Homogenization of bentonite plugs – what are the issues?

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Function: Limitation of water flow and radionuclide migration through drifts and shafts

Requirement: Low permeability of seal zone
- Compression of the EDZ around the seal to reduce water permeability
- Use of swelling clay for seal (bentonite MX80 or equivalent)
  - Water permeability of $10^{-11}$ m/s
  - Swelling pressure: 4 to 5 MPa max
  - Length equal to 2 diameters (or 20 m) at least

Compression of EDZ and self sealing of the host rock

To manage uncertainties on the final EDZ permeability → hydraulic cuts of the EDZ filled with bentonite
Installation of bentonite mixture…

Challenge: Filling a cavity diameter 8-10m, length 20m with pellets/powder mixture

FSS (DOPAS Project)

Several mixtures tested

Filling also:
• submittal voids,
• extra space to fill due to breakout
• hydraulic cuts of the EDZ
Control the initial properties of the material introduced in the facility – focus on bentonite density variability

**Proposition:** Development of technics to locate heterogeneous zones (density, water content...)

Knowledge about the initial distribution of density is essential to understand and predict the behaviour of the bentonite component

**Broadband spectroscopy method – proposal from SATIE (Ecole Normale Supérieure)**

**Principle**

Electromagnetic reflectometry probe.

**Large probe** ($R \cong$ several cm): proportionate for example to the size of the pellets in the bentonite mixture.

The probe is sensitive to the dielectric properties and therefore to the hydromechanical characteristics of the bentonite.

**Objective:** Design of a probe sensitive to bentonites over the [1MHz 3GHz] frequency range and its experimental validation.
Bentonite behaviour during hydration phase

Objective Understanding the physical processes and reorganization of swelling clay (pellets/powder mixture) during hydration phase

- Is there any heterogeneous distribution of mechanical loading on components around the bentonite such as retaining concrete plugs, concrete liners or host rock?
- What is the role of initial voids on final properties?
- What is the impact of heterogeneous flow arrival on reorganization of the clay?

Final state of bentonite component after full saturation

Objective: Understanding the role of local heterogeneity zones on water and gas flow through the engineered barrier.
- Consequences of localized heterogeneities in terms of preferential pathways need to be investigated

Work that could be done in a joint project...
REM a full instrumented mock-up

Cylinder (1m height, 1 m diameter) filled with pellets (32mm)/ crushed pellets mixture

Hydration (from the bottom) started in October 2014

Sensors
- 30 for total pressure (+ 4 on top)
- 30 for relative humidity
- 5 for interstitial pressure
- 4 for strength (on bolts)

Estimated resaturation time >10 years
BHN experiment
Natural resaturation of bentonite in URL

- Installed in May 2014

Mixture pellets 32 mm + crushed pellets (MX80)

Bentonite plug is at 7 meter depth between to concrete plugs

Bentonite plug length = 3 m, diameter = 75 cm

Sensors
- 10 load cells
- 9 RH sensors
- 3 pore pressure sensors

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NSC a large scale sealing experiment

Sand/bentonite bricks
Seal of 5 m long 4,6 m diameter
Pellets/powder mixture to fill interface between host rock and bricks

318 sensors in the bentonite core
- Pore pressure : 98
- Load cells : 76
- RH (Capacitive 64, Psychrometer 64, FDR 16)

88 sensor in the concrete plug
- Deformation 36, displacement 16
- Pore pressure 20
- tomography(INERIS) 16

Beginning of hydration: January 2014

Hydraulic tests of interfaces 2017
Summary: Work that could be done in a joint project

- Participation to development of technics to measure properties of bentonite at facility scale (density, water content...)
  - Possibilities to add new devices proposed by partners in our new URL experiments

- All data for at least 3 large scale experiments REM, BHN, NSC
  - Including
    - Bentonite mixture characterisation (THM-gas behaviour)
    - Lab tests realised to understand and quantify some processes
    - Details about design, geometry, installation
    - Sensors responses
    - Numerical simulations

- Constitution of modelling groups around a set of consistent experiments to improve knowledge about specific processes

- Resources needed:
  - At least 20 men/month for Andra
  - Direct financial support for SATIE (ENS)