Parameter study of bentonite based drift sealing concepts in German repositories in crystalline

Victoria Burlaka, Michael Jobmann, Philipp Herold
BGE TECHNOLOGY GmbH, Research and Development

BGE TEC
BGE TECHNOLOGY GmbH

Introduction

Within the framework of the R&D project "Development of a safety and verification concept for a repository for heat-generating radioactive waste in crystalline rock in Germany" (**Christa-II**), BGE TECHNOLOGY GmbH has developed a conceptual design for drift seals. The conceptual design includes concrete based abutments and main sealing elements made of bentonite. For the bentonite sealing different design variations are in consideration, see Fig. 1. Bentonite can be installed **A**) in combination with bitumen as an element with short term sealing function and with a gravel filled chamber to homogenize saturation, **B**) as a single sealing element.

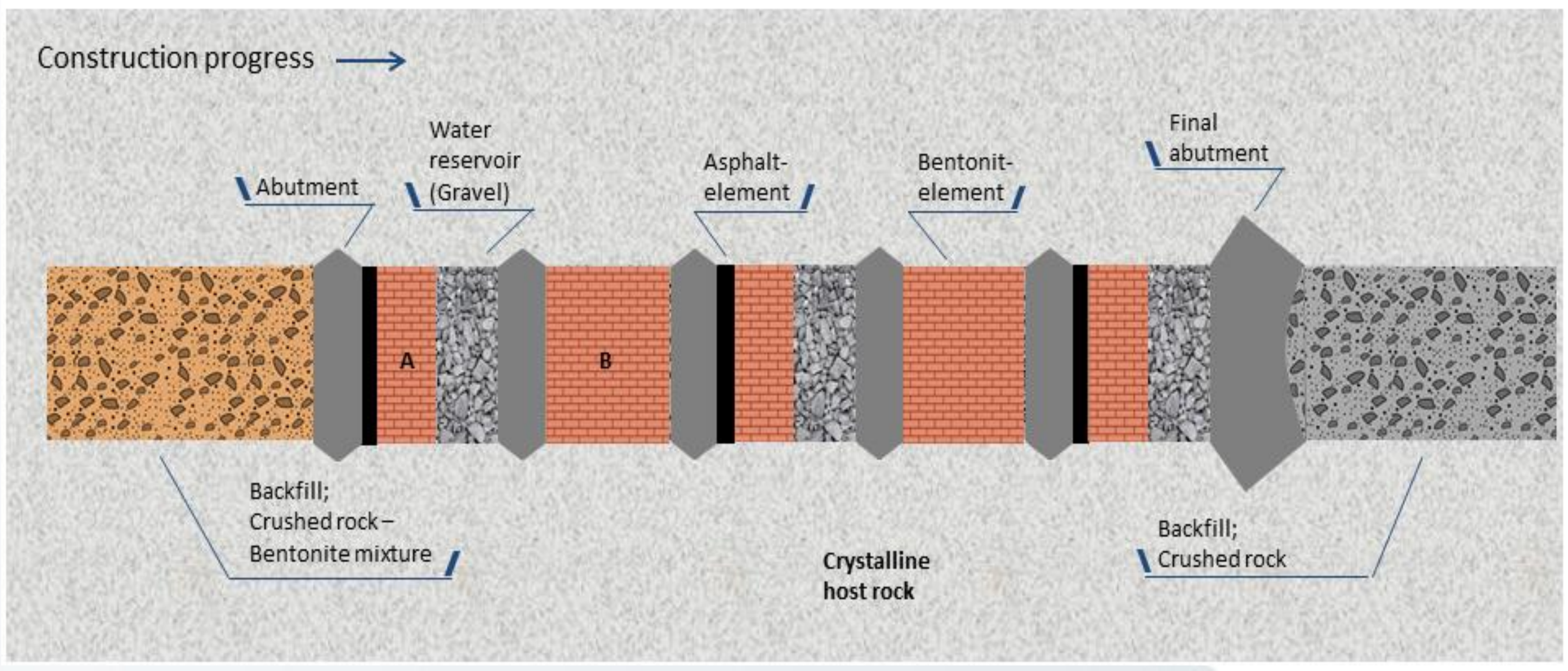

Figure 1: Conceptual design of a main drift seal for German repositories in crystalline host rock with different designs of bentonite based sealing elements, denoted as A and B

Three-dimensional modelling

Three-dimensional simulations using **TOUGH2 code** have been performed in order to reveal duration of water saturation of various bentonite sealing plug configurations under isothermal conditions. Figure 2 shows mesh discretization in the model.

The first part of the present study was focused on investigation of **influence of permeability of bentonite** on duration of water saturation. Permeability of bentonite was varied **from 10^{-15} m² to 10^{-19} m²**.

The second part of the study considers model with **initial permeability of bentonite of 10^{-14} m²** and then **increased permeability of bentonite of 10^{-17} m²** due to swelling. Asphalt elements in 10000 years are degraded and the goal of the study was to investigate evolution of water saturation of bentonite plugs after degradation of asphalt elements. Intrinsic, flow property parameters and initial water saturation in materials are given in Table 1.

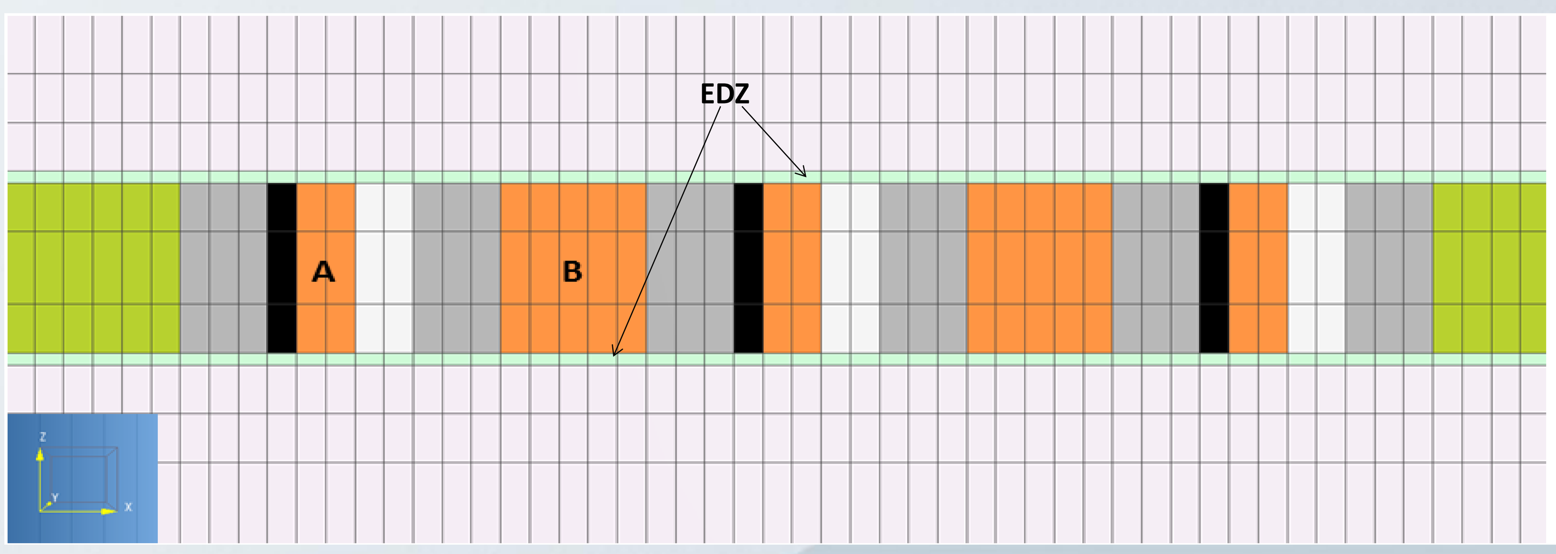

Figure 2: Enlarged mesh of the access drift area in the xz plane

Material	Permeability [m²]	Porosity [-]	Gas entry pressure, P_0 [MPa]	Water retention curve shape parameter, λ [-]	Maximum capillary pressure [MPa]	Initial water saturation [%]
Crystalline host rock	10^{-19}	0.01	-	-	-	100
Bentonite plug	10^{-14} -10^{-19}	0.3	0.5	0.363	9	45
EDZ	10^{-18}	0.05	0.15	0.55	10	95
Backfill in drift	10^{-16}	0.3	0.09	0.55	7.41	45
Asphalt	10^{-23}	0.01	-	-	-	100
Abutment	$2\cdot10^{-17}$	0.2	0.15	0.55	10	20
Gravel	10^{-13}	0.4	-	-	-	100

Table 1: Material properties, parameters of capillary pressure and initial water saturation used in the simulations

Results

Results of simulations of **the first case study** (see Fig. 3) with varying permeability of bentonite from 10^{-15} m² to 10^{-19} m² demonstrate **faster water saturation for bentonite plug A** installed between bitumen and gravel independent of permeability of bentonite due to water suction of bentonite from initially **100 % water saturated gravel**. **Bentonite sealing elements** A and B **are completely water saturated** when permeability of bentonite is of **10^{-15} m² and 10^{-17} m²**. When permeability of **10^{-19} m²** is considered, **full water saturation is not reached up to 1000 years**. The permeability of bentonite influences only on the duration of water saturation of sealing plugs and it's faster when the higher permeability is considered. Figure 4 shows distribution of water saturation in the drift and water flow directions.

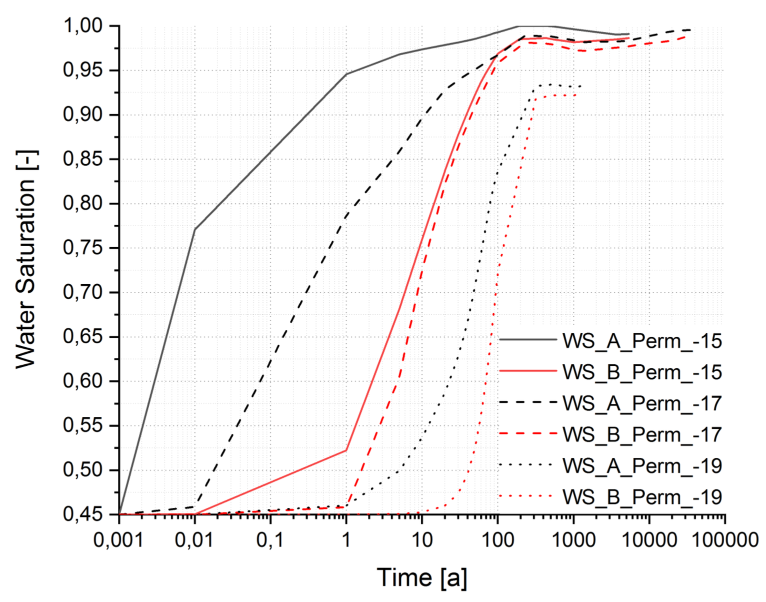

Figure 3: Water saturation evolution in bentonite plugs in the drift, where permeability of bentonite is of 10^{-15} m² (solid lines), 10^{-17} m² (dashed lines), 10^{-19} m² (dotted lines)

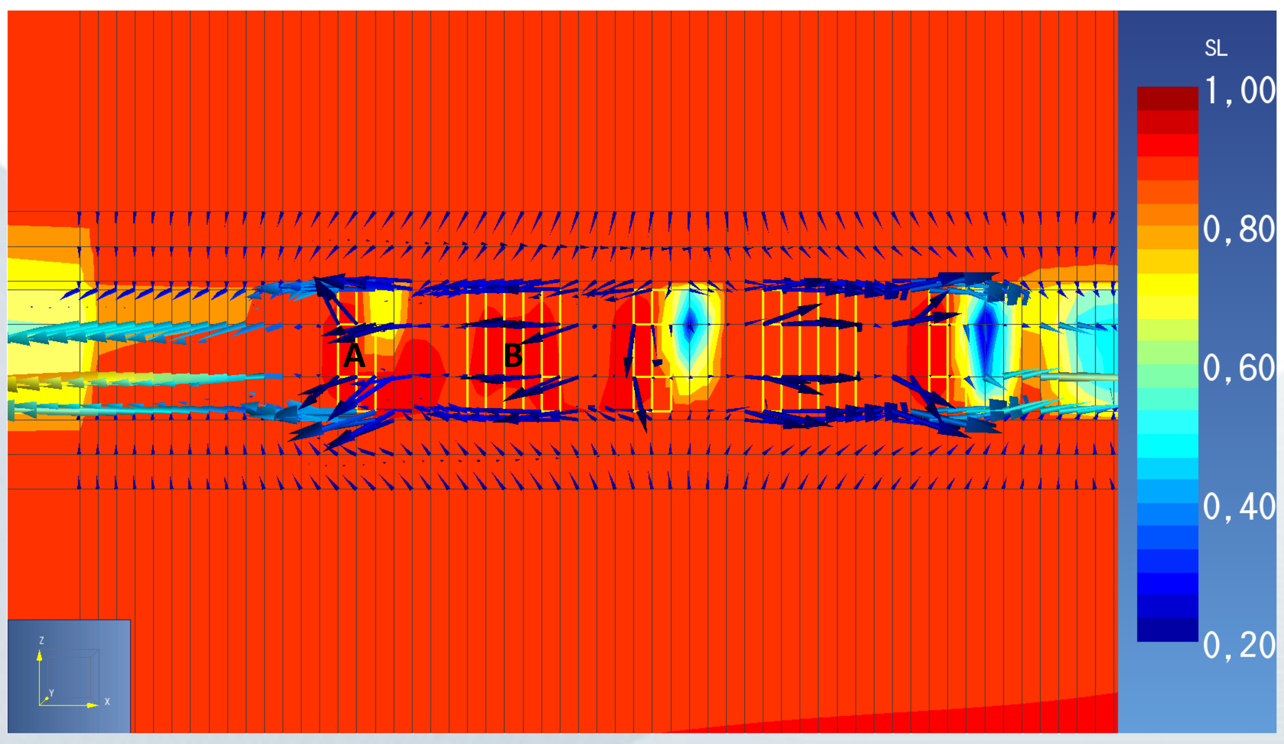

Figure 4: Water saturation distribution in the drift after 1000 years, where permeability of bentonite is of 10^{-19} m², arrows represent water flow directions

Results of simulations of **the second case study** (see Fig. 5) demonstrate that even **after degradation of asphalt sealing elements**, **bentonite plugs** will be **completely water saturated**.

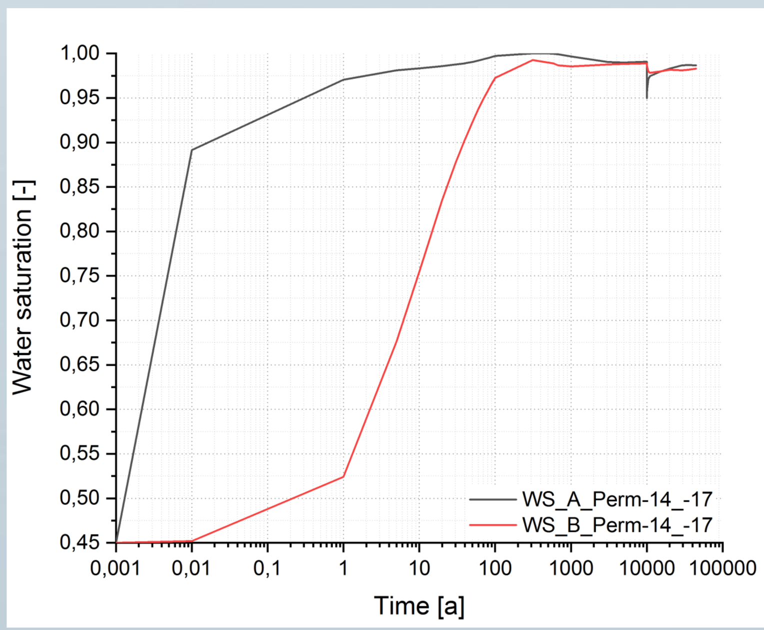

Figure 5: Water saturation evolution in bentonite plugs in the drift with initial permeability of bentonite of 10^{-14} m² and then increased to 10^{-17} m², asphalt elements are degraded after 10000 years

Conclusions

Water saturation of bentonite plug installed in combination with bitumen and gravel (A) takes faster than in bentonite element between abutments (B) due to water suction of bentonite from initially 100 % water saturated gravel. After degradation of asphalt sealing elements, bentonite plugs will be completely water saturated. Therefore, bentonite plugs will fulfill their sealing function even after degradation of asphalt elements.

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