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Macro-scale deformation behavior and characterization of deformation mechanisms below μm-scale in experimentally deformed Boom Clay by using the combination of triaxial compression, X-ray μ-CT imaging, DIC, BIB cross sectioning, and SEM

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Boom Clay is one formation being studied in Belgium as a potential host rock for deep geological disposal of radioactive waste. This poorly indurated clay presents in its natural state favorable properties against the migration of radionuclides: low permeability, low solute diffusion rates, good retention and sorption capacity for many radionuclides and good self-sealing capacity. During construction of disposal galleries, stress redistribution will lead to perturbation of the clay and the formation around galleries of the so-called “Excavation disturbed Zone” (EdZ). The study of deformation mechanisms and evolution of Boom Clay properties at macro but also micro scale allows to assess in a more mechanistic way the evolution of Boom Clay properties in this EdZ.

In this work, we show microstructural investigations of Boom Clay deformed in undrained triaxial compression by linking conventional stress/strain curves with Digital Image Correlation (DIC) and scanning electron microscopy (SEM) imaging of broad-ion-beam (BIB) milled cross-sections to deduce deformation mechanisms based on microstructures at sub-micron resolution. Two specimens, collected in Mol (Belgium) at the European Underground Laboratories (URL) on HADES level, were analyzed: The major principal stress $\sigma 1$ was applied parallel as well as perpendicular to the bedding direction with an initial mean normal effective stress of 4.5 MPa and an initial pore water pressure of 2.3 MPa, which are equal to the in-situ values.

Linking the resulting DIC-derived maps of incremental strains with the corresponding stress/strain curve give not only information about the moment of the shear band development, but also on the way strain evolves within the specimen throughout the rest. Incremental DIC analysis of X-ray tomographic scans performed during loading tests give a time evolution of the strain field, and subsequently allow to detect strain localization which appears close to the stress peak. Regions with a comparable high and low shear strain were chosen and prepared for BIB-SEM investigations.

In this case, shear bands show typical characteristics of uncemented small-grained clay-rich materials deformed at high shear strains including anastomosing shears. At nano-scale, the preferential orientation of clay particles in the anastomosing shears are construed to be responsible for the shear weakness. In addition, the reorientation of clay particles during the deformation leads to the strong reduction of porosity in the shear band. Ductile deformation mechanisms represented by grain-rotation, grain-sliding, bending, and granular flow are strongly involved for the development of the shear band.