Modelling a heating-hydration bentonite-based column test using a double porosity approach

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ABSTRACT

The thermo-hydro-mechanical (THM) behaviour of bentonite-based materials have been extensively studied in the last decades due to their potential use as sealing/buffers in geological repositories for high-level radioactive wastes. In such environments, the engineered barrier system (EBS) is subjected to: i) changes in temperature due to the heat released from the radioactive decay and its propagation through the barrier by conduction and convection; ii) changes in the moisture content due to the water uptake from the rock and the vapour generation and diffusion towards the cooler zones; iii) changes in stresses due to the physical confinement of the bentonite barrier under non-isothermal hydration conditions. In order to understand and quantify the main THM processes that take place at such a closed environment and to minimize the in-situ initial and boundary uncertainties, two laboratory heating-hydration tests have been carried out by CIEMAT in Madrid (Spain). The two 50 cm-height column tests were made of the same filling material used in the in-situ HE-E experiment [1], performed at the URL in Mont Terri (Switzerland). The initial THM conditions inside the columns were similar to the ones estimated in the in-situ emplacement. The heating-hydration laboratory tests have been modelled through a fully coupled double porosity approach under development by the UPC Geotechnical Group that has been implemented in a finite element code. As the double porosity model developed in [2], this new formulation represents the expansive material as two overlapped structural media coupled through a strain mechanism relating the irreversible changes in the arrangement of the clay aggregates to the volumetric deformations occurring at particle level. Nevertheless, the main features of this new double porosity formulation are: i) the description of the mechanical behaviour of the medium from a microstructural point of view; ii) the non-saturation state of the microstructural level; iii) the definition of a water retention curve for each structural level; iv) a coupled hydraulic mechanism controlling the amount of water exchanged between both media and v) the incorporation of thermal effects into the mathematical formulation. Modelling with this new double porosity approach is able to reproduce: i) the changes in temperature during the test and the thermal effects on the re-saturation of the bentonite columns due to the artificial hydration (with water) and to the vapour diffusion from the hotter towards the cooler zones and ii) the continued (and measured) increase of the swelling pressure during the hydration phase of the bentonite column as a result of the re-saturation taking place in both structural levels.

REFERENCES

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