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China-Mock-up post-mortem analysis report

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Date of issue of this report:01/03/2014

Start date of project: 01/03/10 Duration: 48 Months

Seventh Euratom Framework Programme for Nuclear Research & Training Activities		
Dissemination Level		
PU	Public	PU
RE	Restricted to a group specified by the partners of the PEBS project	
CO	Confidential, only for partners of the PEBS project	

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ABSTRACT

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 post-mortem analysis of China-Mock-up is reported after dismantling operation. The post-mortem analysis will be conducted according to a detailed schedule to include the scientific program, the sampling plan and the scenarios. Research performed within post-mortem include basic geotechnical procedures: determination of weight water content, volumetric water content, dry density, atterberg limits, permeability, swell index, swelling pressure, thermo-physical properties; microbiology of bentonite; chemical, mineralogical and geochemical research; corrosion analysis; mineralogical and micro-structural analyses; geochemistry and etc.

KEYWORDS: High-level radioactive waste (HLW), geological repository, bentonite, lab testing, post-mortem analysis

1. Background

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 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 from1st 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.

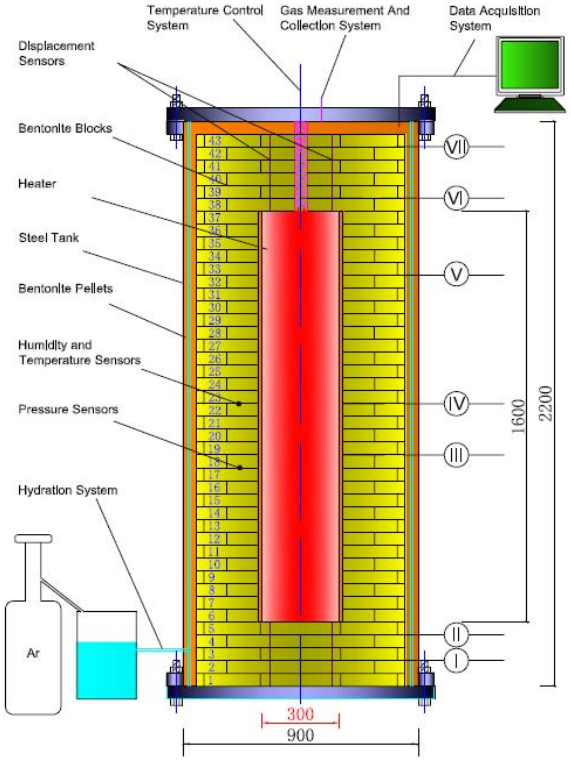

Figure 1 Sketch of the China-Mock-up facility (unit: mm).

2. Analysis procedure

The post-mortem analysis will be conducted according to a detailed schedule to include the scientific program, the sampling plan and the scenarios. Research performed within post-mortem include basic geotechnical procedures: determination of weight water content, volumetric water content, dry density, atterberg limits, permeability, swell index, swelling pressure, thermo-physical properties; microbiology of bentonite; chemical, mineralogical and geochemical research; corrosion analysis; mineralogical and micro-structural analyses; geochemistry and etc.

2.1 Geotechnical procedure

Basic geotechnical procedures include: determination of weight water content, determination of volumetric water content, determination of dry density, determination of atterberg limits, determination of permeability, determination of swell index, determination of swelling

pressure, determination of thermo-physical properties.

They are determined according to Chinese standard for soil test method GB/T 50123-1999.

2.2 Microbiology of bentonite

The goal of the microbiologic programs is to understand which microorganisms contained in ground water can interact with buffer material. The heart of the submitted proposal is to determine the process of works and the survey of methods which aim at finding whether the moist bentonite heated to 90℃ for a long time within the China-Mock-up experiment can contain microorganisms that may have corrosive effects on metallic materials in the designed radioactive waste repository.

1-2 g bentonite will be taken with a sterile hollow drill from every place twice in minimum 10 localities to be determined by temperatures occurring in a bentonite block during operation. Preliminary tests will be conducted to determine the total numbers of single physiological groups of bacteria and identificate the total numbers of single physiological groups of bacteria.

2.3 Chemical, mineralogical and geochemical research

Goals in the field of mineralogical, chemical and geochemical research of samples obtained from the China-Mock-up dismantling are summarized into the following tasks of evaluation of changes of properties of bentonite:

1) Determination of mineralogical changes of a source material at its long term loading;

2) Evaluation of equilibrium states between experimental mixture and aqueous environment;

3) Kinetics of equilibrium setting, determination of sensitivity of the system towards changes of external conditions;

4) Description of geochemical changes of the system in dependence on temperature and pressure gradient;

5) Determination of changes and main causes of corrosion effect of source mixture on samples of metal materials;

6) Obtaining of solid data in the field of mineralogical, chemical and geochemical study with application of geotechnical characteristics for model evaluation of stability of studied material and changes of basic system parameters from a point of view of its application as a

buffer material.

Samples taken using core drilling or line mechanical disintegration are needed in amount of 500 g. Sorption and diffusion experiments are conducted to evaluate the behavior of bentonite.

2.4 Corrosion analysis

The aims of corrosion studies of the samples obtained from China-Mock-up dismantling procedure are summarized in the following items of corrosion- state evaluation for the metal samples placed in the bentonite:

1) Visual assessment of corrosive layers both on steel and copper samples taken from the barrier, as well as on sections taken from steel jacket using digital still camera and optical microscope equipped with a camera connected with computer, to describe in details the homogeneity of layers, to estimate the thickness of corrosive layers and to notice their colors;

2) Identification of corrosive products, both on steel and copper samples taken from the barrier using laser Raman spectroscopy, micro-spectroscopy and X-ray diffraction;

3) Identification of corrosive products on samples taken from the steel jacket by means of Raman spectroscopy and X-ray diffraction;

4) Morphological description of corrosive layers, both on steel and copper samples using scanning electron microscopy;

5) Elemental microanalysis of corrosive layers, both on steel and copper samples using electron microprobe;

6) An integrated description of the set of tested corrosion samples with respect to their position in the barrier or at the steel jacket and with particular attention to their distance from the heating device;

7) Deduction of key influences that determine corrosion process, both inside the barrier and on the steel jacket.

For the necessary knowledge of both the molecular (structural) and elemental composition of corrosive layers on samples from the bentonite it is essential to combine various analytical methods.

Raman spectroscopy and micro-spectroscopy together with results of X-ray diffraction measurements make possible to identify various types of oxides, hydroxides or oxy-

hydroxide as well as other probable compounds in corrosive layers on the surface of the metals.

Scanning electron microscopy allows morphological description of the structure of corrosive layers.

Electron micro-probe provides us with data on elemental composition of corrosive layers.

The combination of above mentioned methods give a more complete description of corrosive layers on individual samples taken from different parts of the barriers. Consequently, we can find out relations of the corrosion processes with the proposed influences of temperature, pressure and/or humidity in individual parts of the barrier at different places of the experimental bin.

2.5 Mineralogical and microstructure analysis

This project aims to study phase transformation and micro-structural modification of bentonite used in the buffer zone during the China-Mock-Up experiment. It is expected that period of 4 years during which the period was run, is sufficient to cause measurable changes in the smectite mineralogy and micro-structural changes. Both parameters are essential for other physical and physico-chemical characteristics as these are vitally connected to the smectite content. Obtained results thus will provide important information on the mineralogical and structural stability of GMZ bentonite under conditions of the China-Mock-Up experiment.

Crystalline phases will be studied by powder X-ray diffraction analysis; Semi-quantitative mineralogy will be determined using the CQPA recalculation program; the thermo-analytical methods belong to standard methods used in mineralogy; Parameters characterising the porous structure of studied materials will be obtained from the sorption analysis using the SORPTOMATIC 1800 apparatus; The microscopic structure of bentonite samples influenced by temperature will be studied using a scanning electron microscope in connection with an energy dispersal micro-analyser; infrared spectrometry will be conducted for the clay samples.

2.6 Geochemistry

One of the critical point in the estimation of long term stability of barrier material bentonite

is, if the bentonite at the particular conditions of high radioactive waste disposal sealing, realized in China-Mock-Up experiment, reached equilibrium with water phase.

In principle, there are three possible eventualities in bentonite interactions with surroundings during China-Mock-Up experiment, which have crucial meaning for long term stability of waste disposal sealing: 1) there are no changes and no interactions with water environment; 2) there is gradual dissolution of bentonite till the stage of full saturation of water phase with respect to the bentonite; 3) there is gradual dissolution of bentonite till the stage of stationary state.

Samples of bentonite from buffer material acquired at China-Mock-Up dismantling at selected points. More than 30 samples will be used for geochemical research. Pore water from selected samples (around 30 samples) will be leached and centrifuged without contact with air. Main parameters for water phase will be measured (pH, Eh, conductivity). Leachate will be analyzed for main components.

3. Conclusion

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.

4. References

The National Standards Compilation Group of People's Republic of China., 1999. GB/T 50123-1999 Standard for soil test method [S]. Beijing.