A study on swelling and gas migration behaviour of the bentonite layer in a Japanese subsurface disposal facility for radioactive waste

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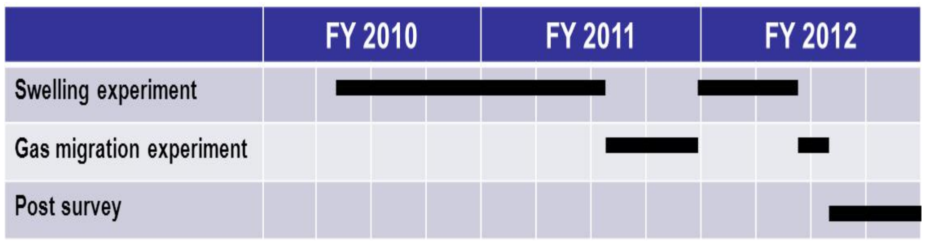
Background

In Japan, core internals and operational wastes containing relatively high concentrations of radioactive materials are planned to be disposed of in subsurface disposal facilities. These wastes also contain small concentrations of long-lived radionuclides. This disposal is planned in a cavern-type facility constructed below 50m underground. Here wastes are surrounded with low diffusivity concrete and a low permeability bentonite layer to limit interaction between the waste and groundwater. For this disposal system, it is important to confirm the stability of barrier system under stress from the swelling pressure of the bentonite and hydrogen gas pressure generated by corrosion of metallic waste.

Experiment

To gain understanding of the swelling and gas migration behaviour of the bentonite layer, JNES has carried out experiments in an engineering scale model, which has one fifth the thickness of the bentonite layer in the disposal facility. These ran for three years from FY 2010 through FY 2012 (Table 1). In the experiments, we simulated groundwater flow permeating the disposal facility and gas flow generated by corrosion of metals an illustrated in Fig. 1.

Table 1 Time schedule



	FY 2010				FY 2011				FY 2012			
Swelling experiment		■	■	■	■	■	■		■	■		
Gas migration experiment							■	■		■	■	
Post survey											■	■

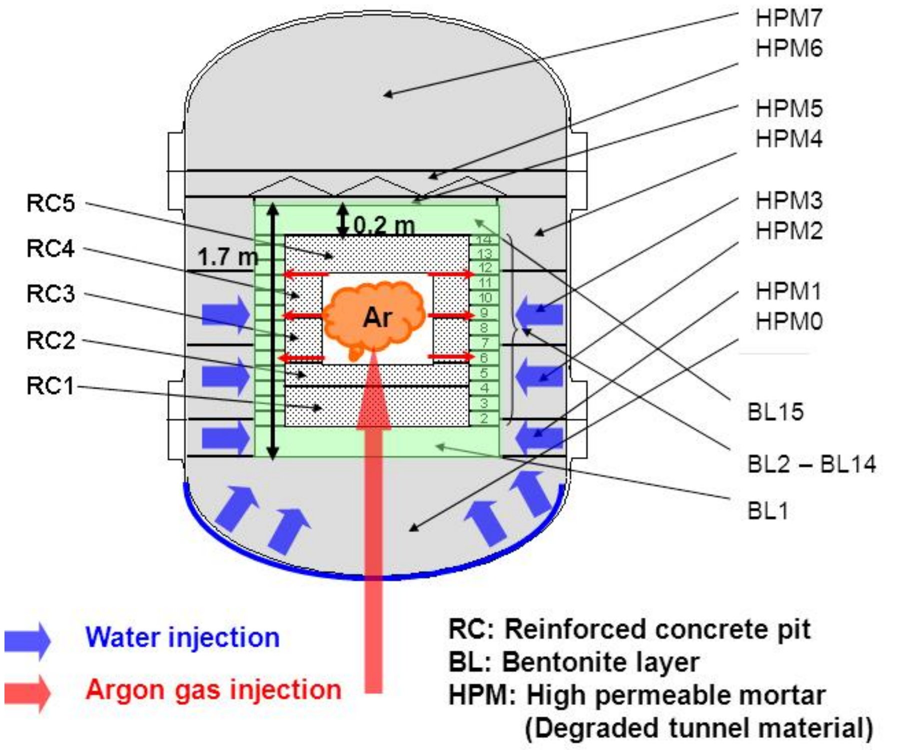


Fig.1 Concept of the engineering scale model of the bentonite layer in the disposal facility

Results

In the swelling experiment, the pore pressure and total pressure on saturation of the bentonite layer were obtained. We simulated the degree of saturation of the bentonite layer by a two-phase flow analysis, as shown in Fig.2, which is consistent with the saturation profile obtained by TDR (Time Domain Reflectometry). Also the gas breakthrough was observed as shown in Fig.3. As gas injection continued after gas breakthrough, the internal pressure of the bentonite layer increased to balance the external pressure. It was suggested that gas flow paths in the bentonite layer opened by gas breakthrough tend to re-seal with the drop of gas pressure after the breakthrough. While we gas breakthrough paths were indicated by a change in external TDR responses over time as indicated in Fig.4, we could see no clear traces of this path by post experimental surveys.

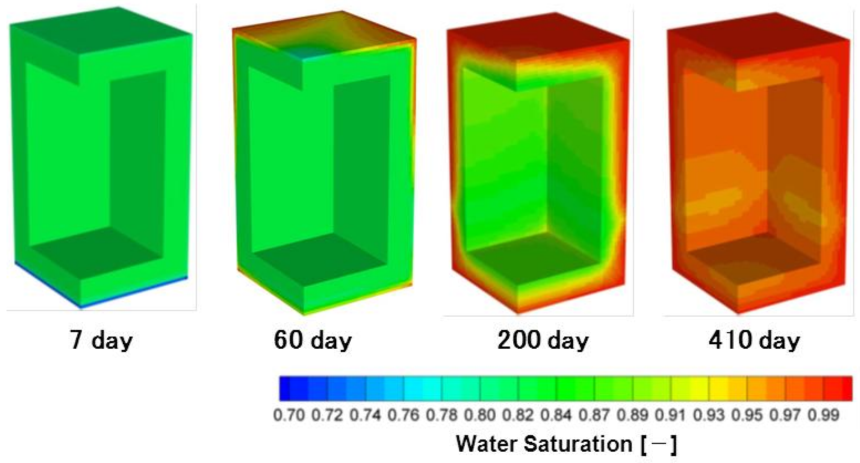


Fig.2 Simulated saturation distribution in engineering scale swelling experiment (FY2010 - FY2011)

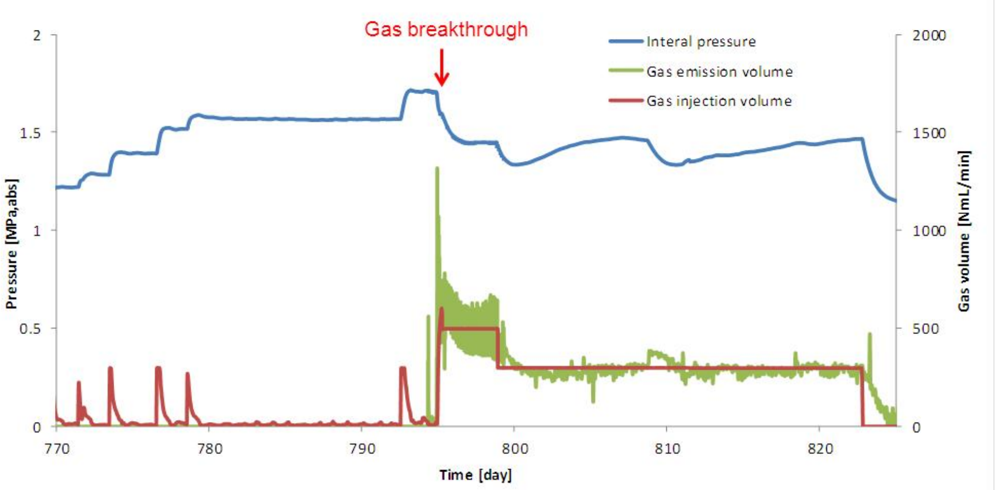


Fig.3 Internal pressure, gas injection volume and gas emission volume in the engineering scale gas migration experiment (FY2012)

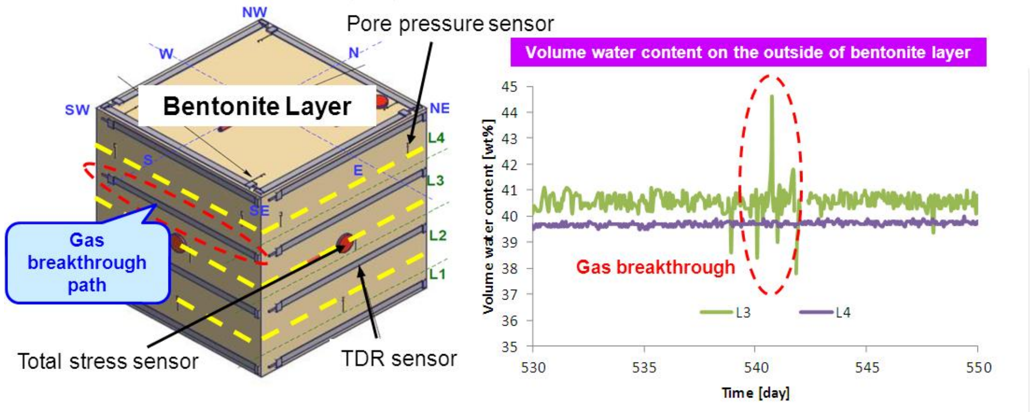


Fig.4 Evidence of the gas breakthrough path (FY2011)

Conclusions

It is found that similar swelling pressure is generated on all bentonite side layers, the same gas breakthrough pressure was generated by two gas migration experiments and the breakthrough path is sealed with the gas pressure decrease, with the initial properties of the bentonite layer (low permeability) recovered after sealing.

In future, we are going to identify gas breakthrough paths by analytically simulating the gas migration behaviour of the engineering scale model data.

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