Priority Subjects — **Establishment of Optimal Risk Management**

Development and Systematization of Long-Term Safety Assessments

Background and Objective

For the smooth disposal of the radioactive waste being generated by nuclear power plants, operations must focus on securing safety. As storage capacity of the low-level radioactive waste (LLW) in nuclear plants is growing tight, the licensing safety of pit and sub-surface disposal require review based on a planned schedule. Moreover, in regards to high-level radioactive waste (HLW), the Japanese government is engaged in various efforts such as investigating direct disposal, securing safety in the future, the systemization of site selection and so on.

In this project, R&D of LLW disposal aims to develop methods to evaluate the variation in long-term quality and durability of engineered barriers in order to build a reliable technology. R&D of HLW disposal aims to develop methods to evaluate the long-term stability of the geological environment of a disposal site from the surface.

Main results

1 Evaluation of the durability of a bentonite-based engineered barrier

In radioactive waste disposal facilities, bentonite-based engineered barriers are mainly used for inhibiting the migration of radioactive nuclides. However, since gas permeability of the barrier is very low, it is necessary to evaluate the effect of hydrogen gas pressure, which is generated inside the barrier by anaerobic metal corrosion. Gas migration tests and their numerical simulations are conducted using computer code originally developed by CRIEPI. It was proved that the gas migration tests can be estimated with good accuracy using the computer code (Fig. 1).

The bentonite-based engineered barrier can be altered by alkaline solution leaching from cementitious materials and, as a result, its performance may be affected after a prolonged period. At CRIEPI, we have investigated the mineralogical alteration and the change in permeability of the compacted bentonite under alkaline conditions (Fig. 2). These results were systematically summarized, and future issues were clarified concerning the reduction of uncertainty in the long-term assessment of bentonite properties (N20).

2 Improvement of age estimating method for evaluation of long-term geological stability

Evaluation of long-term uplift is performed as part of the evaluation of geological stability during the selection of HLW disposal sites. It is necessary to estimate the ages of terraces with a sufficient reliability as a criterion of the evaluation. Weathering indexes, such as weathering rind thickness and efficient porosity of terrace gravels, vary greatly, making it difficult to obtain reliable age data. To solve this problem, the application method was revised by careful limiting observation and sampling horizons in a terrace gravel bed. This revision made the weathering index more reliable and applicable to terrace correlation (Fig. 3).

3 Evaluation of long-term behavior in the near-field of a disposal repository

To clarify the long-term behavior of the bedrock and buffer material in the near-field of a disposal repository at the closure stage, centrifugal model tests for which a time-acceleration effect can be expected, have been performed by CRIEPI. The new model test, which considers the heat generation of the HLW, was conducted at a centrifugal force field of 30 G using a 1/30 scale model with a confining pressure of 6 MPa (corresponding to 300 m in depth) and a waste temperature condition of 95°C for 80 d which is equivalent to around 200 years. The result suggested that water distribution in the buffer changes by the influence of the heating of the model waste (Fig. 4). Hence, we will perform further experiments to evaluate the long-term geomechanical behavior in the near-field, by comprehensively considering the coupled thermo-hydraulic-mechanical interaction.

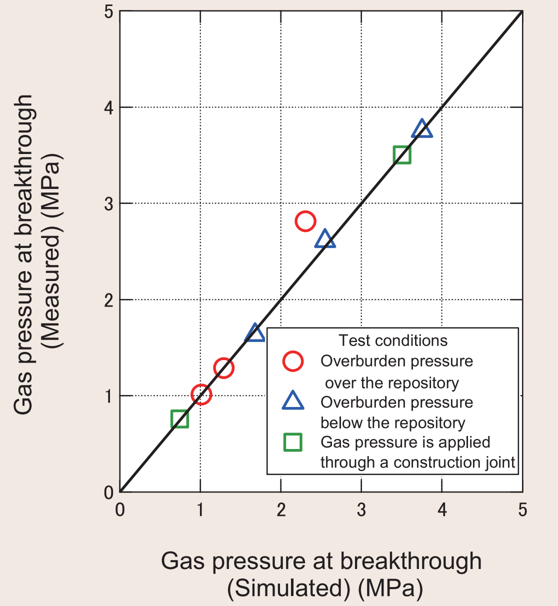

Fig. 1: Relationship between measured and simulated results of gas pressure at breakthrough

In the gas migration tests, overburden pressure right below the repository or right over the repository was applied to the specimen to investigate the effect of overburden pressure on the gas migration characteristics of compacted bentonite. Gas migration tests were also conducted using a test apparatus with a small gas inlet in order to observe the effect of inlet size on test results. Numerical simulation of these test results was conducted using computer code was originally developed by CRIEPI. Fig. 1 shows that the test results can be accurately simulated using CRIEPI's code.

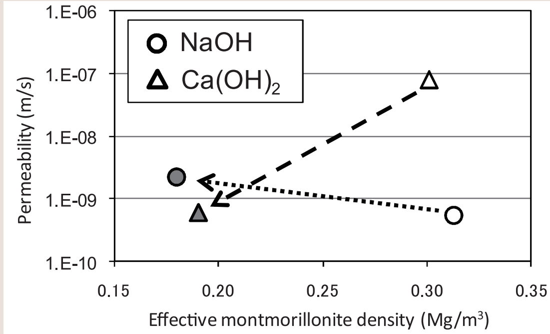

Fig. 2: Change of effective montmorillonite density and permeability of compacted bentonite-sand mixture during a permeability test using NaOH and $Ca(OH)_2$.

The alteration behavior and change of permeability of bentonite-sand mixture (15 wt% of bentonite) were investigated. In the test using NaOH, the permeability of the sample increased as the effective montmorillonite density decreased. In the test using $Ca(OH)_2$, although the effective monnmorillonite density decreased, the permeability of the sample decreased by more than two orders of magnitude due to the pores of the sample becoming blocked with C-S-H precipitation.

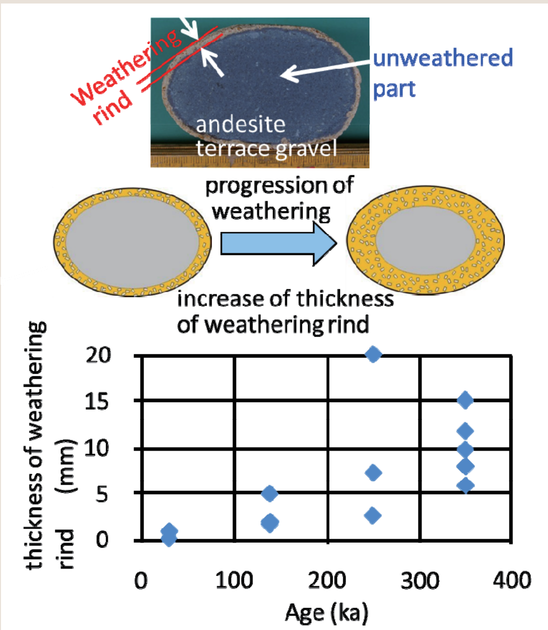

Fig. 3: Relationship between thickness of weathering rind of andesite terrace gravel and terrace age

Weathering rind of andesite terrace gravel thickens with the passage of time. Therefore weathering index enables age to be estimated by the relative sequence of terraces on particular kinds of gravel.

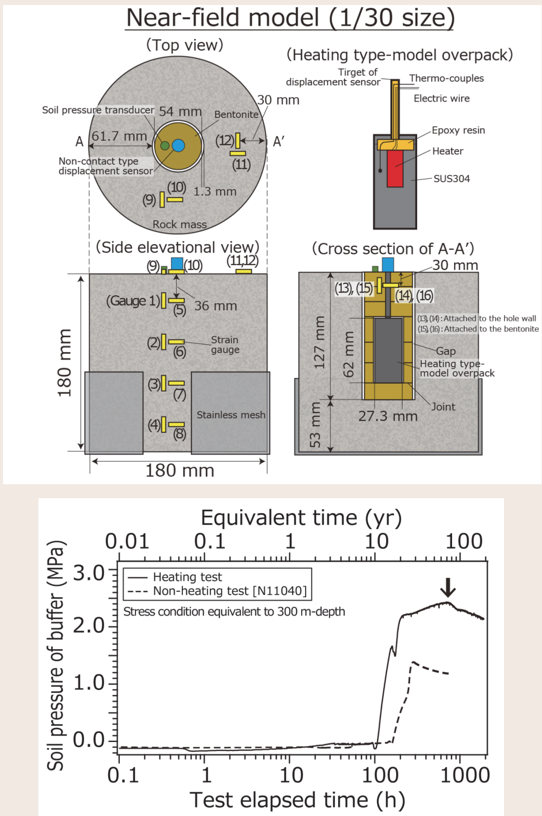

Fig. 4: Long-term centrifugal near-field model test which considers the heat generation of the HLW

The result of a centrifugal near-field model test under "non-heating" and stress-constraint conditions showed that the soil pressure of the bentonite buffer increased rapidly after around 100 h in the elapsed test time, then tended to decrease (dash line). The tendency toward a decrease was interpreted to deform the bedrock and the disposal hole. In contrast, the value of the soil pressure under "heating" and same stress conditions changed to a decrease tendency at the arrow in Fig. 4 (solid line). The flow rate of the injection water also changed at that time. It is inferred that the water distribution in the buffer changes due to heating of the model waste.