is widely accepted in the literature (Al-Mukhtar et al. 1996, Koliji et al. 2006, Gens et al. 1995) that these soils, especially the compacted clays, have two levels of structure: the soil microstructure defined as the elementary particle associations within the soil aggregates, and, the macrostructure corresponding to the arrangement of these soil aggregates and the relation among the structural units. In general, behaviour of these materials is associated with certain complexities which cannot be described by classical soil mechanics without accounting for the soil structure effects. Therefore, one of the key issues in description of the coupled hydro mechanical processes in natural or compacted clays is the explicit consideration of soil structure and its effects on the macroscopic behaviour of the material.

EXPERIMENTAL CHARACTERIZATION OF SOIL STRUCTURE
In this research study, the experimental technique of neutron tomography followed by image processing is used to study the soil structure and its evolution induced by external mechanical loading during the one-dimensional compression of a double structure soil. Neutron tomography is a non-destructive technique for investigating the distribution of neutron attenuating materials. This technique, together with computed tomography algorithms, yields the three-dimensional array of the volume of the sample in terms of local neutron attenuation coefficient as it is shown in Figure 1(a). Reconstructed volumes of the sample are processed by a sequence of spatial filters, segmentation and morphological operations in order to study the evolution of soil structure. Accordingly, the macro porosity of the sample at different loading steps is obtained for the sample.

Experimental results revealed that significant change in macro porosity is observed only with occurrence of plastic (irreversible) deformation. Further analysis of geometrical properties of the pores indicate that a reconstituted state of the material with fully removed structure could be achieved only through the combined occurrence of both volumetric and devoratic plastic deformations. Moreover, unsaturated oedometric testing of these materials show that soil structure becomes more brittle at higher values of suction and therefore more pronounced degradation of structures with occurrence of plastic deformations is anticipated at higher values of suction. This phenomenon is ascribed to the evolution of soil fabric and decrease of macro pores as a results of suction increase (Cuisinier and Laloui, 2004).

REMARKS ON CONSTITUTIVE MODELLING
As a first step in inclusion of soil structure effects in constitutive models, a state parameter has to be introduced in order to reflect the current structure of the material. A candidate for this parameter is the
degree of soil structure defined here as the normalized value of macro void ratio with respect to its initial value $e_0^m$, namely:

$$ R = \frac{e^m}{e_0^m} \quad (1) $$

This state parameter represents an internal scaling variable which is equal to 1 for the soil with initial structure and equal to zero for a fully destructured soil. Figure 1(b) depicts, on the basis of tomography results, the variation of degree of soil structure versus the plastic strains of the sample (only volumetric effects are considered) at different loading steps. Evolution of degree of soil structure observed in this figure can be well reproduced by a decreasing exponential function of volumetric plastic strain $\varepsilon_P^v$:

$$ R = \exp(-\omega \varepsilon_P^v) \quad (2) $$

In this relation, $\omega$ is a material parameter that controls the rate of structure degradation with plastic deformation. It should be mentioned that rate of structure degradation, and consequently the rate controlling parameter, might be subjected to changes depending on the humidity, temperature and chemical condition of the soil. The evolution rule proposed here could be directly employed to make inclusion of soil structure effects into constitutive models and to describe the extra features of soil behaviour stemming from the current structure of the material.

As a concluding remark, it is noteworthy that the structural parameters in proposed models should be determined on the basis of experimental observations at both pore-scale and macro scale of the material.

References:


