BGE TECHNOLOGY NEWS

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BGE TECHNOLOGY GmbH

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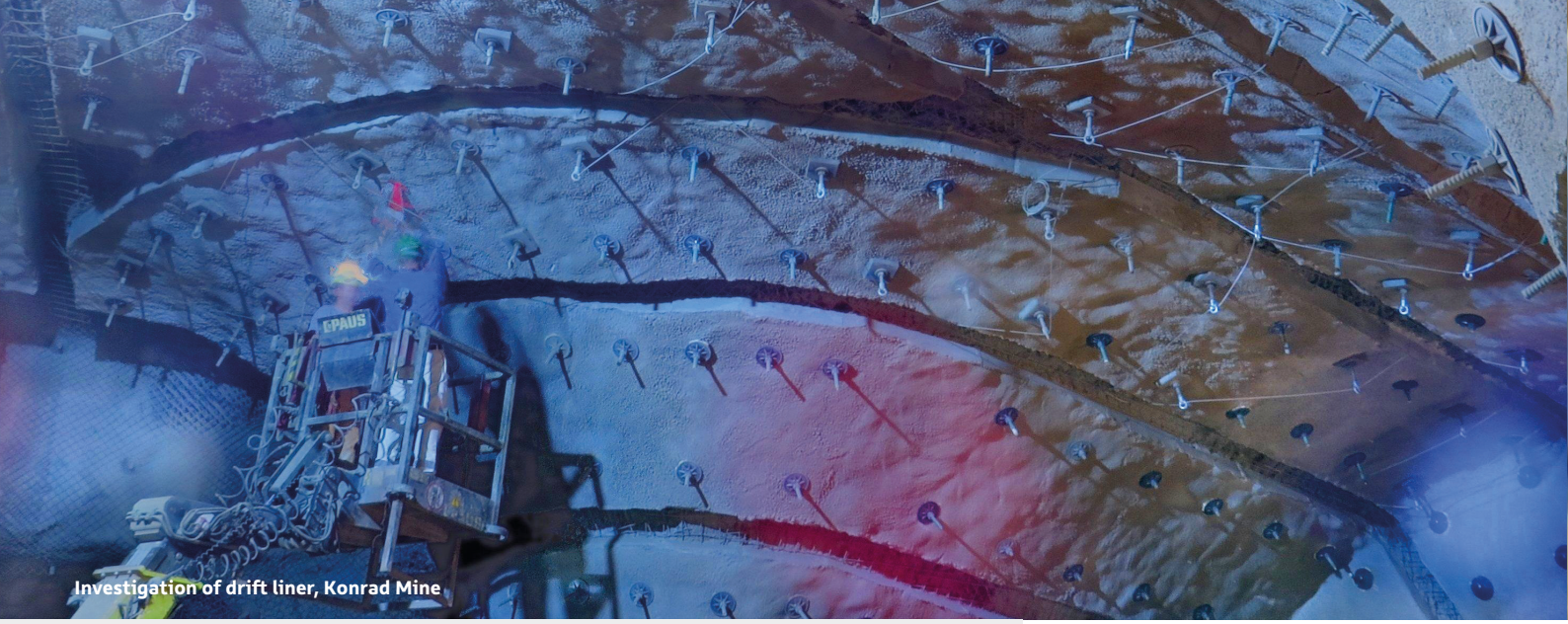


Investigation of drift liner, Konrad Mine

Dear Readers,

In Germany, a new site selection process was started in order to identify the site for the disposal of heat-generating HLW/SF that guarantees the best possible safety for 1 million years. Potential host rocks are salt, clay, and crystalline rock. The new site selection process carried out by our parent company, BGE, attracts much attention both in the German public and on an international level. What is often overlooked is that in Germany, deep geological repositories are the only options to dispose of long-lived low- and intermediate-level radioactive waste.

Currently, the LILW Morsleben Repository (ERAM), situated in a former salt mine, is under licensing for closure, and the Konrad Repository, situated in a former iron ore mine in sedimentary rock with clay cover, is under construction. Furthermore, the retrieval of the waste from the Asse Mine is in the planning phase while stabilisation and sealing measures are carried out to enable future waste retrieval. BGE TECHNOLOGY GmbH is strongly involved in these BGE projects. In addition to research work regarding safety cases for HLW/SF in different host rocks, our competence thus covers practical dimensioning tasks, including design and selection of suitable construction materials – e.g. dimensioning of lining systems required to guarantee operational safety as well as backfilling and sealing measures to ensure long-term safety, taking into account constructability, thermomechanical, hydraulic, and geochemical issues. Several examples of our activities are described in more detail on the following pages. This practical experience refers to salt and claystone.

For crystalline rock, only little experience is available in Germany. Although, BGE and BGE TECHNOLOGY GmbH benefit from highly valuable international experience concerning this host rock, the German concept of safe containment of the radioactive waste requires additional research.

Happy Reading!

Dr. Nina Müller-Hoeppe

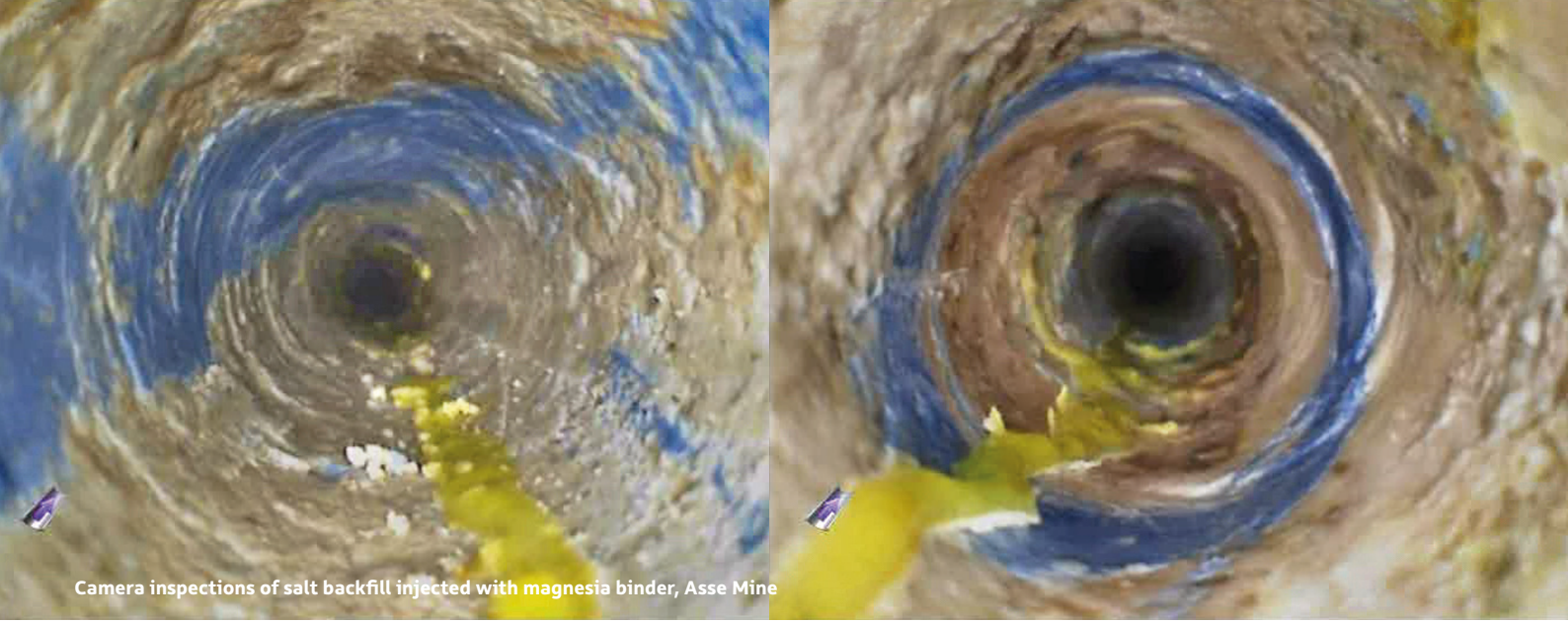
Drift Lining Systems for HLW Repositories in Claystone

The R&D study "Support structures for underground openings in a HLW/SF repository in claystone – AGEnT" prepared by BGE TECHNOLOGY GmbH and DMT GmbH & Co. KG, funded by the German Ministry for Economic Affairs and Energy, has been concluded successfully. The study is a contribution to the ongoing development of German repository concepts for HLW/SF in claystone and tried to solve potential conflicts between major requirements.

Based on potential host rock formations in Germany and the requirements for support structures regarding operational safety aspects and retrievability, the interactions of rock pressure, rock properties, geometry, and support concept were investigated by means of variation calculations. As a result, favourable properties of support structures were identified, and it turned out that the use of concrete-based support structures should be preferred. Systems with a high steel content are less favourable because the steel content in a repository should be minimised for long-term safety reasons.

Especially for large and long-living drifts, wedge block linings with a compressible outer mortar layer are recommended as lining systems. For this concept, the behaviour over the operational lifetime was determined by means of hydro-mechanical calculations. The results showed the resilience of the material model approach used as well as the optimisation potential of a rigid segment lining with compressible backfill.

Concretes that comply with the specifications of standard EN 206 are currently used for support structures. To ensure the passivation of steel reinforcement, these concretes have a high pH value. For a future HLW repository, a low-pH concrete that contains high proportions of reactive additives, e.g. silica fume or fly ash, was developed. The mixture is designed to allow the use as cast-in-place concrete and as ready-mixed concrete (wedge blocks).



Camera inspections of salt backfill injected with magnesia binder, Asse Mine

Successful Consolidation and Sealing of Backfill in the Asse II Mine

Low- and intermediate-level radioactive waste was disposed of in the Asse II salt mine between 1967 and 1978. Because of the high excavation ratio, the short distances to non-saline, water-bearing adjoining rock in some areas, and the long operating time of the mine, rock fracturing and solution inflows occurred. As forecasts of the inflow rates and hydrochemistry are uncertain, it was decided to retrieve the waste. In case of uncontrollable inflow rates, an inert salt solution is to be pumped into the openings. To protect the emplacement chambers, flow barriers are currently built, and extensive backfilling measures with magnesia binders are carried out to stabilise the mine.

Crushed salt already backfilled in the chambers compacted over time, and roof clefts were generated. To improve the load-bearing capacity and the tightness of the backfill, BGE TECHNOLOGY GmbH started a programme that included an initial survey, the planning and implementation of backfilling and grouting measures, and a final data evaluation. Part of the site survey was to gather all relevant data for a detailed planning process, i.e. to determine the crack inventory as well as the pore spaces and mineral composition of the salt backfill. Based on this, backfill and injection materials were selected, and new, long-term stable materials were developed. Subsequently, it was possible to select the equipment, to define the procedure for online data analysis, to specify the grouting strategy, and to develop a quality assurance programme. By filling and injecting progressively smaller cavities and thus increasing the degree of filling, it was possible to gradually increase the pressures required for the grouting process, injecting first suspensions of increasing fineness and then solutions. Drill cores and borehole camera inspections demonstrated the increasing stabilisation and tightness of the backfill. An analysis of the injection data showed that all project goals were met.

Compaction of Crushed Salt for Safe Containment (R&D Project KOMPASS)

KOMPASS is a joint project of GRS, BGE TECHNOLOGY GmbH, BGR, IfG, and TUC in cooperation with SANDIA (USA) running from 01.08.2018 to 31.07.2020.

Rock salt formations are a host rock option for the disposal of high-level, heat-generating radioactive waste in Germany. Mine excavations in such a host rock will be backfilled with crushed salt that will be compacted over time by the mine's convergence and ends up in restoring the intact rock salt barrier. With regard to the German safety concept, which stipulates a containment providing rock zone, the hydraulic properties of compacted crushed salt are of high relevance for the long-term safety, especially at low porosities close to those of the intact rock salt barrier.

The main objective of the KOMPASS project was to create a sound experimental basis to determine the crushed salt properties at low porosities. To this end, investigations of pre-compacted test specimens with low porosities were carried out. To ensure that the specimens experimentally pre-compacted at accelerated speed are equivalent to crushed salt slowly compacted in situ, accompanying microstructural investigations were carried out to gather data for an eventual comparison. The aim was to validate the methods used for pre-compaction. Additionally, first experimental set-ups were tested to investigate the mechanical behaviour of the material systematically linked to its hydraulic behaviour. To create a basis for the numerical modelling of crushed salt's increasing barrier capabilities, comparative calculations were carried out using data from 3 laboratory tests. This was to evaluate the constitutive models and their specific options to analyse the effects of decreasing permeability. Furthermore, the installation conditions of salt backfill in a repository were specified, and natural and technical analogues underpinning the restoration of the rock salt barrier were identified.

The work will be continued in a follow-up phase as a joint project of the above-mentioned partners together with COVRA (Netherlands). The KOMPASS project was funded by the Karlsruhe Project Management Agency on behalf of the German Federal Ministry for Economic Affairs and Energy and the US Department of Energy.

Development of a Constitutive Model for Crystalline Rock

According to the German safety requirements for the disposal of heat-generating radioactive waste, the implementer has to define a Containment Providing Rock Zone (CRZ) that, in conjunction

Semi-mobile mixing and pumping plant, Asse Mine

with the engineered barrier system, has to ensure the safe enclosure of the radioactive waste in the repository for a period of 1 million years.

A sound basis for the safety demonstrations are predictive model calculations based on validated constitutive models and the corresponding rock parameters. Within the framework of the R&D project CHRISTA-II, BGE TECHNOLOGY GmbH develops a concept that is to demonstrate the integrity of crystalline rock formations. The integrity criteria, which are qualitatively defined in the regulations, need to be quantified to be able to numerically demonstrate compliance with the requirements. A first approach for a quantified dilatancy criterion is being developed during the CHRISTA-II project. This approach is based on the constitutive model of Hook & Brown, which has proven itself in tunnel construction for more than two decades. However, this constitutive model currently still has the disadvantage that it is an isotropic material model. The main objective of the new research project BARIK is the development and testing of an extended 3D Hook-Brown constitutive model that is able to take into account anisotropic strength behaviour within the intact rock matrix and in a fractured crystalline rock with different fracture dip angles. Both projects; CHRISTA-II and BARIK, are funded by the Karlsruhe Project Management Agency on behalf of the Federal Ministry for Economic Affairs and Energy.

Ensuring Backfill Material Quality at the Konrad Mine, Germany

The former iron ore mine Konrad is currently being converted into a repository for low- and intermediate-level radioactive waste. As part of its future operation, backfilling measures will be carried out. More precisely, cement-based materials will be pumped into the emplacement chambers after shotcrete walls have been constructed. In addition, voids will be backfilled with crushed rock. The cement of the backfill mixture will be pneumatically conveyed from the surface to the underground mixing plant where the crushed rock will already have been stored. Special-purpose vehicles will transport all materials necessary for the backfilling measures. To ensure a smooth work progress and compliance with the objectives of backfilling, the requirements for the raw materials and the ready-to-use materials have to be specified. Furthermore, the material properties have to be determined using suitable testing methods, and the quality of the materials has to be checked.

BGE TECHNOLOGY GmbH is certified according to DIN EN ISO 9001:2015. We cooperate with many certified testing institutes and have extensive experience in the development, use, and quality control of backfill materials and the implementation of construction measures. For the Konrad mine, we have consequently been commissioned with the demanding task of developing the quality assurance programme to ensure and demonstrate the implementation of the backfilling measures in compliance with the respective requirements. Production control of the technical equipment and installations as well as conformity control of the raw and backfilling materials is intended. In addition to this, in-plant and independent third-party inspections will be provided. All measures take into account the special aspects of mining, of the equipment used, and the specific boundary conditions for the disposal of radioactive waste. This way, BGE TECHNOLOGY GmbH contributes to the commissioning and successful operation of the first German repository that has been licensed in accordance with the German Atomic Energy Act.

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

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