Gas migration in natural and swelling clays - small scale experiments and image analysis.

LABORATORY :

PSE-ENV/SEDRE/LETIS

CONTENT OF THE WORK :

The long term disposal of High Level or Intermediate Level and Long Lived (HL- or IL-LL) radioactive waste is a primary investigation topic in industrialized countries using nuclear power for large-scale energy production. In France, it is considered at 500m depth, within a Callovo-Oxfordian (COx) claystone, chosen for its low hydraulic conductivity and high sorption capacity for most radionuclides. The disposal site Cigéo would be a multi-barrier system composed of the geological barrier (COx), the so-called Engineered Barrier (EB) and of waste packages.

This work is part of the research conducted by IRSN in connection with the Cigéo project aimed at understanding and modelling of physico-chemical phenomena that are important for the safety of the future facility. As a significant production of hydrogen is expected inside the geological repository, this gaseous phase could have an impact on the hydro-mechanical behavior. the host rock and of the EB such as bentonite plugs and therefore potentially impact the transport of radionuclides.

In France, the COx claystone has a high overall porosity (of the order of 20%), more than 90% of which is composed of pores with less than 100nm diameter, which leads to very low permeability. The spatial organization of this porosity is still poorly known, as its connectivity is controlled by pores smaller than 10 nm, which are difficult to characterize experimentally. For EB and specifically sealing systems, bentonite pellet/powder mixture is one of the candidate sealing materials because of its low permeability, high radionuclide retardation capacity and its high swelling potential upon hydration. This material, corresponding to a mixture of bentonite powder and highly compacted bentonite pellets is initially obviously highly heterogeneous. The degree and distribution of heterogeneities will vary during hydration and the average dry density might be not sufficient to characterise its final state and containment performance.

Gas migration is one of the phenomena whose understanding is strongly linked to that of the clay materials microstructure (host rock and EB). To overcome the dependence on arbitrary initial configuration, it is possible to use models of porous media at different scales: from the centimetric scale for lab models to the sub-micrometric scale for 3D X-ray -tomography imaging.

The work proposed in this post-doctoral fellowship is divided into two parts and consists mainly in working on the characterization of the microstructure of clay materials (COx and bentonite pellet and powder mixture) and their relationship to gas migration. The first part is on the impact of gas migration of the HM behavior of bentonite pellet-powder mixtures. It is proposed to continue an ongoing work conducted in a decimetric size constant volume infiltration cell allowing independent control of axial and lateral hydraulic boundary conditions and increase of gas pressure at the bottom (located at UPC, Barcelona). The aim is to investigate the effect of initial structural heterogeneities on gas transport processes. Gas injection will be carried out at different saturation levels. The samples will be subjected to hydraulic and gaseous loads, both asymmetric and mimicking the real saturation scenario of vertical sealing systems. A complementary PMMA cell will be used to perform a microstructural analysis of the mixture in its initial state and during gas/water injections by X-ray micro-tomography. In parallel, it is planned to carry out the microstructure acquisitions by X-tomography of several argillite samples (COx or Boom clay) at several levels of water saturation obtained by imposing controlled relative humidity.

The second part proposed concerns the image analysis tools of microtomography to improve the segmentation of low contrast grey level areas (extraction of saturated and desaturated pores) and the morphological descriptors construction to be able to generate equivalent synthetic structures. It will be possible to use the 2D tools developed at LETIS (texture analysis, random walkers and 3D active contour methods) or to start a new approach based on neural networks (CNN/DL). The methods set up should eventually become available to the scientific community in the form of Fiji software plug-ins.

DESIRED SKILLS :

Unsat-soil mechanics ,porous media, two phase flow, , image analysis

CANDIDATE BACKGROUND

PhD in geomechanics

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WHERE and WHEN:

Fontenay-Aux-Roses, France + several stays in Barcelona(Spain)

Duration : 18 mois

Start: April-Septembre 2020

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Desired skills

Unsat-soil mechanics

Porous media

Two phase flow

Image analysis