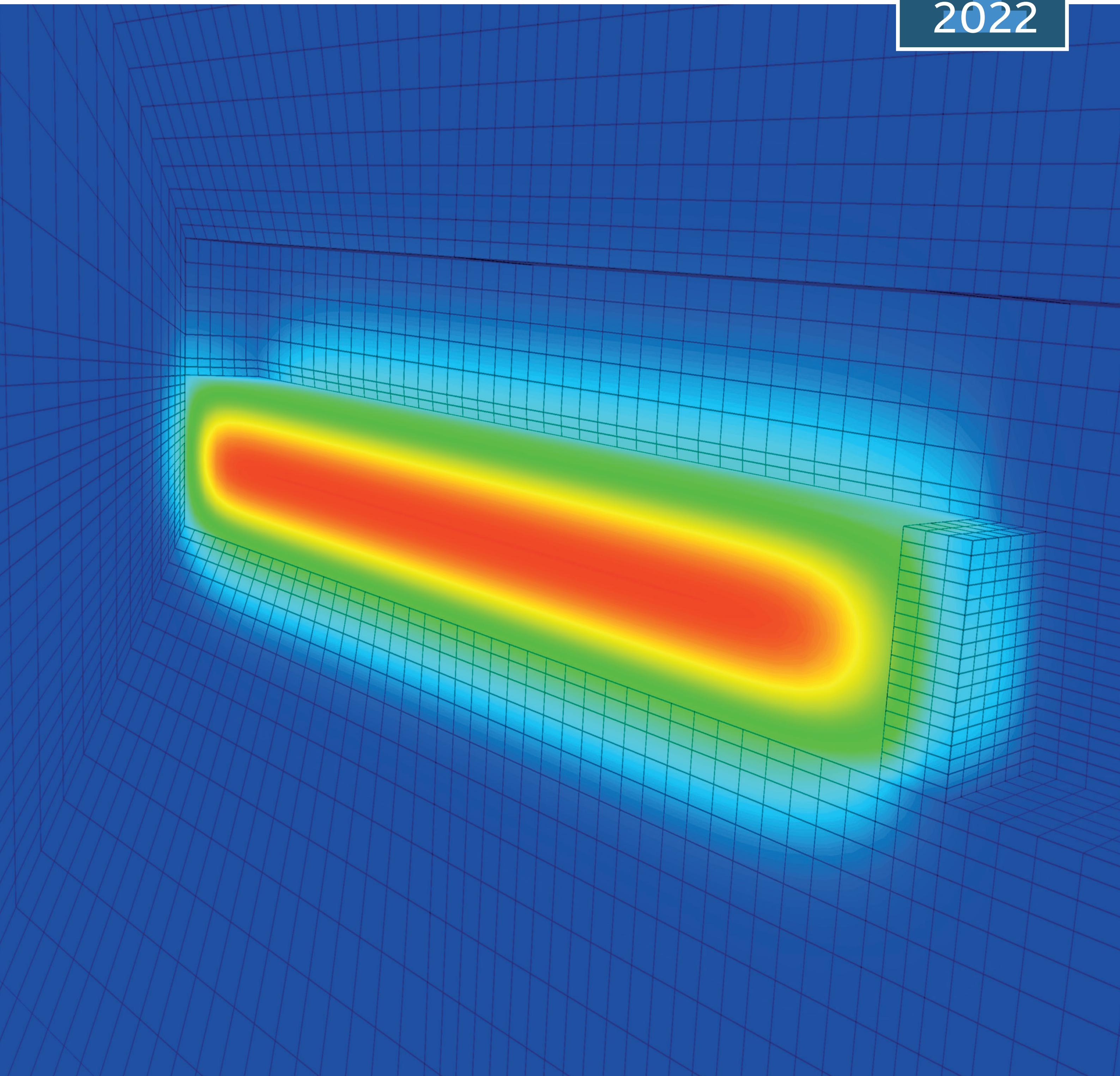
BGE TECHNOLOGY NEWS

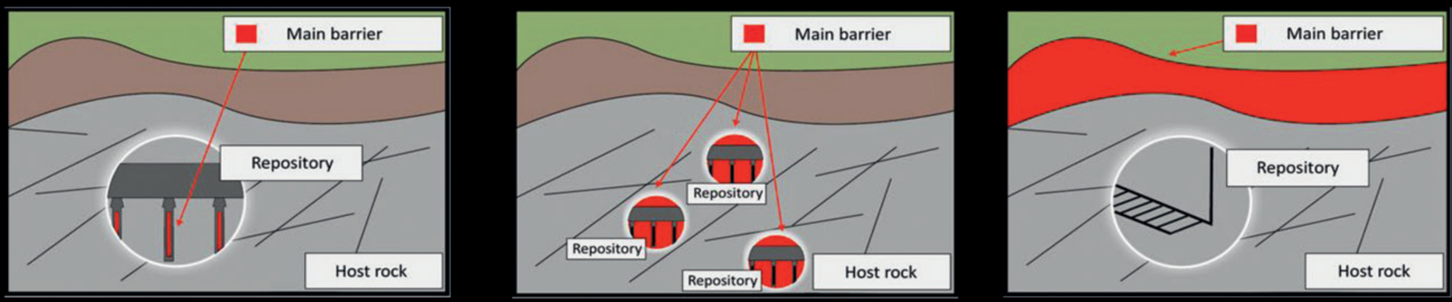
1
2022



Thermal modelling of hydration heat during construction of a concrete barrier in the Teutschenthal Mine (Germany)

BGE TEC
BGE TECHNOLOGY GmbH

- REPOSITORY RESEARCH IN CRYSTALLINE ROCK – THE CHRISTA-II PROJECT
- ROCK-MECHANICAL ANALYSES FOR THE KONRAD REPOSITORY – STABLE DRIFT SUPPORT FOR DECADES
- A NEW APPROACH TO USING EXISTING MATERIAL MODELS IN ANY NUMERICAL CODE WITHOUT IMPLEMENTATION
- BGE TECHNOLOGY GMBH ADVANCES NORWAY'S PLANS FOR HIGH-LEVEL RADIOACTIVE WASTE DISPOSAL IN DEEP BOREHOLES



Principle options for disposal in crystalline rock formations

Dear Readers,

Another year has passed and a new one is about to start. Unfortunately, the pandemic still has us in its grips, and caution is advised. However, a new year always is a good occasion for good resolutions, plans for the coming time, and the start of new projects. Personally, I see a lot of very exciting new tasks and changes in 2022, which are mainly connected to my new position as head of the research and development department of BGE TECHNOLOGY GmbH. I am happy to hold this position and develop the science and technology of nuclear waste disposal further. I am also proud to do this together with our highly motivated team of well-experienced engineers and scientists.

In the past few years, we recognised a certain kind of transformation in different fields of our daily business. Naturally, the employment of new colleagues and change in responsibilities belong to these transformations. Additionally, national and international programmes develop and the demands of our partners and clients change. R&D in the field of nuclear waste disposal is of course still essential but the focus and tasks are changing. The various radioactive waste management programmes are at different stages of development but in general, a change from basic research activities to more specific research can be detected. A lot of important work that creates the basis of today`s activities has been carried out. Now it is time to go a step further. The contributions in this newsletter are to a certain extent examples for this development. Safety cases in crystalline host rock allow both, the concept of containment providing rock zone and the concept of safety guaranteed by engineered barriers. However, the specific conditions in crystalline rock and the use of various safety concepts requires the development of new safety assessment strategies. Our project CHRISTA II contributes to this development. The application of MFront in the field of radioactive waste disposal ties in with the experience in the nuclear industry. At the same time, it offers the opportunity for a standardised platform of material models. Additionally, the collaboration with NND represents a good example for how lessons learned and new ideas such as the deep borehole disposal concept can be transferred to other or early-stage national programmes. Finally yet importantly, the work carried out for BGE shows the application of knowledge within a complex geotechnical situation.

I invite you to discover our newsletter. I hope you enjoy reading it.

Take care and stay healthy!

Philipp Herold

Head of Research & Development Department

Repository Research in Crystalline Rock – The CHRISTA-II Project

On behalf of the Federal Ministry for Economic Affairs and Energy (BMWi), the Project Management Agency Karlsruhe (PTKA) has commissioned BGE TECHNOLOGY GmbH, BGR, and GRS with the research project CHRISTA-II. In this project, a draft for the methodical procedure for the safety assessment of repository systems in crystalline rock in Germany was developed, taking into account the Ordinance on Repository Safety Requirements (EndlSiAnfV). Following an analysis within the scope of a preliminary feasibility study, three possible options for the safe containment of the radioactive waste were defined. These are emplacement in several ´multiple CRZ' (CRZ = containment providing rock zone), the ´modified KBS-3 concept' (based on the Scandinavian container concept), and the ´overlying CRZ' (based on overlying clay or salt layers).

For the method development, three generic geological site models were


Drift lining in the Konrad Repository (Germany)

developed by BGR. The system analysis is based on the comprehensive description of the repository systems by means of FEP catalogues that map all components and processes of the repository system. Such FEP catalogues were prepared for all three emplacement options. Crystalline rock formations differ significantly from other host rock types due to their fracture networks, so that concepts for integrity assessment that have already been developed for salt and claystone cannot be adopted directly. Especially for the option „multiple CRZ", a newly developed modelling concept based on a combination of fracture network models and continuum models was proposed and tested. To assess safe containment, the indicators described in the Ordinance on Repository Safety Requirements were specified and exemplarily applied to the three emplacement options. Finally, open questions were identified that need to be clarified for a future safety assessment for a repository at a crystalline site.

Rock-mechanical Analyses for the Konrad Repository – Stable Drift Support for Decades

The underground infrastructure rooms and the access drifts of the Konrad repository are in service during the entire operating phase of the repository. The mine openings and access drifts inside the controlled area are supported by one- or double-shell anchor/shotcrete lining, which must be stable without the need for renovation/refurbishment and maintenance. To achieve this goal, BGE TECHNOLOGY GmbH carries out numerical analyses for dimensioning, which are followed by more detailed design work by a subcontractor of BGE for their implementation. These analyses comprise the Ramp 380, which connects the infrastructure rooms, the radiation protection room, and the E-truck service room. In this context, several huge numerical models are applied whose extensions represent several hundred metres underground. Each of them is discretised by up to 2.5 million zones. The models also take into account the excavation process in order to capture its influence on stability. The underlying constitutive model of the clay- or carbonate-rich host rock layers includes anisotropic elasto-plasticity with strain softening. Faults are considered as well.

The time sequence modelled comprises the construction state, the dimensioning of the temporary support system, and the determination of the rock pressure-induced loading of the concrete lining during the operating phase of the repository.

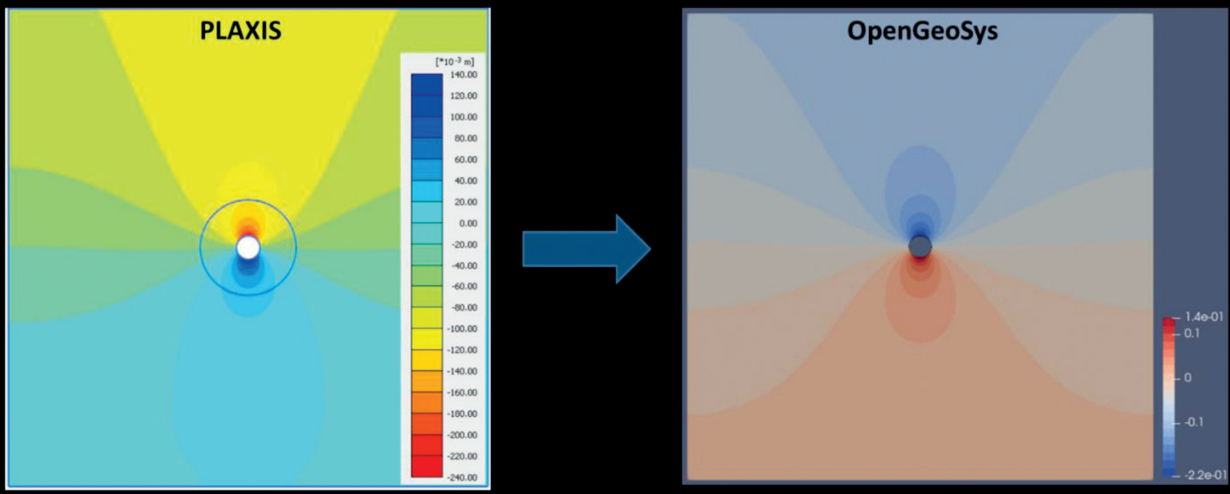
The simulation of the drift excavation or drift widening to diameters of up to 8 m – 9 m demonstrates an adequate level of stability. Due to heterogeneous and anisotropic rock properties, typical heterogeneous displacements occur. As securing means until the concrete lining is finished, fully bonded anchors with lengths between 4 m to 6 m in drifts and up to 8 m in junctions are used.

Due to differential rock movements, the loading of the concrete lining varies as well locally. Local load maxima occur in particular when cross-sections change and in curves. In these cases, an iterative process between planning and numerical calculations has made it possible to minimise the internal forces considerably by specifically taking expansion joints into account. Consequently, the efficiency of dimensioning and the construction process were improved.

A New Approach to Using Existing Material Models in any Numerical Code without Implementation

BGE TECHNOLOGY GmbH was commissioned by BGE with the project PIONIER to develop constitutive material models for claystone and bentonite materials. Together with the Geotechnical Institute of the Technical University Bergakademie Freiberg, Charles University Prague, and the French Alternative Energies and Atomic Energy Commission (CEA), BGE TECHNOLOGY GmbH has developed a new approach to recycle existing implementations of constitutive material models and to make them available in other numerical codes.

Implementing a constitutive material model is a long, tedious, and error-prone process, in particular for soils where a wide variety of models must be taken into account. MFront is a popular code generator developed by CEA, which is based on C++ and which provides interfaces for many academic and industrial solvers, especially through the dedicated Mfront generic interface support (MGIS). Although MFront simplifies the implementation of a new material model, much work remains to be done. Thus, existing source codes of previously implemented models are highly valuable, and the re-implementation of such models in MFront should only be considered if necessary.



Vertical displacement after the excavation of a gallery in a clay fomation using an advanced hypoplastic model (PIONIER Project)

The developed approach consists of using MFront as a tool to the previous implementations. The MFront tools also consider the definition of suitable metadata and handle the transfer of the data from solver to the initial implementation. At this stage, the approach has been used to make available all kinds of constitutive models written in the UMAT format (written in Fortran) into the OpenGeoSys solver, which is built upon MGIS. A benchmarking was carried out to assess the performance of a model for clay soils made available in OpenGeoSys using this approach, which was successful.

BGE TECHNOLOGY GmbH advances Norway's Plans for High-level Radioactive Waste Disposal in Deep Boreholes

Norway's inventory of high-level radioactive waste originates from the research reactors in Halden and Kjeller, which have been decommissioned. NND (Norsk Nukleær Dekommisjonering) is in charge of the disposal of radioactive waste in Norway. For high-level waste disposal, this includes two alternatives: a deep geological repository (mined repository) or deep borehole disposal (single deep emplacement borehole). BGE TECHNOLOGY GmbH works together with the Finnish AINS GROUP and VTT (Technical Research Centre of Finland) to assist NND.

As part of the ongoing project, our experts have recently developed a purpose-designed borehole canister for the disposal of HLW and spent fuel elements in Norway. The design was driven by canister safety functions such as containment, radiation shielding, sub-criticality, limiting corrosion, and operability. In addition, processes that have an effect on the long-term post-closure performance of the canister were taken into account. In this process, our team quantified these design requirements for the canister. The team's idea was to design a simple but robust canister that – in combination with the other barriers – can provide isolation as well as containment over the required time. The canister itself was not designed to provide all the safety functions for the entire time.

The team designed the canister so that it can accommodate all potential waste types. Thus, the canister dimensions are defined by the maximum length and diameter of the different spent nuclear fuel assemblies or waste packages from reprocessing. The canister consists of an outer shell made of stainless steel and an insert to cover the different spent nuclear fuel elements. The outer shell of the canister is fixed. For the different types of waste, purpose-designed inserts are used. The number of fuel elements is limited by sub-criticality, for example. The borehole canister can also be used without an insert for waste from reprocessing, such as CSD-V canisters. The proposed single canister design simplifies manufacturing and the complexity of the encapsulation process.

Within the scope of a recent assignment from NND, the team currently develops a detailed process for encapsulating Norway's spent nuclear fuel in the designed borehole canisters.

Our work over the past two years has successfully pushed forward the disposal concept development and the overall radioactive waste management programme in Norway.

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

BGE TEC
BGE TECHNOLOGY GmbH

Published by: BGE TECHNOLOGY GmbH
Eschenstraße 55 · D-31224 Peine
www.bge-technology.de
January 2022
Edited by: Dr. Andree Lommerzheim
Layout and print by: Druckhaus Giese & Seif, Peine