BGE TECHNOLOGY NEWS

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Construction work at the Konrad mine (Germany)

BGE TECHNOLOGY GmbH

Participants of the IAEA Consultancy Meeting on Site Selection Criteria in May 2023

Dear Readers,

While summertime often brings a lull in the news cycle, with newspapers filling their pages with stories of the world's largest pumpkin or new pictures about Nessie, we at BGE TECHNOLOGY GmbH have exciting and captivating updates to share with you. Rest assured, we won't bore you with tales of peculiar vegetables or sonar studies at Loch Ness. Instead, we bring you our latest developments in the world of nuclear waste disposal.

Let's start with the URF network project initiated by the International Atomic Energy Agency (IAEA). This project aims at compiling the best practices in site selection criteria for deep geological repositories. By summarising national programmes and developing a draft document, we provide guidance to Member States for effective site selection.

Next, we have been assisting ONDRAF/NIRAS in designing the operation and closure of a future Belgian repository for high-level waste and spent fuel. Our focus is on enhancing operational safety through methods like HAZID and SWIFT analysis. By updating the transport system and considering additional shafts and safe zones, we improve safety and identify areas for further concept development.

Now, let's dive into the crucial sealing system of a repository. The SalVE joint project explores the use of molten salts as sealing materials for high-level waste repositories in rock salt. Our team, in collaboration with TU Bergakademie Freiberg and the Institute of Geomechanics GmbH Leipzig, has conducted extensive research and experiments. We have identified promising salt mixtures, such as the preferred 49.5% $AlCl_3$ and 50.5% NaCl mixture, and discussed processing, transportation, application, and potential areas for their use.

Last, our BARIK project focuses on developing an extended three-dimensional material model for anisotropic strength behaviour in rock masses. We aim at implementing and testing this model in different computer codes, ensuring accuracy and relevance in safety investigations. By considering the Biot coefficient as a hydromechanical coupling parameter, we improve our understanding of the strength behaviour of crystalline host rocks.

So, forget about the oversized vegetables and monster mysteries and get ready for a dose of intellectual stimulation and scientific excitement. After all, who needs the trivial when you can delve into the extraordinary and interesting world of nuclear waste disposal?

Stay tuned and enjoy the reading!

Christian Müller

BGE TECHNOLOGY GmbH Supports IAEA in Preparing a Document on Site Selection Criteria

Effective site selection criteria contribute significantly to a deep geological repository (DGR) programme, as they support an effective discrimination of regions at the successive stages of site screening and selection. Therefore, the URF network of IAEA initiated a project to start identifying the best practices in the use of site selection criteria and the planning of corresponding siting procedures in IAEA member states. The results will be compiled in a Technical Report.

The project schedule provides preparatory work by a core group, which consists of representatives from 10 countries with advanced DGR programmes (Canada, Czech Republic, France, Germany (represented by BGE TECHNOLOGY GmbH), Japan, Korea, Sweden, Switzerland, UK, and USA). These consultants will report on the experience from their national site selection programmes and will support IAEA in preparing the content of the report. The resulting draft document will be discussed in plenary technical meetings with all interested countries of the URF network.

Preparatory work incl. the preparation of a draft document have been carried out in 2019 and – after interruption by the corona-pandemic – work continued with a virtual meeting of the core group in March 2023 and an in-person consultancy meeting in Vienna from May 23 – 26. At these meetings, upgrades of national site selection programmes were given, and preparatory work for the document

Drill cores of Freiberg gneiss used as samples for laboratory tests to determine the rock properties (R&D project BARIK)

continued (incl. definitions of vocabulary, development of the document structure, categorisation of site selection criteria, common issues vs. different issues in the national programmes). In the coming weeks, the core group members will provide IAEA with additional information for the preparation of a draft document. This document will be discussed at a virtual meeting of the core group in October and at a plenary meeting in Vienna from November 27 – December 1, 2023. Thus, by ensuring the integration of a broad range of practical experience in establishing and using site selection criteria, a guidance document will be prepared that can effectively support starting member states in developing their national programmes on that topic.

An Extended Hoek–Brown–Based Anisotropic Constitutive Model for Fractured Crystalline Rock (BARIK)

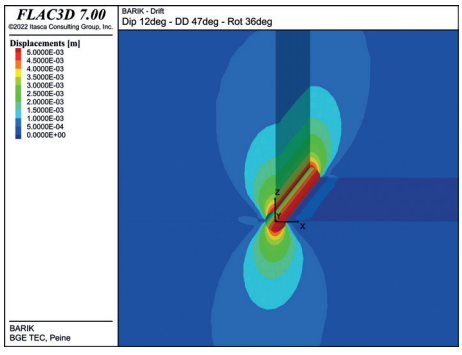
Through the Project Management Agency Karlsruhe (PTKA), the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Con sumer Protection has commissioned BGE TECHNOLOGY GmbH and TU Bergakademie Freiberg, Institut für Geotechnik with the R&D project BARIK.

The disposal of heat-generating radioactive waste in deep geologic formations presents significant challenges due to the complex material behaviour of fractured crystalline rock. To address these challenges, the BARIK constitutive model, an extension of the Hoek-Brown model, has been developed.

The disposal of radioactive waste in crystalline rock repositories requires a thorough understanding of the behaviour of the fractured host rock. Fractured rock is characterised by its anisotropic, nonlinear, and loading path-dependent behaviour. The BARIK model addresses this need and plays a crucial role in assessing the integrity of the containment-providing rock zone.

The BARIK model extends the Hoek-Brown model to account for up to three fracture systems. It allows separate consideration of the matrix and joint behaviour, each with its own strength properties and failure criteria. By accurately representing the strength-reducing properties of fracture systems, the model facilitates barrier integrity verification. Implementation of the BARIK model in FLAC3D and MFront for OpenGeoSys allows for precise evaluation and identification of potential discrepancies arising from different codes.

The BARIK model enables various calculations, including isotropic-elastic, orthotropic-elastic, isotropic-elasto-plastic, and orthotropic-elasto-plastic calculations of the matrix. This versatility makes it a valuable tool for site selection, construction, and long-term safety assessments of underground repositories. The model's compatibility with the dilatancy criterion has been evaluated, confirming its suitability for conducting integrity assessments.



Results of geomechanical modelling using the BARIK constitutive model in FLAC3D, illustrating displacements in a drift in crystalline rock

The development of the BARIK constitutive model represents a significant advancement in understanding and modelling the complex material behaviour of fractured crystalline hard rock. Its implementation in numerical codes allows for comprehensive evaluations, ensuring the safe disposal of radioactive waste. The BARIK model contributes to the field of deep geological disposal by providing insights into the behaviour of fractured rock and thus helps in the design of safe repositories.

Operational Safety Analysis for ONDRAF/NIRAS

Within the scope of a framework agreement, BGE TECHNOLOGY GmbH supports the Belgian Waste Management Organisation ONDRAF/NIRAS in the design of the operation and closure of a future Belgian repository for HLW and spent fuel. The current focus lies on the assessment and further development of operational safety based on the current reference layout of the facility and the planned operational processes for transport, emplacement, and backfilling. For this analysis, different well-established methods such as HAZID and SWIFT analysis were used.

During the analysis, the major processes for surface and underground transport, emplacement, and backfilling were analysed. The evaluation of the different individual recommendations has led to the definition of a set of core themes that should be addressed. Some of these themes recommend changes to or modifications of the current design and equipment that are supposed to have a posi-

Borehole filled with NaAlCl4; to the right: cooling funnel (R&D project SALVE)

tive impact on operational safety. The update of the transport system can be highlighted as a good example for such a positive impact. In the new operational safety analysis that takes into account the updated transport system, significantly fewer hazardous events connected to transport and emplacement were identified. The new transport system has a positive impact on operational safety.

Concerning the repository layout, potential escape routes in case of external or internal events were analysed. A major question was if and how additional galleries or surface connections could improve operational safety. The current layout allows for escape in sufficient time. The implementation of additional shafts does not automatically improve the escape route situation. Additional shafts provide more flexibility as they represent paths to alternative safety zones. Other helpful measures are the installation of additional safety zones at selected places inside the underground layout.

The SalVE Project – Intermediate Results

On behalf of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection, the Project Management Agency Karlsruhe (PTKA) has commissioned BGE TECHNOLOGY GmbH and the Institute of Geomechanics GmbH Leipzig with the R&D project SaLVE.

The joint project SalVE, which investigates the suitability of molten salts as sealing materials for HLW repositories in rock salt, is approaching its final stage. Based on an intensive literature review and a variety of experiments, the project group achieved a better understanding of the possibilities and the challenges of this type of building material. The final results of the investigation will not be published before early 2024. Here are a few insides in advance.

At the beginning, the project team, consisting of experts of TU Bergakademie Freiberg, BGE TECHNOLOGY GmbH, and the Institute of Geomechanics GmbH Leipzig, focused on the constraints given by the underground conditions and the repository concept. Out of the large variety of pure and mixed salts, the project team systematically condensed a number of candidate molten salts. Only inorganic salts with a melting temperature below 200°C were chosen at the first stage, which led to eight remaining main groups of salt mixtures. For various reasons, such as a high reactivity with the host rock, availability, and processing complexity, only three groups remained. These are salt mixtures with a) aluminium chloride (or bromide), b) (poly-) sulphides and sulphur, and c) copper chloride (or bromide). The selection process led to less than 30 candidate salt mixtures of which two were selected for further investigation. The preferred mixture consists of 49.5% $AlCl_3$ and 50.5% NaCl. The oversupply of NaCl reduces the hygroscopic behaviour of the $AlCl_3$ while the ratio of both salts limits the melting temperature to around 160 °C. The fluid has a low viscosity and therefore fills up even small cavities. It furthermore forms a firm bond with the adjacent rock salt. A major challenge origins from the cooling and crystallisation process. During the cool down phase of the melt, the just solidified salt will decrease in volume until it reaches ambient temperature in the underground location. Depending on the conditions, the material forms different sizes of crystals, creates a cooling funnel on top, encapsulates gas bubbles, and develops a microscopic structure of cracks. All these effects are challenging when it comes to its potential application as sealing material.

In its final report, the group will not only describe the experiments but also how to process, transport, and apply the hot liquid materials. Furthermore, potential areas for application will be discussed.

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

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