Long-term Performance of Engineered Barrier Systems

PEBS Newsletter No. 8

The PEBS project, initiated in 2010, reaches its final stage in February 2014. The 8th – and final – PEBS Newsletter provides an overview on some major research results of the project and gives a brief summary of the "International Conference on the Performance of Engineered Barriers" – the final event within the PEBS project.

Overview on the major research results of the PEBS project

At the beginning of the PEBS project the existing uncertainties regarding the evolution of the engineered barrier performance were assessed. The major areas of uncertainty were captured in four "cases". As the PEBS project is nearing completion, first conclusions for these four cases can be drawn.

Case 1 – Water Uptake in the Bentonite Buffer

Water uptake of clay components in the engineered barrier system (EBS) is one of the key safety-relevant processes identified in the framework of the PEBS project.

Conventional thermo-hydro-mechanical (THM) models of large-scale heater experiments with a high hydration rate and water supply show a good agreement in the water uptake. However, at late stages of the hydration process these models predict a faster resaturation than is actually observed.

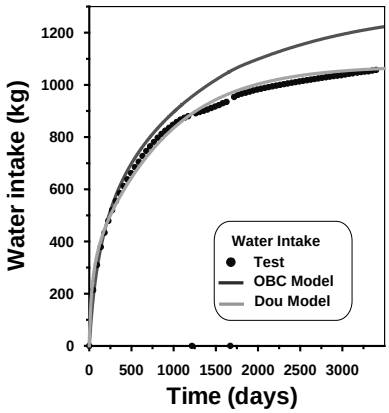

Figure 1: Measured water uptake in the FEBEX mock-up test and results of a conventional THM model (OBC) and a double porosity model (Dou) (MAYOR et al., 2014).

Various model variants (double porosity, thermo-osmosis, Darcy threshold) were analysed, achieving a good representation of the hydration process at late stages (Fig. 1). Results, however, do not clearly permit identification of the processes actually relevant.

The context from long-term safety is clearly improved – it can be stated that even though saturation is not yet fully reached (e.g. after 15 years of FEBEX mock-up test), the safety function is fulfilled because sufficient swelling pressure and low hydraulic conductivity is reached throughout the barrier at 85-90% average saturation.

Thus, the model uncertainty in water uptake appears to be of minor relevance from a long-term safety perspective.

Case 2 – EBS Performance at Temperatures above 100°C

In Case 2 the performance of a bentonite barrier subjected to temperatures above 100°C under variable saturated conditions, and its relevance to clay based disposal concepts, was investigated.

As a result of the HE-E experiment, laboratory investigations and coupled numerical modelling, the understanding of the thermo-hydraulic evolution of the buffer at temperatures above 100°C was improved (Fig. 2). However, some uncertainties remain regarding swelling and hydraulic properties of bentonite for peak temperatures above approx. 125°C.

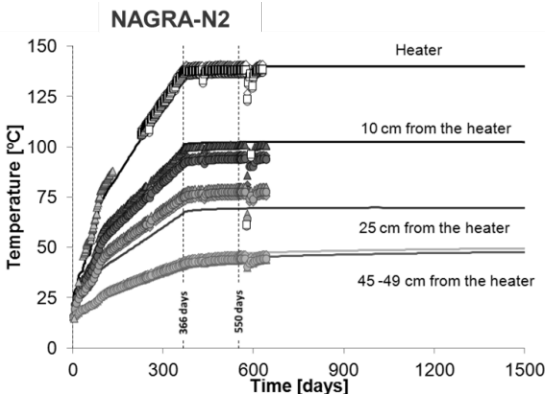

Figure 2: Measured and modelled temperatures in the granular bentonite section of the HE-E experiment at different distances from the heater (GAUS et al., 2014).

The continuation of the HE-E and the initiation of the new FE experiment will provide the opportunity for further investigations and improvements of existing models.

In the Nagra safety assessment context, indications are that the effects of early high temperature processes in the bentonite barrier have generally low relevance to long-term safety.

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Case 3 – HM Evolution of the Buffer

To evaluate the sealing ability of clay based EBS, it is essential to understand the evolution of their mechanical properties during and after the saturation phase.

Results from in-situ and laboratory experiments as well as from an analytical model helped to improve the understanding of the mechanical processes in the EBS. One of the findings is that the homogenisation of a bentonite buffer is efficient; even if it is installed as a mixture of high density blocks and low density pellets. It was also observed that even in a partially saturated buffer a sufficient swelling pressure can develop. Furthermore, it was found out that heating will affect the mechanical properties of bentonite; however the effects are small below 100°C (SELLIN et al. 2014).

Uncertainties in the mechanical processes occurring during the resaturation phase have been better constrained through PEBS studies – the uncertainties in the long-term performance of bentonite barriers have thus been reduced in some important areas.

Case 4 - Impact of the Geochemical Evolution of Bentonite Barriers on Repository Safety Functions

Case 4 focuses on the effects geochemical processes on the properties of the clay-based barrier and their relevance for the safety functions. The main uncertainties which were identified include the thermally-induced mineral changes and the interactions at the canister/bentonite and bentonite/concrete interface.

Thermally-induced mineralogical changes are expected to be relevant mostly at temperatures above 150°C. It is recommended that this process is further investigated in large scale long-term heating experiments.

The interactions of corrosion products and bentonite indicate that the main properties of the bentonite remain unaltered. Under unsaturated conditions iron corrosion products penetrate much less than 1 mm into the bentonite. For the most part, the coupled THC numerical models reproduce the experimental data.

The interactions of bentonite and concrete produce an altered layer of bentonite several millimetres thick (<5 mm) which is cemented by the precipitation of new minerals in the pore space (Fig. 3). These mineral phases are mainly Ca-carbonates and Ca-, Mg- low crystal size hydrated silicates. The hydration of bentonite proceeded in spite of this layer. Coupled THCm numerical models capture the main trends in mineral dissolution-precipitation.

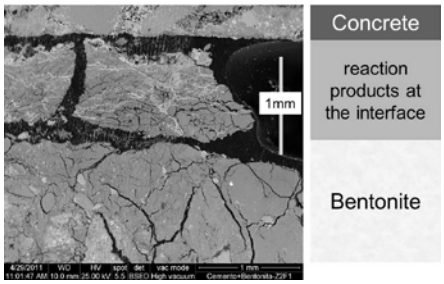

Figure 3: Back scattering SEM image of calcium-rich veinlets affecting 1 mm at the bentonite/concrete interface in a CIEMAT 4.5 year experiment (CUEVAS et al., 2014).

While there are still open questions regarding the conceptual geochemical model, the pore clogging processes, and the final parameters and properties of the altered zone, current models indicate that the thickness of the altered bentonite will be bounded.

The “International Conference on the Performance of Engineered Barriers” – the final event of the PEBS project

Figure 4: Conference group photo.

On February 6-7, 2014 the “International Conference on the Performance of Engineered Barriers” was held at the BGR Hannover, Germany. More than 180 participants from 17 countries used this opportunity to present and discuss the current state of research on the performance of engineered barriers in geological repositories for high-level nuclear waste.

Conference objectives

As the PEBS project is nearing completion, the conference provided a platform to disseminate the outcomes of the project to the scientific community. The research results of the PEBS project played a central

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role; however, they were put in context through presentations of research results also from other projects and activities. The conference was rounded up by a panel discussion with international experts, which provided a summary of topics relevant for the design of future joint projects.

Conference topics

The conference was opened by Prof. Kümpel (BGR), followed by a presentation by Mr Christophe Davies (EC) on the status of the Euratom FP7 Research and Training Programme and an outlook to Horizon 2020. The keynote lecture was given by Mr Peter Wikberg (SKB), giving insight into the implementation of a deep geological disposal concept in Sweden. The 48 presentations from inside and outside PEBS were grouped in nine sessions:

- Overview on the Research Results of the PEBS Project
- New Insights from In-situ Experiments in Clay-rich Formations
- New Insights from In-situ Experiments in Crystalline Host Rock
- Investigating Gas Interaction in Laboratory and In-situ Experiments
- New Insights from Laboratory Experiments
- Design and Construction of Engineered Barriers
- Numerical Modelling of Thermo-Hydro-Mechanical-Chemical Processes
- Numerical Modelling of In-situ Experiments
- Improvements in Performance Prediction

Sessions were complemented by a poster exhibition, with a strong focus on new insights gained from laboratory experiments.

The main questions which were discussed in the panel discussion included:

- What are the key remaining scientific-technical questions for engineered barriers?
- How can programmes in early phases of development become involved in joint research and training activities?
- How can activities contribute to clarity and thus to acceptance by stakeholders beyond the expert community and interest groups or organizations?

References

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For more information on the structure and the outcomes of the PEBS project and on the International Conference, please visit the PEBS website:

www.pebs-eu.de