Water retention properties and microstructure of bentonite pellets/powder mixture

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In situ compacted MX80 powder/pellets mixture is one of the candidate sealing materials for deep underground repositories, not only because of its low permeability, high swelling capacity and high radionuclide retardation properties but also for operational advantages (lower compaction effort, reduced gaps between the rock and the seal). Once installed in the repository, these sealing materials will be subject to coupled hydro-mechanical loadings: hydration due to the infiltration of pore water from the natural barrier and mechanical confinement resulting from the engineered barriers. It is therefore essential to understand their behavior under such loadings when assessing the overall repository safety.

In this context, the French Institute of Radiation protection and Nuclear Safety (IRSN) has launched the SEALEX project (SEALing performance Experiments) to which this work is closely related. SEALEX is dedicated to *(i)* test the long-term hydraulic performance of sealing systems in normal conditions for different core compositions (MX80 bentonite pellets/powder or sand/MX80 mixtures) and conditionings (pre-compacted blocks or in-situ compacted), *(ii)* quantify the impact of intra core geometry (construction joints) on the hydraulic properties of sealing systems, and *(iii)* quantify the effect of altered conditions (decrease of the swelling pressure caused by the failure of the concrete confining plugs) on the performance of the sealing system. The SEALEX experiments are emplaced in the Tournemire Underground Research Laboratory (Toarcian argillites) via horizontal boreholes (diameter 60 cm) excavated from recent drift (2008). Each experiment (Figure 1) consists of a bentonite based core mechanically confined at both ends, which represents a generic seal mock-up except for the artificial saturation system (porous filters located at both core ends) (Barnichon et al., 2012). A number of materials are being considered as seals; the current work focuses on the mixture of MX80 bentonite powder and pellets with a proportion of 20/80 in dry mass used in the last two SEALEX in-situ tests.

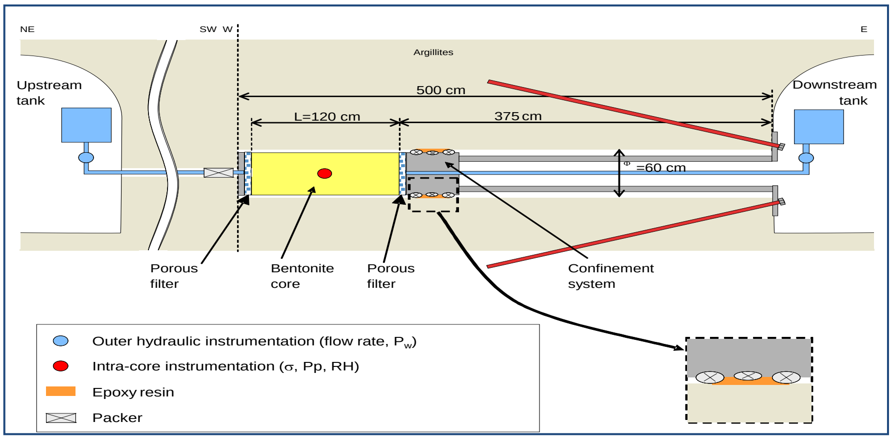

Figure 1 . Layaout of the in-situ SEALEX tests. (Barnichon et al., 2012).

The paper deals with an experimental investigation aimed at studying microstructural features of the mixture and the water retentions properties. A series of Mercury Intrusion porosimetry tests (MIP) and microfocus X-ray computed tomography (μCT) observations are being conducted to investigate the microstructure of the material.

A μCT horizontal cross section of single pellet of MX80 bentonite compacted at an initial dry density of 2.12 g/cm^3 and water content *w*= 7.25%, (initial suction, *s* = 132.4 MPa) is shown in Figure 2a. The μCT technique allows distinguishing the various components of the material according to their density and atomic composition. Some fractures are observed within the pellet due to the swelling of the material during the storage phase. In fact, pellets was fabricated at a water content of 5%; while, the measured initial water content is 7.25% indicating that the pellet had already swollen before this image analysis.

Figure 2b shows μCT horizontal cross section of a pellet tested at lower dry density (1.33 g/cm^3) and higher water content *w*= 24.57% (*s* = 9 MPa). A clear difference is observed between both images due to suction value. At s = 9 MPa, the pellet has increased its volume because of free swelling conditions (a volumetric deformation of 52% is measured, (Figure 3d)). Grey levels are related to different dry density values; as we know, there is a relationship between swelling and dry density: the higher the dry density, the more swelling the sample during hydration (e.g. Saba et al., 2013). Accordingly, aggregates within the pellet swell in a different way and a lot of fractures are observed.

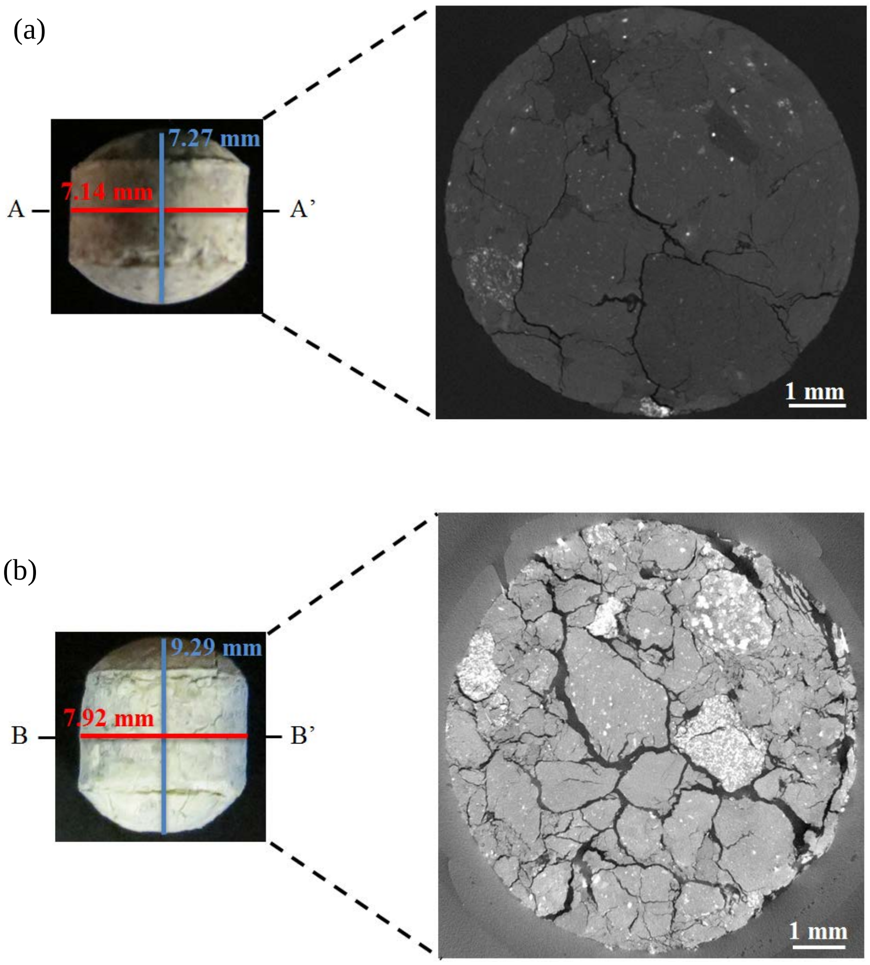

Figure 2. View of a Pellet and μCT cross section (a) at the initial state and (b) at s = 9 MPa.

Several methods are being used to determine the water retention properties of the mixture. Figures 3(a, b) show data determined by vapor transfer technique and by psychrometer measurements using a chilled-mirror psychrometer WP4 Dewpoint potentiaMeter (Decagon Devices, INc).

The evolutions of volumetric deformation and void ratio of a single pellet with suction measured during the wetting path are shown in Figures 3(c,d). As in any clayey soil, suction in the powder/pellets of bentonite is composed by the sum of (i) a capillary term (due to the attraction exerted by capillary menisci), (ii) an adsorption term linked to the physico-chemical attraction exerted by clays on water molecules and of (iii) an osmotic term related to the salt concentration of pore water (negligible in most terrestrial soils). In this case, it is observed that MX80 bentonite powder and pellet data shown in Figure 3(a) are very similar; this means that suction is governed by the adsorption term and the capillarity term can be neglected. This is in agreement with the results of Yahya Aissa (2001) on FoCa7 clay.

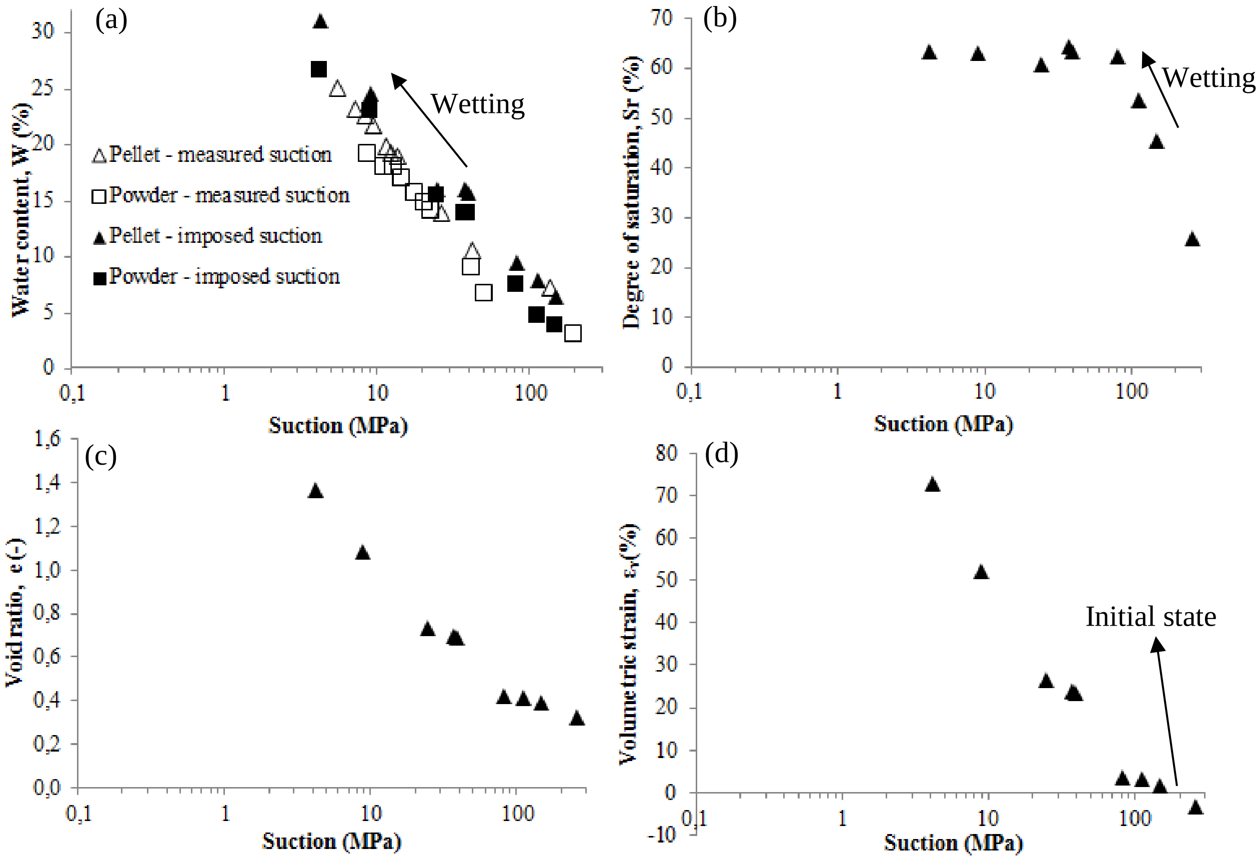

Figure 3. Water retention curve for MX80 bentonite pellets and powder determined by vapor transfer technique and WP4 Dewpoint potentiaMeter (a, b). Evolution of the pellet void ratio with suction (c) and of volumetric strain with suction (d).

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