Long-term Performance of Engineered Barrier Systems

PEBS

PEBS Newsletter No. 3

This newsletter presents the latest results from the PEBS Heater-Experiment managed by NAGRA at the Mont Terri site and some information from our Chinese partner BRIUG.

Design, construction and start of the HE-E experiment

In the early post-closure period the buffer is expected to experience the maximum temperature. In this phase the buffer is largely unsaturated and the thermal evolution of the EBS is likely to be controlled by the effective thermal conductivity of dry buffer. The main source of uncertainty arises from the possible scale effects in the determination of the thermal conductivity. The HE-E experiment targets the very early post-closure period.

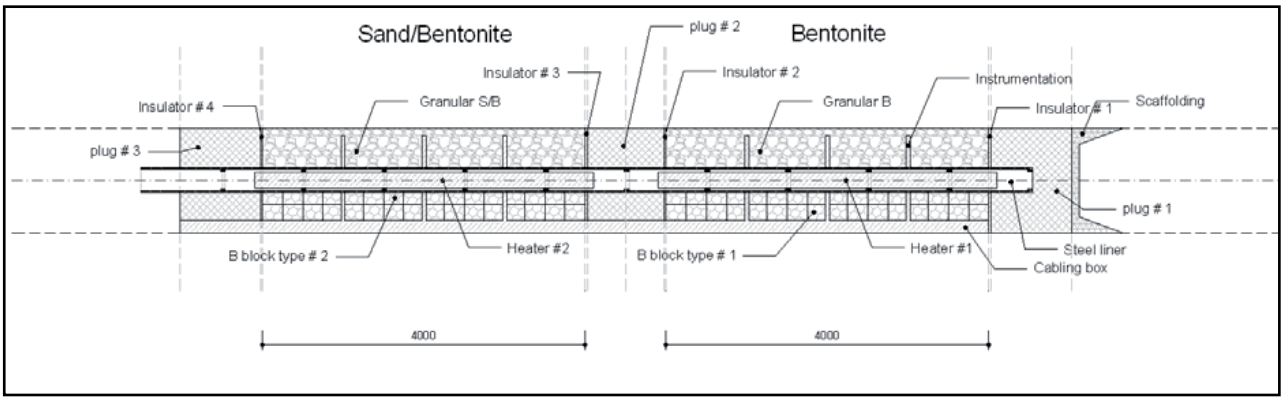
The HE-E experiment is a 1:2 scale heating experiment based on natural resaturation of the EBS and a maximum heater surface temperature of 140°C. The experiment was designed and constructed as part of the PEBS project and started in June 2011. The heater temperature is to increase almost linearly to its maximum value in a period of 1 year, after which the temperature will be held constant for the years to follow. The experiment is planned initially to run for 3 years. Its location is the Mont Terri URL (Switzerland) in a 50 m long microtunnel of 1.3 m diameter. The test section of the microtunnel was characterised in detail during the Ventilation Experiment.

The aims of the HE-E experiment are an investigation of the early non-isothermal resaturation period and its impact on the thermo-hydro-mechanical behaviour, namely: (1) to provide the experimental data base required for the calibration and validation of existing THM models of the early resaturation phase (2) to upscale thermal conductivity of the partially saturated buffer from laboratory to field scale (pure bentonite and bentonite-sand mixtures).

The experiment (see Figure 1 below) consists of two independently heated sections, whereby the heaters are placed in a steel liner supported by MX80 bentonite blocks (dry density 1.8 g/cm^3, water content 11%). The two sections are fully symmetric apart from the granular filling material. While section one is filled with pure MX80 bentonite pellets (named Nagra section), section 2 is filled with a 65/35 granular sand/bentonite mixture (named GRS section). This allows comparison of the thermo-hydraulic behaviour of the two EBS materials under almost identical conditions.

The HE-E experiment is especially designed as a model validation experiment at a large scale and a each experimental step is accompanied by a modelling programme. This benchmarking of THM process models and codes should enhance confidence in the predictive capability of the recently developed numerical tools. It is the ultimate aim to be able to extrapolate the key parameters that might influence the fulfilment of the safety functions defined for the long-term steady state.

The construction of the HE-E experiment took place between December 2010 and June 2011. In first instance a U-profile railway was installed in the 50 m long tunnel. Subsequently the host rock was instrumented. The instrumentation modules (Figure 2) were then towed into the tunnel causing the heater liner elements to be joined into one continuous liner.
An auger, adapted to the 1.3 diameter of the tunnel, was developed to emplace the granular EBS material (Figure 3). Emplacement densities, established



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during off-site tests, ranged for the MX80 around 1.45 g/cm³ while for the sand/bentonite mixtures densities were estimated to be 1.50 g/cm³. The test section tunnel was closed off by concrete plugs providing thermal insulation and a vapour barrier. Finally the two 4 m long heaters were emplaced in the central liner. All materials in place (Opalinus Clay host rock, the EBS and the heater surface) are extensively instrumented to capture the thermo-hydraulic response, by first establishing the initial conditions before heating started and then recording conditions during the heating phase

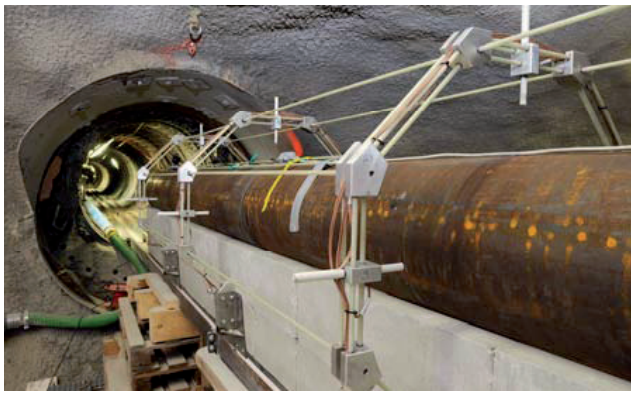

Figure 2. Construction of the instrumentation and liner modules at the microtunnel mouth (Picture Comet Photoshopping Gmbh)

Figure 3. HE-E construction: emplacement of the MX80 pellets in the microtunnel in the Opalinus Clay at Mont Terri using the auger technique (Picture Comet Photoshopping Gmbh).

From the start of the experiment in June 2011 the heater surface temperature increased steadily and a temperature of 80°C was reached at the end of September 2011. At that time a hostrock/EBS temperature of 26°C was reached illustrating the strong temperature gradient within the EBS.

Information from Chinese Partner BRIUG

Deep geological disposal is internationally recognized as the most feasible and effective way to dispose of high-level radioactive waste (HLW). Repositories are generally designed on the basis of a multiple barrier system concept mainly composed of engineered and natural barriers between the HLW and the biosphere. The buffer/backfill material as one of the most important components in the engineered barrier system is the last line of defence between waste container and host rock, and will be subjected to temperature increase due to heat emitted by the waste and hydration from water coming from the adjacent rocks (Gens et al, 2010). The buffer/backfill material is designed to stabilize the repository excavations and the coupled thermo-hydro-mechanical-chemical (THMC) conditions, and to provide low permeability and long-term retardation (Wang, 2010). A bentonite-based material is often proposed or considered as a possible buffer/backfill material for the isolation of the HLW. To guarantee the long-term safety of the engineered barrier, it is necessary to conduct research on coupled THMC behaviours of bentonite under simulative geological disposal conditions, and subsequently to reveal the property changes of the bentonite over a long period of time.

To understand the complex behaviours of the buffer/backfill material located in the coupled THMC environment, in recent years, there has been an increasing international interest in the construction of large-scale mock-up experimental facilities in the laboratory and in situ such as the Long Term Experiment of Buffer Material (LOT) series at the Äspö HRL in Sweden (Karnland et al, 2000), the FEBEX experiment in Spain (Lloret & Villar, 2007), the OPHELIE and PRACLAY heater experiments in Belgium (Li et al, 2006, 2010, Romero & Li, 2010) and the Mock-Up-CZ experiment in the Czech Republic (Pacovsky et al, 2007) etc. The experimental results and achievements obtained from these large-scale experiments provide important references for investigation of the behaviours of bentonite under simulative nuclear radioactive waste repository conditions.

At the present stage, the Gaomiaozi (GMZ) bentonite is considered as the candidate buffer and backfill material for the Chinese repository. Lots of basic experimental studies have been conducted and favourable results have been achieved (Liu et al., 2003; Liu & Cai, 2007a; Ye et al. 2009a). In order to further study the behaviour of the GMZ-Na-bentonite under relevant repository conditions, a mock-up facility, named China-Mock-up, was proposed based on a preliminary concept for a HLW repository in China. The experiment is intended to evaluate THMC processes taking place in the compacted bentonite-buffer during the early phase of HLW disposal and to provide a reliable data base for numerical modelling and further investigations.

The overall approach is based on performing experiments according to the needs for additional studies of key processes during the early EBS evolution. The study will make use, to the extent possible, of ongoing experiments being conducted in the laboratory of Beijing Research Institute of Uranium Geology (BRIUG).

Content of the next Newsletter

The following Newsletter will include an overview of the proposed Regulatory Authority Workshop in April 2012 and the Bentonite Week in October 2012. For more detailed information see the PEBS web site:

http://www.pebs-eu.de

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