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Coupled Hydro-Mechanical Processes in Bentonite: Numerical Simulation of Lab-Scale Re-Saturation Experiments in an Expansive Clay-Based Geotechnical Barrier

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One concept for future radioactive waste disposal is the use of a multi-barrier system to ensure containment and retardation of radionuclides. An important aspect of the multi-barrier system is the geotechnical barrier, which is used as a buffer around the canisters in the deposition area and as backfill to seal the tunnels. Bentonite, due to its ability to swell with the uptake of water, is the preferred material for buffers. The efficiency of the buffer is the highest when after the re-saturation process a spatially homogeneous density and water content of the buffer is established. Investigations into the homogenization process have been carried out as part of the EU-Funded BEACON project (Bentonite Mechanical Evolution).

In the framework of the project, efforts are made in parallel to develop advanced constitutive models describing the mechanical evolution of bentonite and to use the developed models to perform numerical simulations of an array of bentonite homogenization experiments at various spatial scales. In the development of the constitutive models, the project focuses on the aspects crucial for the mechanical evolution, such as irreversibility and stress-path dependencies.

The numerical simulations of the homogenization experiments have been performed using the open-source, multi-platform, scientific modeling package for coupled thermo-hydro-mechanical-chemical (THMC) processes in fractured and porous media OpenGeoSys (OGS). Two lab-scale re saturation experiments of varying complexity were simulated using the Richards' approximation of the two-phase hydraulic model, coupled with a linear, poro-elastic mechanical model, together with a linear, saturation based swelling law. The model proved a good candidate to capture the overall behavior of the bentonite re-saturation both qualitatively and quantitatively. Comparison of the simulations to the experimental data suggests specific aspects of the coupled hydro-mechanical behavior to be included in improved constitutive models. The knowledge gained from the numerical simulations will be channeled into the development of new formulations of the process and constitutive models in OGS, foreseen to be used for the next phase of the project. The existing Richards' model, however, provides a good foundation to extend the model with complexities specific to the mechanical processes in bentonite.

This contribution will focus on the basic understanding of processes responsible for the mechanical evolution of bentonite and its application in the numerical simulation of lab-scale re-saturation experiments in bentonite.