

## THE MECHANICS OF ACTIVE CLAYS CIRCULATED BY SALTS, ACIDS AND BASES

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### ABSTRACT

The minerals of chemically sensitive clays are electrically charged. This charge is said to be *fixed* (in contrast to that of *mobile* ions) and is located partly on the faces of the clay units (the *permanent* and negative charge), and partly on the edges of clay particles (the *variable* charge). The charge located on the particle edges is modified by the pH of pore fluid, via surface complexation mechanisms that involve the hydrogen and hydroxyl ions, H<sup>+</sup> and OH<sup>-</sup> respectively.

The experimental evidences show that the changes of the chemical content of the electrolyte circulating in materials with fixed charge, induce volume changes, shrinking and swelling, and modifications of mechanical properties. The intensity of chemo-mechanical couplings is strongly dependent on the value of the fixed charge.

The key point is that chemo-mechanical effects are mostly reversible, provided an appropriate chemical loading cycle is applied. Metallic ions do not bind permanently to the minerals and do not modify the fixed charge. Acids and bases on the other hand modify the fixed charge at particle edges, thus affecting edge-to-face associations between particles.

An elastic-plastic model that accounts for electro-chemo-mechanical couplings in clays, due to the presence of dissolved salts and acids and bases, is developed.

Within the proposed constitutive framework, chemically sensitive clays are viewed as two-phase multi-species saturated porous media circulated by an electrolyte. The developments are embedded in the framework of the thermodynamics of multi-phase multi-species porous media. This approach serves to structure the model, and to motivate constitutive equations. The present extension capitalizes upon the earlier developments by Loret et al. (2002), Gajo et al. (2002) and Gajo and Loret (2004), which were devoted to modelling chemo-mechanical couplings at constant pH.

Four transfer mechanisms between the solid and fluid phases are delineated in the model: (1) hydration, (2) ion exchange, (3) acidification, (4) alkalization. Thus all fundamental exchanges at particle level are fully taken into account. Only mineral dissolution is neglected, since experimental observations indicates a negligible role of

mineral dissolution for active clays at room temperature. In particular, the newly considered mechanisms of acidification and alkalization directly affect the electrical charge of clay particles and thus have a key role in the electro-chemo-mechanical couplings. Due to the reversibility of chemo-mechanical couplings, these four mechanisms are seen as controlling both elastic and elasto-plastic behaviours (Gajo and Loret, 2007). Depending on concentrations and ionic affinities to the clay mineral, these mechanisms either compete or cooperate to modify the compressibility and strength of the clay and may induce swelling (volume expansion) or shrinking (volume contraction).

The proposed framework is sufficiently rich to allow for an accurate simulation of recently performed laboratory experiments on clay samples submitted to intertwined mechanical and chemical loading programmes, involving large changes in ionic strengths and pH and leading to large volumetric strains and relevant changes of stiffness and strength.

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