Micro-macro modelling by the method of discrete elements (DEM) of the long-term behaviour of shaft seals under hydraulic-gas loading

Context: The thesis proposed here, in collaboration with IRSN (France) and the CNSC (Canada), is closely linked to the long-term performance of the shafts sealing envisaged in Cigéo (www.cigéo.com) as well as their robustness with respect to gas-induced disturbances:

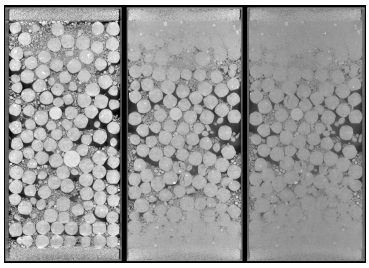
1) These seals consist of swelling clays (Na-montmorillonite) in the form of a polydisperse assembly of highly compacted pellets and crushed pellets, in a strongly desaturated initial state (initial suction larger than 100 MPa).

2) Particularity notable, their transient of saturation is strongly asymmetric:

- In the upper part, the saturation of the shafts seals will occur mainly by the waters coming from the upper layer. This saturation will become total on, at minima, a few decimeters in only a few years. It will then extend to the rest of the nucleus over a few thousand years. The upper face of the cores will therefore undergo a very rapid hydraulic loading of up to about 3 MPa;
- The lower part will remain strongly initially desaturated and will gradually saturate itself in a few thousand years.

3) In addition to this heterogeneous (de) saturation field, the gas (dihydrogen) produced by anoxic corrosion of the numerous metallic components present in Cigéo will progressively solicit the base of the seals the clay core, and therefore very asymmetrically.

Objective: This thesis aims to improve the understanding of the complex behaviour of this multi-scale material, subjected to hydraulic loading and gas loading, both asymmetric. These results are expected to provide relevant interpretation bases for the hydromechanical behaviour of future seals, in particular:



Evolution of the structure of a sample (pellets + powder pellets) following an imbibition (by the lower and upper faces) to:

- t = 0 day (left)
- t = 4 days (centre)
- t = 8 days (right)

(Molinero, 2017)

- The influence of initial heterogeneities in the mixture on macroscopic behaviour;
- The persistence of heterogeneities in the (pseudo) final state and their impact on local swelling pressure, and gas migration.

Challenges: To better understand these phenomena and, ultimately, to model them correctly, this thesis aims to address the following three challenges:

1) Construct a relevant discrete element (DEM) representation of the initial structure of the polydisperse granular mixture, both in terms of the solid phase and the poral domain, both having multimodal distributions;
2) Develop a modelling of the evolution of the structure of the material under composite loading (mechanical and imbibition), in particular the evolution of the different porosities;
3) Take into account the migration of gas under hydromechanical loading, mainly considering migration at the intergranular pore scale.

Practical information

Type of contract: 3-year contract, starting from September-October 2018

Host laboratories: 3SR laboratory, UMR CNRS 5521 (E.D. I-MEP2), Grenoble Alpes University

Contacts (until 5th June)

Bruno Chareyre (3SR): bruno.chareyre@3sr-grenoble.fr

Nadia Mokni (IRSN): nadia.mokni@irsn.fr