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Thermo-hydro-mechanical modeling of clayey geological medium: Theoretical framework and numerical study

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In recent years, interest in argillaceous rocks has increased because they are being considered as potential host geological media for underground repositories of high-level radioactive waste (HLW). The host rock around the repository cells, containing the exothermic waste canisters, will be submitted to various coupled mechanical, hydraulic, and thermal phenomena. For a proper understanding and appropriate modelling of the excavation damaged zone around repository cells at elevated temperatures, the combined effects of those phenomena should be considered in an advanced constitutive model. The thermo-hydro-mechanical (THM) model presented herein is dedicated to non-isothermal unsaturated porous media. The model is developed within the framework of elastoplasticity, which includes features that are relevant for the satisfactory prediction of THM behaviour in argillaceous rocks: anisotropy of strength and stiffness, behaviour nonlinearity and occurrence of plastic strains prior to peak strength, significant softening after peak, time-dependent creep deformations, permeability increase due to damage, and shrinking of the elastic domain and the degradation of stiffness and strength parameters with temperature.

The model was applied to the numerical simulation of a full-scale in situ heating test conducted on Callovo-Oxfordian (COx) claystone, in the Meuse / Haute-Marne Underground Research Laboratory, simulating a heat-emitting, high-level radioactive waste disposal concept. The interpretation of the test was assisted by the performance of a numerical analysis based on a coupled formulation incorporating the relevant THM phenomena. Initial and boundary conditions for analysis, as well as material parameters, were determined from a comprehensive field and laboratory experimental programme. Thermal, hydraulic, and mechanical observations in COx claystone were discussed. The numerical analysis was able to accurately reproduce the behaviour of the experiment.

The performance and analysis of the in situ test have significantly enhanced the understanding of a complex THM problem, and have proved the ability of the theoretical formulation to provide adequate modelling capacities.

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