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Temperature-damage-permeability coupling in clayey soils and rocks

ABSTRACT:
Storage of exothermic radioactive waste in deep low permeability geological formations such as clayey rocks and plastic clays is a solution considered for long term repositories. However the excavation of underground galleries creates a damaged zone (EDZ). The effect of the damage zone on the transport properties of the geological barrier has been widely studied.

Within the framework of the TIMODAZ European project, emphasis has been put on the effect of temperature. As a partner of this project, the current work is performed to investigate the coupling effect between temperature, damage and permeability on Boom clay and Opalinus claystone through an experimental study.
View to the experimental difficulties related to the low permeability materials, a new hollow cylinder triaxial cell with short drainage path specifically designed to study the thermo-hydromechanical behaviour of very low permeable materials is developed during this work. The tests and the numerical analysis show that the short sample drainage path reduces significantly the time needed to resaturate an initially unsaturated sample and it also permits to achieve drained conditions (i.e. negligible excess pore pressure during testing) with a higher loading rate.

For Boom clay, the effect of the pore water thermal pressurisation on a sample with a preexisting shear band is investigated. The undrained heating under shear stress decreases the effective stress on the sample which leads to its failure. An existing failure plane in the sample behaves like a preferential weakness plane which can be reactivated by pore water thermal pressurisation. The estimated shearing resistance along the sheared plane is smaller than that of the intact material.

For the Opalinus claystone, drained heating on a saturated sample shows that this claystone behaves like a slightly overconsolidated material (thermo-elasto-plastic behaviour) with transition from expansion to contraction at 65°C. The decrease of the permeability of the sample before and after the heating-cooling cycles proves the irreversible volumetric compaction of the sample. The undrained heating test on the Opalinus claystone induces an excess pore pressure in the sample which cannot be explained by the difference between the free water thermal expansion coefficient and that of the solid matrix. The back analysis of the results shows a higher value for the water thermal expansion coefficient as compared to that of free water. Permeability measurements at 25°C and 80°C on samples previously damaged by deviatoric loading show no significant effect of damage on the permeability of the samples. These results confirm the good sealing capacity of both clays at various temperatures.

Key words:
Boom clay, Opalinus claystone, temperature, permeability, laboratory testing