Call for ideas on a future Collaborative Project on Bentonite Homogenization

Background and objectives

PEBS

The main aim of the project PEBS (Long-term Performance of the Engineered Barrier System) was to evaluate the sealing and barrier performance of the EBS with time. The focus was to study the processes in the early evolution of the repository system and to evaluate the impact of the processes on the long-term safety functions.

The sealing ability is essential for the engineered clay barriers in all repository concepts. This is normally achieved by a swelling pressure and a low hydraulic conductivity. The swelling pressure may also impact the impact the barriers in the repository. The mechanical properties of the installed EBS, that may consist of a mixture of blocks, pellets and engineering voids, will be entirely different from the situation after full saturation. It is therefore important to understand:

1. The mechanical evolution during the saturation phase
2. The final situation after equilibrium

A good knowledge of the mechanical evolution is necessary to ensure that a given design is sufficient to meet the performance targets.

The main focus in the PEBS was on thermal and hydration issues. However, the mechanical homogenization was studied in the excavation of the EB experiment. Within this topic the summary some of the findings from PEBS are:

- The homogenization of a bentonite buffer is efficient; even it is installed as a mixture of high density blocks and low density pellets. The EB experiment has confirmed that a highly saturated bentonite barrier was able to seal all the initial voids.
- Numerical analysis is a useful tool to predict the resulting heterogeneity in the barriers after hydration. For the EB experiment; it can be observed that the results obtained from the modelling are consistent with the dismantling observations.
- Models have indicated that the final heterogeneity of mass in a bentonite barrier may depend on the wetting history

However, even though the homogenization in the EB was reasonably efficient, there are still remaining differences in dry density over the cross-section of the test. These range from ~1,300 kg/m^3 to ~1,450 kg/m^3, which would mean a substantial difference in swelling pressure and hydraulic conductivity over the cross-section.

General

The primary function of a bentonite barrier is to ensure that the transport of various substances through it is dominated by diffusion. The swelling pressure in the bentonite is expected to seal all gaps and ensure that the rock and the buffer are in good contact with each other. It is therefore important that the swelling pressure is maintained.

Water uptake after deposition of the buffer, backfill and seals, which are inhomogeneous at emplacement, will lead to swelling. This causes all gaps in the buffer, between rock and buffer and between canister and buffer to disappear, and the buffer to be homogenized. However, some inhomogeneity will remain due to friction in the bentonite. This residual inhomogeneity is of importance for the design premises and the configuration (voids, pellets and blocks) with which the buffer, backfill or seal is deposited.

Generally, in both design specifications and long term assessments of bentonite barriers it is assumed that homogenization will occur and that the hydro-mechanical properties of the barrier will be equivalent to the properties of mean installed density. This is an optimistic approach, and in that sense, different from most (all) other approaches in radioactive waste management. This approach may be valid under many circumstances; however the range of conditions for the validity has not been demonstrated.

It is especially important to know the degree of homogeneity/heterogeneity of the barrier at the end of the transient period. It is inevitable that various types of heterogeneity will be present at the end of construction. Therefore the question is how heterogeneity will evolve during the transient period.

- Average dry density is not sufficient to characterize the state of the barrier, maximum hydraulic conductivity will be controlled by the zone with the lowest dry density
- Swelling pressure will not only depend on the average dry density achieved but of the wetting/deformation history of the barrier as well
- Heterogeneity may be enhanced by thermal effects
- Heterogeneity may also be caused by other processes such as erosion; the degree of homogenisation achieved by the subsequent sealing of the erosion pathway remains uncertain.

In this context, bentonite exhibits a quite complex mechanical behaviour showing a degree of irreversibility in various situations under both saturated and unsaturated conditions. Irreversibility leads in a natural way to heterogeneity.

Irreversibility has been conclusively demonstrated in a series of tests performed by Clay Technology on saturated compacted bentonite samples. Those tests also show that existing mechanical models have difficulties reproducing this behaviour. There is less information concerning the equivalent situation under unsaturated conditions although it is likely that irreversible behaviour may be even more significant.

There is therefore the need to carry out fundamental laboratory tests on bentonite under saturated and unsaturated conditions in parallel with constitutive model developments specifically aimed to the description of irreversibility. It should also be noted that there is practically no information on the irreversibility of mechanical behaviour of pellets-based materials that are becoming an increasingly popular component of barriers and seals.

Finally, there is the possibility that heterogeneity will continue to evolve in the long term due to creep phenomena (bentonite creep only in the case of crystalline rock, bentonite and host rock creep in the case of argillaceous rock). The issue of bentonite creep has never been seriously addressed; it is not easy as it involves the very long term.

Objective

The overall objective of the project is to evaluate the performance of an inhomogeneous bentonite barrier. This will be achieved by cooperation between design and engineering, science and performance assessment. The evolution from an installed engineered system to a fully functioning barrier will be assessed. This will require an increased understanding of material properties as well an increased understanding of the fundamental processes that leads to homogenization and improved capabilities for numerical modelling. The output will be a verification of the performance of current designs for buffers, backfills, seals and plugs and an improved handling of mass losses in long term assessments.

Proposed work areas

According to the PEBS and LUCOEX project conclusions and additional inputs received from other projects and interested parties, further research and demonstration activities are required in the following areas:

A: Strategy aspects:

A1) Review of currents designs for bentonite barriers in the European disposal concepts. This will include performance targets as well as manufacturing and installation aspects.

A2) Review of the assessment strategy for the evaluation of the performance of the bentonite barriers, with special attention given to the treatment of remaining inhomogeneities.

A3) Definition of the technical basis for the design of the barriers

B: Assessment aspects

B1) Definition of case studies for the verification of the performance of current barrier designs

B2) Definition of case studies for the verification/validation of quantitative models, based on results from laboratory an field tests

C: Scientific aspects

C1: Development of conceptual approaches for the mechanical evolution of a bentonite barrier

C2: Laboratory testing to gain understanding of material properties

C3: Modelling of cases for the verification/validation of quantitative models.

C4: Evaluation of data from (existing) field scale experiments

C5: Investigation of a natural analogue, e.g. a drill core through a bentonite deposit

D: Practical implementation

D1: Feedback to design/engineering, are current designs adequate or can they be improved?

D2: Feedback to safety assessments: how should the homogenisation process be described and how should an inhomogeneous system be treated?

Approach

The above list is not exhaustive and other ideas and proposals related to monitoring can be presented at the workshop. All proposed activities aim to produce a significant step forward from the current state-of-the-art on the description and handling of the mechanical evolution of a bentonite barrier. It is considered that the project benefits can be maximized with a comprehensive approach to the problem.

The project should therefore include research on scientific, methodological, strategic, and stakeholder involvement aspects, technology development, as well as the integration with the safety analysis and design strategy. In particular, demonstration activities should be carried out both at laboratory and full scale, preferably already existing URL experiments, and should include, if possible, studies of a natural analogue.

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