Workshop Underground Disposal of Hazardous Waste

Geotechnical barriers - shaft and drift sealings - selected German research projects

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Outline

1. Targets of shaft sealings
2. Existing shaft sealings for salt mines and gas storages
3. Research projects shaft sealings –
   shaft sealing Salzdetfurth
4. Targets of drift sealings
5. Existing drift sealings for salt mines
6. Research projects drift sealings –
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   drift sealing CARLA Teutschenthal
7. Research topics - Conclusions
1. Targets of shaft sealings

Principle scheme of Shaft Sealing Systems in Rock Salt

Pressure from
• the upper side (mostly fresh water)
• the disposal side (salt water or gas)
• both sides

Ground water
Overburden/cap rock
Salt level
Rock salt
Hazardous waste
Surface
Shaft Landing
Shaft sump
Support column for Shaft Landing
Sealing element II
Sealing element I
Filling column II
Filling column I
Filling column with salt
Water-tight shaft construction
2. Existing shaft sealings for salt mines and gas storages
Shaft Sealing System
Gas Storage
Burggraf - Bernsdorf

Gas pressure: 3.7 MPa
Sealing pressure: 4.2 MPa

Upper Abutment
Combination Seal
Hydraulic Sealing System
Lower Abutment

33 m
7 m
Shaft Sealing System Glückauf II (Safekeeping 1993)

Example of a Shaft Sealing System with upper and lower Sealing Elements against fluid pressure from both sides (6 MPa)
Shaft sealings for nuclear waste repositories
(low and intermediate radioactive waste)

• Shaft Konrad 1 und 2
• Shaft Asse 1 und 2 (not finally decided)
• Repository Morsleben (ERAM), Shafts Martensleben und Marie
3. Research projects shaft sealings – shaft sealing Salzdetfurth
In-Situ-Versuch Schottersäule Schacht Salzdetfurth II

Performer: K+S, DBE, IfG Leipzig
Sealing Drilling Shaft Test - Salzdetfurth

Performer: K+S, TU BAF, DBE, IfG Leipzig
In situ Test Salzdetfurth – Sealing Performance

Infiltration Rate
5.8 \times 10^{-11} \text{ m/s}
4.4 \times 10^{-11} \text{ m/s}
Special Technical Devices for Sealing Performance Tests at Technical University Bergakademie Freiberg

D = 0.8 m  L = 2.0 m  $p_{\text{max}} = 100$ bar
Systematization of shaft sealing systems

Clay – Bitumen/Asphalt – Sealing with Concrete Abutment

Series Connection Clay (Bentonite) – Bitumen/Asphalt

No contact between Clay (Bentonite) – Bitumen/Asphalt (e.g. WIPP)

Bentonite Sealing Element + Gravel Column (Type Salzdetfurth)

Systems without Concrete abutment
4. Targets of drift sealings
Target: minimal flow through sealing element, contact area and EDZ

- Pressure side
- Sealing element
- Flow through excavation disturbed Zone (EDZ)
- Flow along contact area
- Flow through sealing element
5. Existing drift sealings for salt mines

• Short term sealing element: 1-4 / 10-13
• Long term sealing element: 5-7 / 7-9
• Abutment (4, 10) Brine-Concrete with standard aggregate
• Sealing element (2, 12) with ring-seal (3,11) Bentonite-Blocks FS50 (50 % silica sand)
• Main-Seal with FS50 (7) und FS70 (6, 8) (70 % silica sand)
• Gravel-Sand-Intersection (5, 9)
• (No current fluid pressure load)
6. Research projects –
drift sealing Sondershausen
drift sealing CARLA Teutschenthal
IN SITU DRIFT SEALING EXPERIMENT IN THE SALT MINE SONDERSHAUSEN

- main sealing element I
- additional sealing element
- prismatoid-shaped static abutment
- pressure chamber II
- bentonite bricks
- salt bricks
- pressure tubes
- sealing slots
- pour-asphalt
- brine canal
- 13° sealing slots
- pressure chamber I

Dimensions:
- 0.6 m
- 1.25 m
- 3.5 m
- 3.50 m
- 5.0 m
- Ø 3 m
## PROPERTIES OF PRODUCED BENTONITE BRICKS
(by Preiss-Daimler Industries GmbH - Feuerfestwerke Wetro)

<table>
<thead>
<tr>
<th>Type</th>
<th>FS50</th>
<th>FS40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bentonite content [%]</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>Hydraulic conductivity (NaCl-brine) [m/s]</td>
<td>$2 \times 10^{-11}$</td>
<td>$10^{-12}$</td>
</tr>
<tr>
<td>Swelling Pressure by constant volume (NaCl-brine) [MPa]</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

Standard size (250 x 125 x 62.5) mm
In Situ drift sealing experiment GV 1 (from 3) in the salt mine Teutschentahl - CARLA

Volume: 163 m$^3$
365 t MgO-Beton

Monitoring:
- Temperature
- Contact pressure
- Distribution of strain
- Deformation
- Permeability of the system
Test of a new Asphalt Sealing Constructions

Deformation characteristics - rheology

Parameter (mixture dependent):

- Young Modulus: 60 MPa
- Poisson's ratio: 0.498
- Bulk modulus: 5 GPa
- Shear viscosity: $10^{10} - 10^{11}$ Pas

Nonlinear time- and temperature dependent behavior!

Parameter determination on the basis of creep tests

\[ \eta_M = 7.61 \times 10^{11} \text{ Pas} \]
\[ \eta_K = 9.81 \times 10^{10} \text{ Pas} \]

\[ E_M = 2.34 \text{ MPa} \]
\[ E_K = 4.86 \text{ MPa} \]

Daten: axialDehnung_E
Modell: Burgers
Gewicht: Keine Gewichtung.
Chi^2/DoF = 1.27E-6
R^2 = 0.99854

P1: 200000 ± 0
P2: 1.3865E12 ± 200632989.89028
P3: 7512429.64637 ± 21291.55892
P4: 4638334.03611 ± 9371.94153
P5: 305444427493.04504 ± 1411649826.95496
Test of a new Asphalt Sealing Constructions

insitu tests in the potash-mine „Teutschenthal“

general assembly of the borehole sealing experiment (Ø30cm)
Current experimental Research - 1

New Evolution of Asphalt Sealing Elements for Shafts and Drifts
- Test of new asphalt compositions
- New emplacement operations

Grouting for EDZ- and Contact-Enhancement
- 2-component-bitumen-grouting
- epoxide resin

Test of Bentonite sealing elements with equipotential segments

Self sealing backfill material
in situ testing SVV-GRS and AISKRISTALL
Moisture measurement in Bentonite sealing elements

Drift sealing system in Carnallitit (Teutschenthal Salt Mine)
  MgO-Concrete-Plugs (mixed in situ and shotcrete)

Long term stability of MgO-concrete

Solution controlled crystallization
  Testing in Teutschenthal-mine (IfAC – TU Bergakademie Freiberg)

Concepts to transcribe the proof of safety from Eurocodes to long term sealing elements
  ÜBERSICHT (DBE)
Conclusions to shaft and drift sealings for hazardous waste repositories:

• Shaft sealings
  – Research concerning shaft sealings far advanced
  – Some detail problems to solve (e.g. EDZ, Hot construction technology Asphalt, etc.)

• Drift sealings
  – Research concerning drift sealings not so far advanced as to shaft sealings
  – Further large scale tests necessary (e.g. injection testing, hot asphalt technology for vertical panels, etc.)

• Main used materials: Bentonite-bricks and Bentonite-mixtures, asphalt, compacted rock salt, concrete with salt aggregates, brine concrete
Thank you for your attention!