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Numerical modeling of hydro-mechanical coupled effects in the cyclic deformation (CD-A) experiment: First results and comparison with observations

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The Mont Terri rock laboratory is situated in a clay formation in the northwestern part of Switzerland and is the place of several research focused experiments. These experiments enable the study of relevant coupled effects in the Opalinus Clay formation, an important material in the context of radioactive waste management due to its possible use as geological barrier. Our study focuses on the cyclic deformation (CD-A) experiment, which aims at investigating the coupled hydro-mechanical (HM) behavior of the material, e.g. shrinkage, swelling, changes in permeability. These processes can affect the stability and integrity of the rock. The experiment encompasses seasonal variations such as natural cyclic humidity changes due to winter and summer and consists of two niches. While one niche is open to the influence of the surroundings and hence, subjected to the effects of the seasonal changes of air humidity, the other niche is kept under controlled, high humidity conditions. Long-term quasi-continuous as well as repeating measurements for parameters such as relative humidity, water content, temperature, electrical resistivity and deformation, e.g. tunnel wall convergence via laser scans, are carried out amongst others (start in October 2019). These monitoring data are used as input for calibration and validation of numerical models.

In this contribution we numerically model the HM coupled effects in the context of the CD-A experiment using a macroscopic poromechanical approach. The mathematical model consists of the mass balance of the solid and the liquid phases with displacements and pore pressure as independent variables. Furthermore, it considers unsaturated flow by the Richards approximation. The model is solved numerically with the finite element method using the open-source software OpenGeoSys (OGS 6). Based on a literature review on the material properties of the clay sandy facies and experimental data, a two-dimensional model has been setup stepwise considering (i) in-situ initial pore water pressures and stresses, (ii) the effect of excavation, (iii) the experimentally based seasonal climatic conditions in the niches and (iv) the effect of bedding-induced anisotropy on the HM coupled behavior. With this numerical investigation, we evaluate the temporal evolution of the unsaturated zone. The Nuclear Magnetic Resonance (NMR), Electric Resistivity Tomography (ERT) and Taupe measurements indicate the spatial and temporal evolution of the seasonal hydraulic effects near the niches within the first experimental year. A first comparative study indicates qualitative agreement between monitored ERT data and simulation results and

offers paths for model improvement and extension such as in the context of shrinkage-induced cracking.