Mechanical Characteristics of Cement-mixed Sand in Triaxial Compression Tests

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1. INTRODUCTION

Recently, sand behaviors with/without cementation have been studied intensively by using triaxial test under different loading conditions to investigate creep, pre-peak, post-peak and viscous properties. However, the number of study about dry sand case and dry sand with cement case remains limited. This paper presents triaxial test results of four cases: dry sand, saturated sand, dry sand with cement and cemented sand at three different confining pressure levels of 100kPa, 200kPa and 500kPa; under various loading conditions to investigate and compare the difference in mechanical characteristics between each case.

2. MATERIALS CHARACTERISTICS AND EQUIPMENT

In this study, silica sand with number five grading is used. It has a specific gravity of 2.761, maximum void ratio of 1.215 and minimum void ratio of 0.766. The gradation of silica sand No.5 is shown in Figure 1. The material is uniformly graded and contains a very small amount of fine particle. In this experiment, several experiments are conducted using a high-pressure triaxial apparatus as show in Figure 2, which allows maximum confining pressure up to 3MPa. This apparatus has six sensors in order to measure several soil parameters during the experiment: local displacement transducers (LDT), external displacement transducer (EDT), air volume change measured by a differential pressure transducer (aDPT), load cell sensor, cell pressure sensor (CP), pore water pressure sensor (PWP) and water volumetric strain measured by a differential pressure transducer (wDPT).

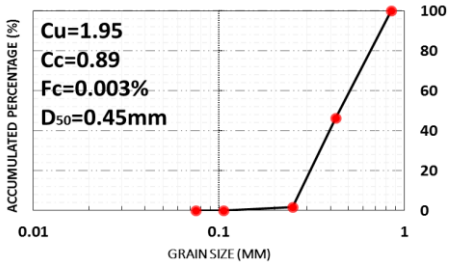

Fig. 1 Gradation of Silica No.5

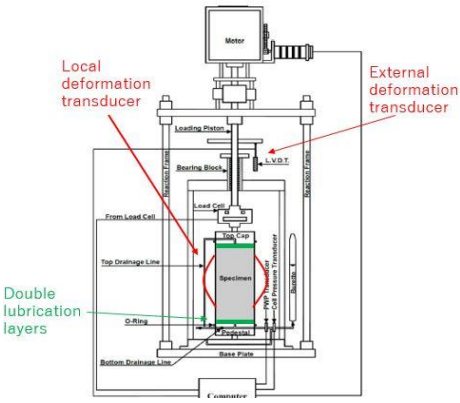

Fig. 2 Triaxial Apparatus

3. METHODOLOGY

3.1 Element test preparation

The Silica Sand No.5 specimens are prepared using air pluviation and dry tamping, pre-calculated weight is also divided into 8 equal in volume layers with 7.5cm diameter and 2cm height. For cemented sand case, specimens are prepared using wet tamping using metal mould with 7 equal in volume layers of 2cm height and one layer is 1cm height.

For saturated sand and cemented sand triaxial experiments, the specimens are saturated using double vacuum pressure (research name) after 6-hour vacuuming. After saturation, B-value ($= \Delta u / \Delta \sigma_c$) is checked whether it is over 90%. Then the specimen is consolidated isotopically at three levels: 100kPa, 200kPa and 500kPa. Finally, monotonic loading experiments are conducted with different loading conditions. For dry sand and dry sand with cement cases, saturation step and backpressure step is removed since the material is completely dry.

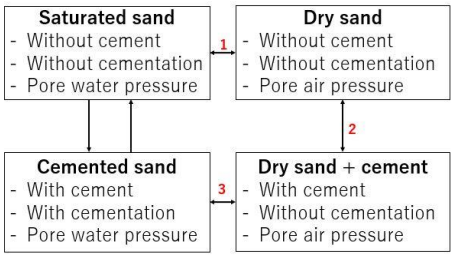

Fig. 3 Four cases comparison

3.2 Four cases of experiment

There are four cases: saturated sand, dry sand, dry sand with cement and cemented sand. In case of dry sand, dry sand with cement and saturated sand, the specimen is prepared in the same manner. As for cemented case, the water to cement ratio is 187% while m_{cement}/m_{sand}=3% in order to minimize the effect of fine particles in dry sand with cement case. The difference in characteristics of four cases is shown in Figure 3. With these four cases as the first series of tests, monotonic loading tests were conducted at a loading speed of 0.0725%/min until reaches 20% axial strain. Conducting experiment on a large range of strain; pre-peak, post-peak and residual strength of material can be investigated.

3.3 Strain rate-dependent behavior study

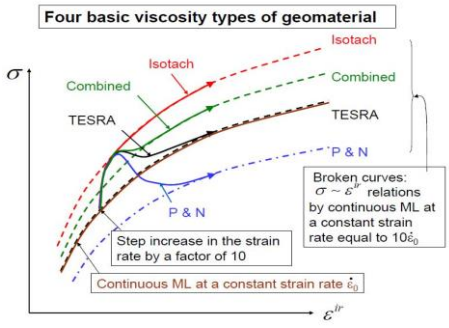

Fig. 4 Four basic viscous property types of geomaterial in shear

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As the second series of tests, several experiments are conducted in order to study strain rate-dependent behavior. There are four types of viscous property found (Tatsuoka et al., 2008) which are shown in figure 4. Isotach is the most classical one: with an increase in ε^{ir} toward residual values, $\Delta\sigma^{v}$ also increases; while for the other three types, with an increase in ε^{ir} toward residual values, $\Delta\sigma^{v}$ decays. In this research, figure 5 shows that the strain rate changes 10 times for every 1% of axial strain. The basic strain rates are $\dot{\varepsilon}$=0.32%/min, $10\dot{\varepsilon}$=3.2%/min and $\dot{\varepsilon}/10$ = 0.032%/min. As for series of experiment, all of four cases (dry sand, dry sand with cement, saturated sand and cemented sand) are conducted for comparison.

4. RESULTS AND DISCUSSIONS

4.1 Monotonic loading triaxial test results

In Figure 6, there is almost no clear difference between dry sand case and dry sand and cement case at high confining pressure of 500kPa, however, as shown in Figure 7 at lower confining pressure of 100kPa and 200kPa, the peak strength of dry sand is higher than dry sand with cement case. At all confining pressures, the behavior of dry sand and saturated sand cases show similar results while cemented sand showed a higher peak strength than the saturated sand case. However, due to the small amount of cement in the specimen, the peak strength of cemented sand case is insignificant comparing to saturated sand case.

4.2 Strain rate-dependent behavior test results

The results of strain rate-dependent behavior tests are shown in figure 8 at the confining pressure of 200kPa (except from cemented sand case due to error). In pre-peak stage, for dry sand, dry sand with cement case and cemented sand, TESRA and Isotach behaviors are not observed clearly in the results, while for saturated case, it is observed that Isotach behavior in this stage. For post-peak stage, all cases show clear TESRA behavior for strain rate changing.

5. CONCLUSIONS

In this research, the result of monotonic loading and changing strain rate tests have been studied in triaxial apparatus and compared among four cases: saturated sand, cemented sand, dry sand and dry sand with cement. In all cases, it is found that the characteristics between dry sand and saturated sand is similar. For monotonic loading tests, at higher confining pressure, the characteristics between dry sand and dry sand with cement cases becomes more similar while the peak strength of cemented sand is not significant comparing to saturated sand due to the small amount of cement. For strain rate-dependent test in pre-peak stage, Isotach and TESRA behaviors are shown clearly on saturated sand case while for other cases, Isotach or TESRA behavior are not shown clearly. At the residual stage, all cases are observed a clear TESRA behavior.

REFERENCES

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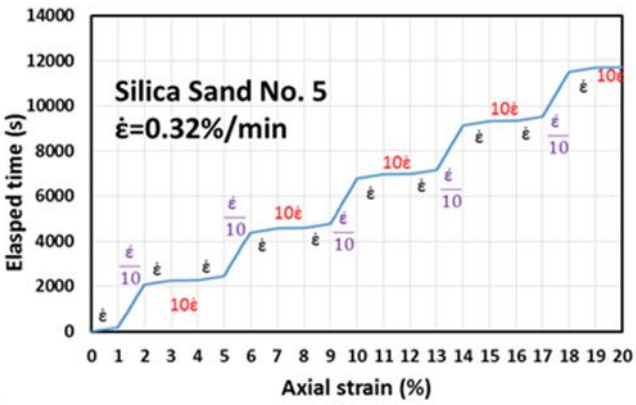

Fig. 5 Axial Strain – Elapsed Time

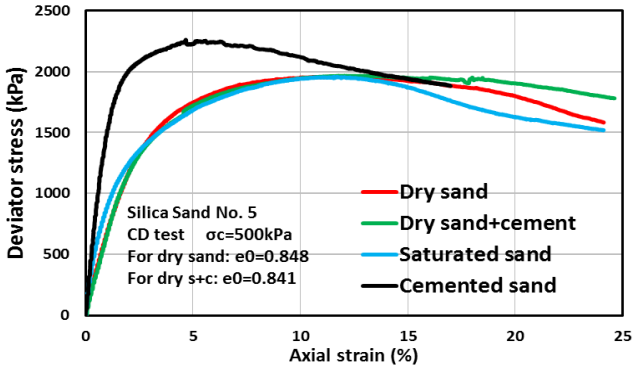

Fig. 6 Axial Strain – Deviator Stress at 500kPa

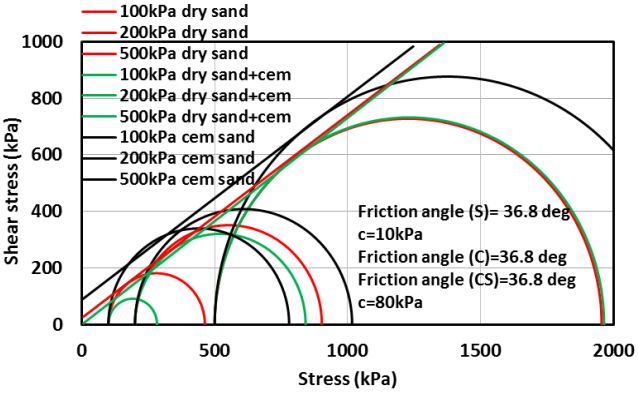

Fig. 7 Mohr Circles at Peak Stress State

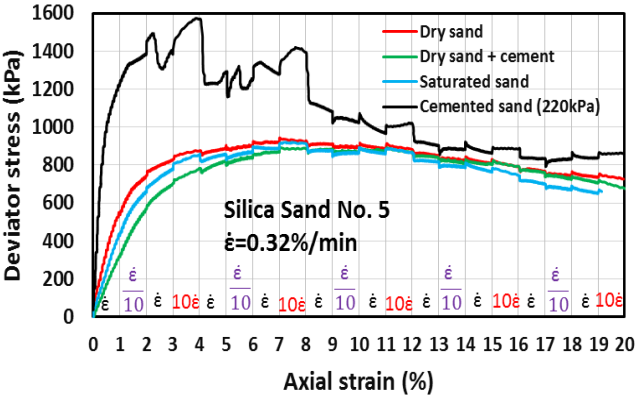

Fig. 8 Axial Strain – Deviator Stress for Strain Rate-Dependent Property