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Studying water infiltration on bentonite/sand blocks with MRI and X-Ray µCT techniques

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Radioactive waste management agencies all around the world are focusing their efforts to provide a reliable technical solution to the Deep Geological Disposal (DGD) concept, in order to store high level (HLW) and intermediate level long lived (IL-LLW) radioactive waste. The protection and isolation of radionucleides is guaranteed by a set of barriers. Bentonite/sand blocks -in proportion of 40/60 on dry mass of the mixture- constitute the main core of the sealing barrier in the French concept run by the French National Radioactive Waste Management Agency (Andra). Its high swelling potential (>2MPa) during hydration, its low hydraulic permeability (<10^{-11} m/s) and its gas entry pressure (<2MPa) make it ideal to seal the DGD galleries excavated inside the host rock used as geological barrier. Bentonite/sand blocks are placed at unsaturated state during construction. Afterwards, water migration – in both liquid and vapour states- from the saturated host rock to the blocks will induce the humidification of the blocks until hydraulic equilibrium is reached, hypothetically reaching the saturation state. As this natural process will take hundreds of years, a multitude of experimental devices have been reported at laboratory [3, 5] and real scale [4] to understand the evolution of water transfer in bentonite mixtures and support the predictions of numerical models [1]. In laboratory experiments, samples made of a compacted bentonite mixture are usually placed inside a rigid cell connected to a water source. The infiltration of water is not measured directly but deduced by relative humidity gradients measured along the specimen height.

Numerical models and experimental results have not yet reached accurate predictions of how long it takes for bentonite mixtures to hydrate until complete saturation or how the unsaturated hydraulic permeability evolves. In this context, there is a motivation to study this phenomena by advanced techniques able to capture, image and quantify water transfer through porous media. Thus, an experimental campaign based on Magnetic Resonance Imaging (MRI) and 3D X-Ray micro computed tomography (µCT) is proposed to analyze water infiltration in bentonite/sand blocks. MRI is extensively used in health sciences to create images where the contrast is given by the water's hydrogen proton content in the different tissues of the body. For geological media, where water content is much smaller than in biological tissues and relaxation times of the porewater are shorter -from 0.1 to 2 ms for compacted bentonite/sand [2]- the experimental requirements are different and less documented. On the other hand, µCT scanning provides high spatial resolution images based on the contrast between the X-Ray absorption properties of the constitutive phases observed. Its temporal variations, in a bentonite/sand mixture, might be the result of concurrent phenomena, namely, porosity and saturation changes together with heterogenous motions induced by hydromechanical couplings -the swelling of bentonite solids when they absorb water-.

On going MRI and µCT experimental campaigns on a PEEK cell aim at proving the suitability of these techniques to track the evolution of water infiltration in compacted bentonite/sand mixtures, characterizing the water front and the water content along the specimen in function of time. At this stage, preliminary MRI tests have shown the potential of Single Point Imaging (SPI) sequence to quantify, with one-dimensional images, the water content along the bentonite/sand specimen based on a linear correlation with its signal intensity. Preliminary X-Ray radiography tests (Figure 1) run on a cylindric cell of PMMA filled with small blocks of 12

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mm in diameter and 10 mm high, prove that X-Ray radiography image analysis gives access to observable and quantifiable increase of absorption associated to the measured decrease in grey level at different transversal sections of the sample. This evolution is linked to the increase of apparent density of the solids -that indeed are absorbing the water-, as described by the Beer-Lambert equation. Even though apparent density increase is goverened by the augmentation of water content, changes in porosity due to the hydromechanical coupling along the sample cannot be neglected. Thus, observing the liquid phase evolution (hydraulics) by MRI, as well as the evolution of the solid/liquid phase (hydromechanics) by 3D-µCT imaging, will potentially provide complementary insight into the mechanisms governing water infiltration in bentonite/sand mixtures.

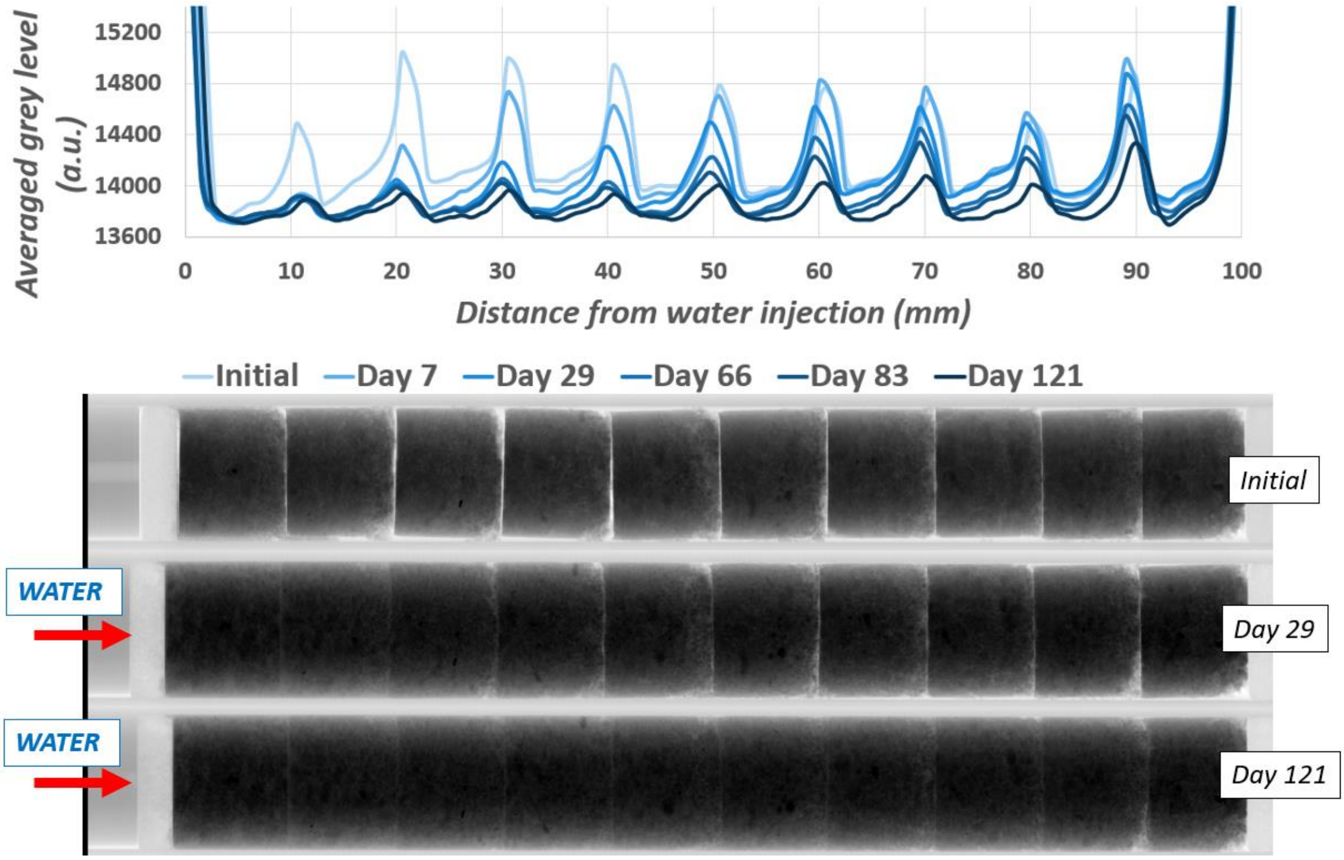

Figure 1: X-Ray radiography analysis on water infiltration in bentonite/sand blocks.

Contributor statement

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