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A thermal-mechanical constitutive modelling for Callovo-Oxfordian Claystone in the context of nuclear waste disposal

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Deep underground geological disposal is widely accepted as one of the most appropriate ways for the long-term safety and management of radioactive waste. The heat generated by the nuclear waste decay brings elevated temperature increase, which may affect the thermo-hydro-mechanical (THM) behaviour of the host rock. A correct evaluation of the thermal impacts on the host rock behaviour is important for the design of the underground geological disposal.

With the temperature increases, thermal pressurization is observed both in the small (laboratory) and large (in-situ) scale tests. Physically, the overpressure induced by the discrepancy of the thermal expansion coefficient between the solid and fluid phases may potentially induce fracture re-opening and propagation. The host rock located in the middle of two adjacent cells may suffer shear or tensile failure, which is dependent on the intensity of the thermal power and the distance between the neighbouring cells. Some research work also shows that soil characteristics like cohesion, elastic modulus and water viscosity are influenced by the rise in temperature [1]. To investigate the thermally induced change on the mechanical property of host rock, triaxial compression tests were conducted at the University of Lorraine at different temperatures (20, 40, 60, 80, 100 and 150 °C), confining pressures (0, 4 and 12 MPa) and samples orientations (parallel and perpendicular to the bedding plane). The results showed the transitory overpressure induced by the thermal dilation during the initial heating, and the degradation of the mechanical strength of the host rock with the increase in temperature [2].

Based on the experimental observations, the triaxial compression tests are represented in a two-dimensional axisymmetric coupled THM model. The modelling is composed of the two steps: isotropic loading (increase confining stress and temperature), and shear process (increase axial loading). The numerical FEM code is LAGAMINE from the University of Liège. The Callovo-Oxfordian (COx) claystone, relying on its low permeability and good plasticity, has been selected as the host rock for the underground geological disposal in Meuse/Haute-Marne in France. The objective of this study is to introduce thermal-mechanical modelling involved with thermal plasticity. The cohesion of the host rock is defined as a function of the temperature to describe the thermally induced change of mechanical behaviour of the host rock. This model will then be validated against experimental observations in the laboratory and further applied to the large-scale heating test.

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