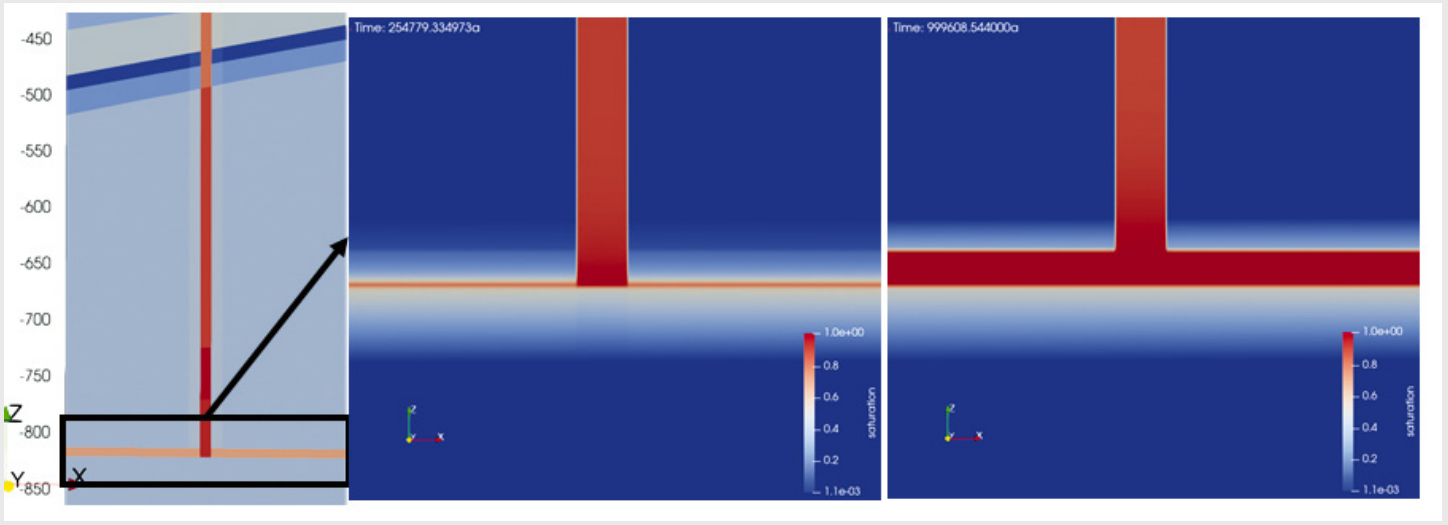
BGE TECHNOLOGY NEWS

3
2024

Investigation site at the Bedretto underground laboratory (Switzerland)

BGE TECHNOLOGY GmbH



Cross section of a shaft sunk in a salt formation (left) and water saturation evolution in the infrastructure area over a modelling time of up to 1,000,000 years (right)

"He who does not doubt will not be convinced" – this saying by the German philosopher Friedrich Hölderlin has been with me for many years and it does not seem to be losing its relevance – even after 200 years. Be it in everyday life when dealing with information and news that require critical examination – think of "alternative facts" or a (deliberately) one-sided presentation of facts. But our sense of reality is also being put to the test by rapidly increasing technical possibilities such as AI-based deep fakes and amazingly real simulations.

Colourful presentations, images, and animations are good ways for us scientists and engineers to present our results and communicate complex physical issues to colleagues or the general public. In such presentations, however, I often find that non-specialists and non-modellers have a different perception of these modelling results. While the modeller himself is aware of the input data and underlying assumptions, and while their influence on the modelling result should (or rather: must) be known, others perceive the result as "reality" or – at the other extreme – doubt it completely.

To counter this, I see two main possibilities: on the one hand, modellers should explain and classify the models, their application limits and the results in the best possible and understandable way. Secondly, practical experiments are a good way of verifying models, improving their forecasting quality, and ultimately of building up confidence.

A good example is a full-scale test of a drift seal in rock salt, which is addressed in this issue. This seal, made of MgO concrete, is to overcome remaining lack of knowledge about the contact zone between the seal and surrounding rock salt. While concepts for rock salt are ready for application and are already being implemented in construction, BGE TECHNOLOGY GmbH is currently evaluating the readiness for implementation of concepts for other host rocks as part of a study. But I don't want to spoil the following articles and wish you

Happy Reading!

Mirko Polster

Hydraulic Integrity Assessment of a Shaft Sealing System in a Generic Salt Repository

In the joint project RANGERS ("Methodology for design and performance assessment of geotechnical barriers in a HLW repository in salt formations"), BGE TECHNOLOGY GmbH (BGE TEC) funded by the Project Management Agency Karlsruhe on behalf of the Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) and Sandia National Laboratories (Sandia) have combined their efforts to illustrate a common methodology for the design and performance assessment of the Engineered Barrier System (EBS). This methodology was applied to verify the hydraulic integrity of the shaft sealing system of a generic repository system in salt-bedded formations. In this regard, the hydraulic resistance of the EBS against inflowing fluids has to be verified.

The numerical model considered for the analysis of the hydraulic evolution through the shaft sealing system consists of a column around the shaft with a diameter of 250 m. This column comprises all the geologic layers around the shaft as well as all the sealing and backfill materials in the shaft. Because the infrastructure area had not yet been designed, the area at the disposal level around the shaft was homogenised in the model column to mimic the volume of the infrastructure area. The materials in the shaft are partially saturated. Because of the very nature of salt of being an almost impermeable material where no Darcy flow can occur, no hydraulic transport was assumed in the salt layers. A hydrostatic pressure is assumed in the water-bearing layers of the overburden.

Over time, solutions existing above the shaft seal penetrate into the shaft

Injection tests at Bedretto underground laboratory site (Switzerland)

seal components according to their flow resistances. The inflowing liquids will eventually reach the infrastructure area. Over a modelling period of 1,000,000 years, the infrastructure area will be saturated progressively. A full saturation is to be expected near the end of the simulation for the hypothetical case, where the seals retain their sealing function, i.e. their permeability over 1,000,000 years remains constant. This modelling result highlights that no fluids will flow into the repository mine under the assumptions considered.

Injection Tests in the BEDRETTO Underground Laboratory (Switzerland)

In the course of the BGE-funded PRECODE project, BGE TECHNOLOGY GmbH carried out injection tests in the Swiss Bedretto underground laboratory between April 3 and 23, 2024. The experiment targeted two 10-m-long near-horizontal boreholes at an overburden of about 1.5 km. The aim of the activity was on the one hand, to demonstrate the feasibility of injecting near-natural (silicatic) fissure fillings into jointed granitic host rock. On the other hand, the goal was to transfer the well-established method for decreasing the rock's hydraulic conductivity from rock salt to a crystalline formation.

The analysis of optical televiewer logs in conjunction with a detailed investigation of the cores allowed the identification of areas with sufficient discontinuity content and ensured the presence of open fissures in each injection segment. The experiments were conducted section-wise, alternating between the boreholes, while the injection segment and monitoring borehole were sealed with packers. Injections were accomplished in two boreholes with three different compounds. Additionally, pre-injections were performed in one of the boreholes. These pre-injections aimed at removing the formation water from the injection section so that the performance of the injection agents without direct water contact could be assessed. The preliminary injection tests were successful, demonstrated by considerable volumes of injected materials that were pressed into the existing fracture network. Analysis of the results is continuing.

Sealing and Backfilling Measures for HLW Repositories

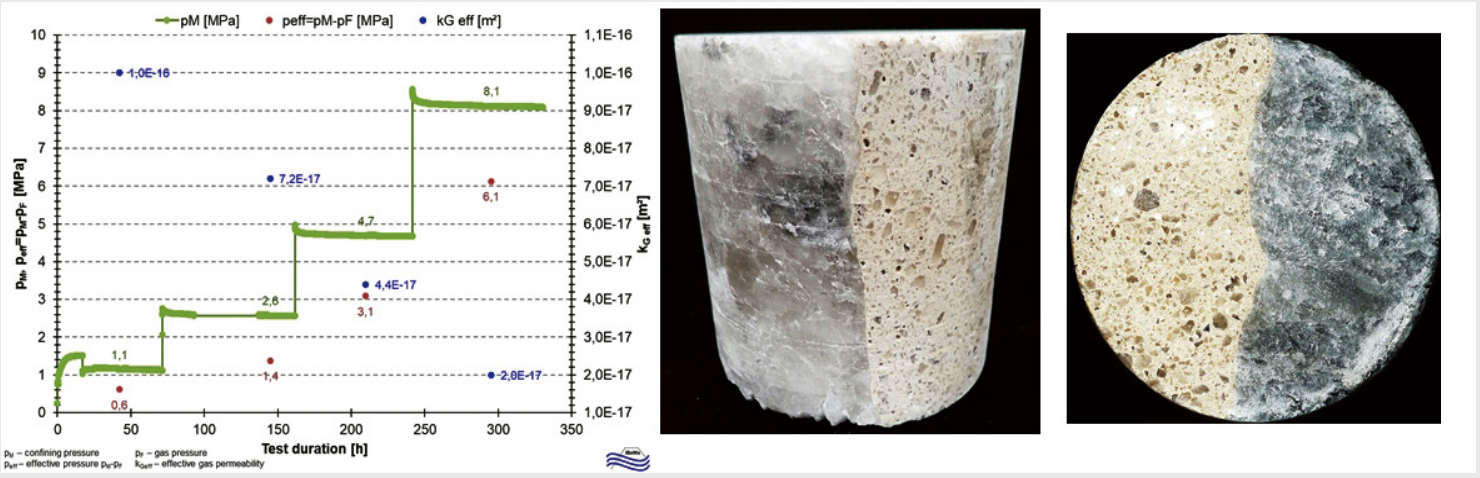
Since the beginning of 2023, BGE TECHNOLOGY GmbH has been working on behalf of BGE on the backfilling and sealing of an underground repository for high-level radioactive waste in the context of the site selection process. In 2023, sealing and backfilling measures of mining and repository mining as well as results of repository research were reviewed and evaluated with regard to their state of development and their applicability for radioactive waste disposal in Germany. The principal result of the evaluation was the proposal of a roadmap for the development of backfilling and sealing measures in line with the phases of the site selection procedure. A classification according to "Technology Readiness Level" (TRL) was used as a benchmark for the development status of the measures.

The TRL of the evaluated closure measures varied considerably. While measures in rock salt are well advanced, particularly due to the work on the closure of the Morsleben Repository and the Asse II mine, a similar degree of maturity for closure of a repository in claystone is not available, and in crystalline rock only for repository concepts, where safe containment is based on engineered barriers. The aim of the current work is to develop backfilling and sealing concepts that can cover the range of possible sites in the site selection procedure with a TRL of at least 3 and that are thus developed to a degree suitable for the current phase of the site selection procedure and corresponding decision making.

R&D Project ELBRock: First Milestones Reached

Two years ago, BGE TECHNOLOGY GmbH and Gesellschaft für Nuklear-Service mbH (GNS) started the joint project ELBRock on behalf of BGE. Within the scope of this project, which is led by GNS, up to three different waste container concepts for high-level and heat-generating radioactive waste or spent fuel will be developed for BGE´s site selection department. These waste container concepts will be especially designed for disposal in crystalline rock. Now, first milestones of the project have been reached.

In the last two years, BGE TEC and GNS first compiled all the information necessary to start the design of the waste containers. This included the geological conditions for crystalline rock in Germany, the high-level waste (HLW) inventory of Germany and a description of the state of the art regarding HLW disposal in crystalline rock. Then, all the requirements for waste containers



Effective gas permeability of a concrete/ rock salt composite sample for several confining pressures depending on the test duration (left), core sample of contact zone (right) *(source: IBeWa)*

according to the German laws and regulations were put together in a list of specifications. As a next step, BGE TEC and GNS started with the development of a generic approach for a complete and unbiased development and evaluation of waste container concepts. For this purpose, three basic functions of the waste containers were derived: Containers must be mechanically stable, leak-tight and protected against corrosion. This resulted in a container model with a body that consists of three layers, where each layer has to provide one of the three functions. For each function, promising materials were identified. In a next step, all possible material combinations were put together with the help of an algorithm. This led to a matrix of roughly 100,000 possible material combinations. These combinations were further reduced following a set of criteria until only 33 material combinations remained. These 33 material combinations were further examined using a value analysis. The results of the value analysis were discussed in a workshop together with BGE. As a result, three combinations were chosen for further design in the ELBRock project:

- Copper containers with an insert made of cast iron
- Stainless steel containers with an insert made of carbon steel
- Nickel alloy containers with an insert made of carbon steel

The selection of these combinations marks the last milestone before the final phase of the project, which will be completed next year with the presentation of the corresponding concepts.

Assessment of Geomechanical and Hydraulic Properties of an MgO Drift Seal (R&D Project FUNGUS)

In October 2023, the R&D project FUNGUS was started as a follow-up of the STROE-FUN III project. The objective of the project is to analyse in situ the time-dependent decrease in the permeability at the contact zone between the rock salt contour and an MgO concrete structure of a pilot seal situated in the Teutschenthal mine. During the test sequences, the decreasing influence of this hydraulic weak point is registered by a new measuring system. Following two measuring campaigns of the preceding project, the first measuring campaign of the FUNGUS project is now completed. Up to now, measuring campaigns were performed every 8 months, demonstrating that the permeability of the contact zone decreased by about half a magnitude (from $5.8 \cdot 10^{-15}$ m² to $2.4 \cdot 10^{-15}$ m²). For evaluating this evolution, it has to be considered that the drift contour was not re-cut before barrier construction. Salt creep induced by lithostatic pressure was continuously monitored during the test and was considered to be the reason for this process. Presently, the permeability level is dominated by the permeability of the contact zone at the bottom. In addition to the in-situ measurements with the new measuring system, the results were confirmed by permeability measurements in boreholes.

Complementary laboratory investigations on test samples gained from drill cores from the contact zone (top figure, right) underpin the pressure dependence of the permeability evolution. During these laboratory tests, the confining pressure was increased in steps (top figure, left). As a result, gas permeability decreased to the level of sorel concrete ($9 \cdot 10^{-18}$ m² to $6.6 \cdot 10^{-17}$ m²). This evolution was proven for brine at contact zones of salt concrete/rock salt already earlier, and now was also verified for gas in sorel concrete/rock salt contact zones. Thus, the first project goal was met.

IBeWa, K-UTEC, Technical University Clausthal, Helmholtz Zentrum Dresden Rossendorf, TS Bau, and GTS contribute to the FUNGUS project, which is funded by BGE.

For further information, visit www.bge-technology.de or scan the QR code below.

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