HYDROMECHANICAL BEHAVIOR OF POROUS ROCK STUDIED WITH NEUTRON TOMOGRAPHY

M. Etxegarai *[1], E. Tudisco †[2], A. Tengattini ‡[1], S. Hall §[3], and G. Viggiani ¶[1]

[1]Univ. Grenoble Alpes, CNRS, Grenoble INP‖, 3SR, F-38000 Grenoble, France
[2]Division of Geotechnical Engineering, Lund University, Lund, Sweden
[3]Division of Solid Mechanics, Lund University, Lund, Sweden

Keywords: neutron tomography, in-situ, hydro-mechanics, rocks

Summary: The coupling between deformation and fluid flow in rocks subjected to deviatoric loading is monitored in-situ with neutron imaging. The experimental approach at the NeXT imaging instrument (ILL, Grenoble) and initial results are presented.

1. INTRODUCTION

The development of new techniques for natural resource exploitation, *e.g.*, hydrocarbon and water production or CO_2 sequestration, is key for the resource engineering industry. The hydro-mechanical behavior of porous subsurface rocks is not well understood due to the complexity of performing a conclusive experimental campaign. Therefore, the changes in the fluid flow due to the deformations during subsurface resource engineering operations should be studied. In particular, the effect of the localized deformation over the permeability must be better analyzed, since fractures, shear and deformation bands can acts as conducts or barriers to flow.

In this work we are developing a new experimental method for in-situ neutron imaging of coupled triaxial deformation and pressure-controlled, multi-phase fluid flow through rocks. This method will help to understand the coupled hydro-mechanical evolution of porous reservoir rocks during deformation.

Neutrons have a low metal interaction enabling imaging through stronger pressure containment vessels than the ones used at x-ray experiments. Previous publications validated the use of neutrons to analyze the mechanical behavior of rocks [1]. Neutrons are also highly sensitive to hydrogen, providing the ideal probe for detecting hydrogen rich fluids (*e.g.*, water and oils) in dense porous materials such as rocks [2]. Furthermore, the possibility to use deuterated versions of these fluids (*e.g.*, replacing water, H_2O, with heavy water, D_2O) enables the flow to be tracked through an already saturated medium. This can be achieved by detecting the front between the two fluids, which have similar flow properties, but very different neutron interactions.

2. EXPERIMENTAL METHOD

Laboratoire 3SR, part of the Université Grenoble Alpes (UGA), in collaboration with the Institute Laue-Langevin (ILL) set up the new imaging beam line in Grenoble, NeXT. The high flux of the neutron instrument enables fast tomographies whihout sacrifying the resolution of the reconstructed images, enabling fast tomography acquisitions aimed at tracking the water front in 3D.

During the experiment, the rock sample is deformed in-situ under triaxial loading condition and high resolution tomography is acquired at different stage of deformation to get information about the micro-structure of the sample. At each loading step light water is pushed into heavy water saturated samples while fast tomographies are acquired. The sample is re-saturated with heavy water before further deformation and this process is repeated until the sample collapses. The deformation fields can be measured from the high resolution

*e-mail: maddi.etxegarai@3sr-grenoble.fr
†e-mail: erika.tudisco@construction.lth.se
‡e-mail: alessandro.tegattini@3sr-grenoble.fr
§e-mail: stephen.hall@solid.lth.se
¶e-mail: cino.viggiani@3sr-grenoble.fr
‖Institute of Engineering Univ. Grenoble Alpes

scans, through Digital Image Correlation [1], and, therefore, a relation between deformation and changes in permeability field can be analyzed.

The setup controls the pressure on the top and the bottom of the sample and the confining pressure, while measuring the volume of the water entering and leaving the sample, and the displacement of the piston, while measuring the axial force.

3. RESULTS

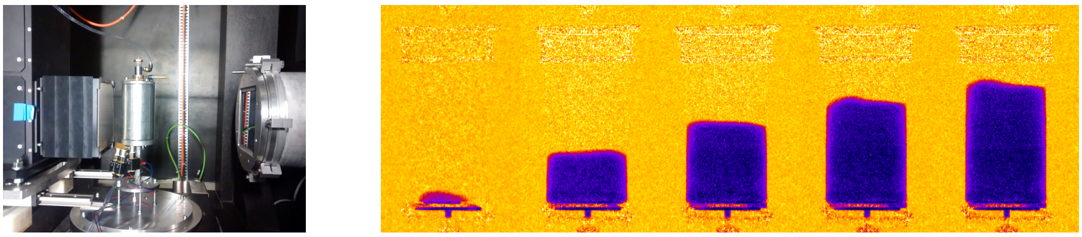
The experimental campaign presented in this abstract is still ongoing. In the first phase, fluid flow experiments were performed on different sandstone samples. The fronts of the normal and heavy water were tracked using neutron radiography in intact and deformed samples. Fig. 1(a) shows the cell used in the neutron beam during this first experimental phase. Fig. 1(b) shows the front of the water pushed, at 19 kPa pressure, into an intact and dry sample of Vosges sandstone.

Aim of the ongoing second phase is to add to this hydraulic characterization the aforementioned mechanical testing, performed by means of alternate high resolution and fast tomographies to capture the evolving strain field and its effect on the permeability distribution, respectively.

References

[1] E. Tudisco & S.A. Hall. Full-field measurements of strain localisation in sandstone by neutron tomography and 3D-volumetric digital image correlation,*Physics Procedia-10th World Conference on Neutron Radiography*, 69, 509-515, 2015.

[2] S.A. Hall. Characterization of fluid flow in a shear band in porous rock using neutron radiography, *Geophys. Res. Lett*, 40, 2613-2618, 2013.



(a) **(b)**

Figure 1: (a). The aluminium cell in the neutron beam. (b) Radiographies of normal water being push through a Vosges intact sample