On the mechanical behavior of expansive porous media with consideration on chemical effects

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Experimental geomechanics highlights that the mechanical behavior of expansive porous media is variable depending on the pore water chemical composition. These porous media are typically characterized by clay particles, whose activity (Skempton, 1953) (and thus propensity to expand) is itself dependent on the pore water chemical composition. Chemical-induced mechanical effects on both shear strength and volumetric behavior are highlighted in the literature (Di Maio, 1996; Castellanos et al., 2008). The physical-chemical origin of this mechanical dependence is still debated. Consequently, geomechanical approaches that can properly include these effects are still limited. The possibility of using a generalized effective stress concept for the mechanical modeling of these materials is an attractive proposition with the following advantages (Nuth and Laloui, 2008): (i) assured transition between saturated and unsaturated states, (ii) uniqueness of the critical state line irrespective of the degree of saturation, (iii) direct inclusion of hydraulic effects and corresponding hysteretic characteristics. In this contribution, we first account for the solid particle-pore water interaction and distinguish the different types of ions and water characterizing expansive porous media (Tuttolomondo et al., 2021). Also, we highlight how the presence of both movable and non-movable ions is essential in defining the pore water chemical composition. Second, we provide an analytical approach for determining the pore water pressure and replace the specified expression in the generalized effective stress definition. The effective stress also depends on a chemical variable related to the interaction between the solid particles and the pore water. The water retention curve (describing the evolution of matric suction at varying degree of saturation) and the effective solute suction curve (representing the evolution of the introduced chemical variable at varying degree of saturation) are essential to account for the retention state of the material and the chemical composition of the pore water at any state of interest. Existing experimental results in the literature, both at saturated and unsaturated conditions, are reinterpreted to investigate the advantages of the proposed geomechanical approach. The results obtained highlight, among others, the following additional benefits when using the proposed extension of the generalized effective stress concept: (i) the uniqueness of the failure envelope irrespective of the pore water chemical composition; (ii) the possibility of predicting elastic strain induced by pore water chemical composition changes (Tuttolomondo et al., 2021). Combined with the provided physico-chemical explanation, these results bring the basis for an advanced stress-strain constitutive modeling.

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