



Macroscopic Behavior of Swelling Porous Media Derived from Micromechanical Analysis

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(Received: 30 November 2000; in final form 27 June 2001)

Abstract. A new macroscopic model for swelling porous media is derived based on a rigorous upscaling of the microstructure. Considering that at the microscale the medium is composed of a charged solid phase (e.g. clay platelets, bio-macromolecules, colloidal or polymeric particles) saturated by a binary monovalent aqueous electrolyte solution composed of cations ‘+’ and anions ‘-’ of an entirely dissociated salt, the homogenization procedure is applied to scale up the pore-scale model. The microscopic system of governing equations consists of the local electro-hydrodynamics governing the movement of the electrolyte solution (Poisson–Boltzmann coupled with a modified Stokes problem including an additional body force of Coulombic interaction) together with modified convection–diffusion equations governing cations and anions transport. This system is coupled with the elasticity problem which describes the deformation of the solid phase. Novel forms of Terzaghi’s effective principle and Darcy’s law are derived including the effects of swelling pressure and osmotically induced flows, respectively. Micromechanical representations are provided for the macroscopic physico-chemical quantities.

Key words: swelling porous medium, homogenization, Poisson–Boltzmann equation, ion transport, electrohydrodynamics, double-layer theory, modified Terzaghi’s principle, electro-osmosis, anomalous osmosis, disjoining (swelling) pressure.

1. Introduction

Swelling porous media are ubiquitous in almost all aspects of life. For example, swelling clays are distributed widely in nature. In agriculture, water adsorption by the clay determines the ability of soils to transport and supply water and nutrients. Compacted bentonites play a critical role in various high level nuclear waste isolation scenarios and in barriers for commercial land fills. In civil engineering and construction swelling and compaction of clayey soils induce stresses which are very troublesome in foundation and structures of buildings. Techniques based on electrokinetics phenomena have been used to extract contaminants from polluted fine grained expansive clay soils. Swelling is a problem to the drilling