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Long-term Performance of Engineered Barrier Systems

Long-term Performance of Engineered Barrier Systems PEBS

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Content

1 Structure of the Projekt

The PEBS project includes 7 work packages. Work packages 1 to 4 and the Chinese work package B are concentrating on research and technical work of RTD type. The work packages 5 and 6 focus on dissemination of results and the management of the action.

2 Work Package 1

The activities in WP1 are concluded and future work will be done with WP4. A final report describes current treatment of the early evolution of the EBS in safety assessments from a number of European national programs (state of the art). The description starts with an overview of the repository concepts. Both HLW and spent fuel repositories are covered as well as both clay and crystalline host rocks. This is followed by an overview of the assessment methodology used in the different programs. One important aspect of the methodology is the definition an application of safety functions. Basically, safety functions are a tool that is used for the evaluation of the performance as a function of time for individual repository components. The uncertainties in the early evolution in the EBS can generally evaluated with aid of the safety functions. The main part of the report describes the treatment of the THMC-process in the EBS and the potential impact on the safety functions. The significance of the identified uncertainties on the evaluation of the safety functions was also discussed. The report also summarizes the uncertainties and defines a number of cases or “scenarios” that will be assessed further within the PEBS project. Despite the differences in repository concepts, the safety functions defined for the engineered clay barriers are similar. The key processes occurring in the EBS in the early evolution of the repository that may affect the long the long-term performance are identical for all concepts on a fundamental level. However, the significance as well as the treatment of the processes in the safety assessment can differ between the concepts.

3 Work Package 2

The three main tasks of WP2 are all well advanced and, in general, according to schedule:

Experimentation on key HM processes and parameters

Activities are related with the maintenance and supervision of the EB experiment at Mont Terri, and the elaboration of the test plan of two pilot boreholes and their drilling, including bentonite sampling and in-situ geophysical testing. A packer system for hydro testing was installed and testing will start as soon as watertight conditions develop. Two infiltration tests were performed with the pellets mixture used in the EB in situ experiment. They were running for 9 months and 4.5 years with measurement of the water intake. In one of them the swelling pressure developed was also measured.

Experimentation on key THM processes and parameters

Because of unfailing sensors PEBS tests proceeded FEBEX mock-up test. Two TH tests have being running for more than 9 years and providing information about the temperature and relative humidity inside the bentonite, what has highlighted the influence of the thermal gradient on the hydration kinetics and the slowness of the saturation process. Two new TH tests have been designed and will be carried out with a sand/bentonite mixture and with pellets of MX-80 bentonite, reproducing the conditions in the *in situ* HE-E test. To support the new TH tests, infiltration tests at laboratory temperature with measurement of the swelling pressure are being performed with the same materials. Related to the study on stress-strain behaviour four series of unconfined compression tests have been accomplished so far where the influence of the following factors on strength was studied: heat on pure sodium bentonite, different textures of the material, ion exchange during saturation and introduction of a fracture before saturation. Further tests series with this and the other mentioned methods will focus on e.g. influence of heating during different parts of the saturation process, cycles of heating and influence of consolidation and water pressure.

From the series accomplished so far the preliminary results show that compared to reference tests heating purified sodium bentonite, removal of the coarser material from the bentonite or the intro-duction of a fracture before saturation will decrease the strain at failure. The largest deviation from the reference tests regarding maximum stress at failure is seen when a fracture is introduced in the specimen before the saturation. Within the first 18 months of the project the new heater test HE-E was designed and constructed according to the description in the DOW.

Experimentation on key THM processes and parameters

To correct the problems detected in both mock-ups, development and implementation of new fixations for the RH sensors and water sampling points have been done. The previous sampling ports were maintained. The position of the mock-ups has been modified, by turning them 90 degrees, to make more accessible the instrumentation rods. All the systems (hydration, heating and data acquisition) were disconnected during this operation and reconnected and verified afterwards. At this time heating was switched on with a target temperature of 30ºC. This must let corrosion to continue at a lower rate, because both experiments were flooded initially. The more problematic point is the sealing of the I/O ports in instrumentation rods during the hydration. First attempts were made at the nominal pressure, but some leakages were observed. Then it was decided to hydrate at a lower pressure (1.6 bar a) and the leakages became negligible. At this time, water was observed in the tubing coming from the sampling ports and most of the RH sensors that worked fine (with values higher than 90%) began to fail (probably due to flooding with high-saline water) and some new leakage were observed. The final decision is to eliminate the RH sensors, because the measured RH-values are closed to 100% and to prevent the leakages coming from the fixations, and to maintain the water sampling ports. One of the tests started during NF-PRO to study the interface concrete-bentonite was dismantled on October 2010, after 4.7 years of operation. One of the tests on medium cells started during NF-PRO to study the interface canister-bentonite was dismantled on December 2010, after running for 4.5 years. THM analysis on the bentonite blocks and geochemical characterization of the bentonite and the interfaces have been performed. It was proposed to perform new experiments under repository conditions at times ranging from 1000 to 3000 years after closure. Six new experiments started on January 2011. These experiments are being performed in small cells, with a total

sample length of 25 mm and a foreseen duration of 1.5 years. The cells are working at 60º C (the expected temperature at times considered). For the conditions at the canister-bentonite interface it was decided to use corrosion products as powered magnetite, since magnetite is the long-term stable form of the corrosion products. To simulate the concrete-bentonite interface a mortar was used. Experiments were designed with two types of bentonite samples: FEBEX standard sample at natural conditions and pre-treated FEBEX bentonite sample that will be depleted in X-Mg (exchangeable Mg) in order to represent more closely the conditions of the bentonite after 1000 years. The cells are weighted once a week to have information of the hydration process.

4 Work Package 3

The five main tasks of WP3 are all well advanced and, in general, according to schedule:

HM modeling of the EB experiment

CIMNE reviewed existing information and performed preliminary conceptual modelling, involving several non-standard models for the buffer hydration which help to explain the experimental observations.

THM modeling of the planned heater test HE-E

TK Consult used a full 3D model, but considered only thermal-hydraulic (TH) effects. CIMNE started with 2D axisymmetric TH scoping computations. The TH model was shown to provide acceptable predictions for the thermal field and the saturation degree in the unsaturated zone. The model results were thus used to help positioning new temperature and relative humidity sensors (in the bentonite buffer and in the rock mass close to the experiment). In the meanwhile, the TH model was also shown to miss some processes influencing the evolution of the pore water pressure in the saturated zone. The need to adopt a fully THM model was put forward to take skeleton compressibility and skeleton thermal expansion into account. By axisymmetric 2D THM scoping computations the set of parameters influencing the development of the pore water pressure peak induced by heating was investigated and the most likely parameter set was determined. This set of computations is described in an independent report: “THM Scoping computations for the definition of an optimal instrumentation layout in the HE-E experiment.” GRS used a fully THM coupled plane strain model for the scoping calculation which is able to consider the influence of a gallery running parallel to the experiment microtunnel. Again, the pore pressure peak was modeled further away from the microtunnel than originally expected. The calculations were integrated by NAGRA and the design of the experiment was modified to take account of the modeling results for the overpressures.

THM modeling of bentonite buffer

Based on Swedish experience 11 cases included the bentonite buffer. The PEBS results includes information about the objective, models used, some main results, and uncertainties of each. Some of the tasks were thought to be of higher relevance with consideration to the PEBS framework and were therefore described in more detail, namely: Analysis of time scale of buffer hydration, analysis of moisture redistribution in dry rock scenario, and buffer homogenization. Other modeling tasks, although in-

cluding the buffer, were considered being more peripheral to the PEBS framework and were therefore just briefly described.

Modeling of THM-C experiments on bentonite buffer

UDC has developed advanced multiple-continua models for clay barriers by improving existing THC(m) models. The improvements include: 1) Accounting for two types of waters in two types of pores (micro and macro domains); 2) Incorporating mechanical and geochemical couplings to account for porosity changes caused by swelling phenomena; and 3) Including reactive gases. The model reproduces the measured cumulative inflow for the last 14 years. The fit of relative humidity, however, shows some discrepancies possibly caused by some model limitations such as the consideration of a single porous space.

Extrapolation to repository long-term evolution

The input from WP1 was evaluated and first ideas regarding the extrapolation task were developed. In addition, UDC has performed the integrated analysis of available data for bentonites including water uptake, water content, temperature, and chemical concentrations from heating and hydration tests performed at several space-time scales. The integration has been performed in terms of dimensionless variables. A special subtask of UDC in Task 3.5 was the compilation and evaluation of the usefulness of natural analogues (NA) for providing support, testing and validation of long-term predictions of current THMC models. The respective activities are summarized in a statement.

5 Work Package 4

WP4 is all well advanced and, in general, according to schedule:

As WP1 started in Month 6 of the project and relies on the outcome of WP1 which closes in Month 12, the activities within WP4 have started later in the 18 Month reporting period. However, during the 1st Annual meeting in Beijing the data flow with respect to WP4 was defined and a clear link between WP1 and 4 was established, by agreeing to define a number of “cases” referring to uncertainties in the current treatment of the early resaturation phase as identified in the outcome of WP1. The reduction of the cases based on the complete list of the process and uncertainties as defined in WP1 was discussed. The following cases for the purpose of WP 4 and providing guidance to WP3.5 were identified: Case 1, uncertainty in water uptake in buffer (T< 100°C), Case 2, uncertainty in T evolution in buffer (T >100°C), Case 3, uncertainty in HM evolution of buffer and Case 4, Uncertainties in chemical evolution.

6 Work Package B

The present process is closely followed by the objectives and details listed in the Grant Agreement.

To evaluate properties of the GMZ Na-bentonite under the coupled THMC conditions, the China-Mock-up has been constructed successfully. The physical model is to simulate vertical placement of a container with radioactive waste. The China-Mock-up is

running to monitor the behaviours of GMZ Na-bentonite barrier at high temperature and with Beishan groundwater. A series of experimental data associated with stress, temperature, moisture and displacement are obtained from different types of sensors distributed in the bentonite blocks.

Some numerical studies have been carried out about the China-Mock-up, with the purpose of evaluating the performance of GMZ bentonite under coupled thermo-hydro-mechanical (THM) conditions. The formulation of coupling heat, moisture (liquid water and water vapour) and air transfer are determined. The model of Alonso-Gens is incorporated to reproduce the mechanical behavior of the GMZ bentonite under unsaturated conditions. With the parameters determined from the experimental investigations, numerical simulations of the China-Mock-up test are carried out by the code of LAGAMINE. The results suggest that the proposed model is able to reproduce the mechanical behavior of GMZ bentonite, and to predict moisture and air motions under thermal solicitations. According to the parametric analysis, the experimental test is highly sensitive to the thermal and hydraulic properties, especially to the water retention curve and permeability. It should be mentioned that some simplifications are conducted in the simulation which probably have an influence on the predictive results. For instance, the steel tank and the carbon steel heater are neglected. Moreover, due to the lack of experimental data at present stage, only a qualitative analysis of the numerical results is performed. Therefore, the numerical simulation realized only can be considered as a preliminary validation of the proposed model. With the progress of the experimental test, a further study will be carried out.

7 Work Package 5

The base for all dissemination efforts was compiled in the COMMUNICATION ACTION PLAN what gives the frame for the PEBS NEWSLETTER and the PEBS WEBSITE. Following additional requests a PEBS POSTER will be prepared. The preparation of the BENTONITE WORKSHOP and TRAINING is advanced. The REGULATORY WORKSHOP has to be postponed. Potential participants asked to arrange the workshop what initially was proposed for month 14 with later deadline for autumn 2011. It is now installed for St. Ursanne at the Mont Terri site for April 25th and 26th in 2012. The conference room is booked and hotel capacities are arranged. Topics and speakers are nominated. The BENTONITE TRAINING at BGR laboratories in Hannover, Germany, and additional actions are offered for October 8th to 11th 2012. PEBS was presented at the International Conference on Environmental Remediation and Radioactive Waste Management ICEM 2011 in Reims and at some workshops together with representatives of the EC in Beijing and Shenzhen (China), March 21st to 25th 2011.