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# EBS Performance Demonstration: 1st Stage R&D Results of Development of Long-term Safety Evaluation Technology of Engineered Barrier System

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## 1. Introduction

Performance demonstration of engineered barriers system (EBS) greatly decreases the uncertainty of the long-term safety of a deep geological repository (DGR) for high-level waste and increases public confidence. Therefore, the in-situ performance of EBS should be validated in an underground research laboratory (URL) which has a similar geological condition with its own national DGR concept. KAERI is carrying out national R&D project for developing key element technologies for in-situ demonstration of EBS performance prior to URL demonstration phase in the national SNF management program [1] [2]. In this paper, the EBS performance demonstration experiments and related design contents conducted in the first stage of the project ('21~'23) were introduced, focusing on the interaction between engineered barrier components.

## 2. Results

Regarding the engineered barrier performance demonstration experiments conducted in the first stage ('21~'23) and related design contents, the interactions between components expected in the disposal environment could be divided into buffer-canister interaction, buffer-backfill material interaction, and buffer-near field rock interaction.

### *2.1. Characterization of the interaction of buffer and canister*

Through the identification of the characteristics of the buffer-canister interaction, the effect of the corrosion product on the performance of the buffer material was evaluated.

#### 2.1.1. An experiment on the interaction characteristics of corrosion products in buffer and canister.

In the first stage, a module was manufactured for securing DB for the buffer material-canister corrosion product interaction characteristics, establishing a lab test device, and long-term field demonstration. In the first year, a module for long-term field demonstration and an lab test device were designed in addition to investigating the characteristics of the buffer material-canister corrosion product interaction and securing DB. In the second year, a preliminary test was performed by manufacturing a field demonstration module and an lab test device for evaluating the characteristics of the buffer material-disposal canister interaction. In the last 3rd year, the field demonstration module was installed into the deep borehole, and the effect of the aerobic corrosion product on the buffer material performance was evaluated using the manufactured test device. To this end, a lab test device for the buffer material-canister corrosion product was constructed, and a corrosion chamber for long-term anaerobic environmental corrosion tests was installed in KURT.

Fig. 1. Experimental device for buffer-corrosion product interaction

#### 2.1.2. An Experiment on the characteristics of interaction gas transfer between buffer and canister.

In the first stage, the factors affecting the gas movement phenomenon in the buffer material were analyzed through literature research, and based on this, a device was designed and constructed to perform a laboratory-scale gas injection experiment. In addition, a gas injection experiment was conducted using the constructed equipment. The experimental equipment consists of a pressure cell capable of withstanding a gas pressure of about 20 MPa or higher and a pipeline system capable of injecting gas and water into a high-pressure cell.

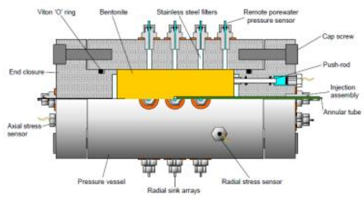


Fig. 2. Conceptual design of gas injector

*2.2. Characterization of buffer-backfill material interaction*

Since the bentonite buffer block and the backfill material have different dry densities, different swelling pressures are caused during the operation process of the disposal site, and changes of the dry density are expected due to interactions. Therefore, it is necessary to understand the changes in dry density of the buffer block and the backfill material due to THMC composite behavior and interaction over a long period of time, and a system that can analyze and predict this is essential.

2.2.1. Experiments on the characteristics of buffer-backfill material heterogeneous interactions.

After deriving the factor influencing the buffer-backfill material heterogeneous transition characteristics, a lab test device was constructed to identify the transition characteristics, and a DB for heterogeneous transition characteristics was constructed by performing tests. The detailed results of this are as follows.

Factors affecting the characteristics of buffer-backfill material heterogeneous transition were derived.

A laboratory-scale experimental device for the characteristics of a buffer-backfill material heterogeneous transition was constructed.

Experiments on heterogeneous transition characteristics between buffer-backfill materials were carried out and DB was constructed.

Bentonite behavior according to heterogeneous transition influencing factors was characterized using X-ray CT.

Heterogeneous transfer characteristics visualization and quantification techniques using X-ray CT were developed and verified.

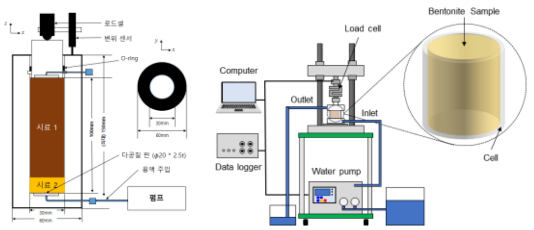


Fig. 3. Experimental device with buffer-backfill material heterogeneous transition characteristics. a. conceptual diagram, b. swelling behavior measurement system

*2.3. Characteristics of buffer-near-field rock Interaction*

It is essential to identify the erosion and piping of the buffer material caused by the groundwater flowing from the joints of the near-field rock, and to evaluate the integrity of the buffer material in the event of erosion/piping of the buffer material.

2.3.1. Evaluation of the integrity according to the occurrence of erosion/piping of buffer materials.

In the first stage, the current status of the buffer material erosion and piping characteristics evaluation research considering the buffer material-near-field interaction was analyzed, and based on this, an lab experiment device for piping and erosion simulation of buffer material (backfill material) by groundwater flowing through the joints of the near-field rock was designed and manufactured, and lab experiments were conducted according to the physical properties of the joints and groundwater. The construction status of the experimental equipment related to this is as follows.

Experimental equipment for evaluation of erosion characteristics of buffer materials: In order to carry out the most widely used artificial joint experiment for the bentonite buffer erosion experiment, the test device was constructed, and the erosion characteristics of the bentonite buffer according to the dry density, groundwater flow rate, and the buffer were preliminarily evaluated.

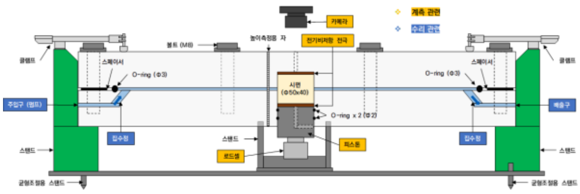

Fig. 4. Design of artificial joint experimental equipment

In order to more clearly confirm the penetration behavior of the buffer in the absence of flow and perform chemical analysis through sample acquisition, additional buffer penetration experimental cells were designed and manufactured to compare the penetration pattern of the buffer according to the shape of the buffer, cation concentration, joint gap, and angle.

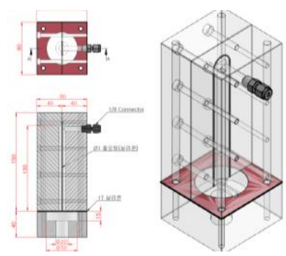

Fig. 5. Buffer penetration experimental equipment

Experimental equipment for the evaluation of buffer piping characteristics: In order to simulate the phenomenon in which the pressure accumulates when a constant flow rate is injected and then the piping channel occurs when a certain pressure is exceeded, a piping-induced experiment site was constructed and related experiments were carried out.

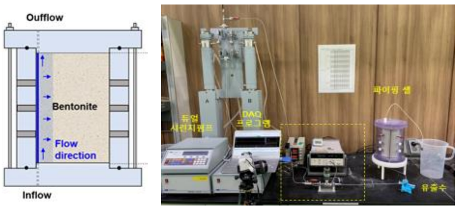


Fig. 6. Experimental equipment for the evaluation of buffer piping characteristics

2.3.2. Evaluation of interaction characteristics of buffer-near-field rock joint behavior.

In the first stage, an engineered barrier coupled behavior/interaction experiment was conducted considering intact rock and disposal conditions, including the construction of buffer-jointed rock long-term integrity test equipment. In the first year, a lab experiment was conducted to evaluate the long-term integrity of the jointed/intact rock, and in the second year, a experiment to evaluate the long-term integrity of the near-field was conducted. In the third year, in connection with the lab buffer experiment-based evaluation of the long-term evolution characteristics of the jointed-near-field rock, a lab experimental device was designed and constructed to evaluate the interaction characteristics between the buffer-near-field rock, and the influence factor analysis and experimental conditions that could affect the behavioral characteristics of the joint rock were designed. The status of the construction of the experimental device related to this is as follows.

MTS 816 Rock Testing System: An MTS-816 experimental system capable of instantaneous pressure test was established because intact rocks and buffer suitable for disposal systems must have a low permeability coefficient

Fig. 7. MTS 816 rock testing system for long-term integrity assessment of joint rock

Hookcell and servo control hydraulic unit: Hook cells and servo control hydraulic units were designed and constructed to perform mechanical and hydrological tests under three-axis compression test conditions.

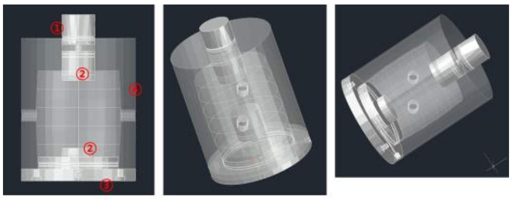

Fig. 8. Conceptual design of Hookcell and servo control hydraulic unit

Divided-bar thermal conductivity measuring equipment: The divided-bar equipment constructed in the first stage was manufactured based on a static method and consists of a main frame including a constant temperature chamber and a copper plate for measurement, a constant temperature circulation water tank, a temperature sensor, and a data collection device.

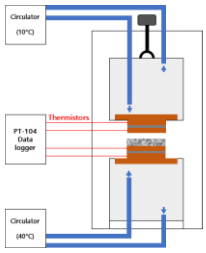


Fig. 9. Conceptual diagram of Divided-bar device

## 3. Conclusions

The EBS performance demonstration experiment performed in the first stage and the related design results were introduced focusing on identifying the interaction characteristics between EBS components. After that, through the second and third stages, TRL 5-level system prototype production, performance evaluation experiments, and performance demonstration test design for this will be carried out.

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