Homogenization of bentonite plugs – what are the issues?

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November 2015

Cigeo Seal Design for horizontal drifts

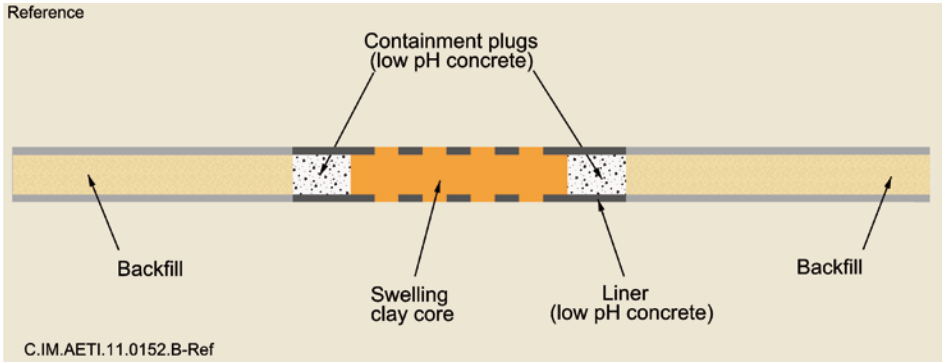
Function : Limitation of water flow and radionuclide migration through drifts and shafts

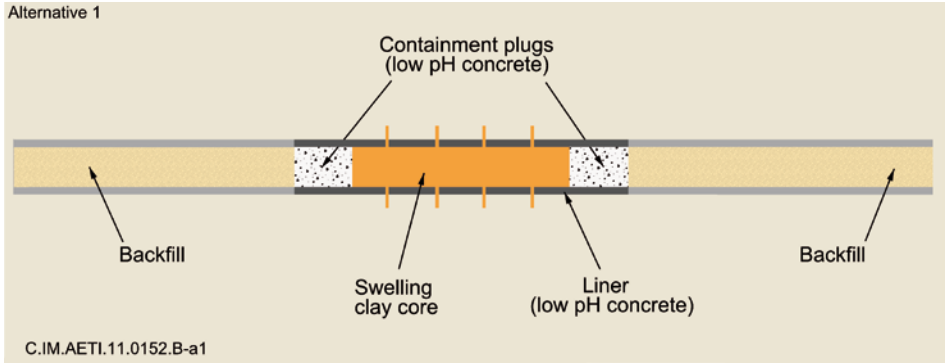
Requirement: Low permeability of seal zone
Compression of the EDZ around the seal to reduce water permeability

→ 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

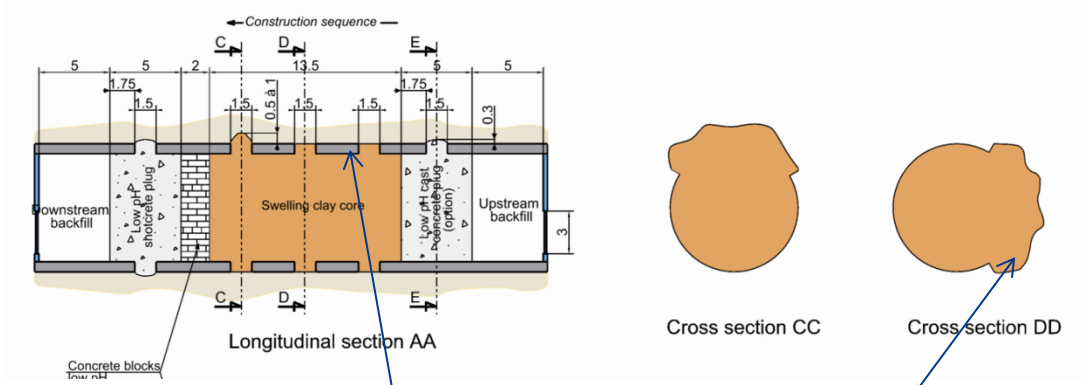
To manage uncertainties on the final EDZ permeability → hydraulic cuts of the EDZ filled with bentonite





Installation of bentonite mixture…

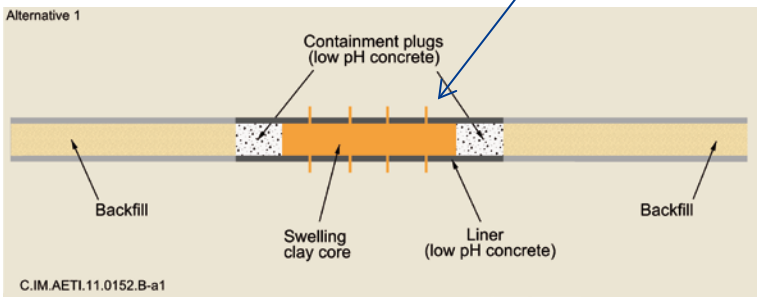
Challenge : Filling a cavity diameter 8-10m, length 20m with pellets/powder mixture



Several mixtures tested

Filling also:

- submittal voids,
- extra space to fill due to breakout
- hydraulic cuts of the EDZ

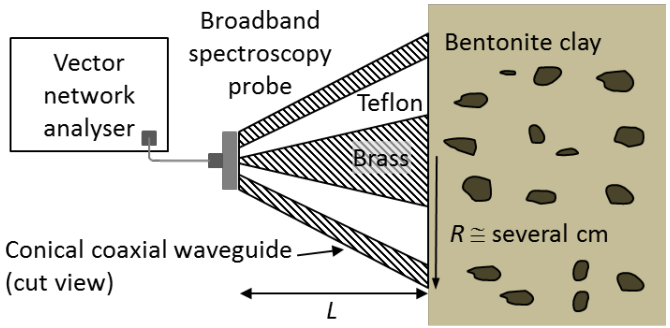


Control the initial properties of the material introduced in the facility – focus on bentonite density variability

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

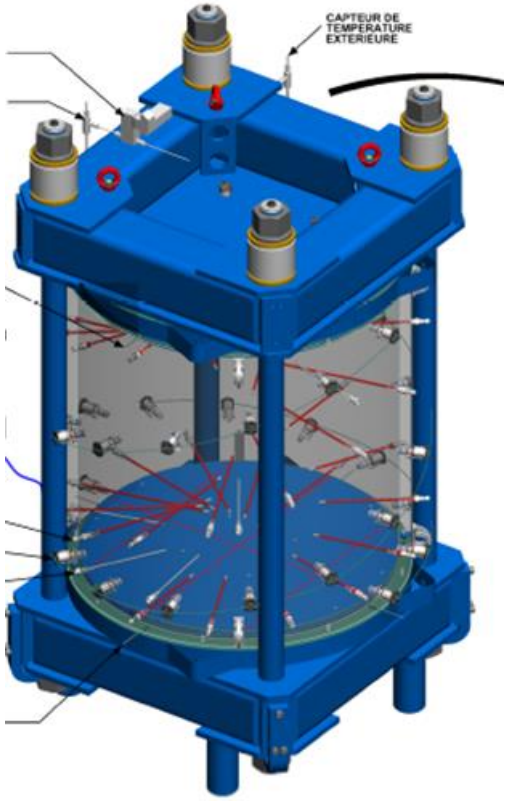
Cylinder (1m height, 1 m diameter) filled with pellets (32mm)/ crushed pellets mixture

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 >10years

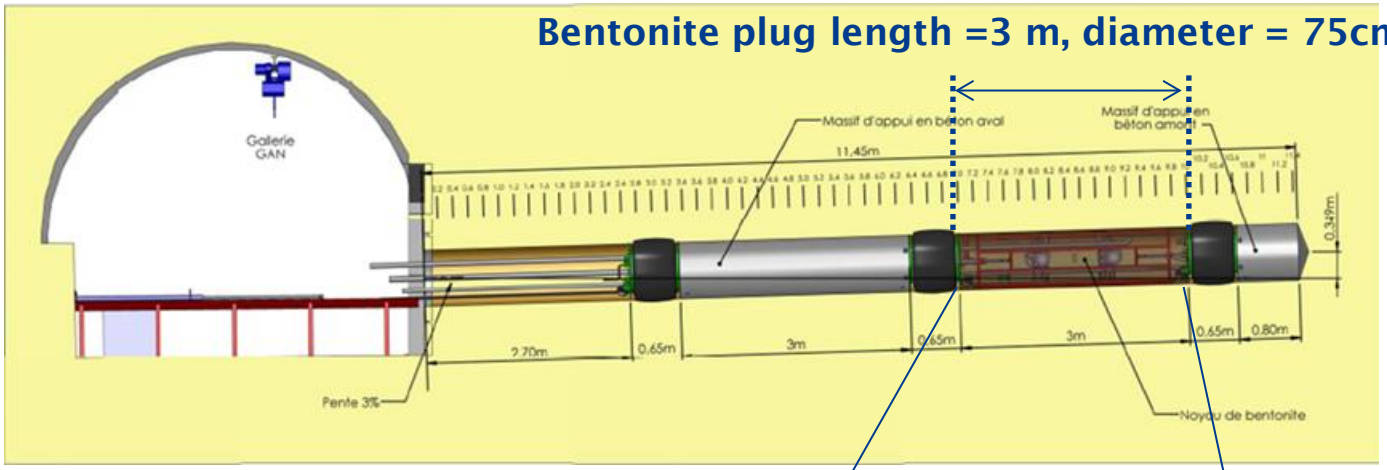


BHN experiment
Natural resaturation of bentonite in URL

- Installed in May 2014

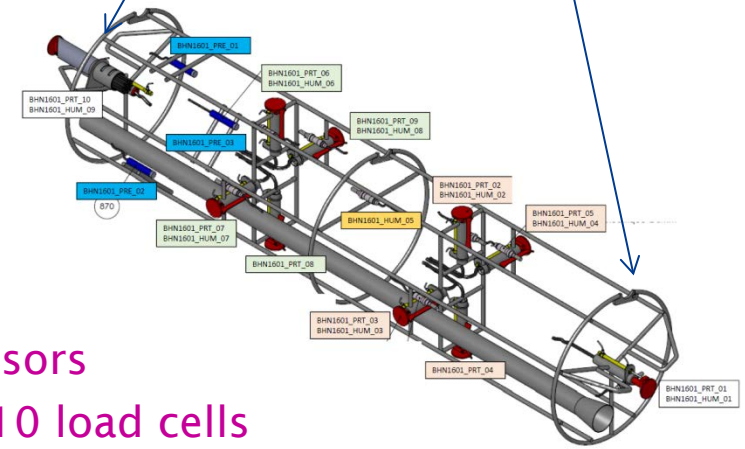
Mixture pellets 32 mm
+
crushed pellets (MX80)

Bentonite plug length =3 m, diameter = 75cm



Bentonite plug is at 7 meter depth between to concrete plugs

3D scan

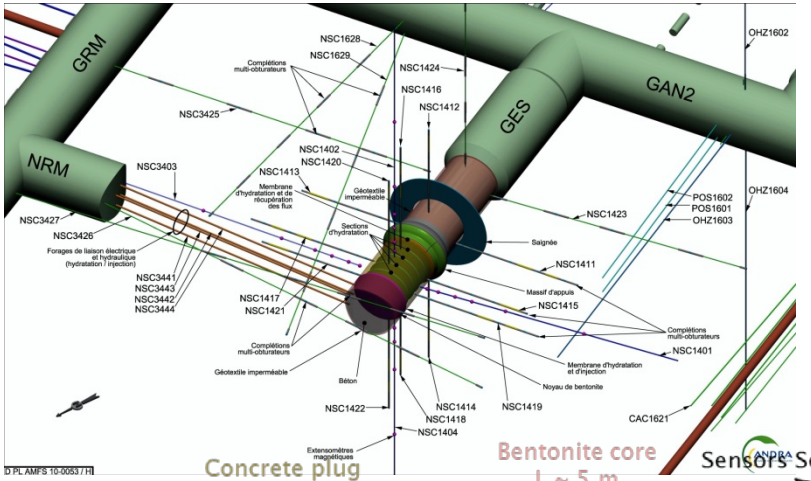


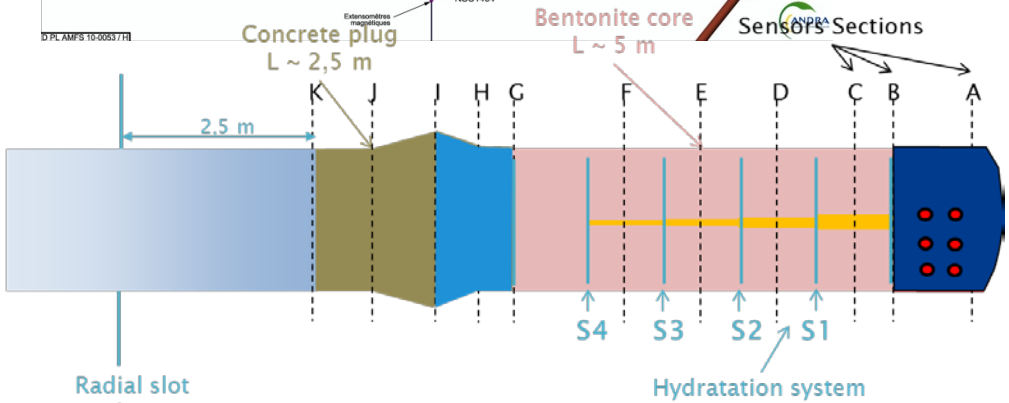
Sensors

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

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