

CONSTITUTIVE MODEL FOR EXPANSIVE CLAYS UNDER CHEMICAL CHANGES

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It has long been recognised that the mechanical and hydraulic behaviour of very active clays is significantly affected by their geochemical environment. These interactions are coupled at different scales making the resulting behaviour quite complex [1]. The interest in the interaction between hydromechanical clay behaviour and chemical variables has been recently reinforced by the potential use of these materials as part of containment systems for hazardous wastes, notably radioactive waste. A characteristic feature of these materials is their sensitivity to the solutes present in the pore water and to the nature of the cations in their exchange sites (e.g. [2-5]).

Here a phenomenologically-based chemomechanical model is presented based on the double structure framework for unsaturated expansive clays described in [6]. The aim is to obtain a constitutive model that it is simple enough to be used in coupled analyses of engineering problems but it incorporates the relevant chemical variables [7]. The chemical variables selected for modelling are the equivalent fractions of exchangeable cations and the osmotic suction. The model considers explicitly the phenomenon of cation exchange that plays a key role in the mechanical behaviour of expansive clays. The constitutive model is developed for unsaturated soils; saturated behaviour is obtained as a limiting case. Currently, only the volumetric part of the model, the core of the formulation, has been fully developed.

The main feature of this conceptual model is the distinction between two structural levels, a microstructural level and a macrostructural level. The macrostructural level is made up of the ensemble of particle aggregates and macropores that can be viewed as forming a granular-like fabric. Other macrofabrics are however possible depending on the type of material considered and on the way it was generated. The behaviour of the macrostructure can be described by concepts and models developed for conventional soils. The microstructural level is defined by the basic physico-chemical phenomena occurring at clay-particle level. The complete expansive soil model requires, in addition, the specification of the interaction between the two structural levels. A basic assumption is that the microstructural behaviour is not influenced by the macrostructure. This is reasonable as it is unlikely that the basic physico-chemical

processes will be affected by non-local variables such a macrostructural fabric. In contrast, microstructural deformations may modify or disrupt the macrostructural fabric causing irreversible deformations. Interaction functions provide the required link between the two levels. Chemical effects are attributed exclusively to their natural seta, the microstructure, but of course the overall behaviour is affected by the interaction between structural levels.

The incremental form for the nonlinear elastic microstructural volumetric strain so given by:

$$d\varepsilon_m^e = d\Omega_m^e = \beta_m e^{-\alpha_m \hat{p}} d\hat{p} - \frac{1}{\alpha_m} e^{-\alpha_m \hat{p}} d\beta_m \quad (1)$$

where \hat{p} is the microstructural mean effective stress, α_m is a model parameter and β_m depends on the exchangeable cation concentrations.

An example of application, in a multi-cation test is shown in Figure 1.

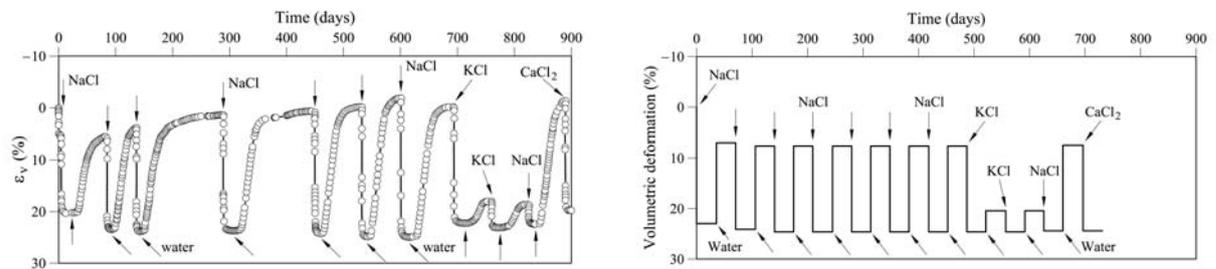


Figure 11. Cyclic exposure of a sodium bentonite to saturated solutions of NaCl, KCl and CaCl₂ under an axial stress of 40kPa. Left: Experimental results (after [8]). Right: Computed model response

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