EDZ AND PERMEABILITY IN CLAYEY ROCKS

Séverine Levasseur[1], Pierre Bésuelle[2], Frédéric Collin[1], René Chambon[2], Robert Charlier[1], Cino Viggiani[2]

1. **Université de Liège, Dpt. ArGEnCo & *F.R.S.*-FNRS, Liège, Belgique (severine.levasseur@ulg.ac.be, f.collin@ulg.ac.be, robert.charlier@ulg.ac.be)**
2. **Laboratoire 3S-R, Université de Grenoble & CNRS, Grenoble, France (pierre.besuelle@grenoble-inp.fr, rene.chambon@grenoble-inp.fr, cino.viggiani@grenoble-inp.fr)**

Deep geological layers are being considered as potential host rocks for the high level radioactivity waste disposals. During drilling in host rocks, an excavated damaged zone – EDZ is created. The fluid transmissivity may be modified in this damaged zone. This paper deals with the permeability evolution in relation with diffuse and/or localized crack propagation in the material. We mainly focus on argillaceous rocks and on some underground laboratories: Mol URL in Boom clay, Bure URL in Callovo-Oxfordian clay and Mont-Terri URL in Opalinus clay.

First, observations of damage around galleries are summarized. Structure of damage in localized zone or in fracture has been observed at underground gallery scale within the excavation damaged zone (EDZ). The first challenge for a correct understanding of all the processes occurring within the EDZ is the characterization at the laboratory scale of the damage and localization processes. The observation of the initiation and propagation of the localized zones needs for advanced techniques. X-ray tomography is a non-destructive imaging technique that allows quantification of internal features of an object in 3D. If mechanical loading of a specimen is applied inside a X-ray CT apparatus, successive 3D images at different loading steps show the evolution of the specimen. However, in general volumetric strain in a shear band is small compared to the shear strain and, unfortunately, in tomographic images grey level is mainly sensitive to the local mass density field. Such a limitation has been recently overcome by complementing X-ray tomography with 3D Volumetric Digital Image Correlation (V-DIC) which allows the determination of the full strain tensor field. Then it is possible to further explore the progression of localized deformation in the specimen (Figure 1; Lenoir *et al.*, 2007).

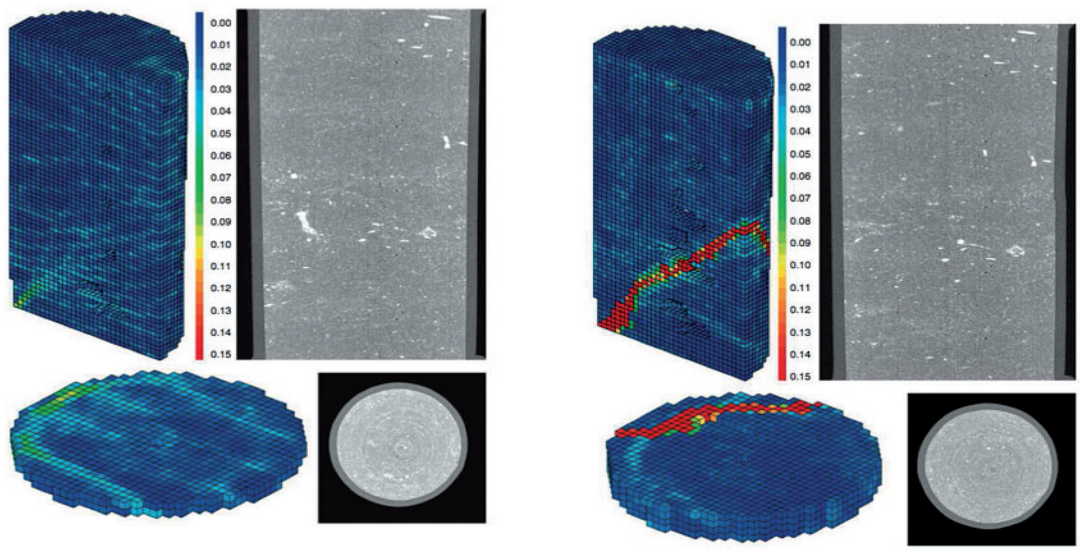

Figure 1: V-DIC-derived deformation maps for load increments (before peak load in left – after peak load in right) of a triaxial compression test on the Callovo-Oxfordian argillite (10 mm diameter). For each case, vertical (along the specimen axis) and horizontal (close to the bottom of the specimen) sections through the CT volume image and incremental maximum shear strain maps for the equivalent sections (color scale is [0, 0.15]) (from Lenoir *et al.*, 2007).

The second challenge is the robust modelling of the strain localized process. In fact, modelling the damage process with finite element codes is not trivial. Strain localisation in classical solid mechanics leads to non-objective (mesh dependent) results for such process. Enriched continuum theories (like second gradient models who introduce an internal length scale) are needed to overcome this drawback. However even if these methods provide objective results, it is recalled that they don't restore uniqueness: multiple solutions are always possible (Bésuelle *et al.*, 2006). It is shown that it is possible to model strain localization as a precursor of fractures (Figure 2). Advantages and drawbacks of different refinement in the FE modelling are discussed.

Permeability depends on strain and on fracture opening. Field observations indicate an increase of permeability of some orders of magnitude within the EDZ. How can be modelled the observed permeability increase? It depends on the kind of FE model used for the solid mechanics part of the problem. Solutions of coupled problems occurring during drilling can be proposed based on direct relations between EDZ damage processes and permeability variations as shown for the modelling of lab tests by Dizier *et al.* (2009) or for the modelling of field experiments by Levasseur *et al.* (2009a). It provides a global evolution of the permeability tensor in EDZ. But, explicit strain localizations can also be considered by means of second gradient modelling or the definition of crack media with interface elements. It permits to modify permeability tensor only in localization bands as shown for the modelling of field experiments by Levasseur *et al.* (2009b).

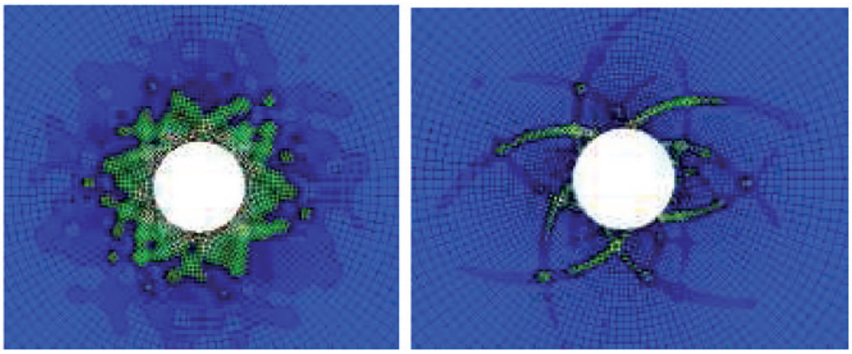

Figure 2: Second strain invariant field for two solutions of the same initial boundary value problem, obtained with second gradient model.

References:

Bésuelle, P., Chambon, R., Collin, F., 2006. Switching deformation modes in post-localization solutions with a quasibrittle material. *J. of Mechanics of Materials and Structures*, Vol. 1, n° 7, pp. 1115-1134.

Dizier, A., Collin, F., Garitte, B., François, B., Chen, G.J., Sieffert, Y., Labiouse, V., Charlier, R., Chambon, R., 2009. Thermo-hydro-mechanical modelling of hollow cylinder laboratory experiments on Boom Clay. *Proceeding of the THMC Conference*, Luxembourg.

Lenoir, N., Bornert, M., Desrues, J., Bésuelle, P., Viggiani, G., 2007. Volumetric digital image correlation applied to X-ray micro tomography images from triaxial compression tests on argillaceous rock. *Strain*, Vol. 43, pp. 193-205.

Levasseur, S., Charlier, R., Frieg, B., Collin, F. 2009a. Hydro-mechanical modelling of the Excavation Damage Zone around underground excavations: application to long term dilatometer experiment in Mont Terri Rock Laboratory (Selfrac Project). *International Journal of Rock Mechanics and Mining Sciences*, submitted.

Levasseur, S., Gerard, P., Charlier, R., Collin, F., 2009b. Modélisation hydromécanique de l'Excavated Damage Zone autour des galeries. *Rapport ANDRA*.