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A Multiscale Theory of Swelling Porous Media: II. Dual Porosity Models for Consolidation of Clays Incorporating Physicochemical Effects

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Abstract. A three-scale theory of swelling clay soils is developed which incorporates physico-chemical effects and delayed adsorbed water flow during secondary consolidation. Following earlier work, at the microscale the clay platelets and adsorbed water (water between the platelets) are considered as distinct nonoverlaying continua. At the intermediate (meso) scale the clay platelets and the adsorbed water are homogenized in the spirit of hybrid mixture theory, so that, at the mesoscale they may be thought of as two overlaying continua, each having a well defined mass density. Within this framework the swelling pressure is defined thermodynamically and it is shown to govern the effect of physico-chemical forces in a modified Terzaghi's effective stress principle. A homogenization procedure is used to upscale the mesoscale mixture of clay particles and bulk water (water next to the swelling mesoscale particles) to the macroscale. The resultant model is of dual porosity type where the clay particles act as sources/sinks of water to the macroscale bulk phase flow. The dual porosity model can be reduced to a single porosity model with long term memory by using Green's functions. The resultant theory provides a rational basis for some viscoelastic models of secondary consolidation.

Key words: swelling clay soil, mixture theory, homogenization, consolidation, swelling pressure, disjoining pressure, dual porosity.

1. Introduction

Swelling clay soils consisting of an assemblage of clusters of hydrous alluminium and magnesium silicates with an expanding layer lattice are widely distributed in the earth's crust. Their behavior is of paramount importance in almost all aspects of life, where they are responsible for many reactions and processes. For example, compacted clays such as bentonite have been extensively used to impede the movement of water through cracks and fissures. They play a critical role in various waste isolation scenerios such as barriers for commercial land fills. In the context of oil and gas production, drilling muds play a critical role ([45, 75]). Swelling clays also play a critical role in the consolidation and failure of foundations, highways and runways. For example, the foundation engineers face problems when a foundation