Prediction of residual strength of soil at super large strain level using the stacked-ring shear apparatus

多層リングせん断試験機による超大ひずみ領域における土の残留強度の予測

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Research Background

In recent years, during the 2016 Kumamoto earthquake and the 2018 Hokkaido Eastern Iburi earthquake, several landslides occurred on gentle slopes (<10-15 degrees) with remarkable runout distances, sometimes exceeding 100 meters. Volcanic ash soil played a significant role in these extensive landslides on mild inclinations.

(Kawamura, 2019) and (Chairo, G. et al, 2017)

Slope failure after 2018 Hokkaido Eastern Iburi Earthquake

Slope failure associated with **large shear deformation**. Evaluation of **residual strength** at **super large strain** level is necessary to investigate.

Objectives

1. To investigate the influence of **friction,** and **soil leakage** of stacked ring shear apparatus on the stress-strain characteristics of sand .
2. To **predict** the residual strength of **natural volcanic ash soil** which induced **large slope failure**.

Materials

Volcanic ash soil (Hokkaido, Ta-d)

Silica sand # 7

How to evaluate residual strength?

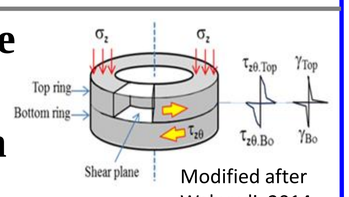
Conventional Apparatus

Unable to apply large strain (**more than around 20 %**)

Not a **simple shear test**

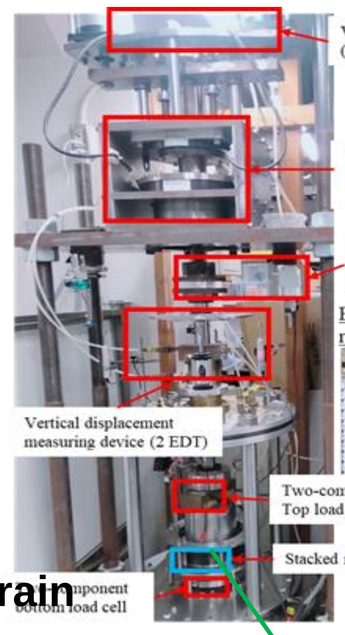
Tri-axial

- **Predetermine shear plane**
- **Non-uniform** stress strain distribution

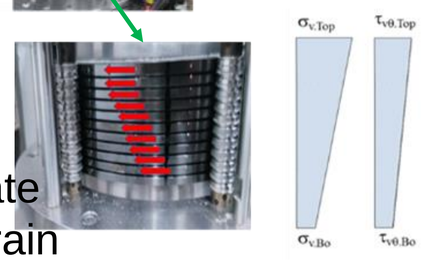


Ring shear

Stacked Ring



- More **uniform stress and strain** distribution
- No **predetermine** shear plane
- Possible to apply for **super large strain (1200 % or more)** and simulate simple shear condition before the strain localization.



Complete view of stacked ring shear apparatus

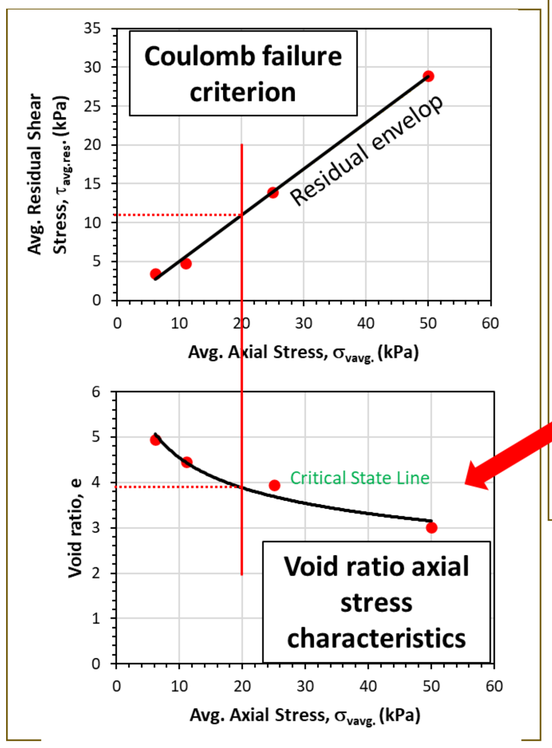
Issues on stacked ring

Friction between soil and rings

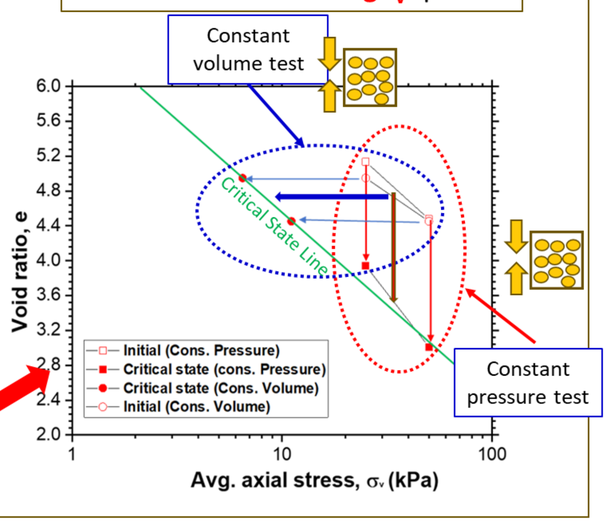
Soil leakage

Prediction of residual strength of volcanic ash soil (Ta-d)

Critical State at e-σ_v space



Volume change characteristics of volcanic soil Ta-d at **e-logσ_v** space



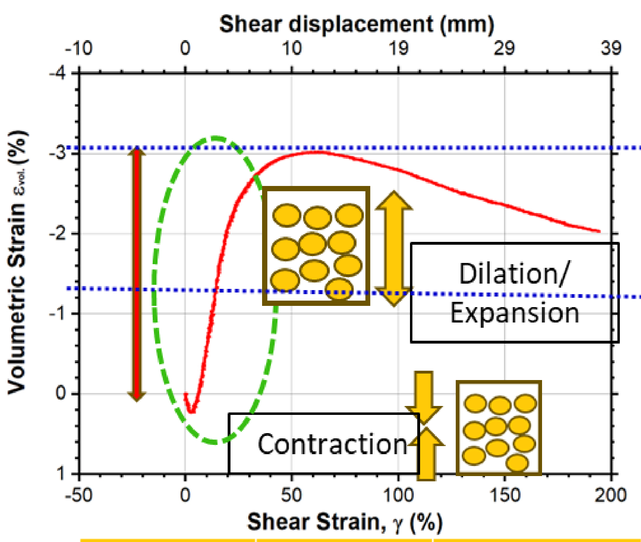
✓Residual strength was defined at the shear strain around 1200%.

✓Volcanic soil exhibited strong contractive behavior, and **single critical state line was observed**.

✓**Void ratio** is very difficult to evaluated after **strain localization.**

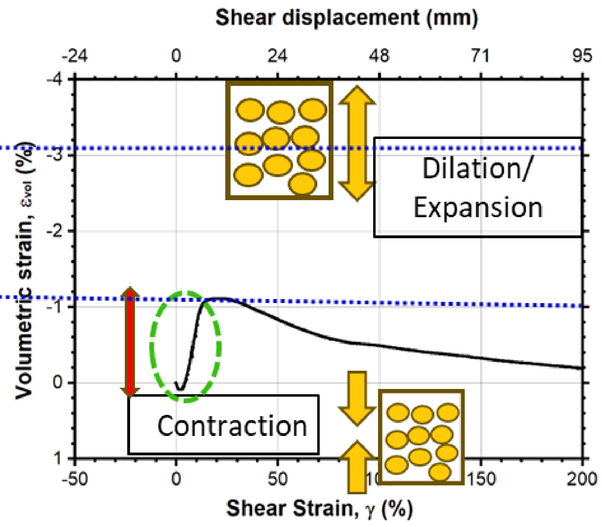
Influence of friction (Stacked ring shear apparatus)

05 Rings



Consolidation (kPa)	Peak strength (kPa)	Residual strength (kPa)
200	159	127

11 Rings



Consolidation (kPa)	Peak strength (kPa)	Residual strength (kPa)
200	153	126

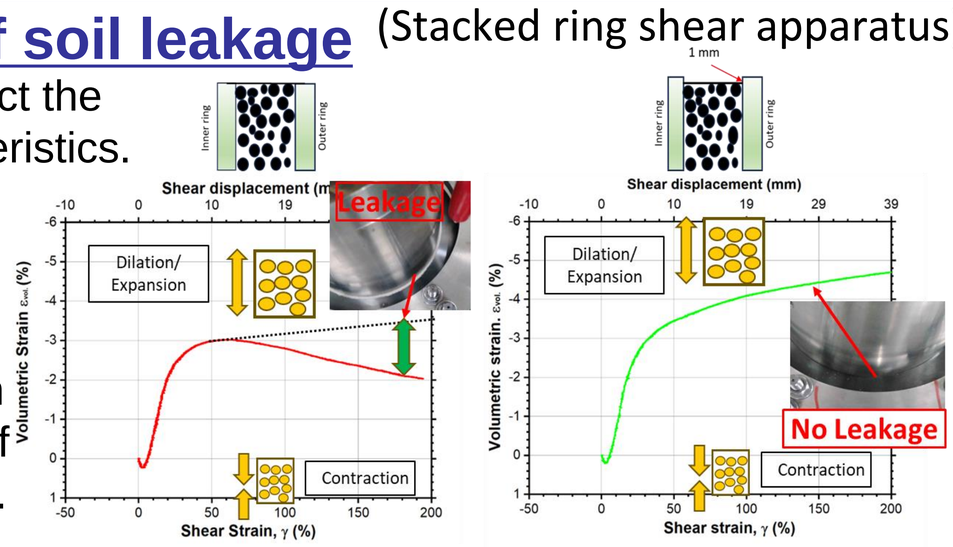
Friction has **negligible effect** on **peak** and **residual** strength.

Dilation characteristics is strongly influenced by **friction**. 05 rings show more dilative characteristics than 11 rings.

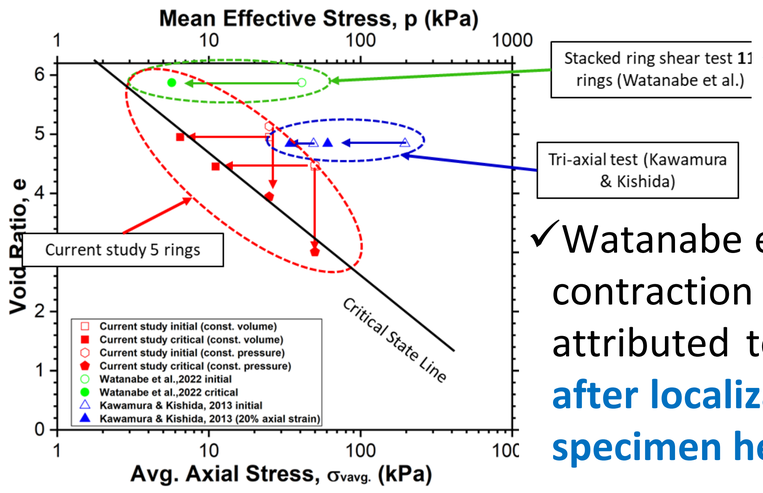
Influence of soil leakage (Stacked ring shear apparatus)

Soil leakage affect the **dilation** characteristics.

Placing the specimen **below 1mm from top ring surface** can solve the issue of leakage problem.



Comparison to previous study



✓**Tri-axial test** may lead to **overestimate** the residual strength.

✓Watanabe et al. found minimal soil contraction differences, potentially attributed to **void ratio challenges after localization**, with variations in **specimen heights** across studies.

✓Stacked ring shear apparatus more **convenient than tri-axial apparatus** for **prediction of residual strength** of **volcanic ash soil**.