Sandia National Laboratories

Verantwortung für Generationen
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DBE TEC
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PTKA
Project Management Agency Karlsruhe
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ELSA – shaft seal project Phase 2

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Outline

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  - Long-term stable (3-1-8) MgO concrete
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- Summary and outlook

Introduction - general

- Shaft seals are the most important elements in the geotechnical barrier system for underground repositories
- Isolation potential of shaft seals has to be as close as possible to the geological barrier
- Potential repository regions of Germany are in salt and clay formations
- Approved shaft seal concepts for HLW- repositories universal suitable for salt and clay formations are not available
- Knowledge and experience from national and international underground waste disposal projects (mostly site-specific) are important resources for the ELSA – Project

Introduction - partners

- ELSA is a joint research project:

TECHNISCHE UNIVERSITÄT BERGAKADEMIE FREIBERG
The University of Resources. Since 1765.

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DBE TEC
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Project director: W. Kulda W. Bollingerfehr, M. Jobmann

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with the following partners:

CMM - KIT
GSES
IBeWa Freiberg
IfG Leipzig
TS BAU GMBH, NL Jena

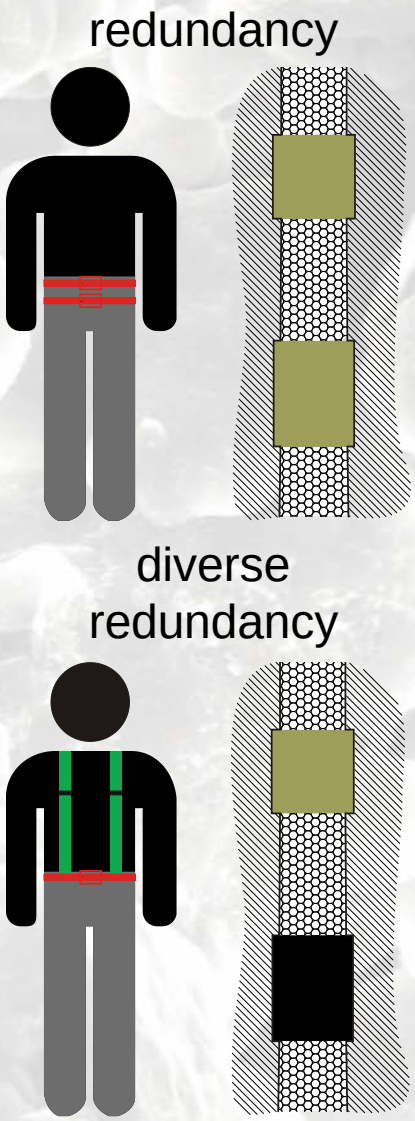
Introduction - project structure

- ELSA project is partitioned in 3 phases:

support code: 02E10921 02E10931	Phase 1: compilation of boundary conditions and design requirements	04/2011 – 01/2013 final report available
support code: 02E11193A	Phase 2: concept development for shaft seals and demonstration of functional components	05/2013 – 12/2015 in progress
	Phase 3: demonstration of the developed sealing concept in full scale test	application in preparation

State of the art - general

- The final report of phase 1 describes the state of art for shaft seals with long-term stability
- Shaft sealing system “Salzdetfurth” is the basic concept
- Concepts of ERA Morsleben, ASSE, KONRAD, WIPP and NAGRA are respected
- Safety analysis projects ISIBEL, ANSICHT and VSG are considered
- HLW- repositories require a distinctive level of safety, so the principle of redundancy or (better) diverse redundancy must apply



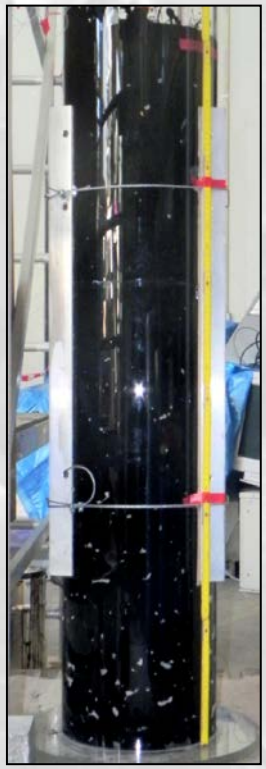
State of the art - diverse redundant concept

- ERA Morsleben shaft sealing

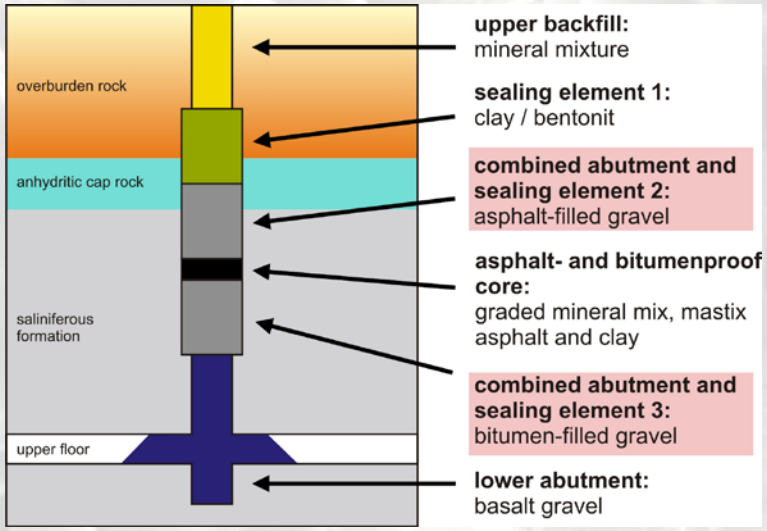
bitumen / asphalt filled gravel column (cast in place)

before casting

30 minutes after casting



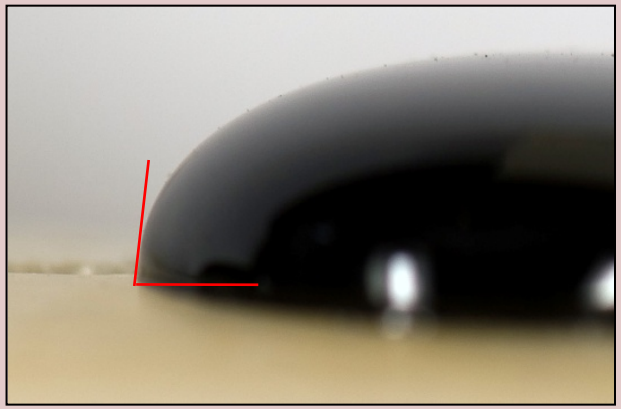
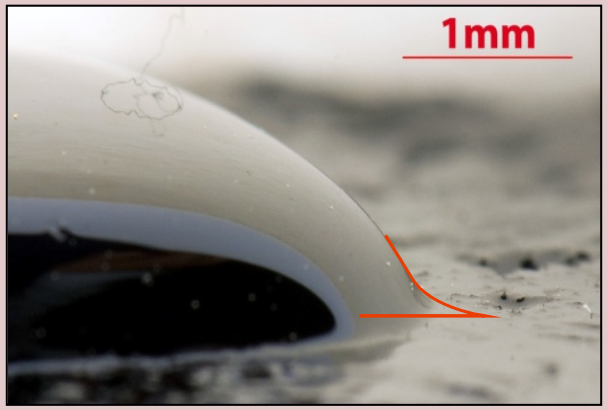
24 hours after casting



full scale test of asphalt / gravel element (BiSETO)

State of the art - latest development

- Bituminous primer for salt (with mining approval)
  - patent no. DE 102008050211

no wetting	good wetting
	

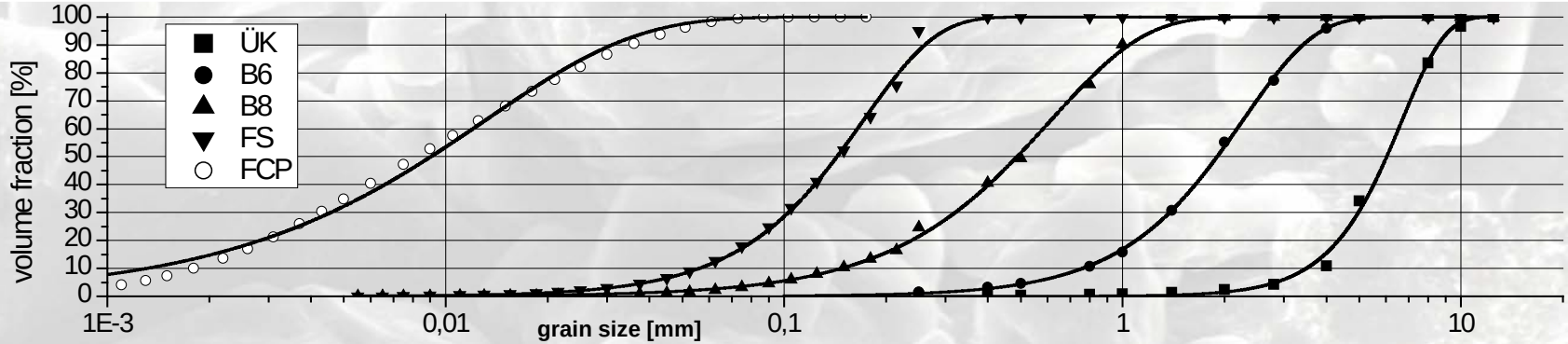
Aims of the project – phase 2

- general:
  - Development of a modular and non-site specific shaft sealing concept for salt and clay formations
  - Test of functional components in laboratory scale and half scale
- specific investigations:
  - producibility of backfill columns from compacted crushed salt (<0.9ρ_0)
  - calottes from Basalt blocks to support a low-settling gravel column
  - abutments and seals from long-term stable (3-1-8) MgO concrete
  - grouting technologies to seal EDZ and contact between host rock and concrete sealing element
  - construction technologies for bitumen / asphalt sealing elements
  - bentonite sealing elements with equipotential layers
  - model-theoretical analysis on different states of construction, as well as loadings and flow processes

Preliminary results – work package TUBAF

- Optimizing the grain size distribution of crushed salt

Fractions from GSES processing plant	Friedland Clay Powder (FCP)	fine salt (FS)	band 8 (B8)	band 6 (B6)	oversize grain (ÜK)
Distribution d_5 – d_{95} [mm]	0.001 - 0.04	0.04 – 0.3	0.1 – 1.2	0.4 - 4	3 - 10
d_{50} [mm]	0.009	0.14	0.49	1.90	6.03
particle density [g/cm³]	2.655	2.198			



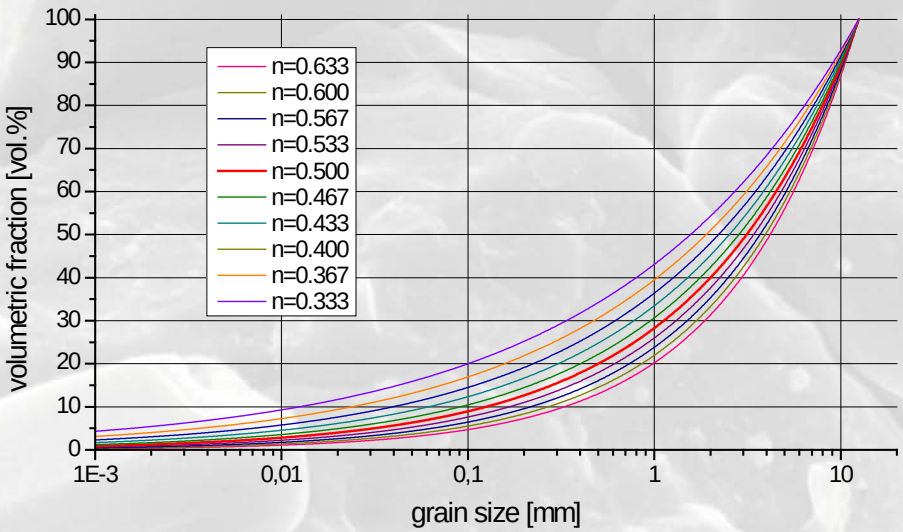
Preliminary results – work package TUBAF

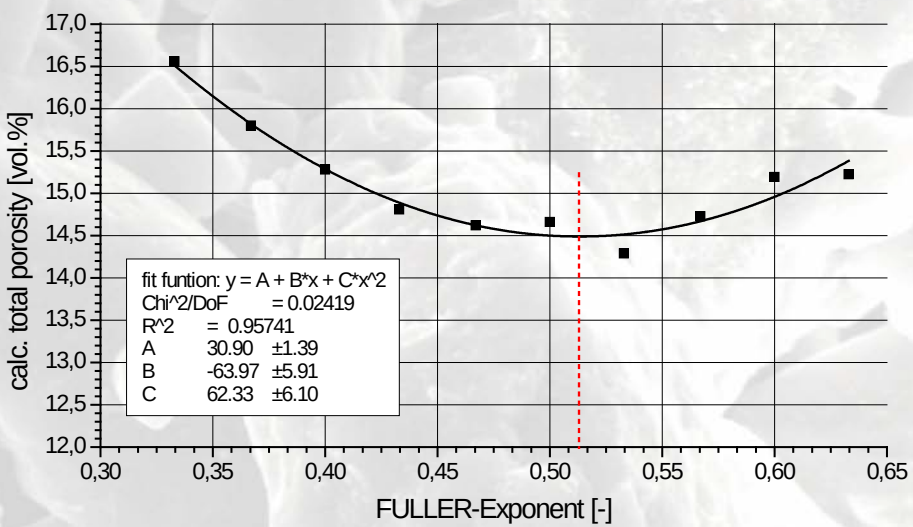
- Optimizing the grain size distribution of crushed salt
  - FULLER-distribution as a first approximation

$$F_F(d) = 100\% \left(\frac{d}{d_{max}} \right)^n$$

d	grain diameter
d_{max}	maximum of the grain diameter
F_F	FULLER volumetric grain size distribution
n	Fuller-Exponent, distribution-coefficient

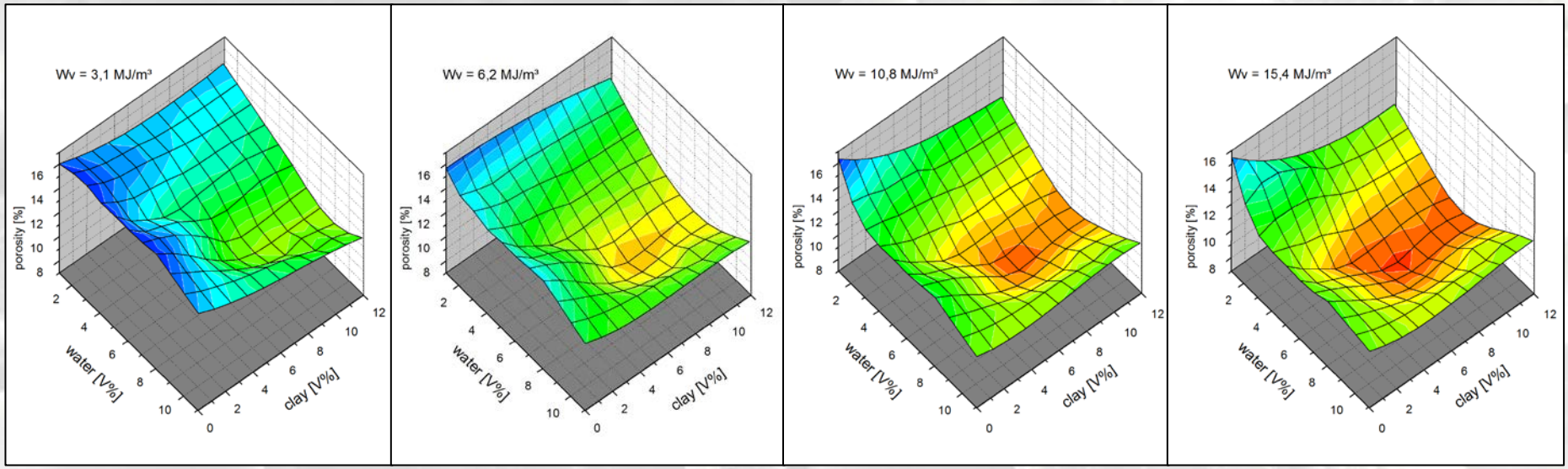
  - Compaction tests with 6 MJ/m³ using a percussive Marshall-compactor on different Fuller distributed mixtures
  - Minimum of total porosity with a FULLER-Exponent of n~0.51
  - 30 % less porosity than REPOPERM material





Preliminary results – work package TUBAF

- Optimizing the water and clay content regarding the compaction energy (according to BUTCHER 1991)
  - optimal clay content is approx. 8 vol% (of dry solids)
  - optimal water content depends from compaction energy
  - for compaction energies > 10 MJ/m³ the optimal water content is approx. 6.2 vol% (mixture specific ~ 2.7 wt%)
  - the lowest gained porosity was 7.7 vol.% @ 15.4 MJ/m³



Preliminary results – work package TUBAF

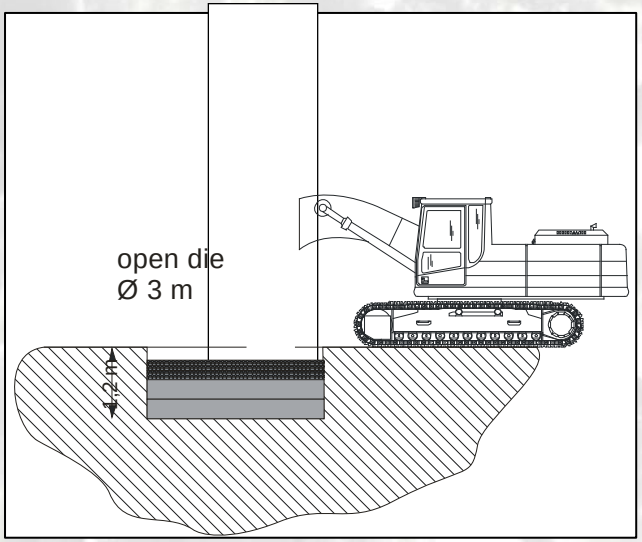
- Emplacement tests of the optimized material
  - in-situ compaction test in drifted dies using conventional vibrating compactors
  - gained porosities ~ 15 vol%
  - further (final) compaction by percussive compactor

Reversible Vibratory Plate (750 kg)

Trench compactor (1450 kg)

Preliminary results – work package TUBAF

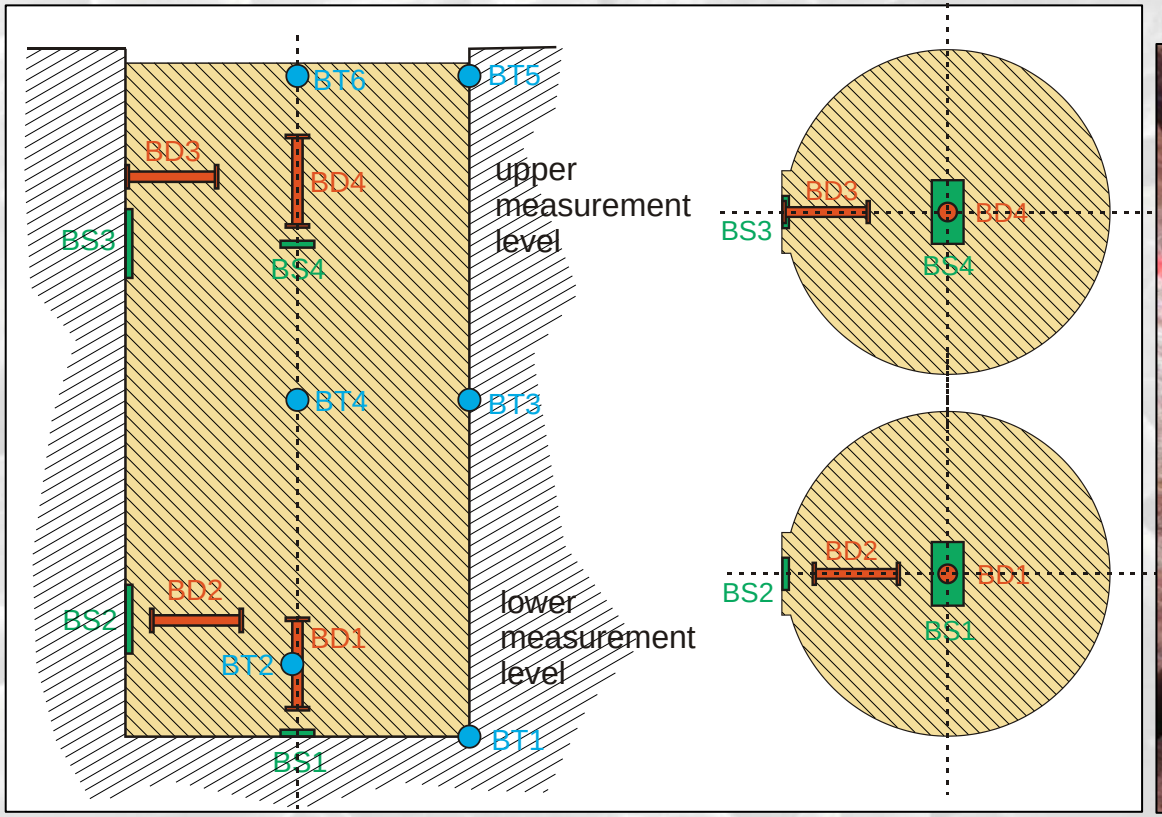
- Compaction by a percussive Compactor
  - using commercial “Rapid Impact Compactor” for feasibility study
  - compactor spec. (hydraulic drive)
    - high blow ratio of ~40 blows per minute
    - falling weight 9000 kg with controllable falling height of 0.3 – 1.2 m
    - controllable energy per blow of 26.5 - 106 kJ (power: 1.1 - 4.2 MJ/min)
    - compaction foots with diameter from 0.8 m to 2.0 m available
  - half scale field test in preparation (may 2015)

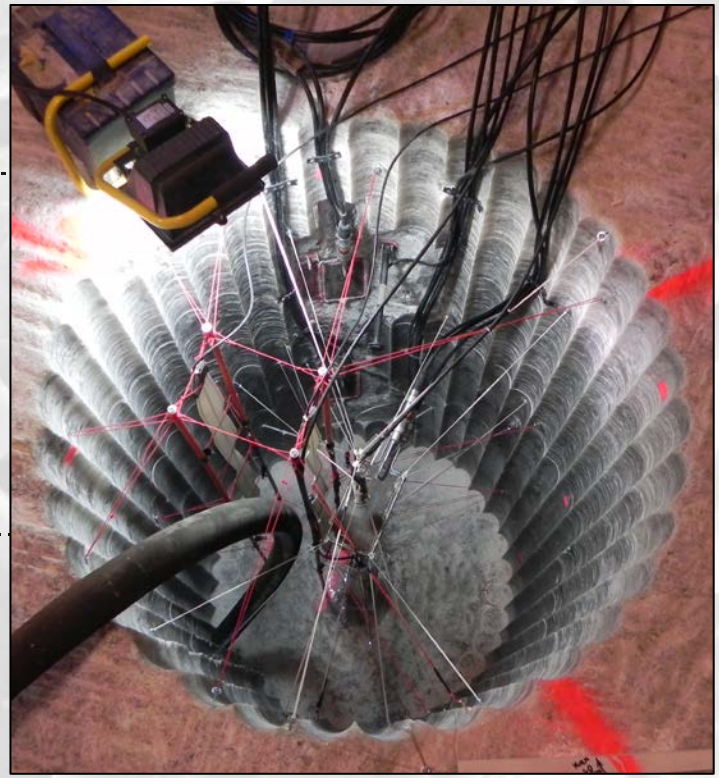


Preliminary results – work package TUBAF

- Long-term stable (3-1-8) MgO concrete
  - construction of a half scale test on in-situ material behavior
  - measuring of temperature (BTx), stress (BSx), strain (BDx) and changing of moisture content (TDR sensors) during construction, hydration and maturing (12 month)

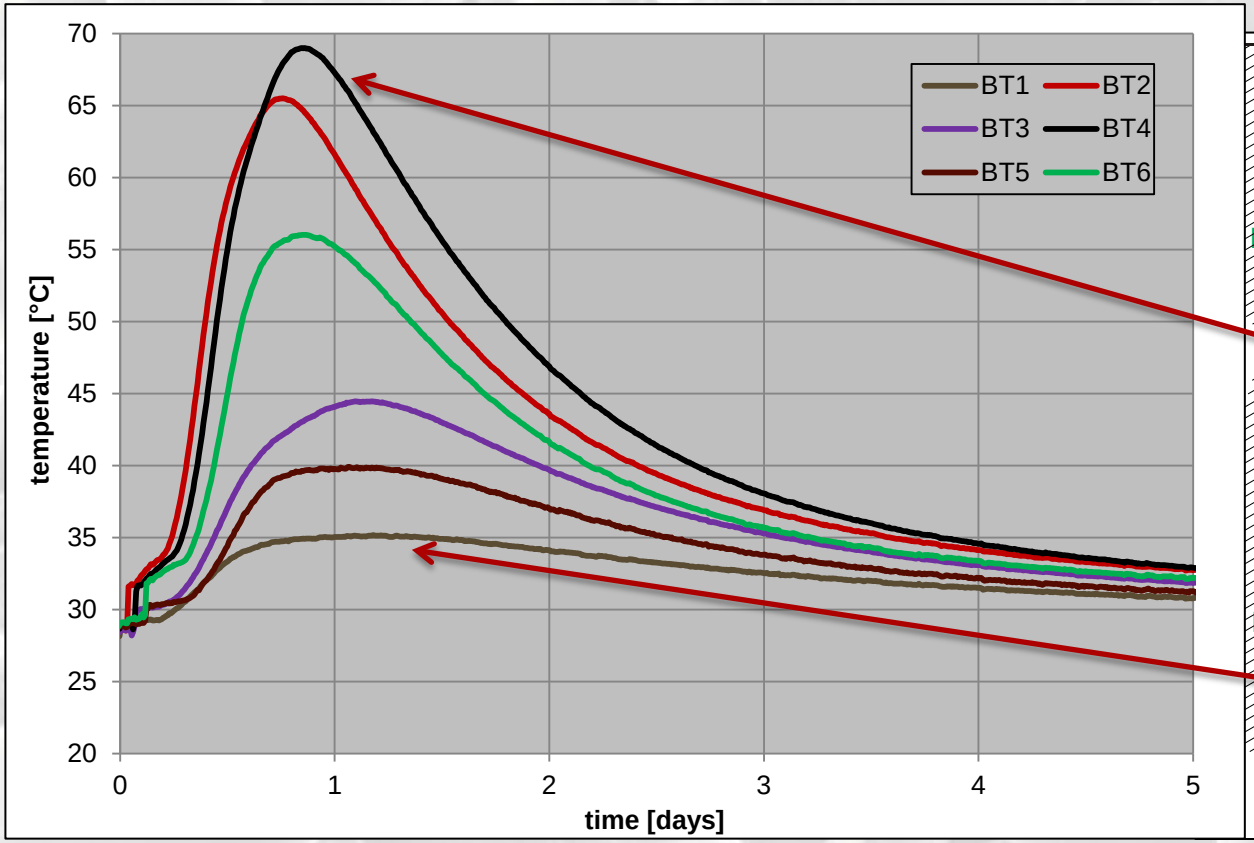
borehole Ø 1m and 2 m deep

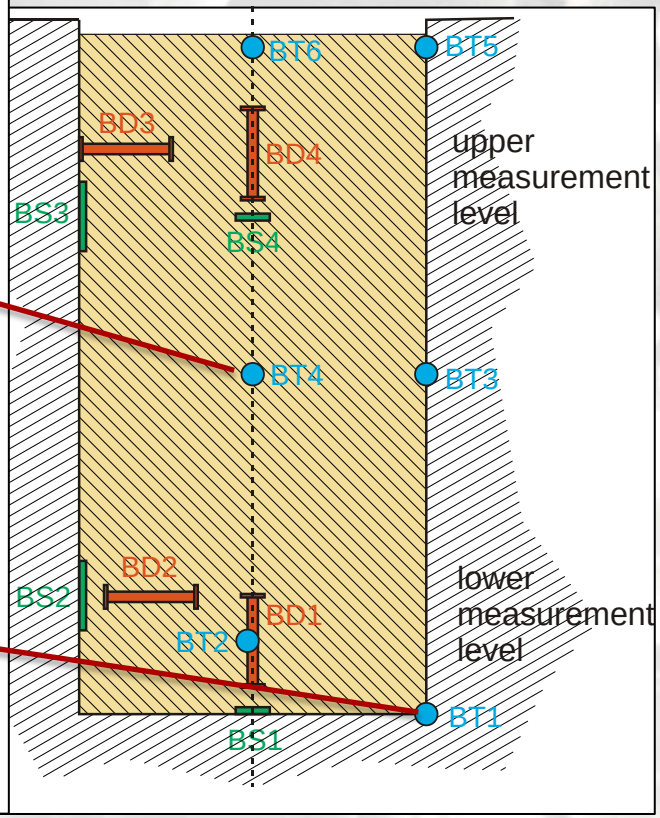




Preliminary results – work package TUBAF

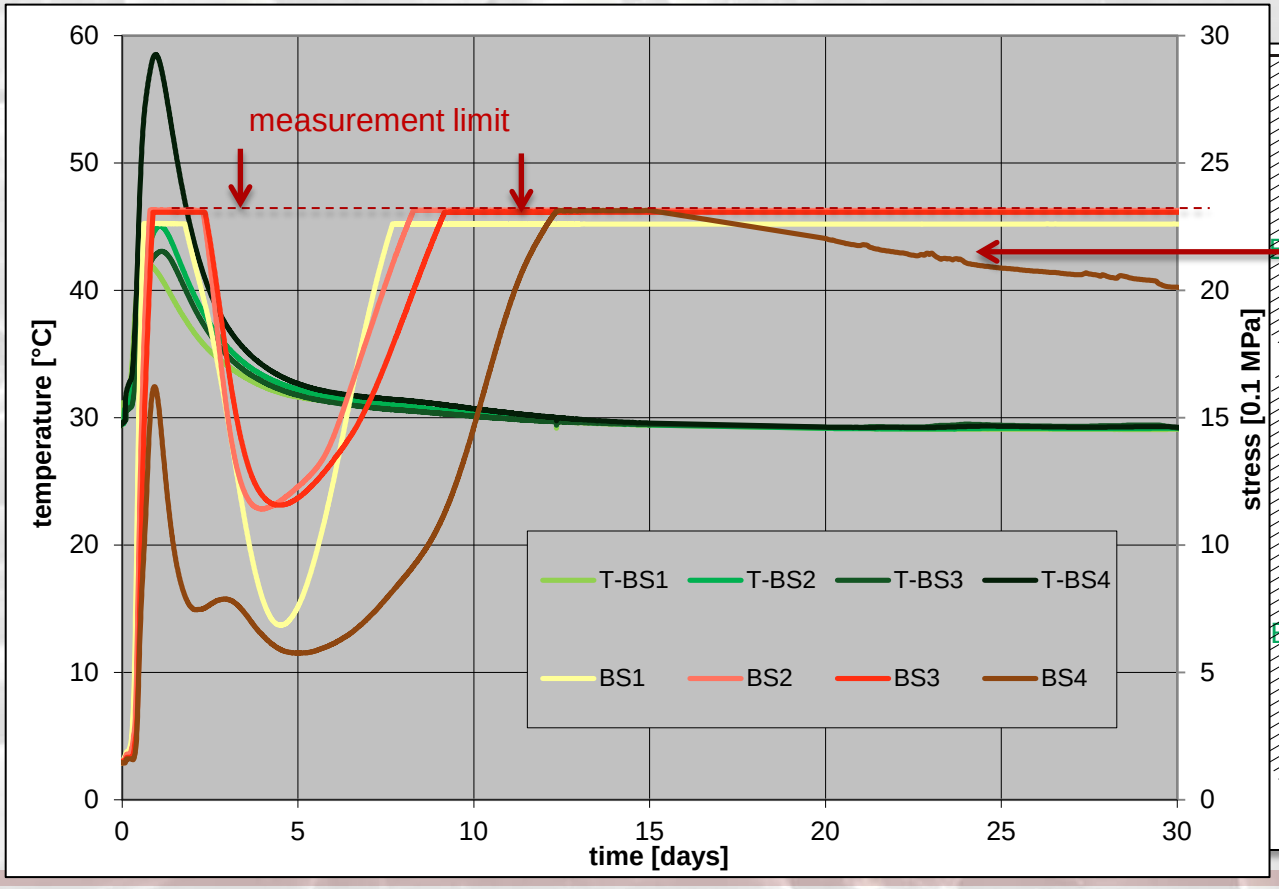
- Long-term stable (3-1-8) MgO concrete
  - max. temperature during hydration reached ~ 40 K above ambient (24 h after placing)
  - heat generation ended after ~ 2 - 3 days of hydration

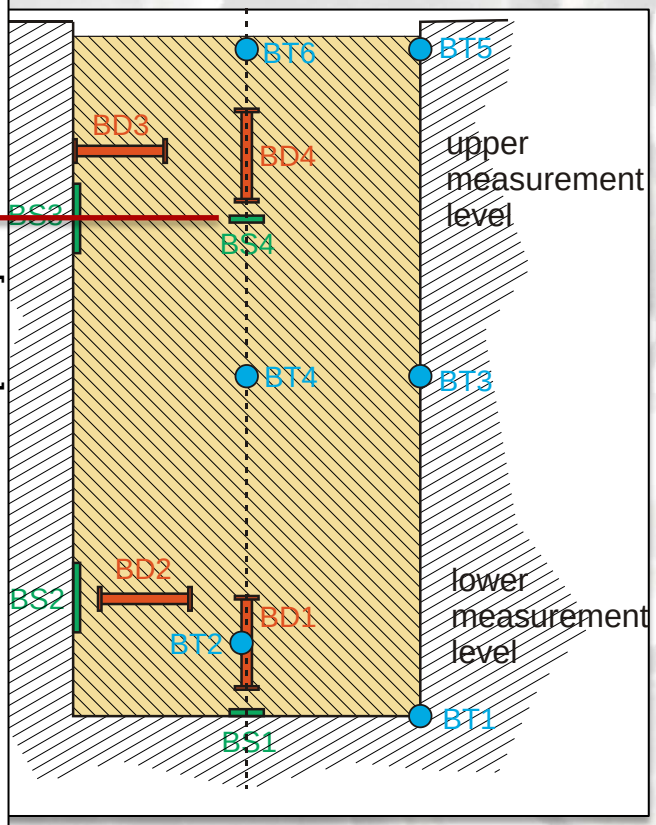




Preliminary results – work package TUBAF

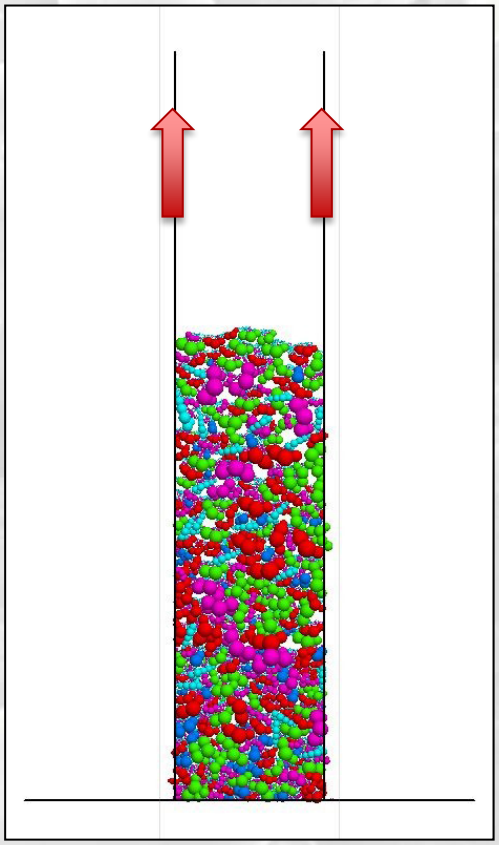
- Long-term stable (3-1-8) MgO concrete
  - thermal induced stress temporally over 2.3 MPa during hydration
  - 5 -6 days after placing the stresses rises again due to crystallization of the 3-1-8 phase, expansion pressure more than 2.3 MPa!

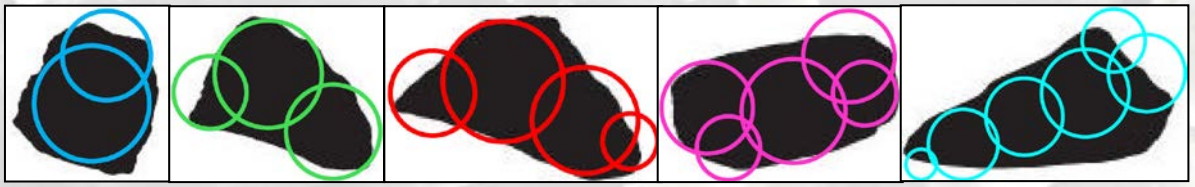




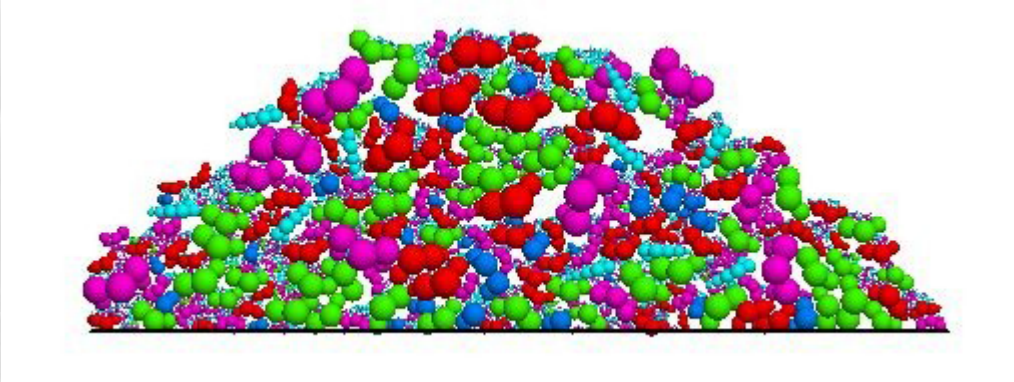
Preliminary results – work package DBE-TEC

- Model-theoretical analysis of a gravel column
  - generating a gravel model with Particle Flow Code (PFC – ITASCA) using particle clumps based of statistical data from CPA
  - calibration on dump tests





classification in grain size with 5 different grain shapes with different aspect ratios (1.4 – 2.8)



all pictures by P. Herold – DBE-TEC

Summary and outlook

- The Phase 1 of the ELSA project states the state of the art and requirements and demands for shaft seals in salt and clay formations. As a result, promising construction materials were optimized, modeled and tested in Phase 2.
- Crushed salt with an optimized grain size distribution gets a better compaction behavior than straight mine-run salt. The addition of a filler-like material (e.g. Friedland Clay Powder) reduces the total porosity and permeability.

  In cooperation with the Institute for Rock Mechanics GmbH (IfG Leipzig) the mechanic and hydraulic properties of the optimized salt/clay mixture will be investigated during further consolidation under insitu stress conditions.

  Backfill columns made from crushed salt and clay probably include an instant sealing function.

Summary and outlook

- MgO-concrete with 3-1-8 phase is long-term stable in thermodynamic perception, has a lower heat generation than common concrete and therefore a lower thermal shrinkage. The MgO-concrete (3-1-8) is an additional material option for abutments and seals in shaft-sealing systems for HLW-repositories.
- The generation of a CPA based particle model to analyze the behavior of a gravel column is nearly finished. After calibration of the particle model, the behavior of gravel columns during emplacement and operation can be assessed by simulations.
- As before, bitumen / asphalt are a good option as a diverse redundant sealing material. The wetting of the bituminous binder with the host rock (salt and clay) can be improved with a patented primer (German mining approval). A “cast in place” bitumen / gravel element is an additional option for a combined abutment / sealing element.

Thank you for your attention!