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Test plan of the China-Mock-up dismantling operation

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ABSTRACT

Deep geological disposal is internationally recognized as a 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, which is composed of engineered and natural barriers between the HLW and the biosphere. According to the preliminary concept of the HLW repository in China, a large-scale mock-up facility, named China-Mock-up was constructed in the laboratory of BRIUG, a heater, which substitutes a container of radioactive waste, is placed inside the compacted GMZ-Na-bentonite blocks and pellets. Water inflow through the barrier from its outer surface is to simulate the intake of groundwater.

It was assumed that the duration of the China-Mock-up experiment would not be shorter than 4 years. Then, after a cooling period, the experiment will be dismantled and all the available results will be collected and evaluated. The test plan of China-Mock-up dismantling operation is reported. The dismantling process and post-mortem analysis will be conducted according to a detailed schedule to include the scientific program, the sampling plan and the scenarios.

KEYWORDS: High-level radioactive waste (HLW), geological repository, bentonite, lab testing, dismantling, sample taking

1. Background

Deep geological disposal is internationally recognized as a 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, which is composed of engineered and natural barriers between the HLW and the biosphere. In the life cycle of the high-level radioactive waste disposal project, the buffer/backfill 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 understand the complex behaviors of the buffer/backfill material located in the coupled THMC environment, in recent years, there has been an increasing interest internationally 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), FEBEX experiment in Spain (Lloret & Villar, 2007), OPHELIE and PRACLAY heater experiments in Belgium (Li et al, 2006, 2010, Romero & Li, 2010) and Mock-Up-CZ experiment in Czech Republic (Pacovsky et al, 2007) etc. The experimental results and achievements obtained from these large-scale experiments provide important references on investigating the behaviors 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 favorable results have been achieved (Liu et al., 2003; Liu & Cai, 2007a; Ye et al. 2009a). In order to further study the behavior of the GMZ-Na-bentonite under relevant repository conditions, a mock-up facility, named China-Mock-up, was proposed based on a preliminary concept of HLW repository in China (Liu et al., 2011). 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 database for numerical modeling and further investigations.

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

2. The T-H-M-C China-Mock-Up experiment

The China-Mock-up is mainly made up of eight components, namely compacted bentonite blocks, steel tank, heater and corresponding temperature control system, hydration system, sensors, gas measurement and collection system, real-time data acquisition and monitoring system (Fig. 1).

It is assumed that the duration of the China-Mock-up experiment will not be shorter than 4 years. Then, after a cooling period, the experiment will be dismantled and all the available results will be collected and evaluated.

The China-Mock-up experiment was assembled completely on 10th September 2010. The real-time data acquisition and monitoring system has recorded all the measurement data from 1st April 2011. And the heater was switched on to reach a low temperature at 30°C from 1st April 2011 until 8th July 2011. The T-H-M-C experiment was commenced on 8th July 2011, and then the power rises at 1°C/day to reach a maximum temperature at 90°C. In order to avoid potential damage to the sensors by a sudden saturation process, the hydration was initially controlled by a water injection rate which was increased gradually from 400g/day to 1500 g/day in the first stage, and the injection was controlled by a constant pressure at 0.2MPa from 25th August 2013. The injection pressure will be gradually increased to 2 MPa.

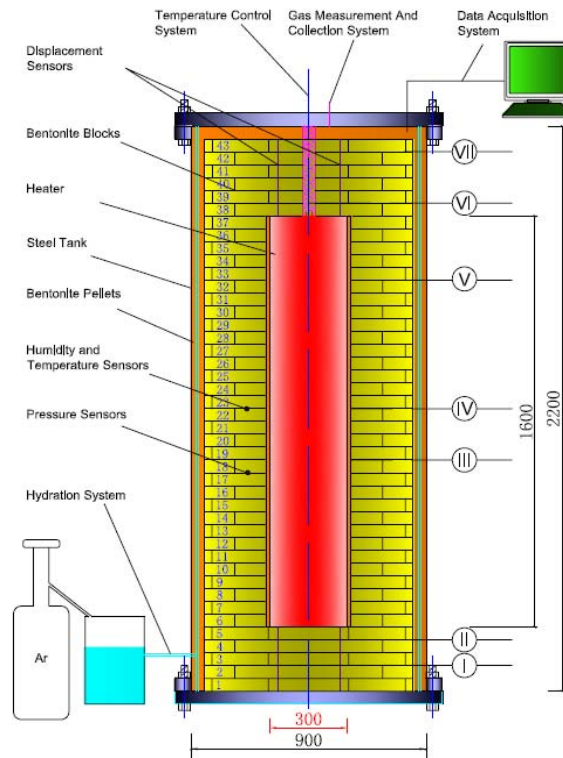


Figure 1 Sketch of the China-Mock-up facility (unit: mm).

3. Dismantling procedure

3.1 Dismantling objective

The course of China-Mock-up experiment provided us with relevant information about long-term behavior of buffer material during the experiment operation. The obtained database is the parametric source for development and precise of mathematical THM model of rheological behavior of buffer material from compacted bentonite blocks.

Another source of information was samples of the bentonite taken by core drilling. Regular drilling enabled the determination of water content profiles and degree of saturation during course of experiment. Taken samples also provided information about change in permeability coefficient, changes in dry density and swelling ability.

From the geotechnical point of view, dismantling will provide especially following information: 1) directly observe the visual information about the state of buffer material and

about corrosion of used materials (sensors, pips and metal samples, etc) after dismantling the upper lid of experimental bin; 2) the analyze of samples taken from buffer material will provide information about the basic physical properties.

3.2 Dismantling operation

3.2.1 Open the experiment bin

Dismantling will be started in specified day and hour. The detailed time and personally strictly organized plan will be followed so as the dismantling will take the shortest possible time.

- 1) Firstly the input of electric power for the heater will be disconnected.
- 2) The inflow of saturating media will be disconnected.
- 3) Interval of reading in data loggers will be changed to 1x at 1 minute.
- 4) The upper lid will be released. All cables from the sensors will not be disconnected if possible.
- 5) The nuts of peripheral bolts will be gradually released. After the full releasing, the upper lid will be moved by crane.

3.2.2 Dismantling of experiment bin content

Bentonite content of experimental bin is formed by 44 layers of compacted blocks. The original assembling height of each segment was 50 mm. Between the wall of cylindrical bin and the barrier from compacted segments there is approximately 5 cm space which was filled with crushed pellets.

After the access to the upper lid, taking samples according to the project will start. Dismantling of the content will be done in all the layers and sampling will be done at the same time. Dismantled sensors will be provided by protective covers since it is decided about their corrosion research or about their recalibration. Samples of metals will be treated in the same way.

3.2.3 Taking samples

Based on the experience from similar foreign projects it is supposed that samples will be taken by two different technologies: core drilling and line mechanical disintegration. Some other way of taking samples may rise from the needs of partner. It can be done when it is technically possible and when it does not negatively affect dismantling project. Core drills

will be oriented vertically and will be done to the compacted blocks. Diameters of core drills are 16 mm and 32 mm. Mechanical disintegration will be done by special wide chisel, by which samples of required shape will be cut. If it is possible the whole segments will be taken out. Samples for water content determination, which require only small weight, will be taken by pips or as a rest from cutting samples.

3.2.4 Samples marking

Each taken sample will be marked according to basic scheme.

A-BBB-CC-D

A- the serial number;

BBB- depth in centimeters, where the sample was taken. The depth ± 0 cm will be defined as the upper edge of experimental bin after dismantling the upper lid;

CC- the distance of taking samples from vertical axis of experimental bin in centimeters;

D- the second polar coordinate of the samples with taking samples time.

For example: 1-100-20-2013.1.1 marks for the first sample taken from depth 100 cm from the upper edge of cylindrical bin, place of taking sample is in 20 cm distance from vertical axis in 1st January 2013.

The detailed description of the sample included information about its shape, dimensions, and history of its thermal loading will be done according to this marking. The database of all samples will be created. Each sample will have its own photo documentation.

3.2.5 Sample protection

Samples taken for water content determination will be immediately weighted with accuracy of 0.001 g and will be placed into the oven. Samples for determination dry density will be weighted and placed into paraffin bath. Other samples for geotechnical tests will be provided with light-protective covering and vacuumed in polyethylene cover. Dismantled sensors and corrosion samples will be protected in the same way. Such treated samples will be placed in special room with stable temperature and relative humidity.

3.2.6 Research performed within dismantling

Research performed within dismantling include basic geotechnical procedures: determination of weight water content, volumetric water content, dry density, atterberg limits, permeability, swell index, swelling pressure, thermophysical properties; microbiology of bentonite; chemical, mineralogical and geochemical research; corrosion analysis;

mineralogical and microstructural analyses; geochemistry and etc.

4. Conclusion

Presented text should become the basic document for work on the multidisciplinary project of China-Mock-up experiment dismantling. The China-Mock-Up experiment is an important milestone of the buffer material study for HLW disposal in China. The observed THMC processes taking place in the compacted bentonite-buffer during the early phase of HLW disposal and the dismantling samples can provide a reliable database for numerical modeling and further investigations of EBS, and the design of HLW repository.

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