Imaging gas migration in bentonite and argillite - in-situ CT scan experiments and image analysis.

LABORATORY :

PSE-ENV/SEDRE/LETIS

CONTENT OF THE WORK :

This project is conducted by IRSN in the frame of research in connection with the Cigéo (project for a deep geological disposal facility for HA/MAVL radioactive waste). It is particularly 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 modify the flows and mechanical conditions of the rock and of the engineered materials such as bentonite plugs and therefore potentially impact the transport of radionuclides. In France, the foreseen solution is geological disposal in the Callovo-Oxfordian argillites. This argillite 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 the realization of the clay cores of seals use of compacted mixtures of bentonite powder and pellets is considered. These mixtures have been identified as exhibiting a very complex hydromechanical behavior governed by the strong initial heterogeneity of the mixture. These initial dry density heterogeneities may partly persist in the (pseudo) final state, and could then lead to non-uniform swelling pressures (spatially and temporally). Gas migration is one of the phenomena whose understanding is strongly linked to that of the microstructure of clay materials. 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 consists mainly in working on the characterization of the microstructure of clay materials (natural and artificial) and their relationship to gas migration, as part of Gas Transfer WP in the EURAD project (European Joint Program).

The major part of this work is experimental and proposes to continue the previous work on centimeter size setups allowing gas injections into bentonite pellets-powder mixtures with the aim of studying the effect of structural heterogeneities on gas transport processes using X-ray microtomography (CT scan). The PMMA cell prototype have been constructed and is now being tested for water and gas injections outside of the CT-scan. The post-doctoral researcher will continue this experimental development by creating an in-CT injection conditions to be able to follow the microstructure evolution during the gas injection. This set-up shall be used to perform a microstructural analysis of the mixture in its initial state and during water (swelling) and gas injections by X-ray micro-tomography. Gas injections will be carried out with different protocols to assess their importance in terms of gas break-through pressure and percolation paths. The existing fixed-volume cell prototype may be upgraded to better fit experimental needs (cf adding sensors). The experience gained with the bentonite cell should be used to design a new cell for studying gas injection in natural argillites. The radial confinement (by a fluid) will be necessary to prevent gas passing at the interface between the sample and the cell walls. Due to a more complex structure of the cell and to smaller sizes of pores in argillites as compared to bentonite mixtures, the diameter of argillite samples will need to be decreased to a few millimeters range.

Finally, a, important part of the work will be related to the image analysis tools to improve the segmentation of low contrast grey level areas (extraction of saturated and desaturated pores) and the construction of morphological descriptors 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 :

porous media, hydromecanical behavior of unsaturated soil, two phase flow, soil mechanics, image analysis, experience in experimental development.

CANDIDATE BACKGROUND

PhD in geomechanics

IRSN
INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

31, Avenue de la Division Leclerc, 92260 Fontenay-aux-Roses

www.irsn.fr

WHERE and WHEN:

Fontenay-Aux-Roses, France

Duration : 18 mois

Start: Sept-Dec 2022

CONTACT :

M.Dymitrowska, N.Mokni

Tél. : 01.58.35.99.85

Mail :

magdalena.dymitrowska@irsn.fr

nadia.mokni@irsn.fr

Desired skills

porous media

two phase flow

soil mechanics

image analysis