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SHEAR BOX TEST ON ARTIFICIALLY MADE EXTREMELY LOOSE SOILS

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INTRODUCTION

Volcanic soils consisting of high void ratio are widely distributed soil type in Japan due to the frequent occurrence of volcanic eruptions since the quaternary period and have caused several slope disasters. Ontake landslide (1984), Takanodai landslide (2016), Izu Oshima slope failure, Hokkaido landslide (2018) are some examples of the large-scale slope disasters that occurred on volcanic pumice layers.

These pumice soils exhibit quite different mechanical behavior when compared with sandy or clay soils. The crushability and cementation effect are the most distinctive features of these soil types. Significant particle breakage can even happen at a low-stress level such as shallow ground and this leads to slope failures. Moreover, these pumice soils exhibit high void ratios. For example, the void ratio of pumice soil samples, which were collected from Hokkaido landslide area in 2018, varied from 5.0 to 7.5. Considering these facts, volcanic soils have been categorized as "problematic soils".

This study primarily focuses on slope disasters, such as muddy flow and long-distance flow, triggered by volcanic pumice layers with a high void ratio. Considering the difficulty in collecting identical soil samples from sites and extremely loose characteristics of the soil type, this study produced artificial volcanic soils in the laboratory using DL clay and Ordinary Portland Cement (OPC). Shear behavior of these soils were tested using a modified shear box apparatus at different confining pressure levels. The standard shear box size (60 mm x 60 mm) was modified (80 mm x 80 mm) to enable the testing of artificial soil specimens in relatively larger scale in order to facilitate large soil grains.

METHODOLOGY

Test material

DL clay which is a fine and non-plastic material, OPC and water are the main materials utilized to produce artificial soil. There are 2 types of specimen sets: Cementation type and Crushable type. Detail of specimen preparation method is given as follows.

Cementation type specimen preparation

Two sets of specimens were prepared: A and B, varying DL clay and OPC quantities with the same water content for all the cases.

(1) DL clay was mixed with OPC at provided mixture ratios (Table1).
(2) Then normal water was added to the mixture and mixed thoroughly for 20 minutes.
(3) The mixture was sieved using a 4.75mm opening sieve.
(4) The prepared mixture was poured loosely into a mold (80 mm x 80mm) (Fig.1) in order to achieve the designed void ratio.
(5) The mold was kept in a moist curing box for 7 days and the test was conducted after the curing period.

Table 1 Details of prepared specimens

Type	Specimen	Mass ratio DL clay: Cement: Water	Vertical Stress (kPa)	Designed void ratio
Cementation	A_c	85:15:25	50,100,300	2.5
Crushable particle	A_{cr}	85:15:25	50,100,150 300	2.5
Crushable particle	B_{cr}	90:10:25	50,100,300	2.5

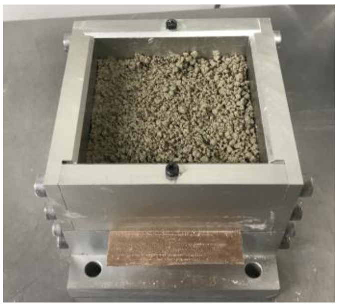

Fig.1 Prepared soil sample (80 mm x 80 mm)

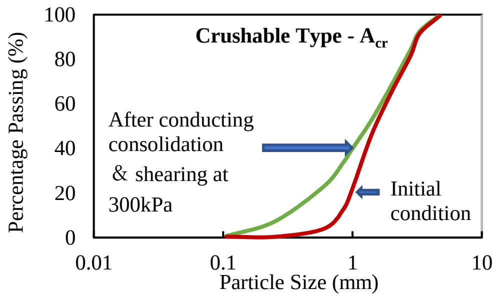

Fig.2 Particle Size Distribution

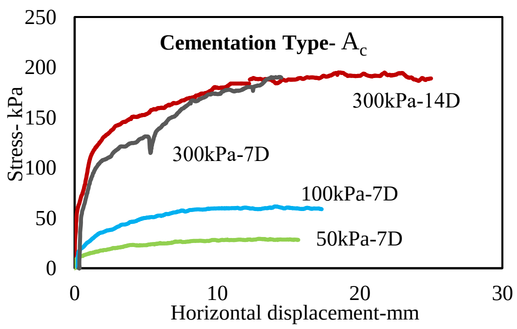

Fig.3 Influence of vertical stress on horizontal stress and displacement relationship for A_c

Keywords: Extremely loose soil, slope failure, Shear box test, Crushability and Cementation effect
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Crushable type specimen preparation

Steps 1 to 3 are the same as Cementation type. Instead of pouring soil into the mold, the prepared soil mixture is kept in a moist curing box for 7 days. After the curing time, the materials were sieved again through a 4.75 mm opening while breaking weakly bonded cemented soil by hand. Then the prepared materials were poured into the mold using air pluviation method. Then shear box tests were conducted at different vertical stresses.

Shear box test

All the test series were conducted under constant pressure levels, with a loading rate of 0.2 mm/min. Table 1 provides the summary of the tests presented in this paper.

RESULTS AND DISCUSSIONS

Particle size distribution test

Fig 2 shows the particle size distribution of A_{cr}. Red color line represents curve of A_{cr} before the test whereas the green color line presents the curve after conducting the test under 300 kPa confining pressure (σ_v).
After the test, fines content has increased due to the particle crushing during compression.

Vertical confining pressure with horizontal displacement

Fig 3 and 4 show the relationship between the shear stress and the horizontal displacement of the specimens A_c and A_{cr} at different σ_v and under the curing periods of 7 and 14 days. Both graphs indicate that as σ_v increases, the strength increases, and strength is stabilized at around 15 mm of the horizontal displacement. Moreover, there is no significant strength gain at 14 days curing compare to that for 7 days curing.

Vertical and horizontal displacement behaviour

Fig 5 represents vertical and horizontal displacements of A_{cr} variation with different σ_v. Here, downward direction indicates negative dilatancy, i.e. reduction in volume. It demonstrates that higher is the σ_v, larger becomes the contraction of the artificial soils. Also, approximately at 15mm horizontal displacement, vertical displacement has become stable.

Comparison of Crushable type A_{cr} and B_{cr}

Fig 6 compares σ_v variation of crushable type A_{cr} and B_{cr} under 7 days curing. A_{cr} specimens have higher OPC quantity than B_{cr}. With all σ_v, A_{cr} shows higher shear stress than B_{cr} due to the cementation effect. However, at 300 kPa, stress increase in A_{cr} compared to B_{cr} is not significant as strength increase at 50 and 100 kPa. Particle breakage may occur between 100 to 300 kPa and therefore its cementation effect will not be that much significant under higher σ_v.

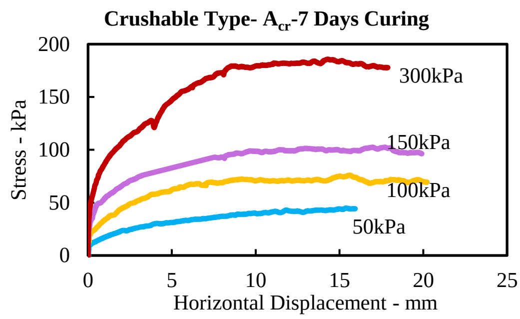

Fig.4 Influence of vertical stress on horizontal stress and displacement relationship for A_{cr}

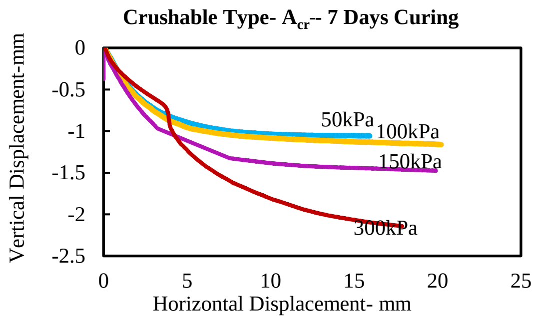

Fig.5 Changes in vertical and horizontal displacement during shearing

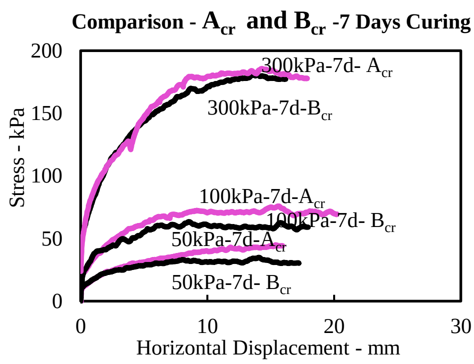

Fig.6 Influence of specimen type on horizontal stress and displacement relationship

CONCLUSIONS

1. Particle size distribution test demonstrates particles were crushing during tests.
2. Cementation and crushable type specimens increase their strength with the increase of σ_v and the strength gain is almost similar in both types at the same σ_v.
3. There is no significant cementation effect on the shear strength between 7 days and 14 days curing periods.
4. When the confining pressure gets larger the contractancy of artificial soils gets higher.
5. At lower σ_v, there is a noticeable strength development between crushable type A_{cr} and B_{cr} due to the cement quantities. However, at higher σ_v, there is not much difference between the strength due to the particle breakage.

REFERENCES

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