

**RESEARCH ACTIVITIES AT RWMC
ON THE BENTONITE RESATURATION PROCESS**

**(3) A BOX-TYPE CELL EXPERIMENT
TO EVALUATE BUFFER MATERIAL HOMOGENIZATION
DURING THE PROCESS OF SATURATION**

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RESEARCH ACTIVITIES AT RWMC

Resaturation Project;

- ✓ The objective is the evaluation of effect of phenomena which will occur in the bentonite barrier during resaturation period on the long term performance of bentonite barrier.
- ✓ The evaluation methods were laboratory tests, in-situ tests and numerical analysis.

(1) OVERVIEW

(2) LABORATORY AND NUMERICAL EVALUATION

(3) A BOX-TYPE CELL EXPERIMENT TO EVALUATE BUFFER MATERIAL HOMOGENIZATION DURING THE PROCESS OF SATURATION

A BOX-TYPE CELL EXPERIMENT



■ Objective of the box-type cell experiment

The objective is the experimental evaluation of how groundwater permeates buffer materials and how the materials are homogenized by swelling.

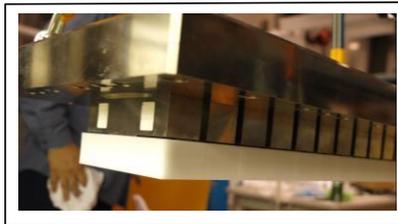
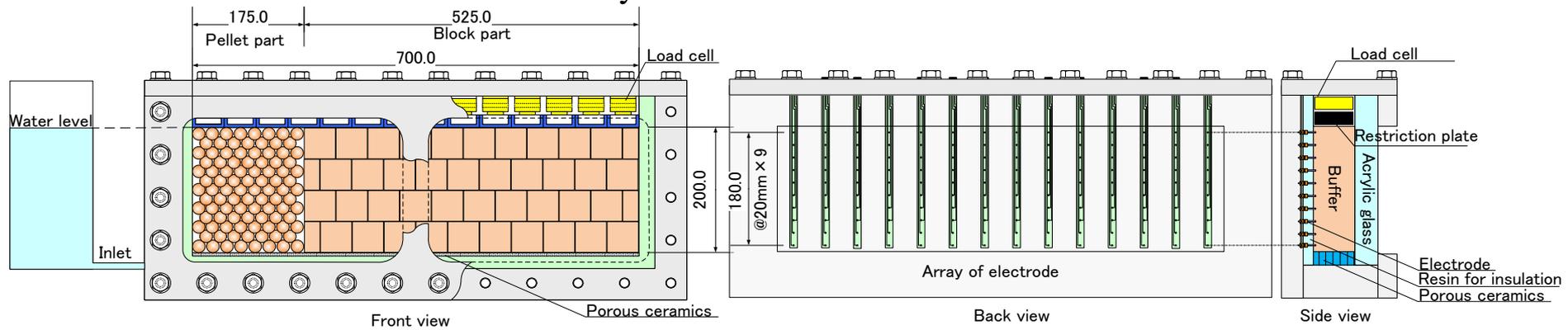
In order to consider the buffer materials with the dry density distribution due to construction, not an element scale test but a medium scale test such as a box type cell test was conducted.



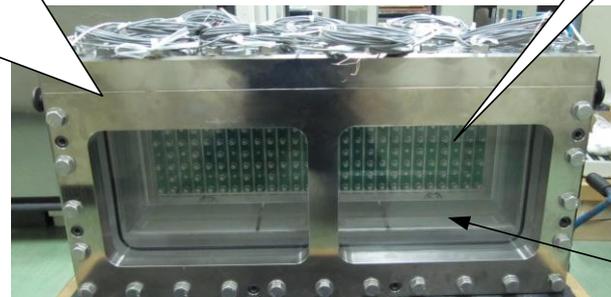
168 bentonite blocks

■ Apparatus

- ✓ Specimen size: 700 mm in width, 200 mm in height and 150 mm in depth
- ✓ Water or NaCl water solution was fed from the bottom with a 20-cm water head difference.
- ✓ The liquid was fed not to flow through but to keep the water level on the top surface of the specimen.
- ✓ The 14 load cells were set in a line between the specimen and the upper lid
- ✓ The 127 electrodes were set in an array on the back panel of the cell to allow the degree of saturation to be estimated from measured resistivity.



A row of load cells



Empty box-type cell

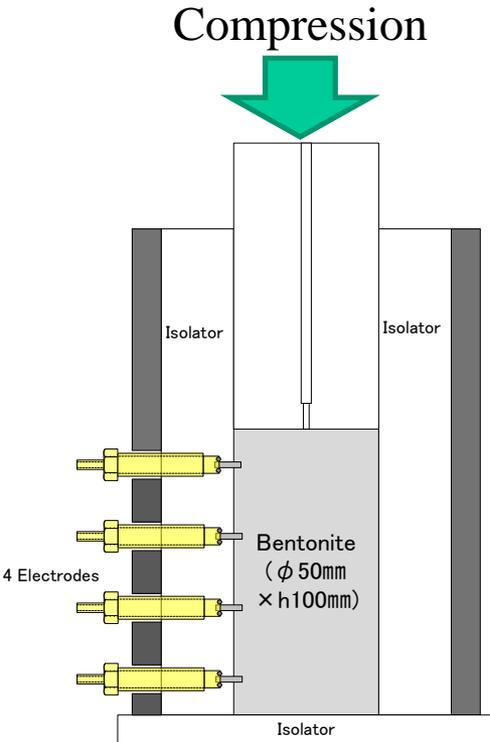


Electrodes on the back panel

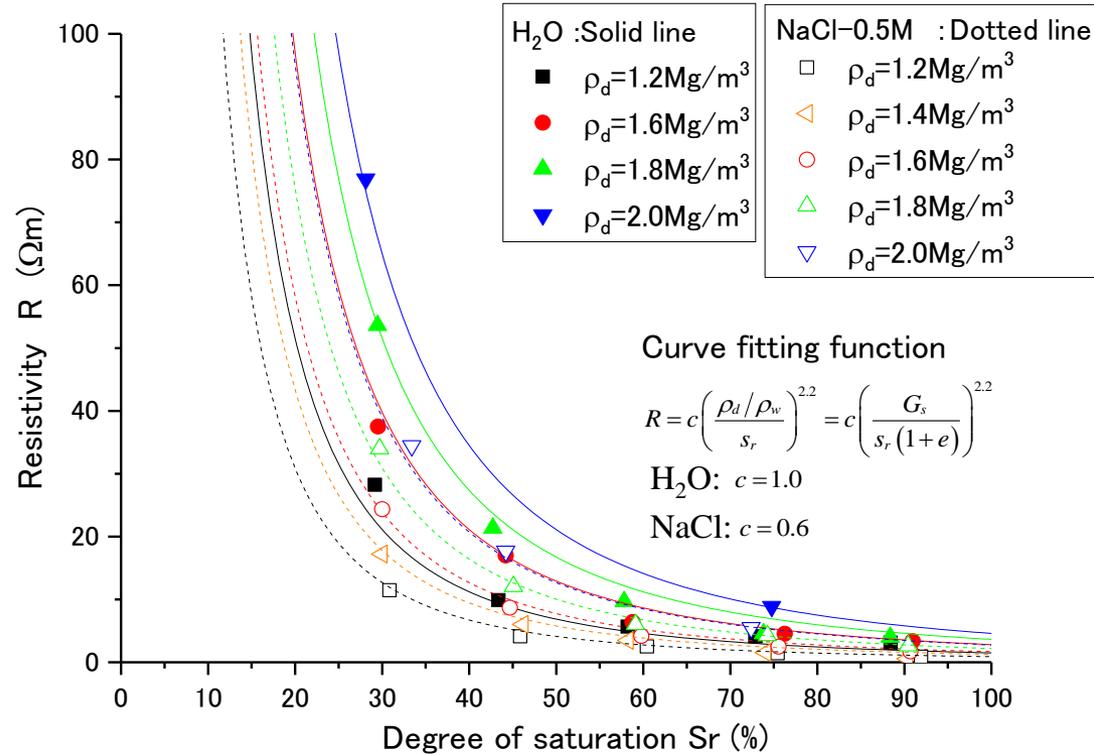
Porous disk

Resistivity and degree of saturation

- The relationship between the resistivity and degree of saturation was obtained in advance.
- The resistivity of bentonite of which water content was adjusted was measured continuously during compression.
- The Wenner's four electrodes method was applied to measurement of resistivity.



Alternate current
1mA, 1kHz of sine wave

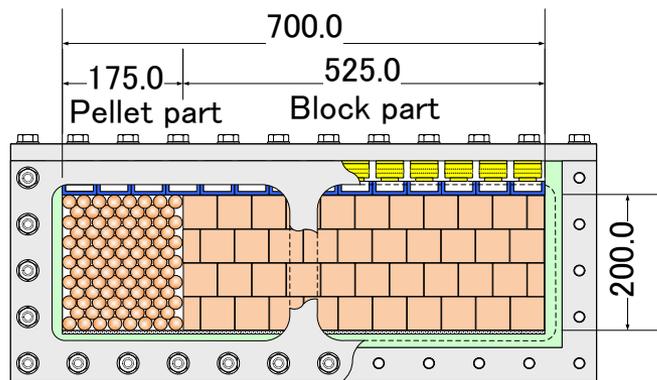


■ Test cases

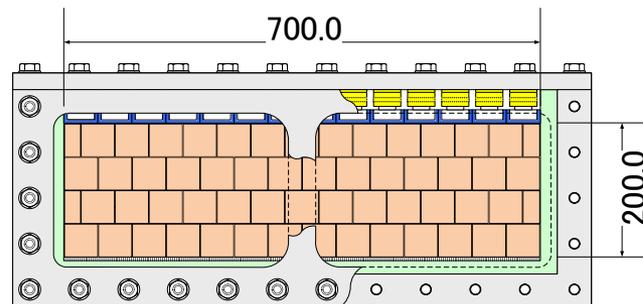
Specimen	Liquid fed	Bentonite block	Pellet	Initial bulk dry density Mg/m ³		Initial water content (Degree of saturation)	
				Block	Pellet	Block	Pellet
Block and pellet	Distilled water	Kunigel V1* with 30wt% of silica sand	Kunigel V1	1.567	1.055	9.94 (36.7)	8.57 (55.3**)
	NaCl water solution (0.5 M)			1.600	1.100	11.0 (43.2)	8.57 (55.3**)
Block	Distilled water				1.566		9.74 (36.3)

* Japanese Na bentonite, The montmorillonite content is approximately 60wt%

** Degree of saturation of each pellet



Block and pellet



One block : 50mm × 50mm × 50mm

Block

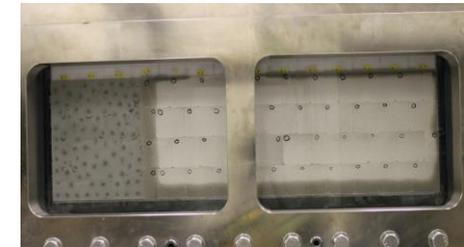
■ Comparison between photo observation and resistivity measurement

- ✓ NaCl water solution filled the gaps of the pellet part first.
- ✓ NaCl water solution permeated block part from the bottom and the pellet part.
- ✓ The temporal changes in distribution of the degree of saturation calculated from resistivity were consistent with the observation results.

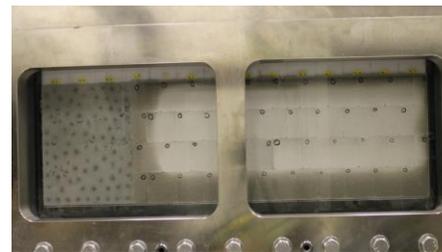
(Block and Pellet+NaCl water solution)



The beginning of feeding NaCl solution



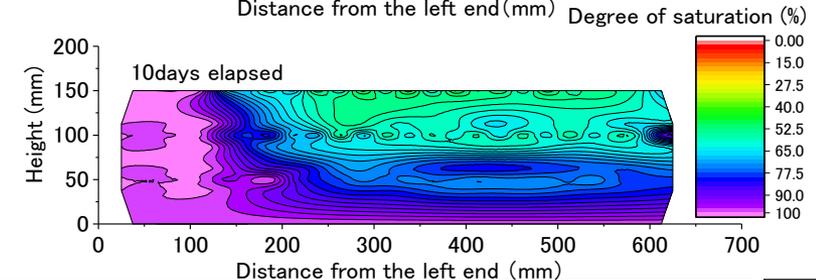
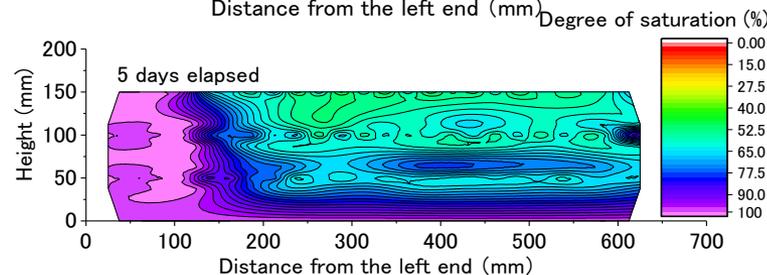
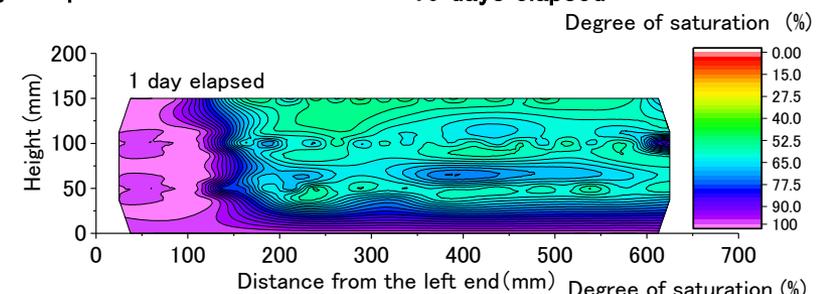
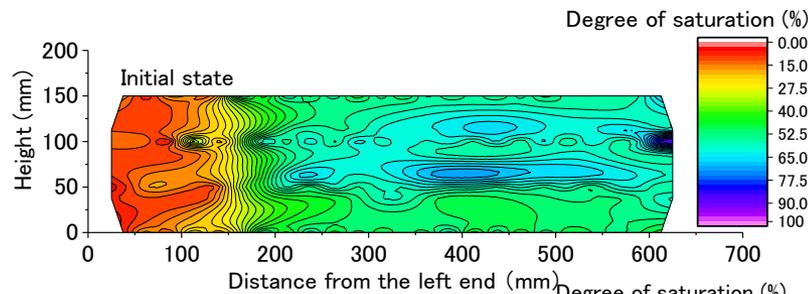
1 day elapsed



5 days elapsed

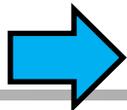
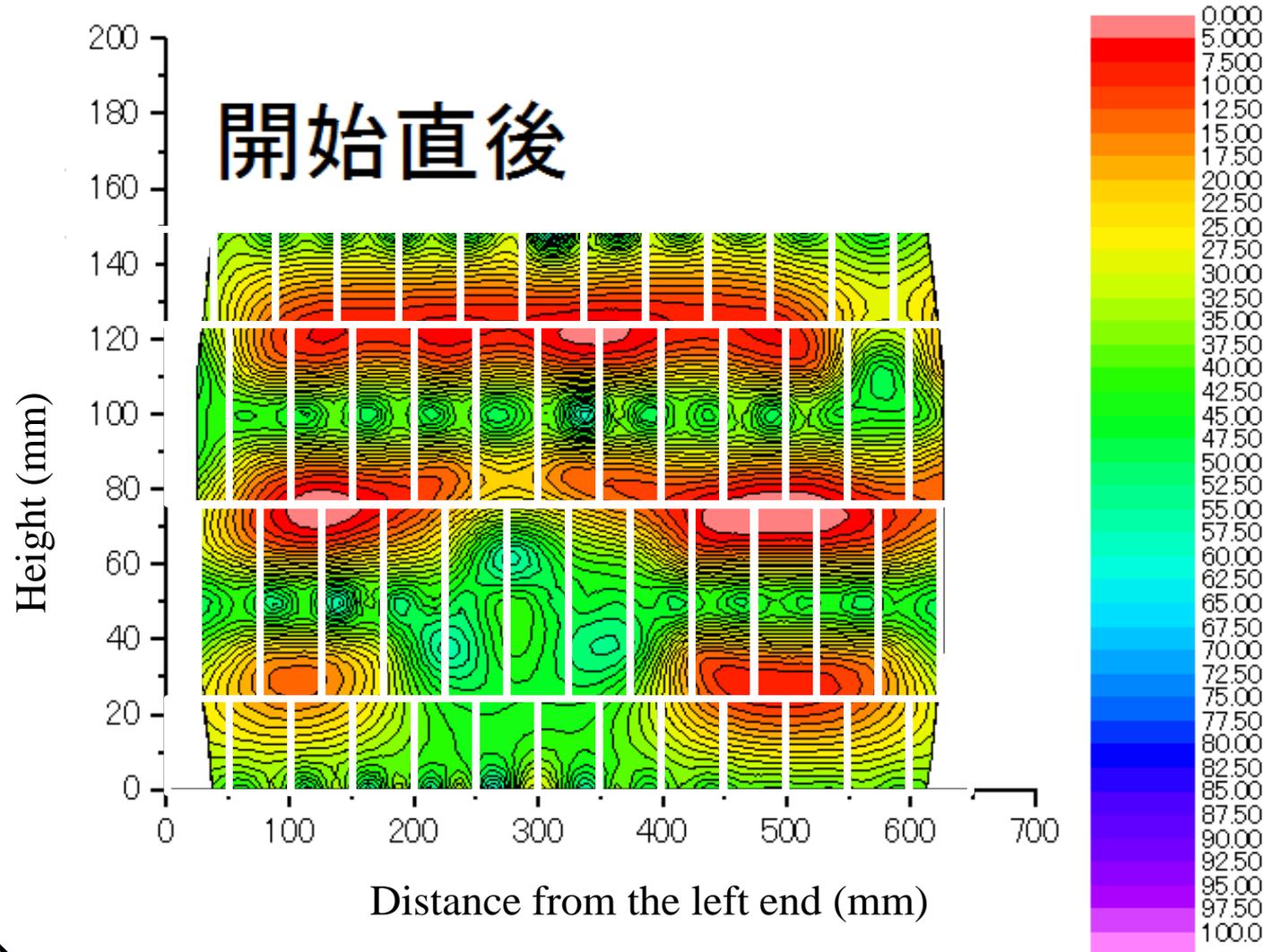


10 days elapsed



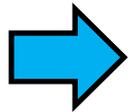
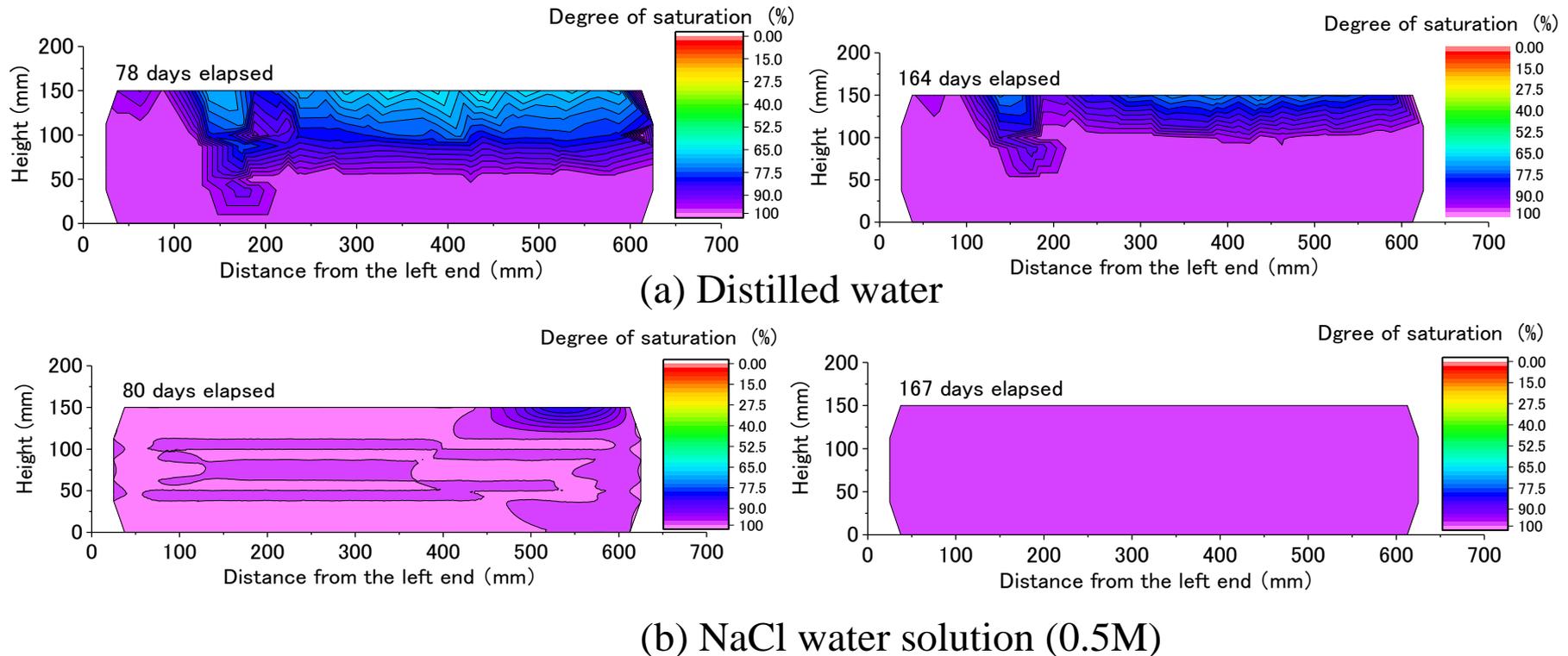
■ Transition of distribution of degree of saturation (Block + distilled water)

Degree of saturation (%)



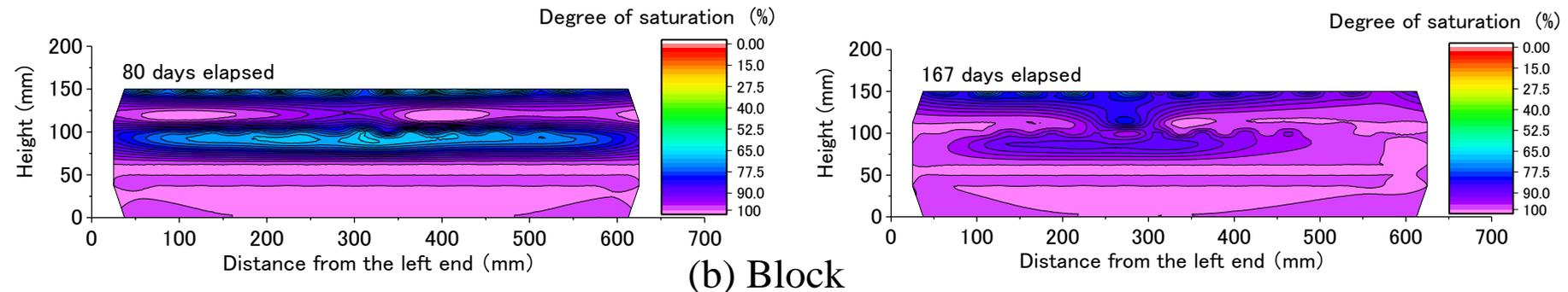
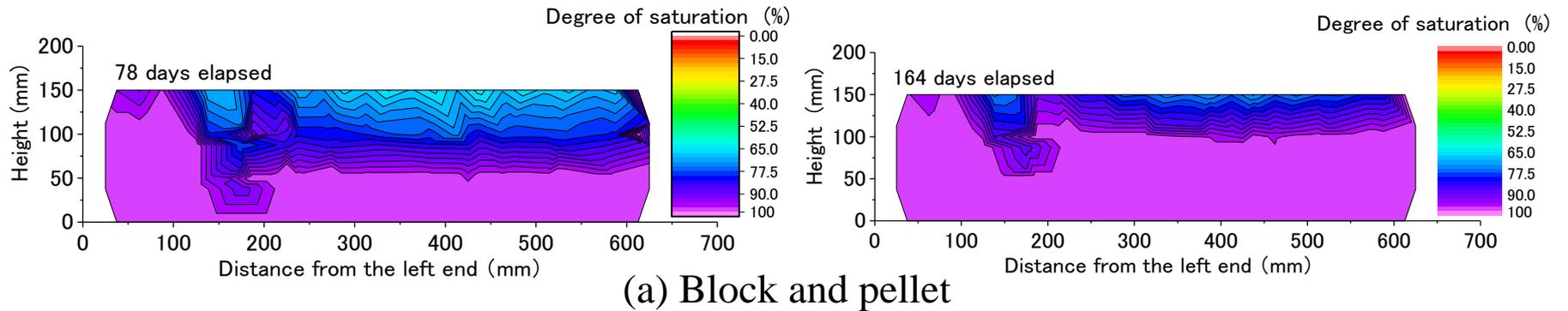
Water appeared to permeate between each block prior to inside of the blocks.

■ Effect of ionic strength on transition of degree of saturation (Block and pellet)



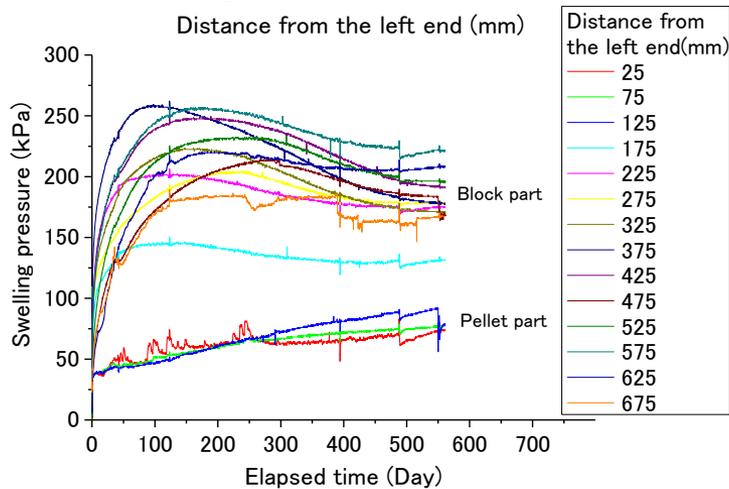
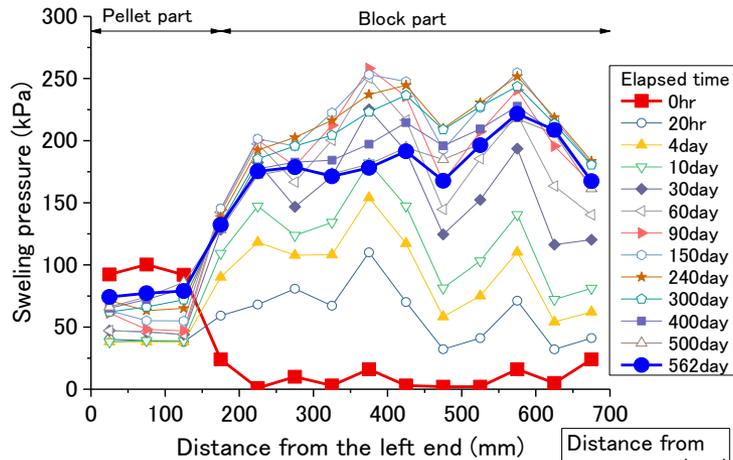
In the NaCl water solution case, the specimen reached full saturation state. The seepage of NaCl solution was faster than that of distilled water.

■ Effect of filling pellets on homogeneous saturation (Distilled water)

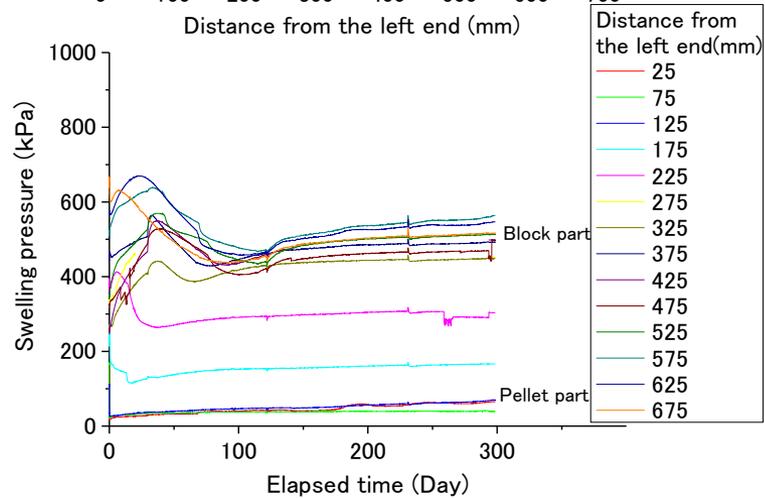
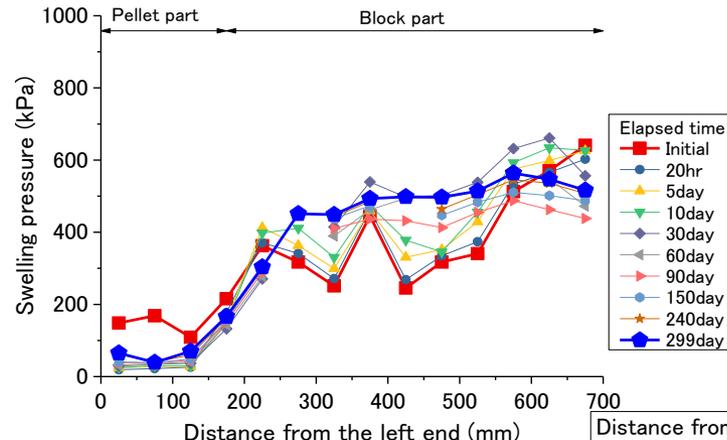


➔ Void air was trapped in the center of the specimen and a low-saturation region remained. The filling pellets contributed to homogeneous saturation.

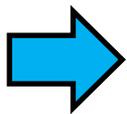
■ Swelling pressure (Block and pellet)



Distilled water

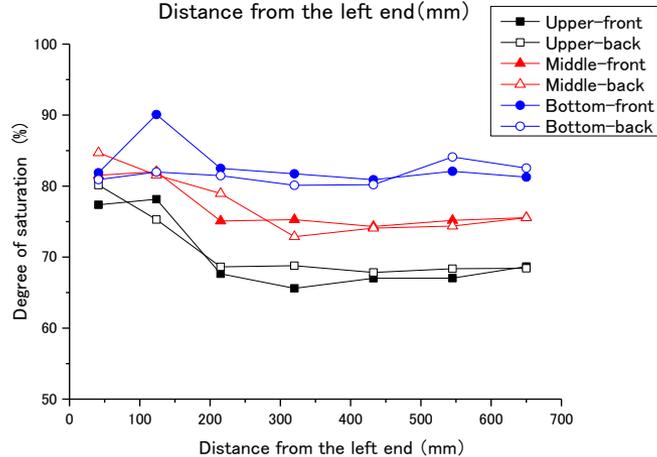
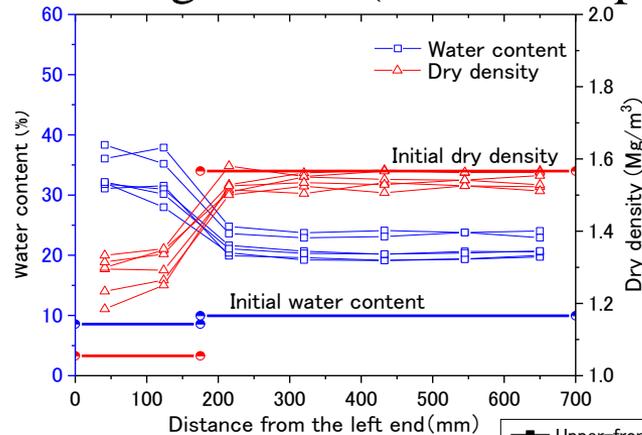


NaCl water solution

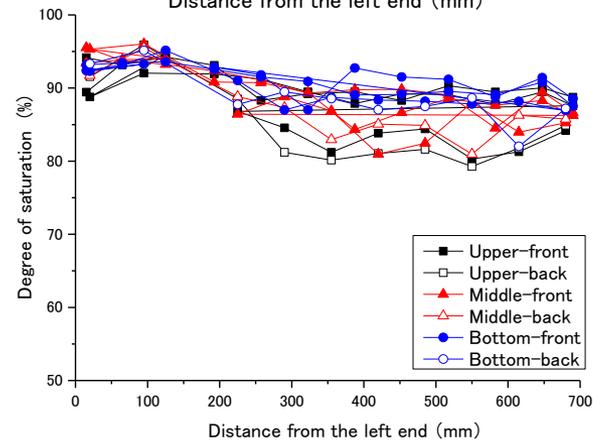
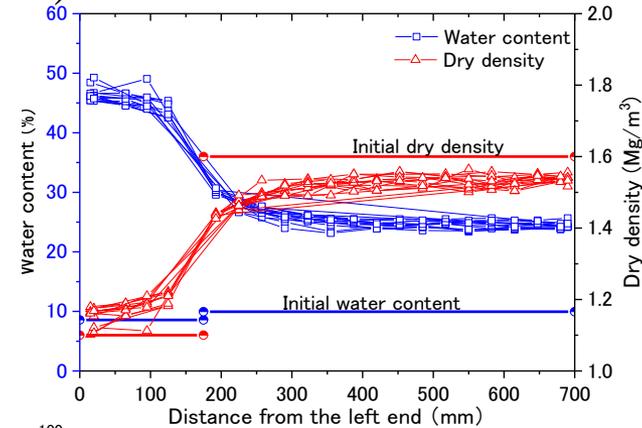


The saw-edged distribution of swelling pressure smoothed over time. Swelling pressure of pellet part increased with decreasing swelling pressure of block part. Swelling pressure distribution did not reach homogenous state even though water was fed sufficiently and swelling pressure reached almost equilibrium state.

■ Dismantling results (Block and pellet)



Distilled water



NaCl water solution

Homogenization of distilled water case was improved in comparison with that of NaCl case. The degree of saturation which was obtained by dismantling was much less than that calculated from resistivity.

Since the sufficient liquid was fed and the degree of saturation decreased with proximity to the upper part of specimen, it will be due to drying during sampling.

■ Conclusion

- ✓ The resistivity measurement was useful for real time monitoring of the seepage status.
- ✓ The seepage of NaCl water solution was faster than that of distilled water.
- ✓ The filling pellets contributed to homogeneous saturation.
- ✓ The dry density distribution remained even though water was fed sufficiently.
- ✓ The results can be considered an appropriate benchmark for testing in HMC multi-physics analysis.

This research is a part of “*Development of Advanced Technology for Engineering Components of HLW Disposal*” under a grant from Japan’s Ministry of Economy, Trade and Industry (METI).

Thank you for your attention.

Appendix

The listed phenomena were homogenization, seepage and erosion.

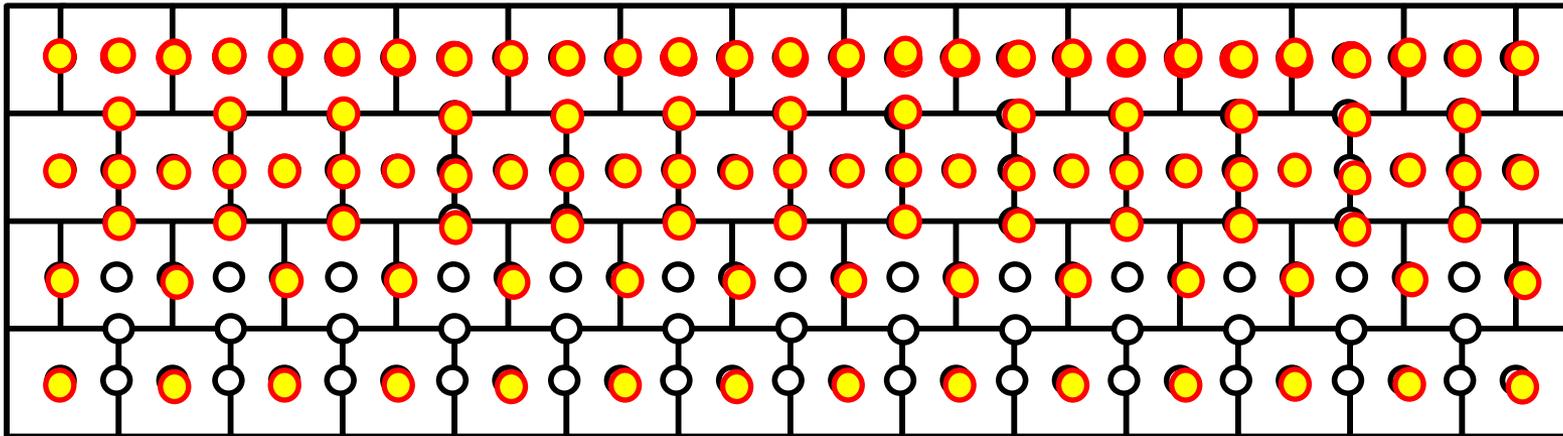
These coupled phenomena and effects of construction quality were also evaluated.

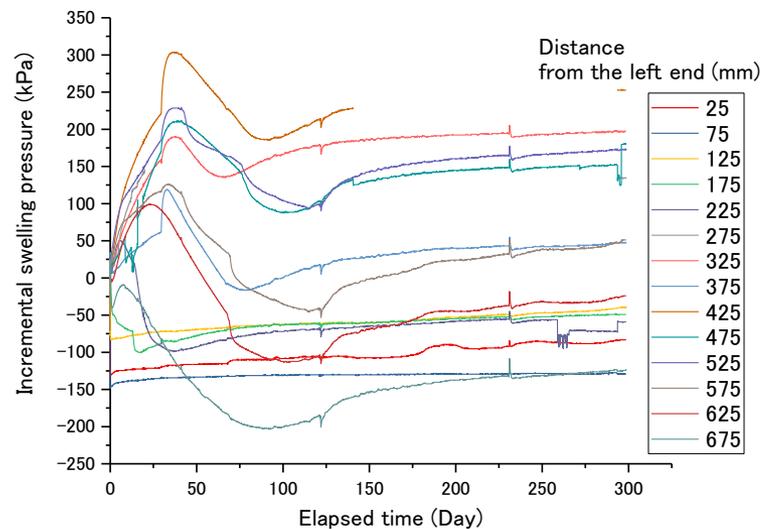
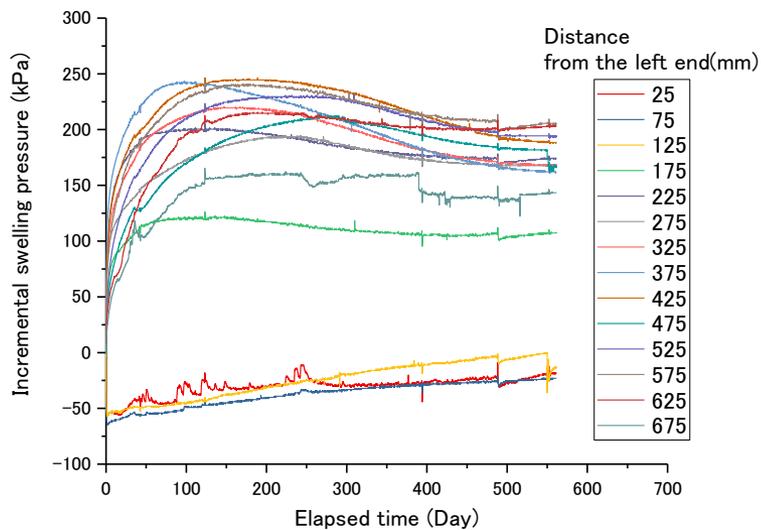
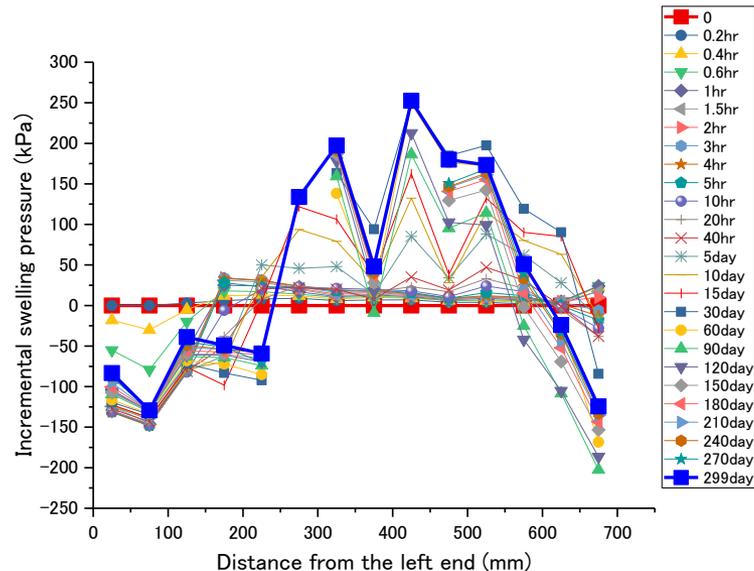
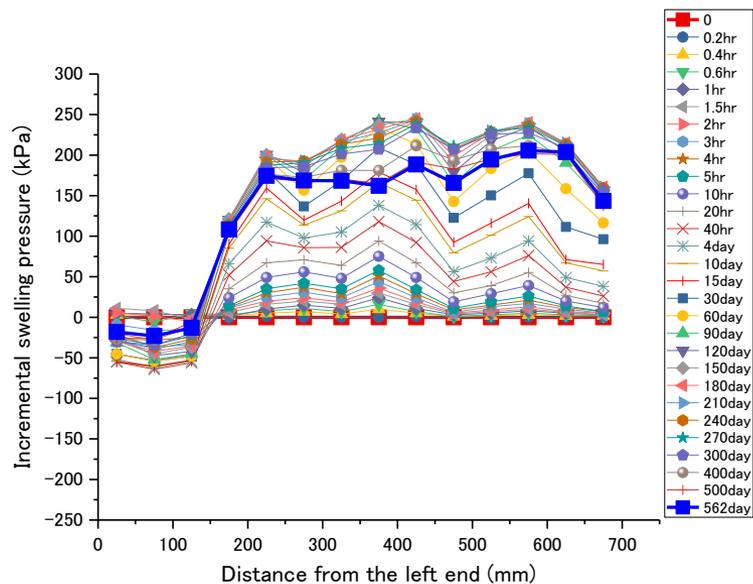
The phenomena which were chosen to evaluate by experiments.

	Laboratory test	Box cell test	Engineering scale	Phenomena
(a): Homogenization of density distribution caused by construction	●	—	—	Homogenization due to swelling
(b): Alteration of Na bentonite to Ca bentonite	●	—	—	
(c): Effects of construction quality on resaturation behavior	—	●	—	
(d): Seepage rate of unsaturated bentonite	●	—	—	Seepage
(e): Evaluation of permeability around interface of buffer	●	—	—	Erosion
(f): Evaluation of permeability around interface of buffer with density distribution caused by construction	—	●	—	
(g): Effects of layout of disposal facility on the re-saturation behavior	—	—	●	
(h): Effects of gas(void air) on the ground water permeation into buffer	●	—	—	Coupled phenomena
(i): Effects of gas(void air) on the ground water permeation into buffer with density distribution caused by construction	—	●	—	
(j): Integrated evaluation of resaturation considering heat, gas, metal corrosion and mechanical deformation	—	—	●	
(k) Improvement of construction technique of buffer materials	●	—	●	Construction effects

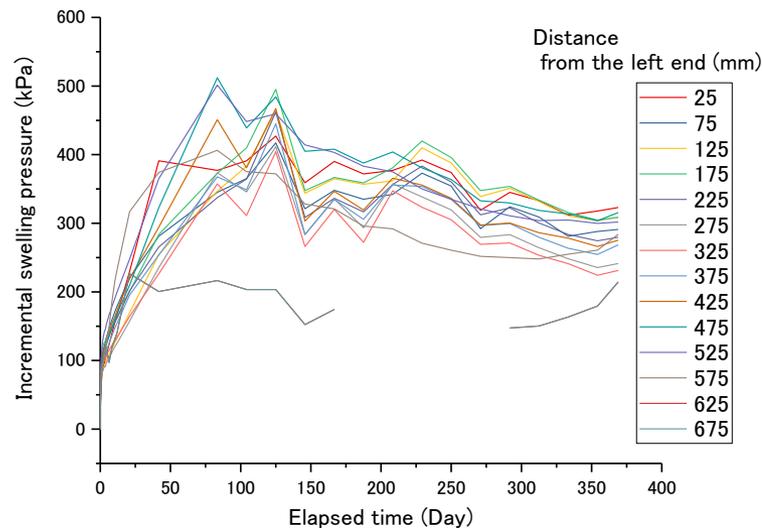
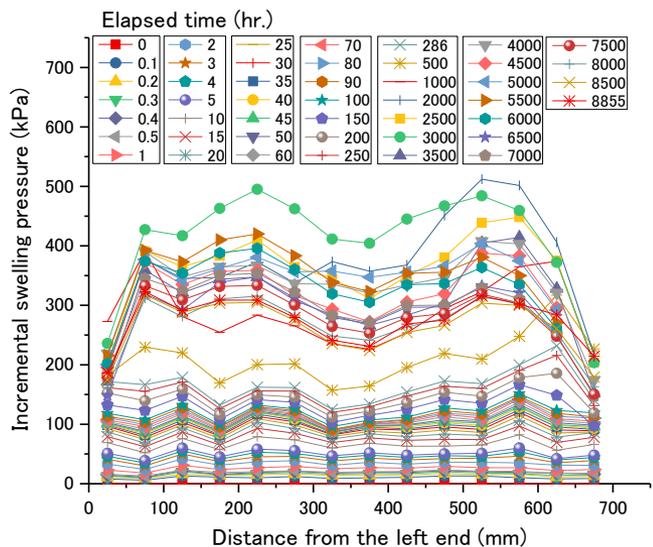
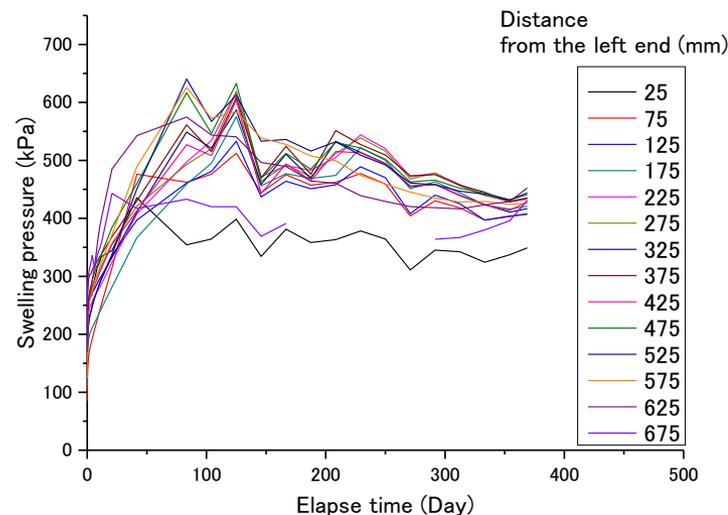
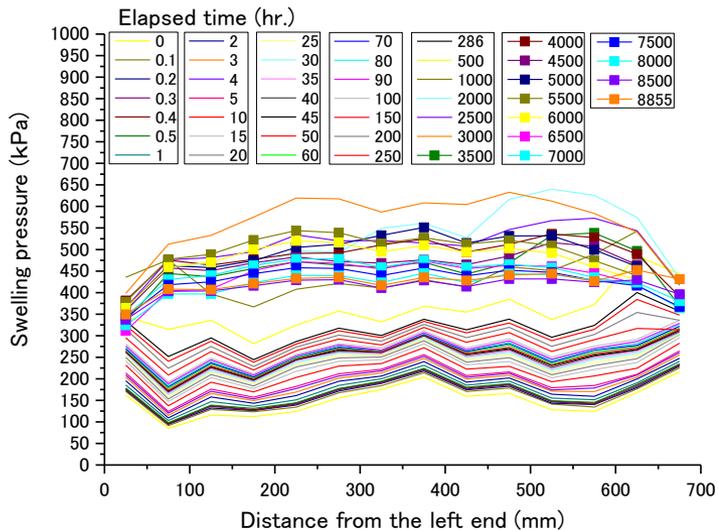
■ Resistivity measurement

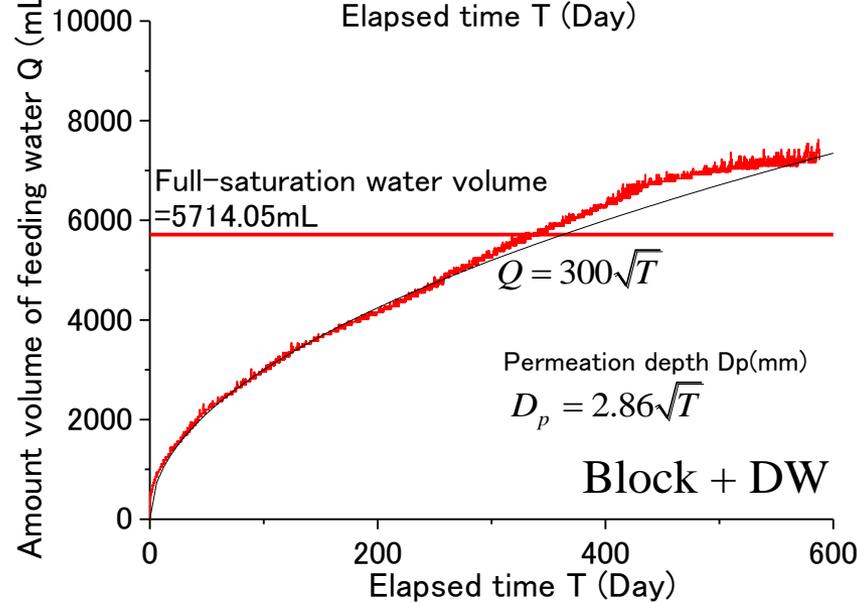
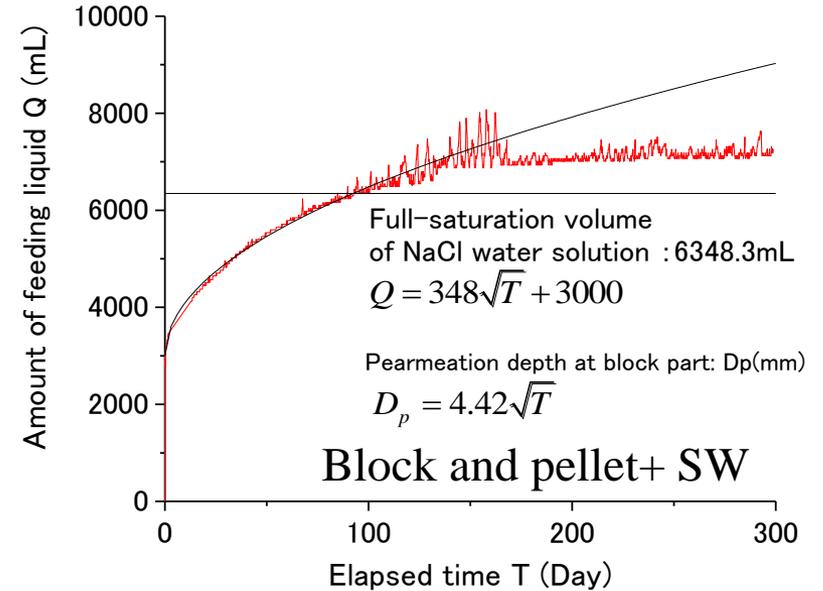
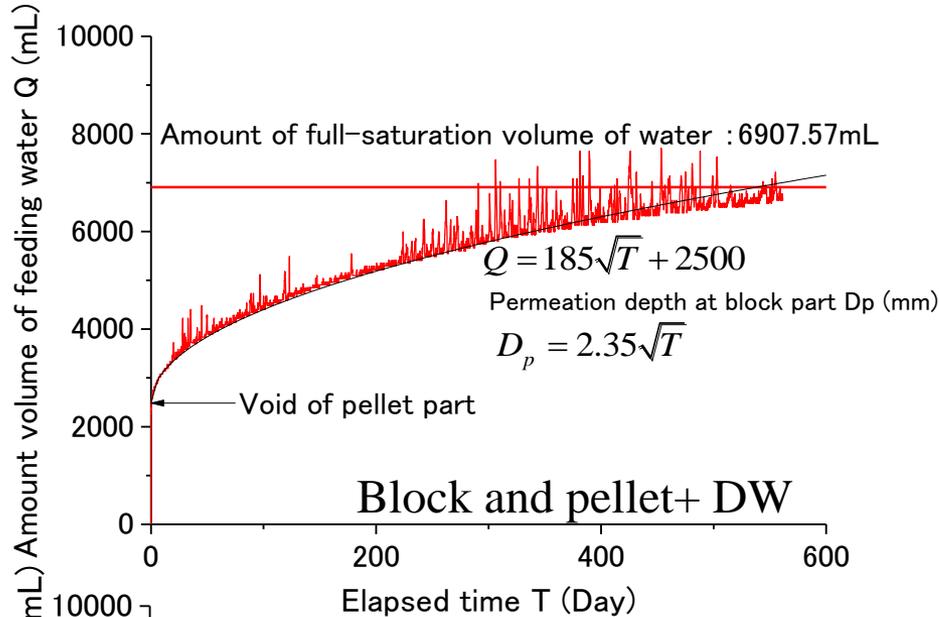
Predetermined set of 4 electrodes among the 127 electrodes was chosen to measure the resistivity with some interval time.





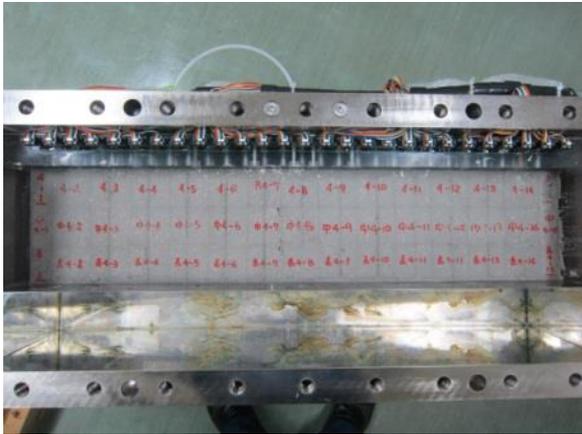
Block only





- ✓ The instant saturation of pellet part was assumed for calculating the seepage depth.
- ✓ The seepage depth is in proportion to the square root of feeding time.

■ Dismantling(Block)



Top surface



Insert of casing



A sample which included the two gaps

The casing was inserted to prevent disturbance of samples. After inserting the casing, the bentonite around the casing was dug.

It was difficult to recognize the gaps between blocks due to swelling.

■ Dismantling(Block and pellet + distilled water)



Top surface



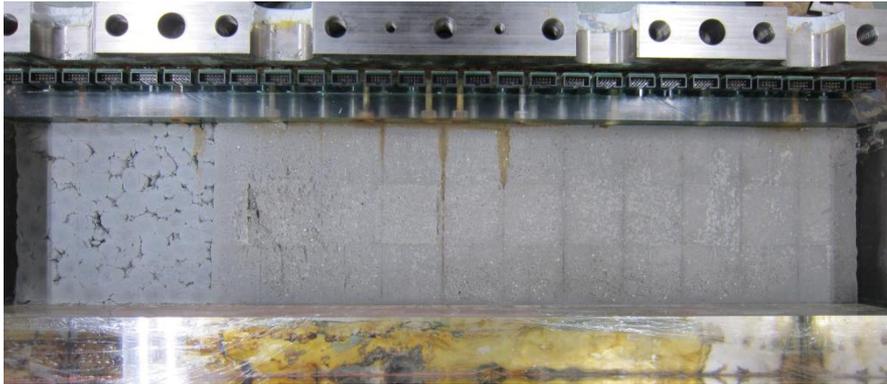
Excavation surface



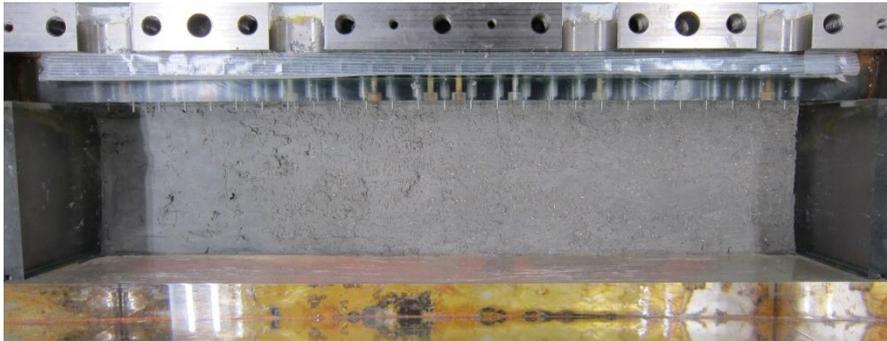
Front view

The gaps between blocks were hardly recognized due to homogenization with swelling but the pellets did not be homogenized perfectly. The gaps between pellets remained on the top surface.

■ Dismantling(Block and pellet + NaCl water solution)

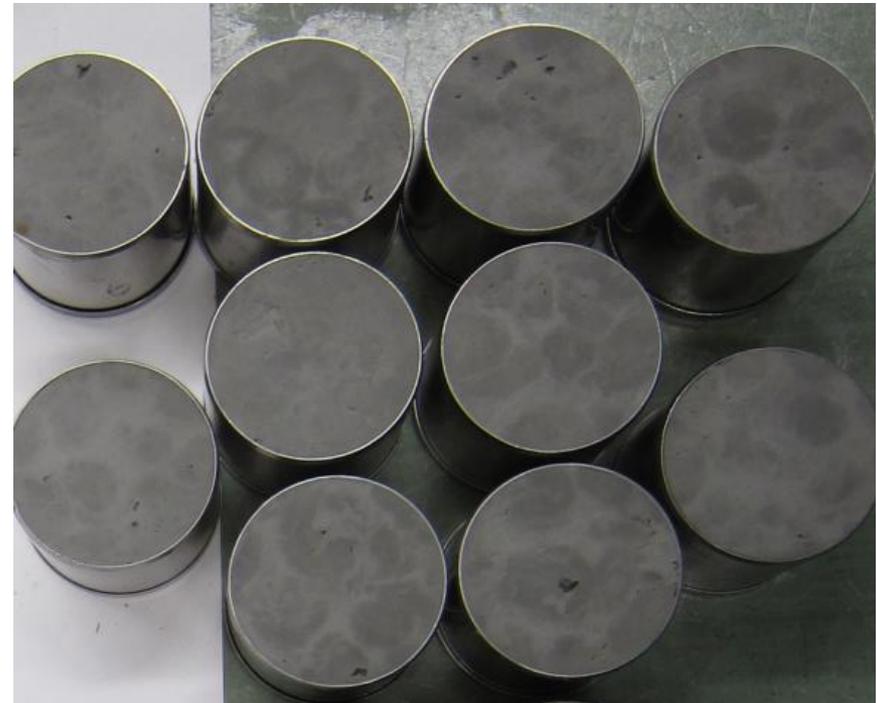


Top surface



Excavation surface

The gaps between blocks were hardly recognized due to homogenization with swelling but the pellets did not be homogenized perfectly.



Samples of pellet part
SKB, RWMC and KAJIMA