Design of concrete-based segmental liners for a potential German HLW/SF repository in claystone

Philipp Herold[1*], Ajmal Gafoor[1], Eric Simo[1], David Seidel[1], Andreas Hucke[2], Sven Bock[2], Benedikt Wöhrl[2], Axel Studeny[2]

[1] BGE TECHNOLOGY GmbH, Peine, Germany

[2] DMT GmbH Co. KG, Essen, Germany

* philipp.herold@bge.de

The German site selection process is ongoing, and in addition to others, claystone is one of the potential host rock formations. From a long-term safety-related point of view, claystone offers several beneficial properties, such as a low permeability or a sorption capacity. The geomechanical properties of claystone are characterised by a low to moderate strength and a rheological deformation behaviour („creep“). Added to this are the changes in properties depending on the water content. From the view of operational safety, this implies the necessity of a regular support structure inside all the galleries and during their complete operational lifetime. However, the complexity of a deep geological repository (DGR) project comprises a wide set of requirements to all safety-relevant systems, structures and components (SSC), including the support structures. The direct transfer and implementation of standardised support structures as known from mining and tunnelling is not possible. The specific characteristics of an HLW/SF DGR requires a special support structure. In previous works, two basic types of support structures were identified [1]. For long-living galleries with large diameters, segmental lining with compressible grouting between rock and liner were identified as preferred option within a wide range of considered depths and rock properties. For small diameter galleries with limited lifetimes and high strength of the host rock, a simpler support structure made of shotcrete, rock bolts and steel mesh is preferred. The actual design of the shotcrete layer as well as necessity of rock bolts and mesh depend on the local conditions. These two basic support concepts were further investigated and specified within a separate study. With the proposed contribution, it is intended to describe the used design approaches and present the results of this more detailed study.

This presentation focusses on the design of the lining for long-living galleries like access or transport drifts. This includes the design of the segmental lining for the drifts themselves and additionally a possible design of the junctions (T-junctions). For the design for the support structures for such long-living galleries, different numerical methods and models were used. This enables the consideration of the anisotropic rock mass behaviour including softening of the material as well as applying an anisotropic stress state. Furthermore, effects like swelling and creeping of the clay rock mass can be taken into account in the models.

For the modelling of the rock mass behaviour during excavation of an access drift a continuum-mechanical approach (FLAC 3D) was used. The geo-mechanical parameters are based on literature data for Opalinus clay. Parameter sets for anisotropic mechanical strength behaviour of the clay as well as the stress state were prepared and used for modelling with the continuum-mechanical approach. However, modelling the segmental lining is difficult with continuum-mechanical tools. Thus, it was decided to use a hybrid (DEM + continuum) approach for the modelling of the segmental lining. The loads from the rock mass were determined with the continuum-mechanical FLAC 3D model and transferred to the DEM-based 3DEC model for the segmental lining. With the DEM-based model, the design of the segmental lining was simulated, taking into account the development of the drift as well as swelling and creeping processes. For simulating the time-depended rheological deformation behaviour, a second parameter set with a reduction of the strength parameters of the rock mass was considered.

Additionally, special focus was given to the junctions between two galleries. All junctions are designed as T-junctions. T-junctions means from a straight gallery (access drift), a second

gallery branches off perpendicularly. The connected galleries can be both long-living galleries or a short-living gallery branching off from a long-living one. For the junctions, a conceptual design of the excavation and of the support structure installation method were developed, and the support structure was designed. In the beginning, the continuum-mechanical approach with the software FLAC 3D was used as well. A model of the junction and the surrounding rock mass was created to identify the stress states inside the rock during and after construction. Based on this results, a geometry of the optimized junction was identified. Radii along the corners of the junction were defined. To capture the time-depend-behaviour of the rock, two different parameter sets were used. The initial parameter set defines the short-term behaviour and the situation directly after construction. Deformations and stress relocations resulting from the time-depend behaviour are considered in a second set of parameters.

Afterwards, the bedding modulus method based on [2] was used to design the support structure of the junction, a concrete-based segmental lining. The rock is simplified as springs in radial and tangential direction. The boundary conditions including the rock behaviour were determined by the use of the initial model. In addition to the bedding modulus method convergence confinement method (in German Kennlininenverfahren) [3] was tested as well to determine the rock deformations. Based on this input, it was possible to analyse the bearing capacity and the deformation of the support structure. The concrete-based segmental lining was modelled explicitly with the software SOFTISTIK. The time-dependent behaviour of the concrete-based segmental lining, a similar workflow was established, including advanced material models for the alteration of the concrete structures (software ATENA).

References

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