BEACON
Bentonite Mechanical Evolution

SWELLING PRESSURE ACTING TO THE CONSTRAINING MATERIAL WITH SLIGHT DEFORMABILITY

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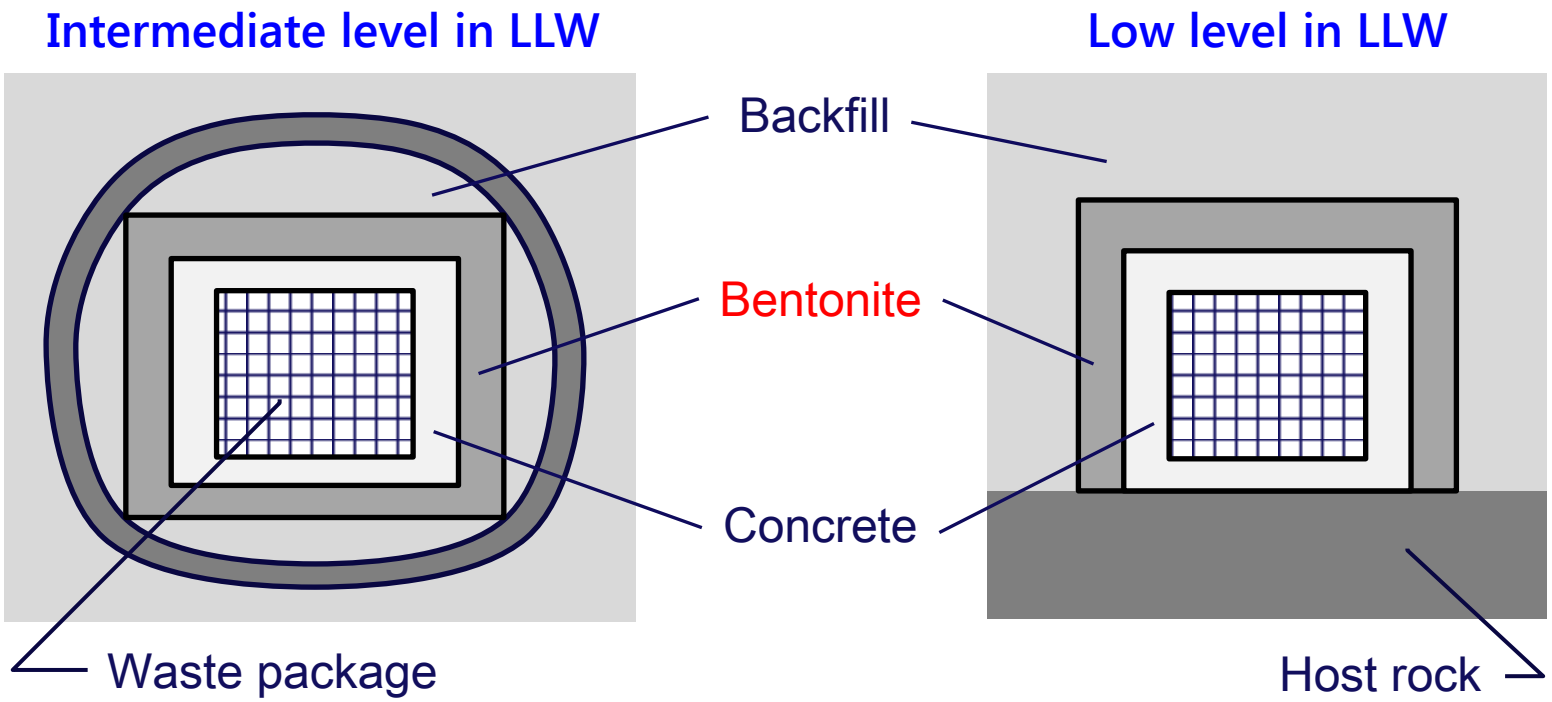
Background

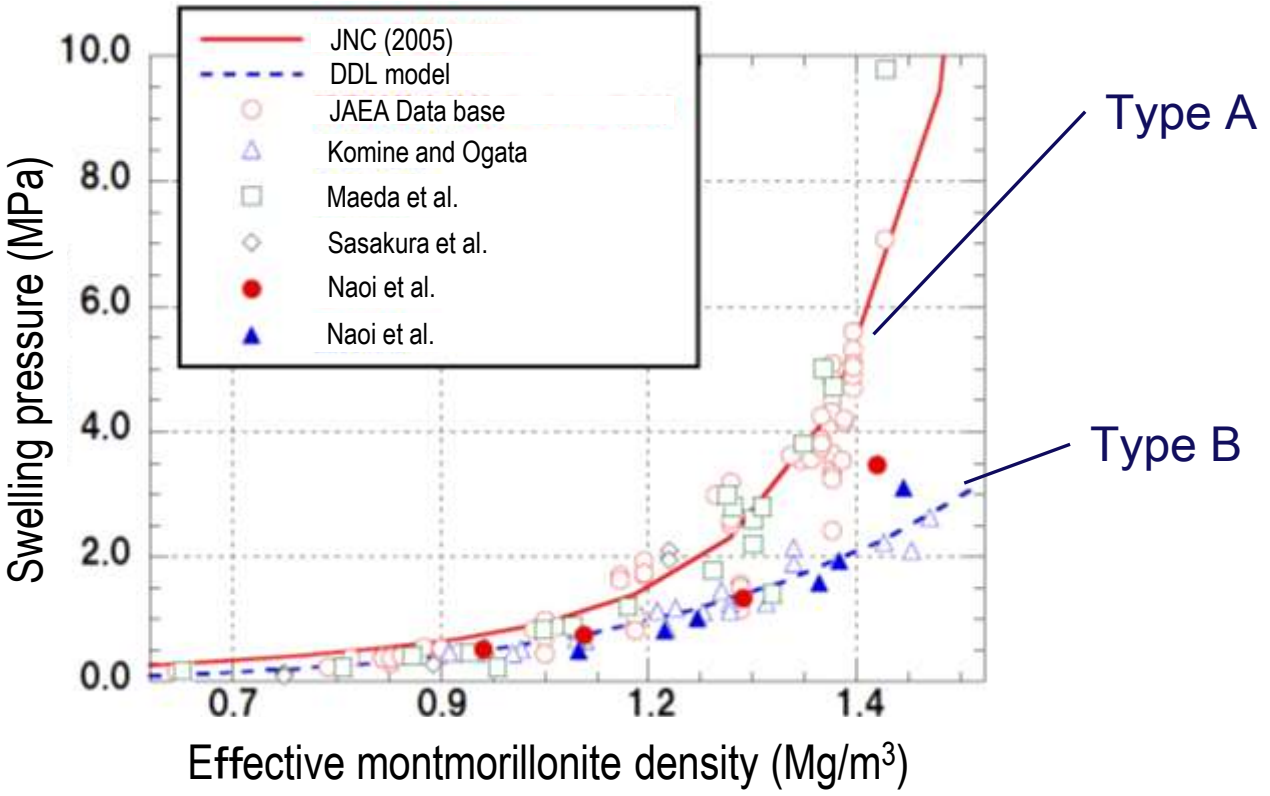
- Bentonite constrained by rigid materials with slight deformability
  - Bentonite-Rock interaction in HLW disposal facilities
  - Bentonite-Concrete / Backfill soil interaction in LLW disposal facilities

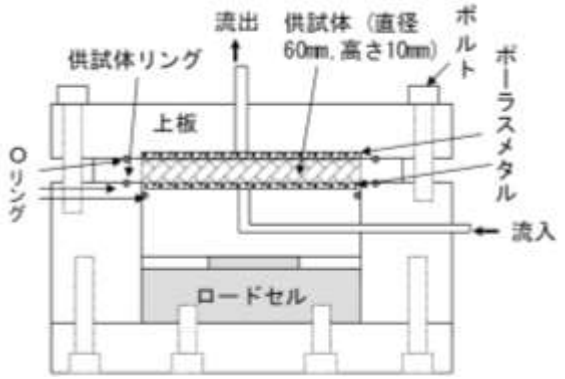


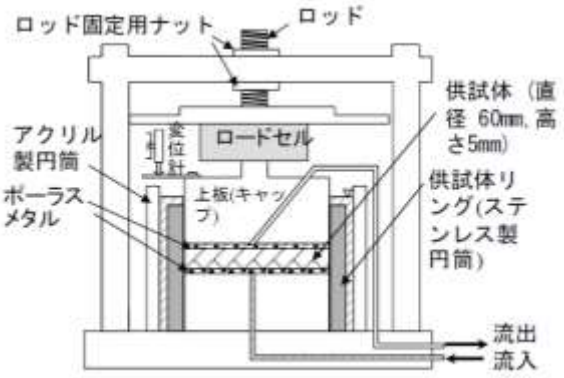
Background

◆Swelling pressure of bentonite measured by laboratory tests

- Difference of the deformability of the experimental apparatus showed different swelling pressure even if same effective montmorillonite density.



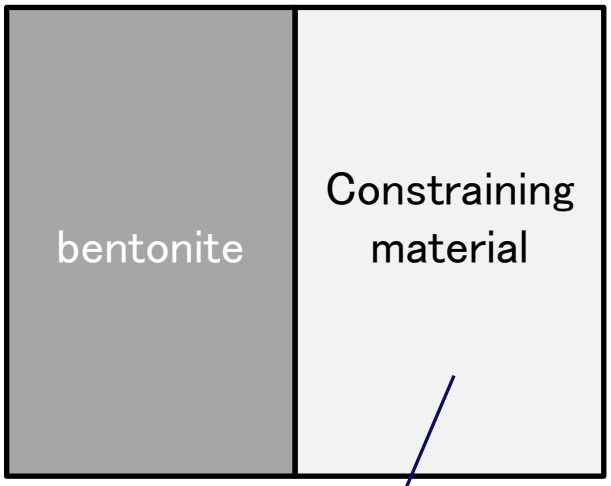




Objective

◆Mechanical interaction between bentonite and various rigid materials

- **To understand how much swelling pressure acts to the constraining material with slight deformability**
- This study investigated the change of the swelling pressure acting to the constraining material with slight deformability, supposing **elastic strain of rocks, by a laboratory test**.
- This study developed **the swelling pressure test apparatus equipped with small strain control.**

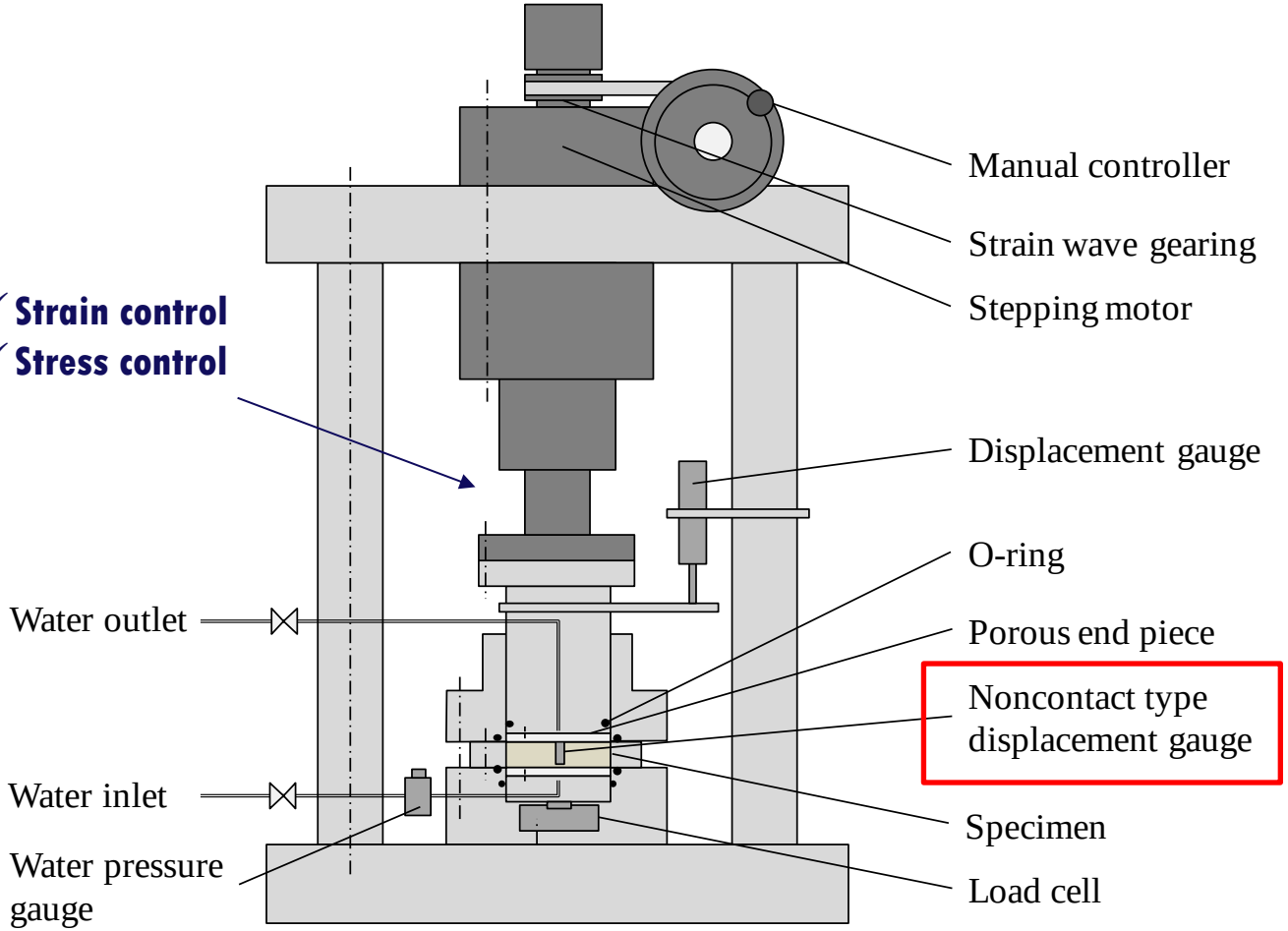


- ✓ Hard rock
- ✓ Soft rock
- ✓ Concrete
- ✓ With fractures
- ✓ etc.

Experimental apparatus

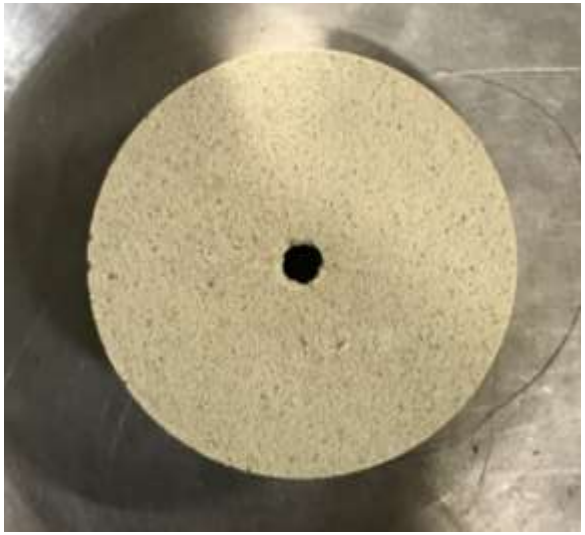
Swelling pressure apparatus equipped with small strain control

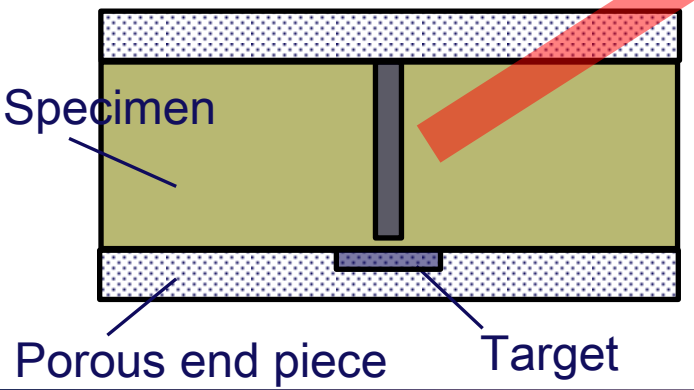
- ✓ **Strain control**
- ✓ **Stress control**



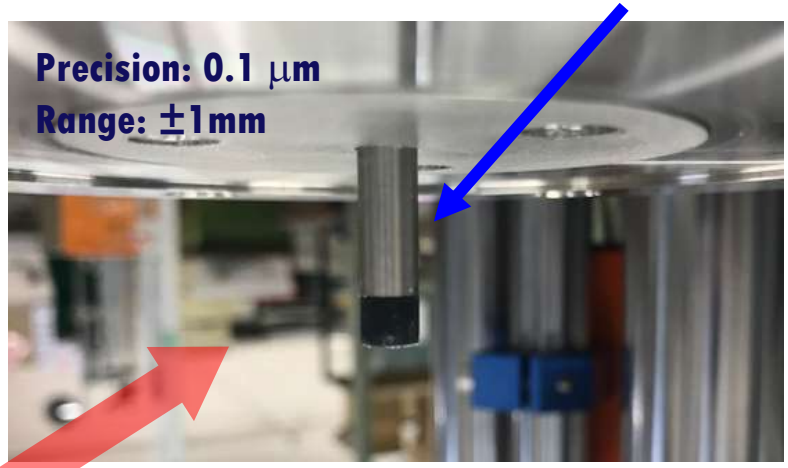
Measurement of height of specimen

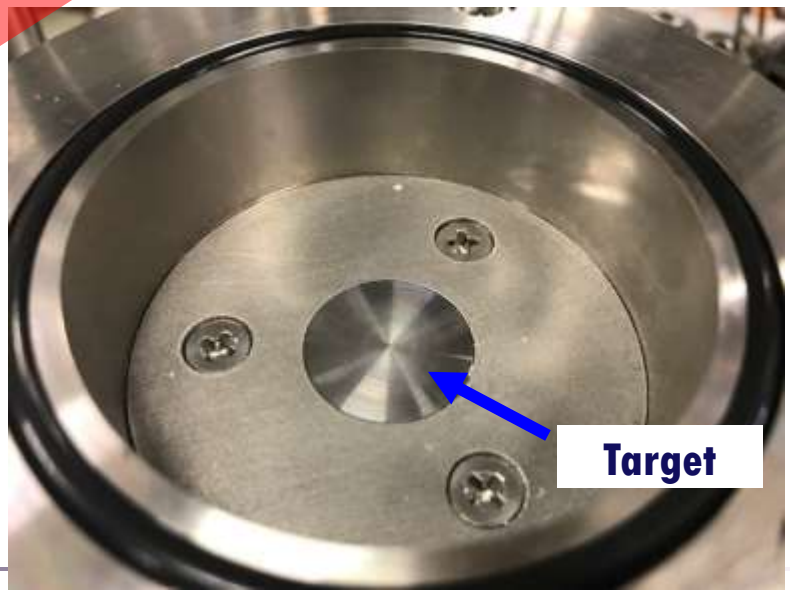
Specimen with a center hole



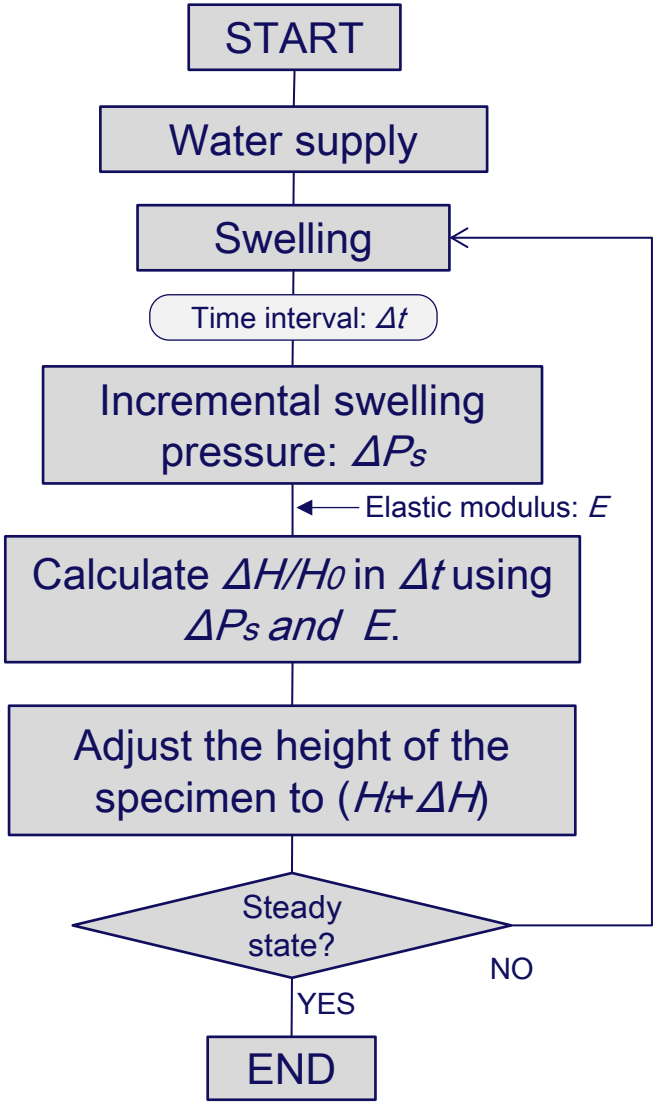


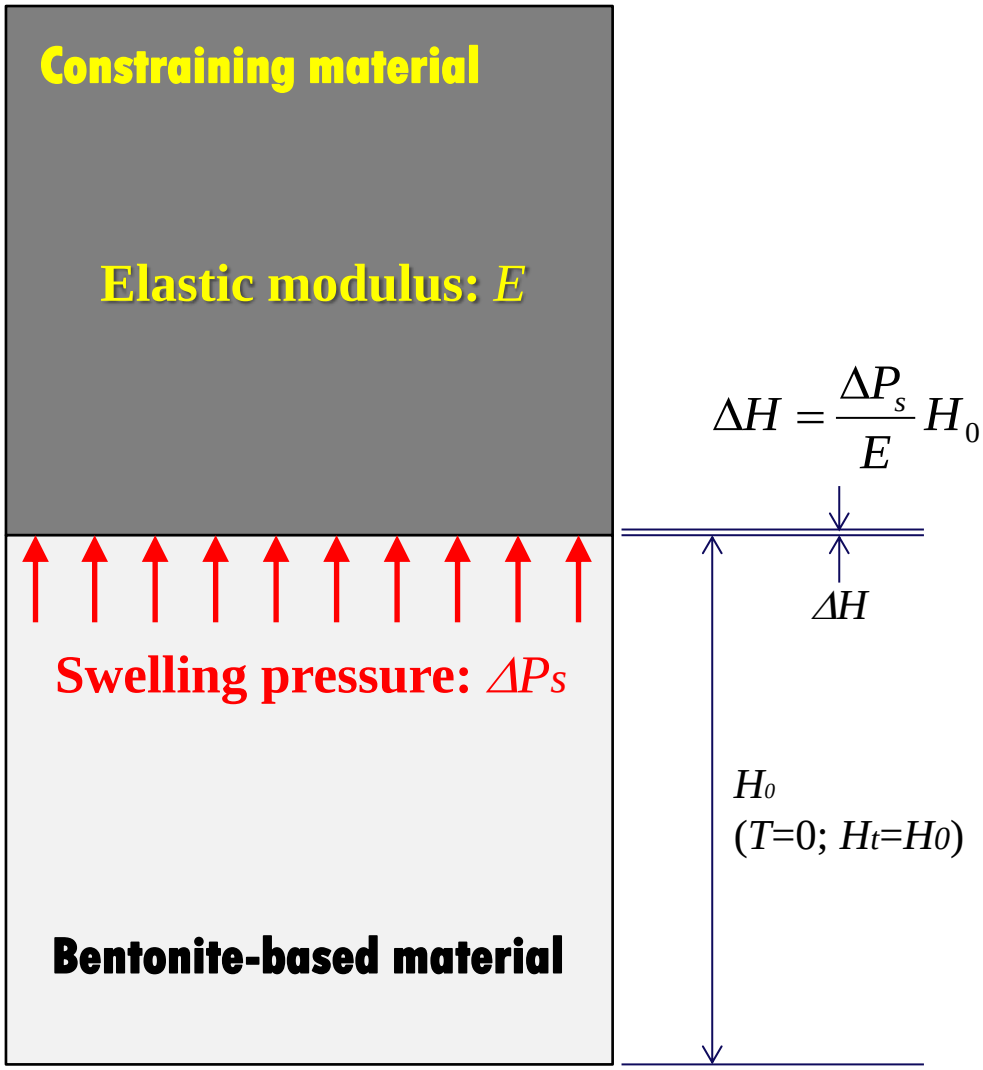
Noncontact displacement sensor





Simulation of elastic micro-deformation





Sample and specimen

Experimental condition

Type of bentonite	Water content (%)	Dry density (Mg/m^3)	*E* (MPa)
Na-bentonite	9.98	1.81	37000
	9.51	1.77	3500
	9.53	1.60	37000
	9.55	1.60	3500
	10.14	1.60	750
	10.06	1.40	37000
	9.83	1.40	750
Ca-bentonite	14.76	1.20	37000
	12.53	1.20	3500

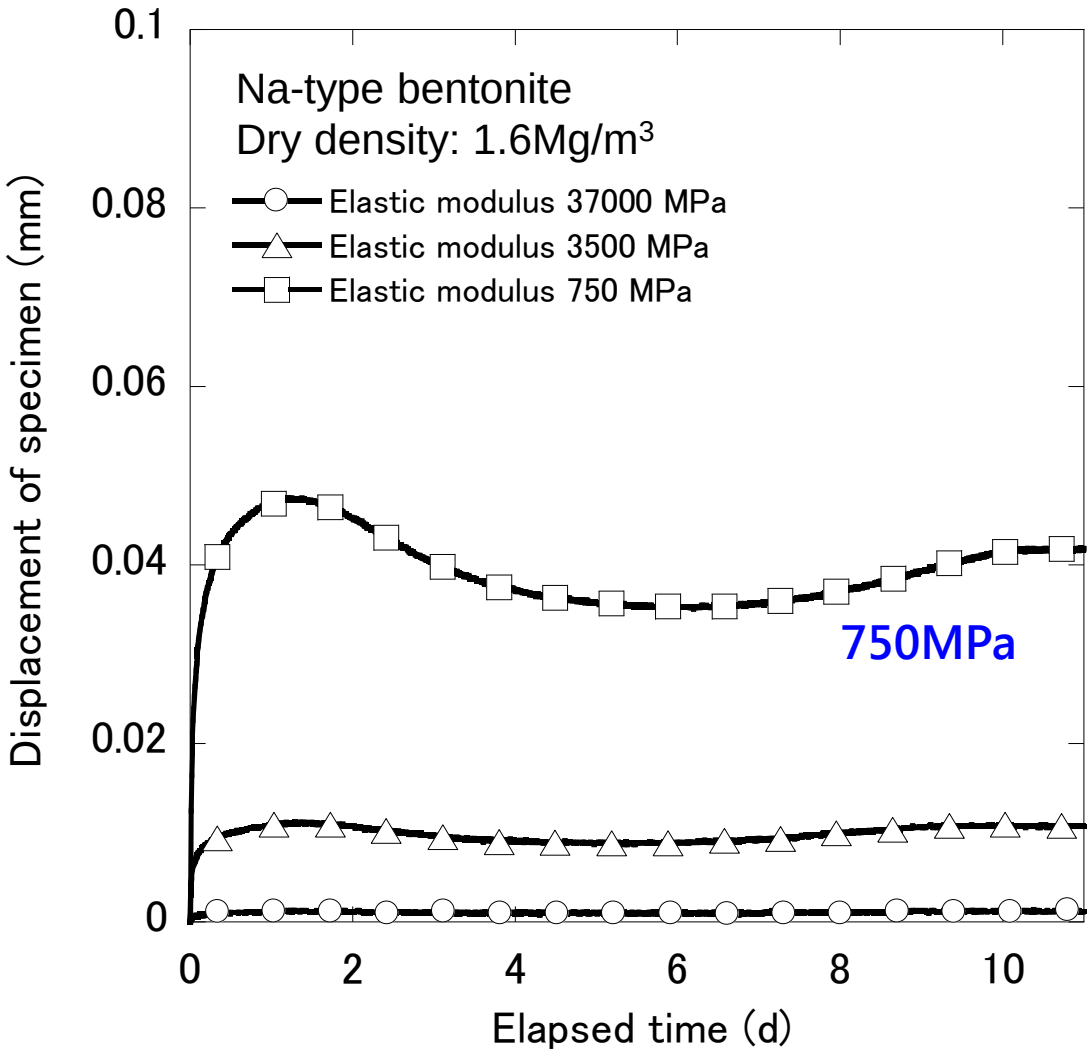
Methylene blue adsorbed of the bentonite

- **Na-type**: 70 mmol/100g
  (extracted montmorillonite: 142 mmol/100g)
- **Ca-type**: 118 mmol/100g
  (extracted montmorillonite: 150 mmol/100g)

Mold for specimen procedure

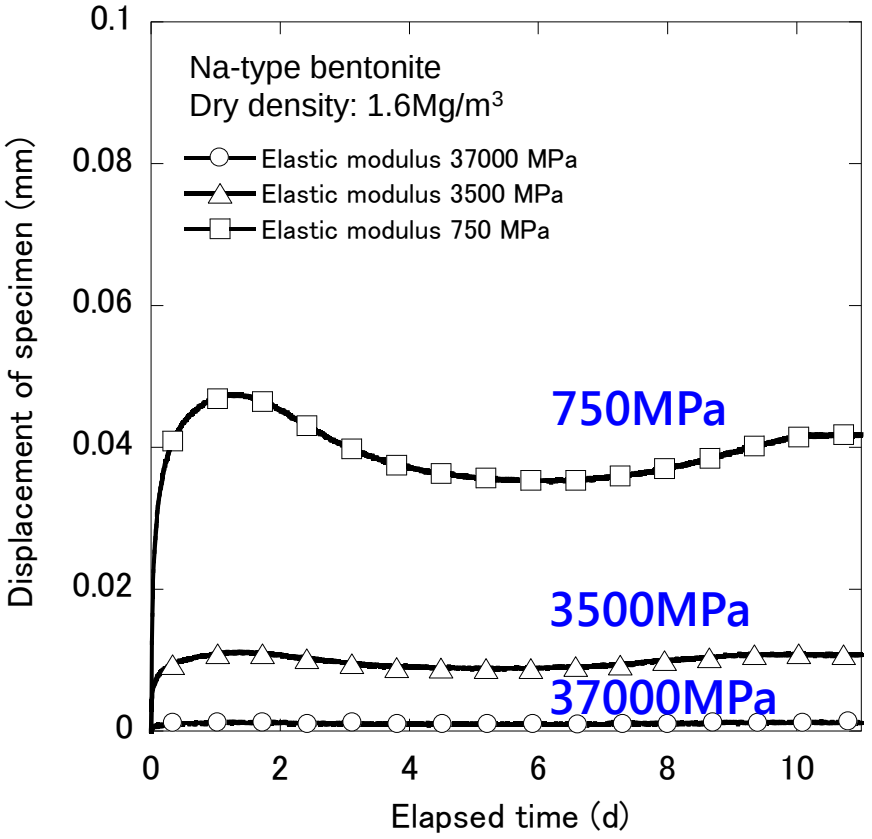
Axial loading

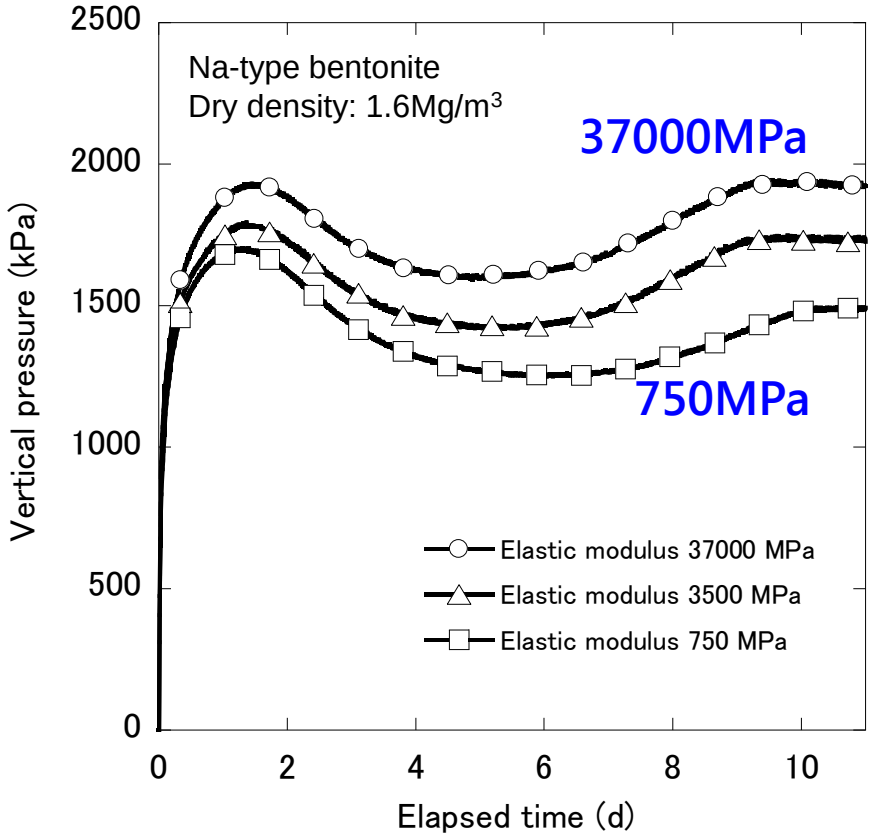
Slight deformation when swelling pressure evolution



- The setting of the elastic modulus corresponding to a hard rock, 37000 MPa, showed that the displacement of the specimen was only 1 μm.
- In the case of the smallest elastic modulus corresponding to a soft rock, 750 MPa, 40—50 μm of the displacement occurred.

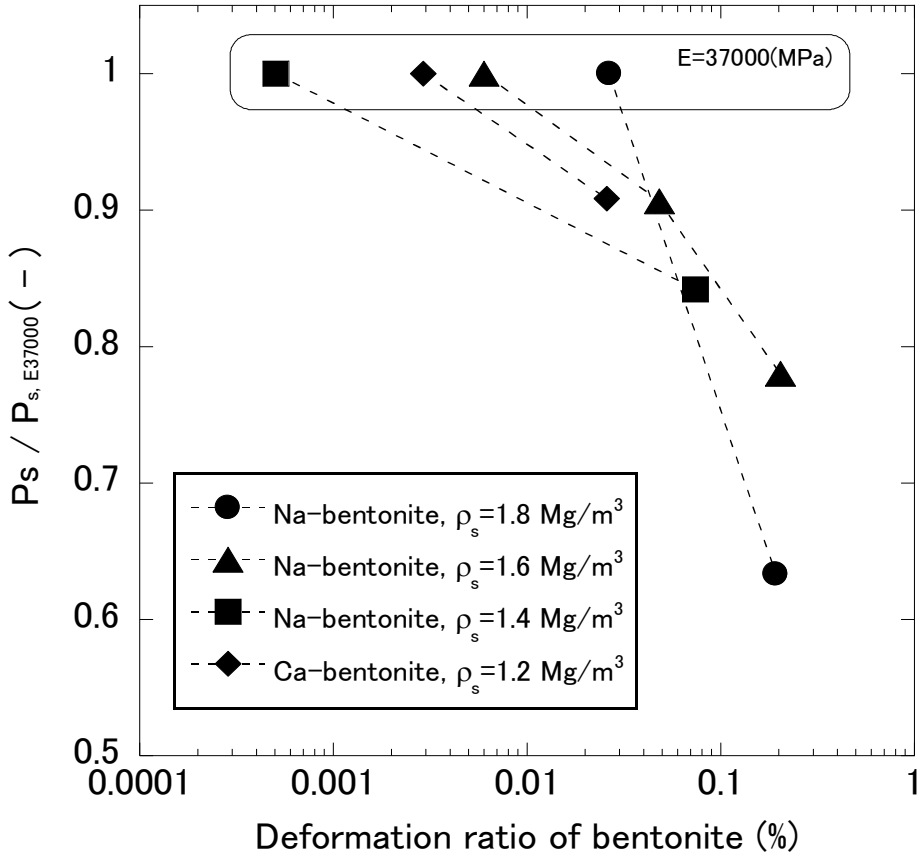
Swelling pressure evolution





- The setting of 37000 MPa showed that the displacement of the specimen was only 1 μm during the swelling pressure increased up to 1.9 MPa.
- In the case of 750 MPa, 40—50 μm of the displacement occurred, and 1.5 MPa of the swelling pressure was measured.

Reduction of swelling pressure caused by slight deformation during saturation



Dry density just after saturation with slight deformation:

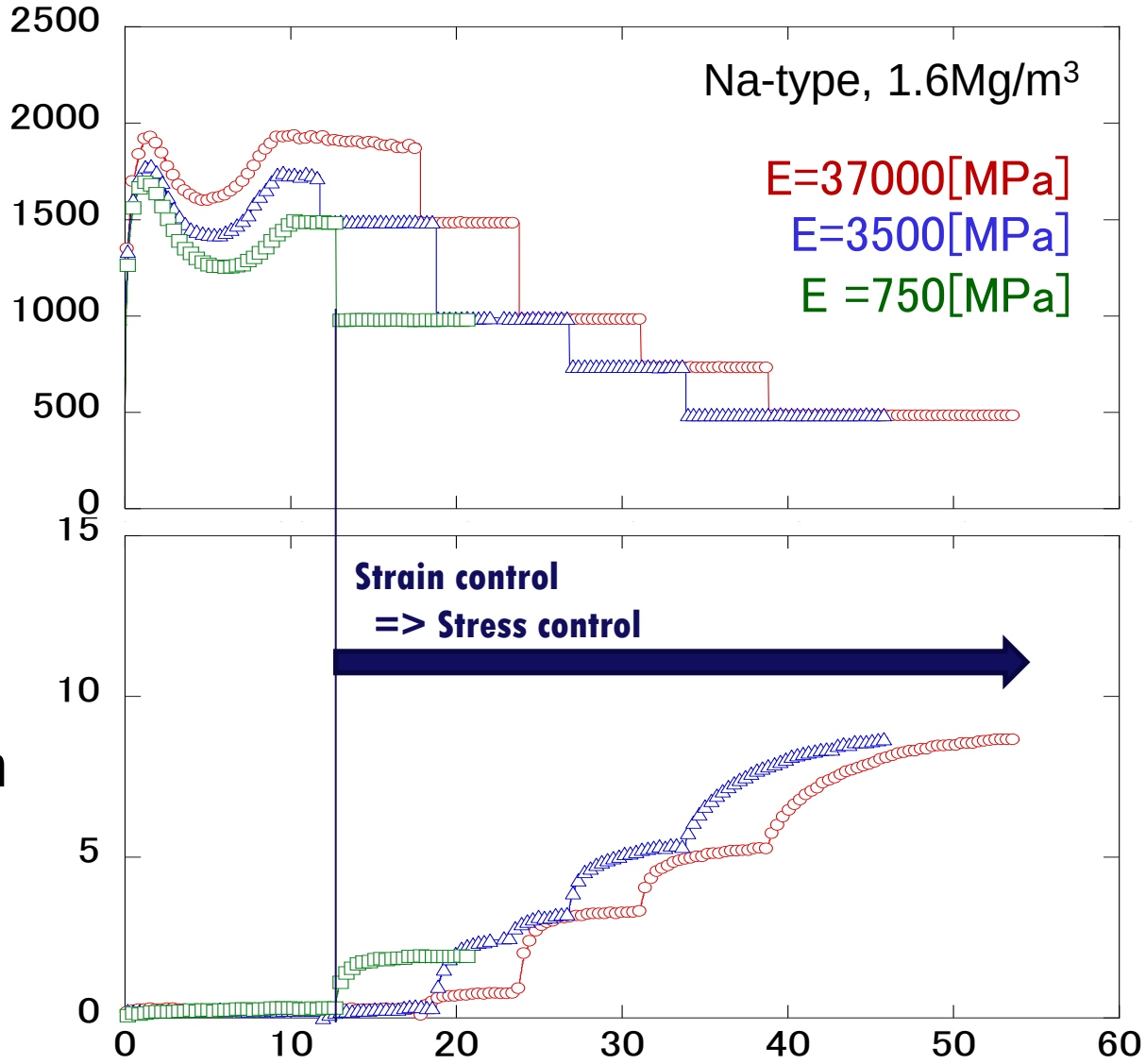
Before saturation (Mg/m^3)	After 0.2% deformation (Mg/m^3)
1.810	1.806
1.600	1.597

- Although the dry density of the specimen was not almost changed by the displacement, **the swelling pressure decreased with slight deformation of the bentonite in saturation process**.

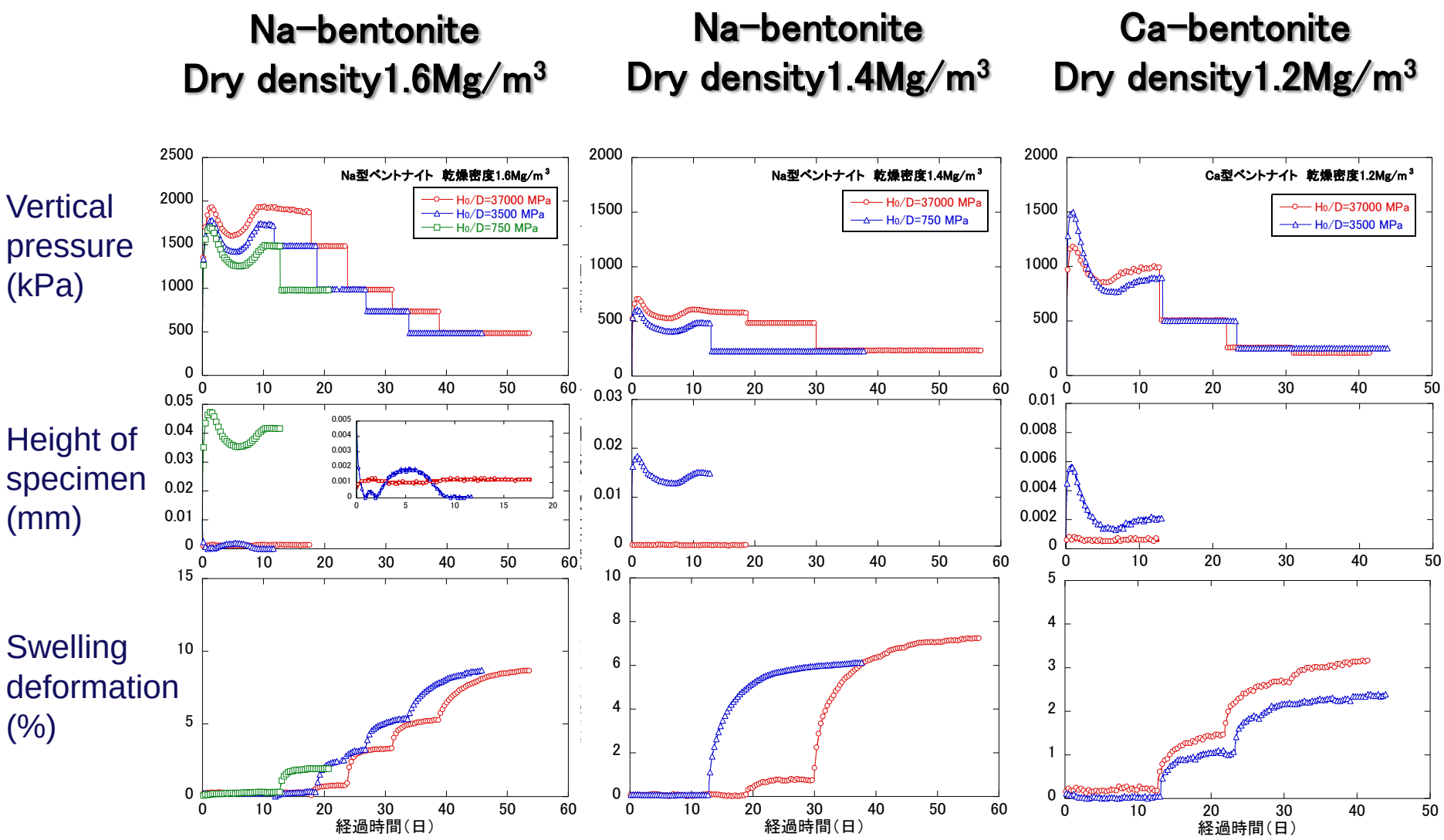
Swelling deformation by unloading

Vertical pressure (kPa)

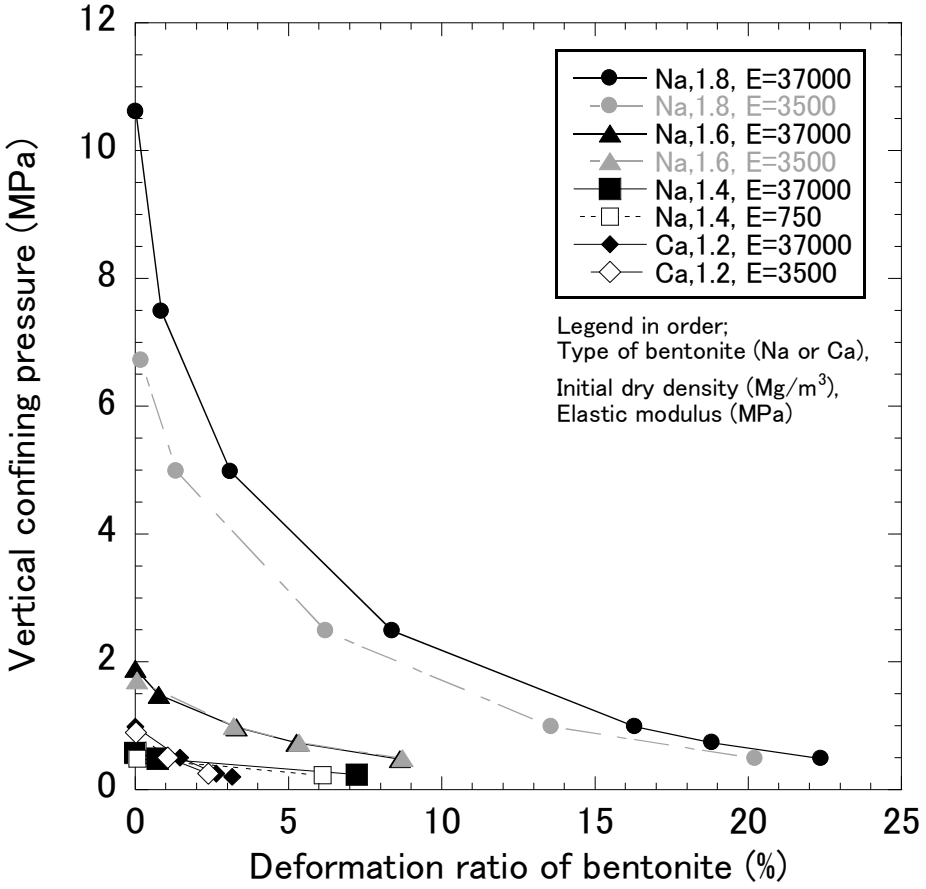
Swelling deformation (%)



Swelling deformation by unloading



Swelling deformation by unloading



- Under the same dry density, **the difference of the vertical confining pressure between each elastic modulus decreased with the increase in the deformation ratio of the bentonite.**

Concluding remarks (1)

How could this work inform a new experimental study in BEACON?

- This study investigated **the swelling pressure of the bentonite acting to the constraining material with slight deformability, supposing elastic strain of rocks, by the laboratory test**.
- This approach leads estimation of the swelling pressure and the swelling deformation of the bentonite, considering boundary conditions in terms of the bentonite-rock interaction.
- **Standardization of the mechanical tests for the compacted bentonite is important to promote the radioactive waste disposal.** In the laboratory test, the deformability of the apparatuses also may influence to the measured swelling pressure (Tanaka, 2011). The new experiment is useful to discuss the experimental method for measuring swelling pressure of the compacted bentonite.

Concluding remarks (2)

Recommendations for BEACON project/ What would I do differently, were I to repeat my earlier study?

- By measuring the realistic swelling pressure in the bentonite-rock interaction through the swelling test in this study, the result will be a parameter to design the facility or useful information for various numerical simulations. It is important to understand the difference of swelling properties observed in laboratory tests and full scale experiments.