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## **Design and construction of a large-scale sand-bentonite seal in in the Meuse/Haute Marne underground research laboratory: NSC experiment**

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During the excavation of a shaft or drift, the rock properties around the underground openings could be altered due to the level of the ratio in situ stresses over strength of the rock. And even in some case, the rock mass could be fractured. One concern regarding waste disposal is that the associated disturbance and damage created in this area around these excavations might change the favorable properties of such formations and thus negatively impact the repository performance. To limit radionuclides migration along drifts and through the EDZ, seals will be implemented in drifts and shafts. These seals will be composed of swelling clay (mainly bentonite) 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 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. Before to reach this ambitious goal, numerous output 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. The experiment is not a demonstration of the seal emplacement technique. Lot of sensors has to be installed in the seal and around it and results have to obtain over a reasonable timescale. That implies that properties and emplacement of the seal could not be fully representative of the forecast seal.

For example, for the sealing material, three criteria were set at the beginning: (i) hydraulic conductivity at saturation equals to  $10^{-11}$  m/s; (ii) swelling pressure between 1 and 3 MPa; (iii) reasonable time for hydration to reach fully saturation in some years. A first major step was the definition of this material and this was carried out by the CEA/LECBA. The finally chosen material is a mixture of Sand/Bentonite (MX80) in proportion 60% and 40% respectively in the form of brick (300 x 200 x 100 mm). With this S/B mixture, the permeability criterion is respected. For the other criteria, swelling pressure depends on the void ratio during the construction of the seal and the time for hydration depends on the number of the hydration membrane inside the S/B mixture.

It was chosen to put NSC experiment at the end of a drift of 4.6 m diameter (in GES drift see figure 1), in order to be sure that flow goes preferential along the seal. The experiment is composed of 4 zones (figure 1): injection chamber (zone 1), seal (zone 2), concrete plug (zone 3) and water thigh drift (zone 4). This seal is implemented in a drift of 5 m long and 4.6 m of diameter (inside the GES drift see figure 1).

The injection chamber will be 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. The detailed design of the instrumentation, delivery and installation are done by the joint venture Aitemin and Solexperts, except for the acoustic measurements into the concrete plug which are done by INERIS.

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. For this distance, the time for hydration is estimated at 3 years. So the second criterion is respected.

The hydration membrane at the interface between the concrete plug and the seal is divided into 12 independent areas (figure 2). 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.

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.

The access gallery in GES (zone 4) is made watertight and a cut-off of 2,5 m depth will serve to inject water into the damaged zone around the drift (figure 1). Indeed, scoping calculations were done with Bright code and showed that the ventilation into the access drift will desaturated 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.

Surrounding the GES drift (figure 1), 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.

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<sup>3</sup> and 2.5 to 3.4 MPa respectively. The third criterion could be met.

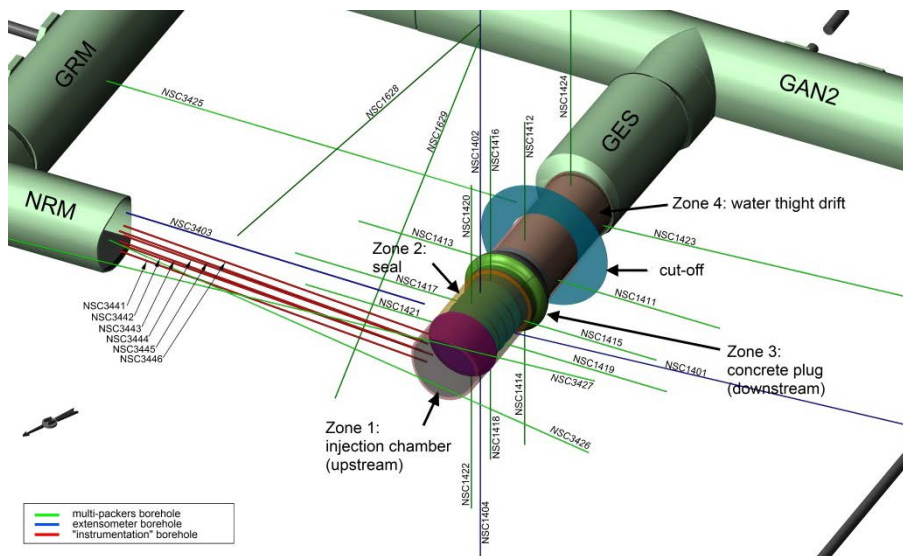


Figure 1 : General layout of the NSC experiment in the Andra's URL

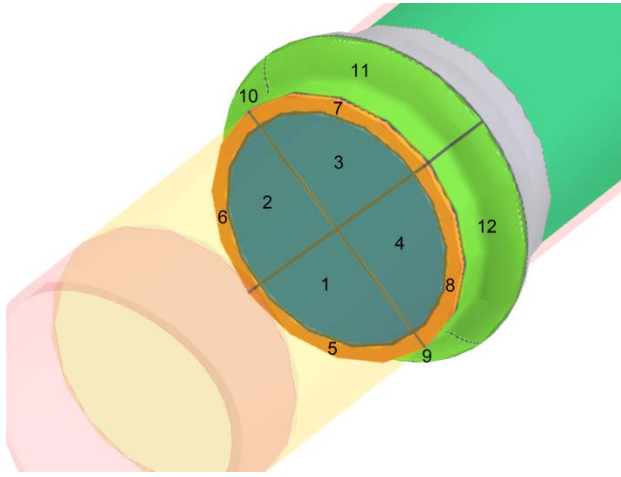


Figure 2: Detailed layout of the membrane at the interface with the concrete plug (zone 3)



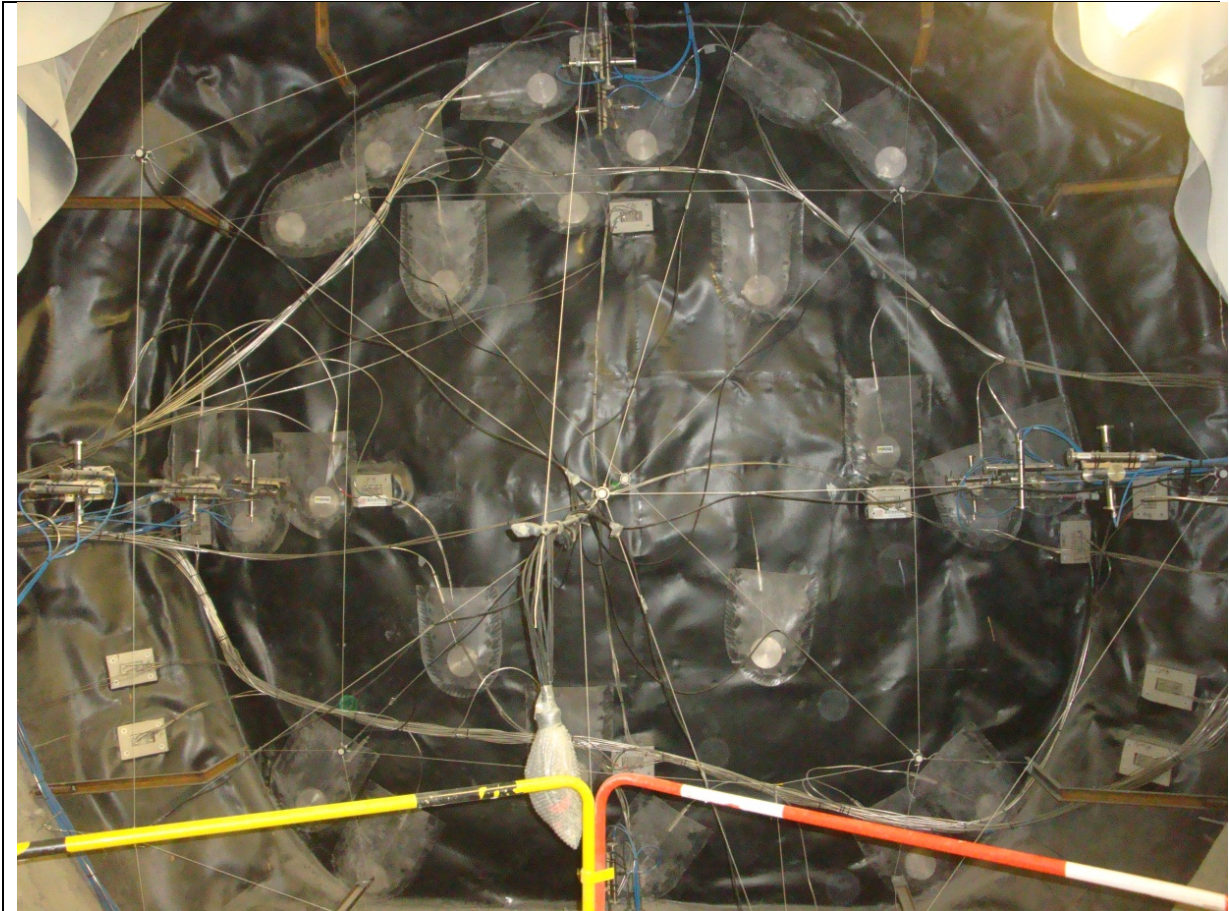
View of the injection chamber before pouring with all the tubing passing through instrumentation boreholes. All the sensors are grouped before the construction of the seal



Construction of the seal wall. In the background, we can see an hydration membrane.



View of the hydration membrane at the interface with the concrete plug (see figure 2)



View of the water-tight membrane at the interface with the concrete plug (see figure 2) and the sensors installed in the concrete plug before pouring

Figure 4: Photography during the installation of NSC experiment