Gas-Permeable Seal Test (GAST) at the Grimsel Test Site

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Partner:
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In L/ILW repositories corrosion of metals and degradation of organic materials produce mainly hydrogen, methane and CO₂.

The concept of the engineered gas transport system allows the release of the gases from emplacement caverns along operational and access tunnels.
Mixtures of sand and bentonite exhibit increased gas transport capacity without compromising the radionuclide retention capacity.
Sand/bentonite mixtures

- Mercury intrusion test
- 80% sand 0.1-0.5 mm
- 20% MX-80 bentonite
- 1.65 Mg/m³ dry density

Manca et al. (2015)
GAST large scale demonstration experiment

Objectives

- Demonstrate the **effective functioning of gas permeable seals**
- Validate and improve current **conceptual flow models** for sand / bentonite
- Determine **up-scaled water and gas permeabilities** of sand / bentonite
### Design and materials

<table>
<thead>
<tr>
<th>Element</th>
<th>Material</th>
<th>Length</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seal element</td>
<td>Sand/bentonite (80%/20%) Horizontal emplacement layers 0.1 m</td>
<td>8 m</td>
<td>46 m³</td>
</tr>
<tr>
<td>Sealing interfaces</td>
<td>Granular bentonite</td>
<td>Ring 0.25 m Wall 0.30 m</td>
<td>~22 m³</td>
</tr>
<tr>
<td>Headspace</td>
<td>Granular bentonite</td>
<td>9 m</td>
<td>~14 m³</td>
</tr>
<tr>
<td>Sealing walls</td>
<td>Bentonite blocks</td>
<td>0.3 m</td>
<td>3.7 m³</td>
</tr>
<tr>
<td>Filters</td>
<td>Gravel</td>
<td>0.5 m</td>
<td>~6 m³</td>
</tr>
<tr>
<td>Bulkhead</td>
<td>Concrete</td>
<td>2.0 m</td>
<td></td>
</tr>
</tbody>
</table>
Instrumentation

- Sensors installed at layer tops on levels L0-L8

- Located on vertical sections S01-S17

- Cables and lines for sensors in sand/bentonite routed to risers in the granular bentonite to main duct below tunnel.

- Other sensor lines routed along tunnel wall and through plug pass-throughs

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Type/abbreviation</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pore pressure external</td>
<td>PPE</td>
<td>39</td>
</tr>
<tr>
<td>Port lines</td>
<td>PL</td>
<td>10</td>
</tr>
<tr>
<td>Total pressure cells</td>
<td>TPW/TPB</td>
<td>23</td>
</tr>
<tr>
<td>Volumetric water content (TDR probes)</td>
<td>TDP/TDL</td>
<td>38</td>
</tr>
<tr>
<td>Seismic sensor housing</td>
<td>SE</td>
<td>34</td>
</tr>
<tr>
<td>Psychrometers</td>
<td>PS</td>
<td>30</td>
</tr>
<tr>
<td>Relative humidity sensors</td>
<td>RH</td>
<td>20</td>
</tr>
<tr>
<td>Temperature sensors</td>
<td>PT1000</td>
<td>3</td>
</tr>
<tr>
<td>Displacement sensors</td>
<td>DI</td>
<td>4</td>
</tr>
<tr>
<td>Flowmeters</td>
<td>FRW</td>
<td>3</td>
</tr>
</tbody>
</table>
Emplacement and compaction

Material emplacement (total 83.4 t)

Distribution to approximately 25 cm height

Layer compaction with rammer and vibrator

Granular bentonite behind sliding wall
QA on site - overview

- Mass balance method:
  - Volume and density for each emplacement layer (MB 2D)

- Laser scanning of each instrumentation layer
  - High-resolution layer surface at instrumentation layers (includes 4-5 emplacement layers) for volume and density calculation (MB 3D)

- Density profiles from Troxler probe (gamma-density)
  - Dry density and water content in shallow holes (35 cm)

- Material sampling with core cutter
  - Dry density and water content of each emplacement layer
  - 4-22 samples per layer
QA on site – dry densities

Sampling scheme

- Core cutter sampling scheme resolves intra-layer density variability.
- Limited depth penetration (2cm) of core cutter probably overestimates layer density.

Averaged dry densities

- Target dry density.
- Min. dry density.

Sampling scheme:

- Troxler
- Core cutter

Core cutter:

- Lower densities
- Higher densities
Mock-up density inspection

- Analysis of S/B layers from Mock-up column (DM 60 cm)
- Dismantling: S/B tends to separate at emplacement layer joints → anisotropy in strength, hydraulic permeability?
- X-ray CT imaging of joint samples resolves discontinuous parameter
Saturation protocol and pressures
Interpretive modeling – saturation phase

350 days

550 days
Acoustic tomography indicates heterogeneous saturation

Day 490

Day 526

Day 552

Layout of acoustic sensors (Section S5)
Post leakage activities and outlook

- Installation of well head that seals the main cable duct to tightly close the system
- Re-routing of cables and lines
- Backfill of void volume surrounding cables / lines in main duct to minimize future loss of seal material
- Saturation restarted September 2015
- Initial characterisation includes sinusoidal testing and pressurisation from both filters
- Continuation of two-sided water injection
Summary and conclusions

- The GAST experiment demonstrates construction and instrumentation of “near full-scale” gas-permeable repository seal.

- Characterisation of the emplaced sand/bentonite using multiple methods shows:
  - Emplaced material above minimum target dry density
  - Core cutter data resolves intra-layer variability but dry densities may be slightly biased; mass-balance densities show greater variability

- Saturation of the large sand/bentonite seal volume
  - Piezometers and seismic tomography suggest heterogeneous saturation
  - Tough models reproduce saturation trend
  - Partial saturation achieved after 550 days but interrupted by leakage (probably associated with instrumentation ducting)

- Saturation restart in September 2015 after duct sealing
  - System characterisation and smooth pressurisation ongoing
thank you
for your interest