PhD proposal 2025

Characterisation of dilatant flows in argillites by gas injection under X-ray microtomography control

ASNR contract in collaboration with LPMS of ENS Paris-Saclay

Key words: hydro-mechanical coupling, X-ray imaging, gas transport

The ASNR is conducting research on safety of geological disposal facilities for radioactive waste. In a clay-rock based disposals, high levels of hydrogen production are expected after closure. This gaseous phase could alter the properties of the hostrock and of the engineered materials. To appreciate gas migration within the disposal on a multi-metre scale the only approach available is based on the generalised Darcy equation describing visco-capillary flows. However, experimental evidence indicate the existence of another mode of gas migration in water-saturated clays [1]. Observations show that the passage of gas is accompanied by a macroscopic expansion of the clay samples without any significant displacement of the pore water. The gas appears to open localised preferential paths that are reversible as long as the gas pressure does not exceed the fracturing threshold of the solid skeleton. More recent results have shown that the dilatation is weaker and more related to microfracturing along the bedding planes. The aim of this thesis is to directly observe and determine the parametric domain of existence of dilatant gas flows in an argillite. An X-ray transparent radial confinement cell will be constructed. Gas injections into a millimetre-sized rock sample will be carried out under the control of X-ray microtomography. The imaging results will be analysed using volumetric image correlation approaches.

The triaxial confinement cell to be developed should enable the in-situ stress state (12MPa corresponding to the French disposal concept) to be restored using a confining fluid. It will be in contact with the sample through an impermeable membrane. The manufacturing process of small cylindrical samples will be optimized to modify their microstructure as little as possible. Slow gas injections will be carried out using a precision pump over a long period. Scans will be taken regularly, in particular before the start of the injection and after the gas breakthrough. The pore spaces will first be segmented using conventional tools (WEKA) in search of percolating pores. However, the images obtained will have a resolution of several μm, which may not be sufficient to directly detect changes in porosity following the passage of gas. For this reason, digital volume correlation (DVC) will be used [3]. By matching images obtained at different times, it is possible to measure displacement fields and reconstruct deformation fields in the volume, thus highlighting damaged or disturbed areas whose density has not been modified sufficiently to be visible in the grey scale images. By adding an appropriate physically based regularisation [4], it is possible to achieve resolutions of less than the size of a voxel (pixel in 3D) for crack opening measurements [5]. Thus DVC will be used to evaluate crack opening fields and to calibrate the parameters of a damage model implemented in the pore-scale gas migration code [6]. An implementation of multi-scale approaches is also envisaged. Background required: Master 2 or engineering degree in solid mechanics, material science or civil engineering

Place of work: Paris region in Fontenay aux Roses (92260)/Saclay (91190), France

Desired start date: 1 October 2025

Application deadline: 10 April 2025

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More information (in French)

ASNR - Caractérisation des écoulements dilatants de gaz dans les argilite (Th ENV25-01) H/F

References

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