Project Acronym NSC (Noyau de Scellement)	**Location** Bure URL, France (Callovo-Oxfordian claystone-COX)	**Type** Field scale experiment Scale ½ (diameter 4.5meters, length 5.1 meters
Lead organiser Andra (France)	**Start date** December 2012	**End date** In progress
Main partners involved in the project	**Characteristics of swelling clay** Pre-compacted bricks sand/MX-80 (60%/40%) Dry density: 2.05 g/cm^3 Initial water content : 6.5% MX80 powder/pellets: Dry density pellets (7mm) : 2.24g/cm^3	**Water Saturation** Artificial and natural
Instrumentation 420 sensors • pore pressure, • relative humidity, • total pressure, • temperature, • strain	**Main elements related to homogenization** Initial heterogeneity of density: • zones filled by compacted brick and zone filled with pellets/powder mixture • Initial gaps	**Interfaces with other material** Bentonite/COX claystone Bentonite/Concrete
Modelling Yes: scoping calculations Groups/Codes : Andra and UPC/Code Bright	**Main processes studied** ☐T ☒H ☐M ☒Swelling pressure ☐Gas transfer ☒Other Water transmissivity of the damaged zone	**Reference concept if pertinent** Tunnel seal in Andra reference concept for radioactive waste disposal

Main objectives of the experiment

To limit radionuclides migration along drifts and through the EDZ in radioactive waste disposal, seals will be implemented in drifts and shafts. These seals will be mainly composed of swelling clay core in between two concrete plugs. After natural hydration from the surrounding rock mass, the bentonite will swell and apply radial pressure against the drift wall. In this context, ANDRA designs and installs a large scale sealing experiment which is called NSC (French acronym for Noyau de SCellement) The main objective is to back analyze the equivalent permeability of the seal in place in order to check the efficiency of such seal. To reduce saturation time, artificial hydration is done and bentonite/sand mixture has been chosen to have high water permeability.

Before reaching full saturation state and starting hydraulic test program, a lot of data will be provided by this experiment on the effect of the hydration of the seal: evolution of the permeability (at the interface seal/claystone and in the surrounding rock mainly the damaged zone), the pressure build up on the concrete plug, water saturation propagation through the bentonite. After full saturation, water permeability of both EDZ and bentonite will be tested.

General description

The experiment is composed of 4 zones (figure 1): injection chamber (zone 1), seal (zone 2), concrete plug (zone 3) and water tight drift (zone 4). This seal is implemented in a drift with a 4.6 m diameter (see Figure 1).

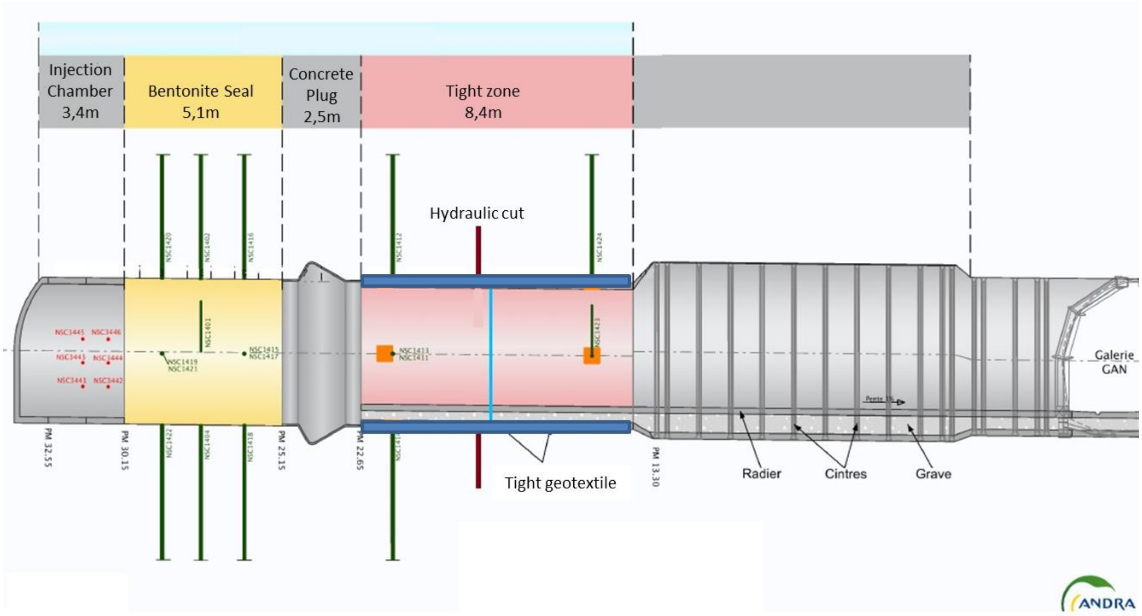


Figure 1 Scheme of NSC experiment

Hydration system: After installation hydration is done by 6 geotextile membrane. 4 of them have been installed directly inside the bentonite core, the two others are at the interface with the concrete plug and at the interface with the injection chamber.

The hydration membrane (Figure 2) at the interface between the concrete plug and the seal is divided into 12 independent areas. This specific design is for distinguish water fluxes from the near-field of the damaged zone, the interface between claystone and seal and water coming through the seal during the performance test.

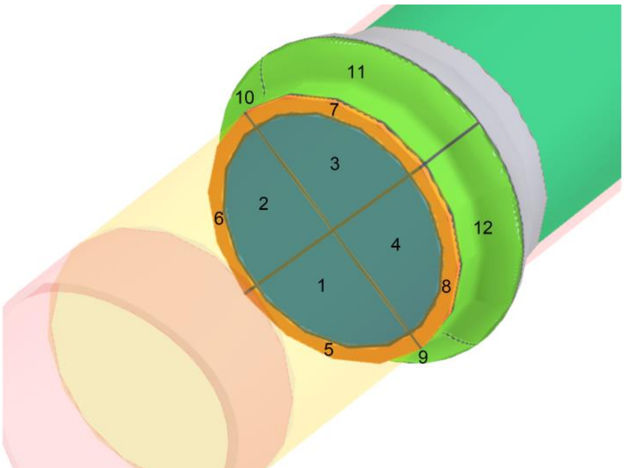


Figure 2 Detailed layout of the membrane at the interface with the concrete

plug (zone 3)

Concrete plug: The concrete plug (zone 3) will be monitored with deformation, displacement, temperature and acoustic sensors. Both concrete plugs of the zone 1 and 3 are dimensioned to a swelling pressure of 7 MPa. The chosen concrete is a low-heat concrete with no reinforcement.

Access gallery: The access gallery in GES (zone 4) is made watertight and a cut-off of 2.5 m. Indeed, scoping calculations were done with Bright code and showed that the ventilation into the access drift will desatured the damaged zone cross the seal. This desaturation will be harmful to get a full hydration of the S/B mixture. To counteract this effect, water will be injected into the cut-off.

Observation boreholes: Surrounding the GES drift (Figure 3), a total of 23 boreholes will be equipped with multi-packers systems to monitor pore pressure (19 boreholes) and the others (4) with extensometer. Into the multi-packers boreholes, hydraulic tests will be repeated to see the evolution of the hydraulic conductivity around the seal in respect to the swell of the S/B mixture.

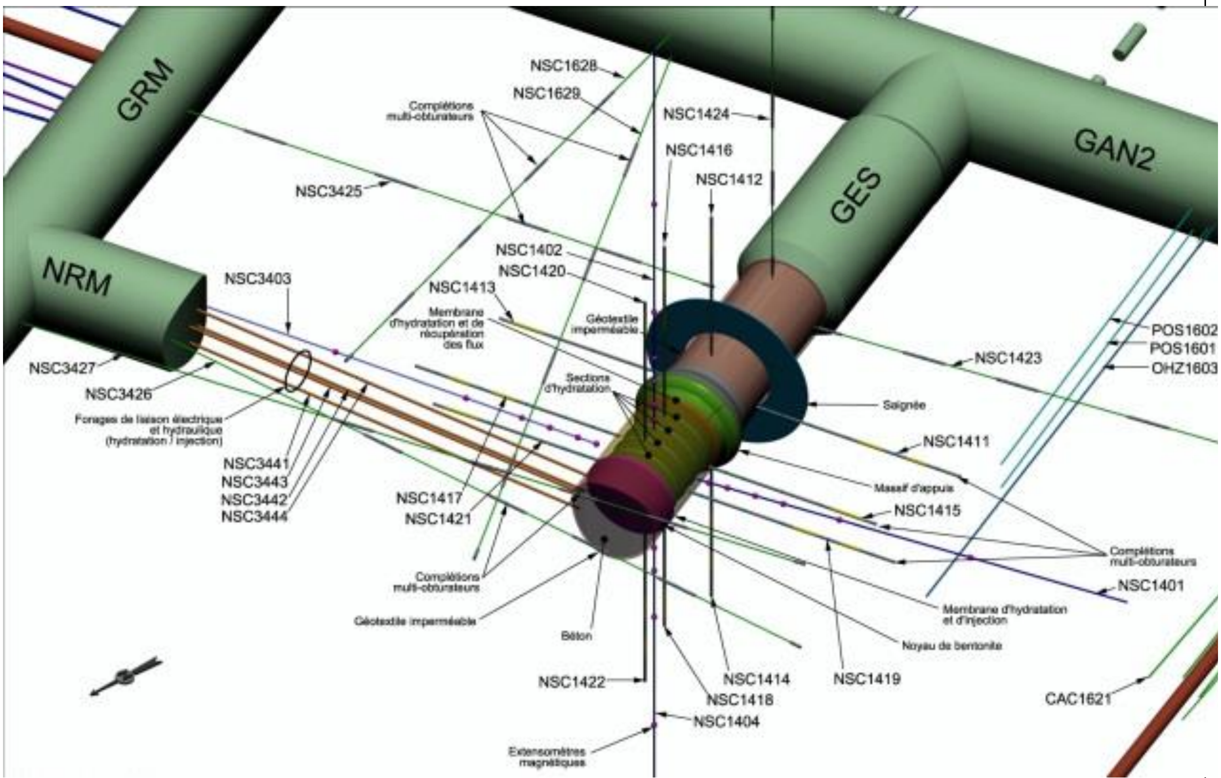


Figure 3 *NSC experiment in Bure URL- observation boreholes*

Bentonite core: The GES drift was excavated in 2012 and all the instrumentation inside GES drift and S/B mixture was installed during 2013. During the construction of the S/B seal, volume and mass of the S/B mixture was controlled. Those measurements were used to estimate the dry density of clay material in the seal and therefore estimate the swelling pressure. The estimated dry density of clay material and swelling pressure are closed to 1.45 kg/m^3 and 2.5 to 3.4 MPa respectively.

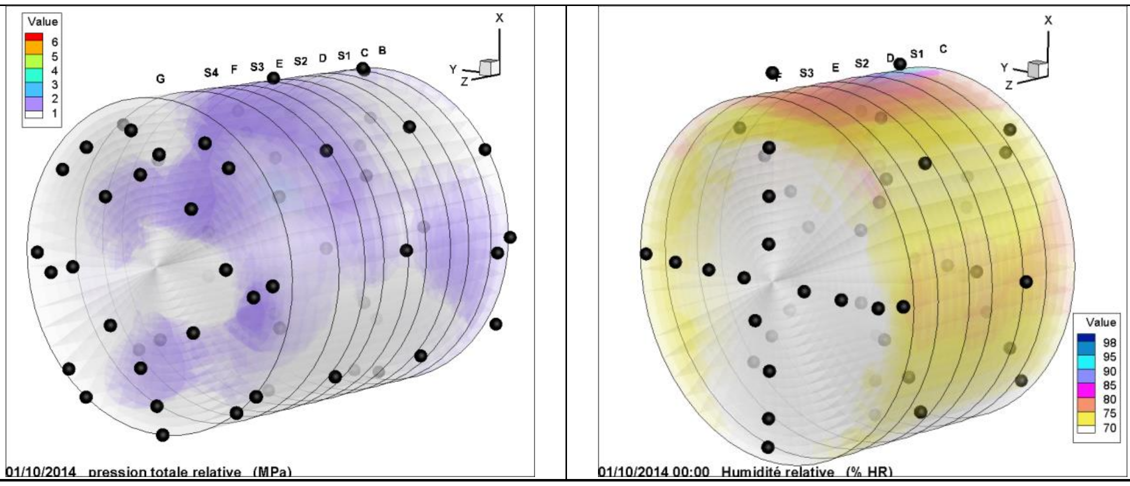
Bricks characteristics: Mass: 13.23 kg, dimensions 301 mm x 201 mm x 100 mm Mixture WH2/sand TH1000 - proportion 40/60 %.
A total of about 80 tons of bricks, 8 m^3 of bentonite pellets and 3 m^3 of powder has been installed (Figure 4). All the gap and technologic voids are filled with pellets/powder mixture.

Figure 4 Installation of bentonite core, wall made with bricks, pellets/powder mixture between claystone and bentonite bricks. Background: hydration membrane

Monitoring: The monitoring instruments, which have been installed in the experiment, are divided in different cross sections. In the seal and at the interface with the concrete plugs (upstream and downstream), is composed of 319 sensors (humidity sensors: 64 capacitives, 64 psychrometers and 16 FDR; pore pressure sensors: 99; total pressure sensors: 76) and 6 hydration membranes. Between each hydration membrane, the thickness of the S/B seal is 1 m. The maximal distance inside the S/B mixture from hydration membrane is therefore equal to 50 cm.

The injection chamber is the upstream part during the performance test and the concrete plug will be the downstream part. To avoid leakage between the two faces of the seal, all instruments installed within the S/B sealing (sensors, hydration membranes and surrounding boreholes) must to be wired towards the injection chamber passing through the concrete plug in 2 tubes system that guarantees the test tightness. All the wires pass through 6 “instrumentation” boreholes between injection chamber and NRM niche.

Example of results: Despite artificial hydration of bentonite, water saturation and total pressure increase slowly. On Figure 5, both total pressure and relative humidity measured inside bentonite core indicate clearly that full saturation hasn’t been reached. All the measures are available (total pressure, relative humidity, pore pressure evolution in the boreholes surrounding…).



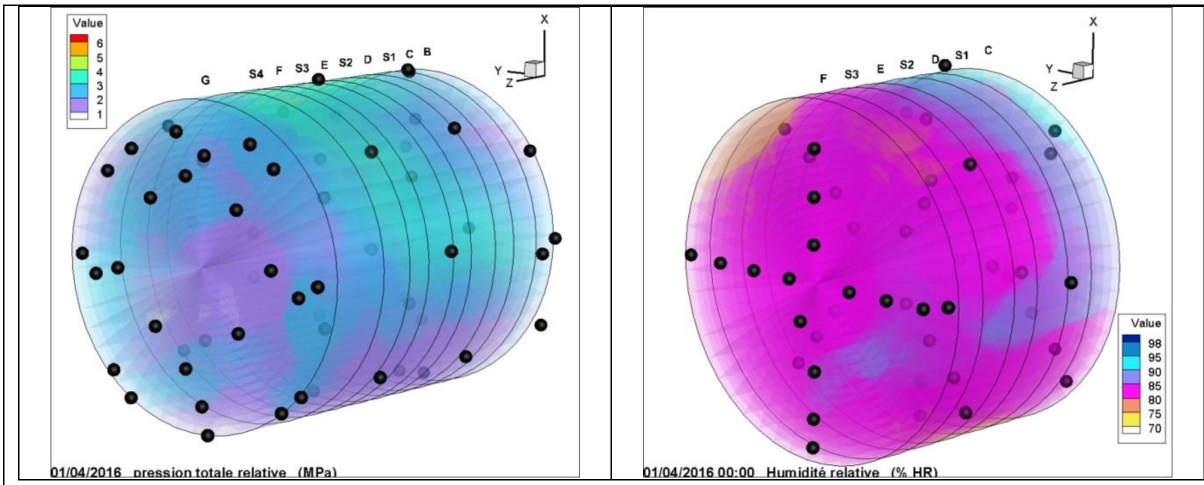


Figure 5 *Left: interpolation of total pressure; Right: interpolation of the relative humidity after 9 months (top) and 2.2 years (bottom)*

Main learning points concerning bentonite homogenization / mechanical evolution and relevance for the project

Water saturation and total pressure measured inside the bentonite don’t evolve in a similar way in all the sections. This heterogeneous response during the transient phase needs to be investigated and especially the role of initial heterogeneities due to variation of density in brick arrangement or to the presence of pellets/powder mixture in gaps.

Hydro-mechanical evolution of a large structure equipped with a high density of sensors (about 420) give an interesting base of knowledge. Especially about how heterogeneities evolve in time and consequences on final performance or effect of heterogeneous water supply on final state of bentonite core.

How could this work inform a new experimental or modelling study in BEACON?

This experiment has a well-defined geometry. The initial characterization THM all the materials involved has been done. A large number of sensors allows to follow the hydromechanical evolution of the bentonite core and of all the material surrounding. Presence of heterogeneities in the system. This lead to consider this experiment as a good candidate to modelling test within WP 5. This experiment has not been proposed before for a benchmark or as a modelling exercise.

References (ideally with web links)

de La Vaissière, R., N. Conil, J. Morel, F. Leveau, C. Gatabin, J. L. Garcia-Sineriz, H. Habos, M. Rey, M. Piedevache, B. Helmlinger and C. Balland (2014). Design and construction of a Large-Scale sand-bentonite seal in the Meuse/Haute-Marne Underground Research Laboratory. International conference on the Performance of Engineered Barriers, Hannover, BGR.

Recommendations for BEACON project (particular point to study)