BEHAVIOUR OF SILICA SAND UNDER REPEATED LIQUEFACTION USING TRIAXIAL APPARATUS

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1. INTRODUCTION

Recently, single and repeated liquefaction phenomena have been being studied intensively by using both model test and element test; for instance, shaking table test, triaxial test and torsional shear test. In Japan, Toyoura sand is frequently selected to be a sample for element tests. However, as a substitute for Toyoura sand, silica sand with number seven grading is also occasionally used in model test. As a result of material difference, data from these two types of test is difficult to compare with each other although their physical properties are similar. In order to confirm behaviour of silica sand with number seven grading under this circumstance, this paper presents result of a series of repeated liquefaction tests using the silica sand in triaxial apparatus.

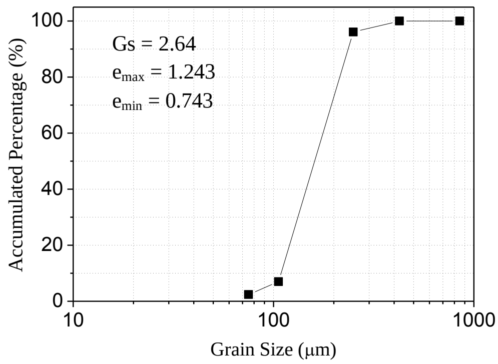

Fig.1 Gradation of Silica Sand No.7

2. EQUIPMENT AND MATERIALS

In this research, silica sand with number seven grading was used. It has specific gravity of 2.64, maximum void ratio of 1.243, and minimum void ratio of 0.743. Gradation is shown in Figure 1. The sample was prepared by air pluviation method by changing the falling height to obtain target relative density. Triaxial apparatus was employed to produce repeated liquefaction. Axial loading was applied by electric motor. Load to the sample can be measured by an inner load cell with a capacity of 10 kN placed above the top cap over the sample. Tubes connected to both top cap and pedestal were linked with low-capacity differential pressure transducer (LCDPT) and pore pressure transducer to monitor volume change of the specimen during consolidation process and pore pressure change during undrained cyclic loading.

3. METHODOLOGY

3.1 Specimen Preparation

Specimen was prepared by air pluviation method through a nozzle to a mold of 150mm height and 75mm in diameter. This nozzle allows slow constant flow rate of material accumulating from the bottom of the mold to the top. Uniform target sample relative density was achieved by varying falling height. Two porous stone were placed on the bottom and top of the specimen. Confining pressure of 30 kPa is applied to the sample to keep it in shape. Sample saturation was done by double vacuum method (Ampadu and Tatsuoka, 1993). By allowing 1.5 hour for specimen to be vacuumed, pore air bubble is enlarged and sucked out of sample before starting the pore water flow; consequently, Skempton B-value over 0.95 can be achieved. It is noted that during sample preparation, counter weight balance of loading piston was employed to avoid specimen disturbance.

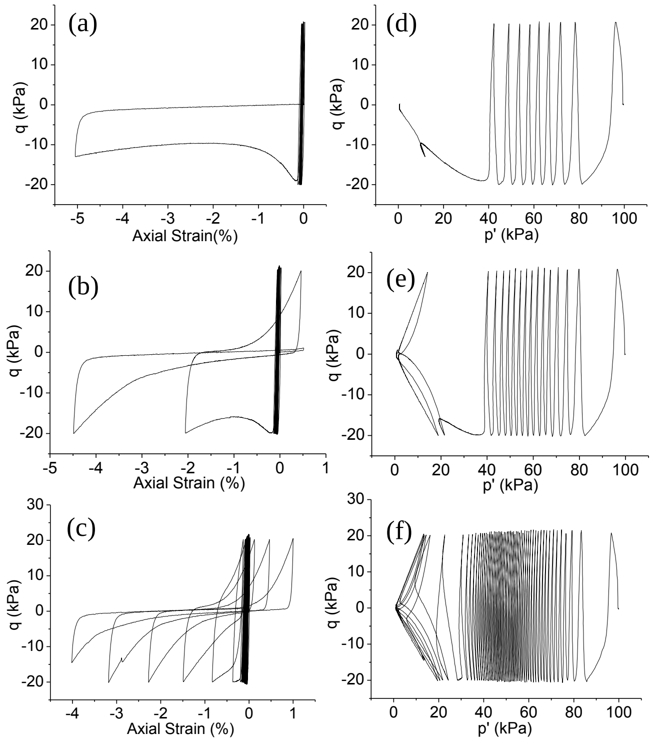

Fig.2 Stress-Strain Relationship of Stage 1 (a), 2 (b) and 3 (c) and Effective Stress Path of Stage 1 (d), 2 (e) and 3 (f)

3.2. Consolidation

After stopping the pore water flow, B-value was checked to confirm degree of saturation. B-value of all the tested samples were ensured to be higher than 0.95. Sample was then consolidated from 30kPa to 100kPa by an increasing rate of 5kPa/min. Consolidation time was 15 minutes before cyclic loading.

3.3. Liquefaction Test

Followed the equation 1 while setting the target value of cyclic stress ratio (CSR), the required single amplitude of cyclic deviator stress, q can be computed.

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$$q = CSR \times \sigma'_c \qquad (1)$$

The load was started by compression followed by extension. Because of undrained condition, excess pore water pressure was gradually generated corresponding with axial strain accumulation. Liquefaction here was set as target double amplitude (DA) axial strain percentage. Once, target DA strain is reached, loading stops and strain is adjusted back to zero. Then, by opening the drainage valve from specimen, excess pore water pressure can be dissipated. This allows the specimen to be re-consolidated. Re-consolidation time was 5 minutes before the specimen was subjected to the next liquefaction stage. An example of repeated liquefaction data is illustrated Figure 2.

4. RESULTS AND DISCUSSIONS

4.1 DA Strain Constant Repeated Liquefaction Test

The objective of this test series is to draw a relationship between the CSR and the number of cycle to liquefy (Nc) in several liquefaction stages. Liquefaction was defined as 5% DA axial strain for each test. An example of test result at CSR equal to 0.1 is shown in Figure 2. In the first stage, sudden large reduction in mean effective stress (p') is observed corresponding with large axial strain. This p' decrease gradually becomes less in the following stages. Liquefaction resistance curve is shown in Figure 3. It can be seen that in every test, Nc increased with liquefaction stages. It also should be noted that because of re-consolidation, specimen relative density increased.

4.2 CSR Constant Repeated Liquefaction Test

In order to study the effect of DA axial strain, CSR of 0.11 was selected, and the cyclic loading was terminated on the extension side in order to eliminate possible effect of induced anisotropy Liquefaction hereby was defined as DA strain 1%, while the DA strain value to stop the cyclic loading was fixed to 1%, 2%, 5%, 7% and 10% for each of the tests. Thus, difference between each test was strain history. Relative density change in each liquefaction stage is shown in Figure 4. A trend can be seen as the larger strain history is, the more increase in relative density. Liquefaction resistance curves of 2 stages and 3 stages are presented in Figures 5 and 6. It is obvious that 1% and 2% DA strain histories show higher liquefaction resistance. However, DA strain history exceeding 5% seems to exhibit random trend.

5. CONCLUSIONS

In this research, repeated liquefaction behaviour of silica sand with number seven grading is studied in triaxial apparatus. Similar CSR and Nc relationship can be observed in each liquefaction stage. The result shows that liquefaction resistance increase with number of stage. In DA strain effect study, CSR Constant test, strain history of 1% and 2% have greater liquefaction resistance than the other. Unlike Toyoura sand (Wahyudi and Koseki, 2015), random trend was found in strain history over than 5%.

6. REFERENCES

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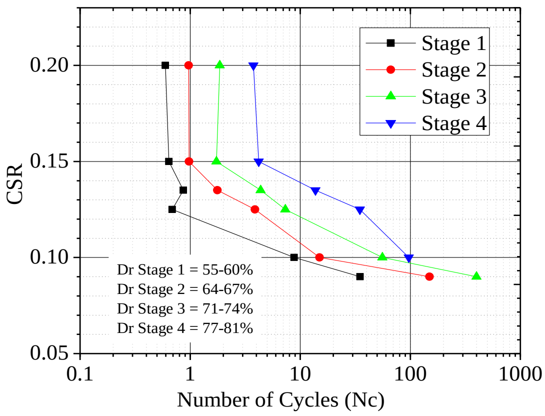

Fig.3 Repeated Liquefaction Curve

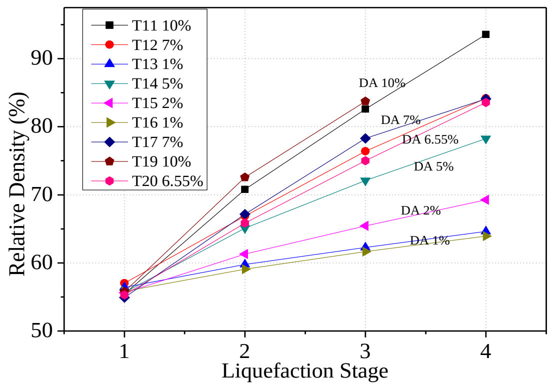

Fig.4 Relative Density Change during Repeated Liquefaction Test

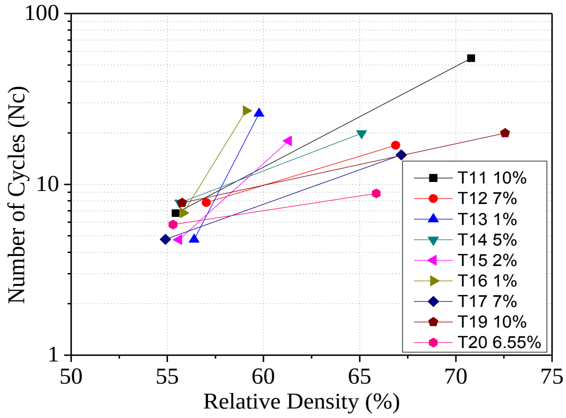

Fig.5 Liquefaction Resistance versus Relative Density of 2 Stages

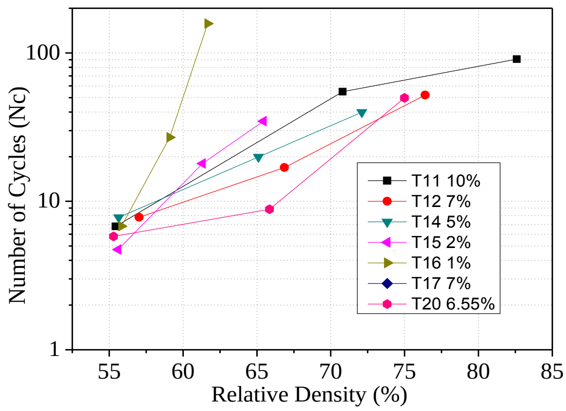

Fig.6 Liquefaction Resistance versus Relative Density of 3 Stages