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A Fully Coupled Thermo Hydraulic Poro-Plasto-Damage Model for Semi-Brittle Geomaterials

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Abstract

The aim of this paper is to present a new elastoplastic damage model for unsaturated porous media. The proposed model within the context of poromechanics is intended for constitutive modeling of semi-brittle geomaterials. Independent stress state variables, namely net stress and suction, are adopted as stress variables of the model which are transformed into the damaged state through the definition of effective damaged suction and effective damaged net stress. The model has been implemented in Θ-STOCK Code and predictive capabilities of the model have been evaluated against experimental results from the literature. The proposed model is shown to give satisfactory simulation results which match the experimental data from a heating test on bentonite samples. The proposed model appears to be robust for modeling of radioactive waste underground repositories.

Keywords: Unsaturated porous media, coupled thermo hydro-mechanical model (THHM), Damage

1. INTRODUCTION

Nonlinearity of behavior of geomaterials was traditionally attributed to slippage and dislocation of particles of porous media skeleton and was therefore modeled using mere elastoplastic models [1,2].

The experimental results from triaxial tests performed by Chiarelli [3] have shown two basic phenomena on the overall mechanical responses of the argillaceous sedimentary formations [4]. Irreversible strains essentially related to plastic deformation by clay sheet sliding which is associated with a progressive damage. Accordingly both of these dissipative aspects should be taken into account; therefore an elastoplastic damage model is required for constitutive modeling of such geomaterials.

Tarantino *et al*. [5] carried out some tests which strongly support the proposition of independent stress state variables by [6]. This would be due to the fact that independent stress state variables can be considered as reflection of the most meaningful physical quantities of an unsaturated medium. In fact, preference of these variables is based upon the supporting experiments. Experimental observations made to date have confirmed the physical appropriateness of the adoption of independent stress variables for the modeling of governing mechanisms of unsaturated media. As cited by Fredlund [7] "*… it is the two independent stress tensors containing stress state variables (i.e., [net stress] σ-u_a and matric suction, u_a-u_w) that form the most general and fundamental basis for the development of a science for unsaturated soil mechanics*." Considering the above, independent stress state variables including suction and net stress are adopted as stress variables of the present model.

In this paper, a new model is formulated within the context of poroplasticity and continuum damage mechanics. The new poro-plasto-damage model involves damage and thermal dependency of plastic yield surface. The model has been implemented in Θ-STOCK Code which is a finite element code for analysis of coupled problems of multiphase porous media. The program is developed by Gatmiri and his co-workers and validated by various research and practical problems of geotechnical engineering [8-13].

Following previous models of Gatmiri [14,15], a fully coupled thermo-hydro-mechanical formulation is employed for the fluid flows and the balance equations of the model. The proposed model is expected to be a useful tool for simulation of complex, coupled response of engineered and geological barriers surrounding heat-emitting waste canisters in the context of geological disposal of high-level nuclear wastes.