COMPARISON OF SILICA SAND BEHAVIOUR UNDER REPEATED LIQUEFACTION USING SHAKE TABLE AND TRIAXIAL TEST

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1. INTRODUCTION

Recently, single and repeated liquefaction phenomena have been 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 although their physical properties are similar. Teparaksa and Koseki (2016) reported repeated liquefaction behavior of the silica sand in triaxial apparatus. This paper presents result of repeated liquefaction tests using the silica sand in 1-g shaking table test and their comparison.

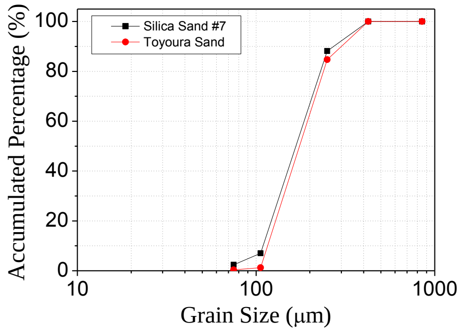

Fig. 1 Gradation of Silica Sand No.7

MATERIALS AND EQUIPMENT

In this study, 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 together with Toyoura Sand. A horizontal ground model was prepared by air pluviation method. Dimension of soil container is 0.60m high, 0.40m wide and 2.60m long. The soil container was made of steel frame with transparent acrylic wall. Piezometer was installed to the soil container to observe ground water condition. The model was instrumented with 14 accelerometers, 14 pore water pressure transducers and 4 laser sensors. Accelerometers and pore water pressure transducers were used for measuring acceleration and pore water pressure in soil while the purpose of laser sensor which is attached on the top of soil container was to monitor settlement of the model. Arrangement of sensors is presented schematically in Figure 2.

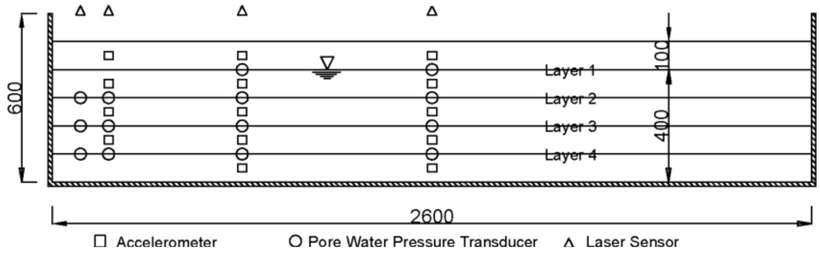

Fig. 2 Shaking table model and instrument arrangement (unit in mm)

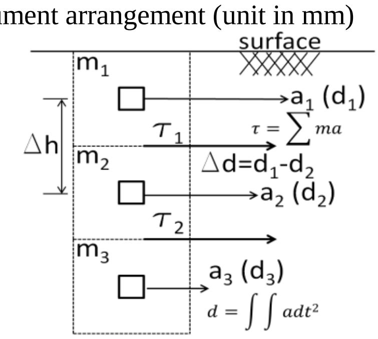

Fig. 3 Computation of shear stress and shear strain

2. METHODOLOGY

3.1 Model Preparation

A 50-cm thick sand layer was prepared by air pluviation method through a sand hopper to a soil container which allows constant flow rate of material accumulating from the bottom of the container to the top. Uniform target relative density of about 50-55% was achieved by adjusting the opening of sand hopper. The sensors are installed when the desired height is reached. At a vertical interval of every 10cm, black-colored sand was placed to observe layer settlement. After finishing air-pluviation process, water was filled in the soil container up to 40cm through pipes installed underneath and water level was confirmed by piezometer. The top 10cm sand layer was left unsaturated.

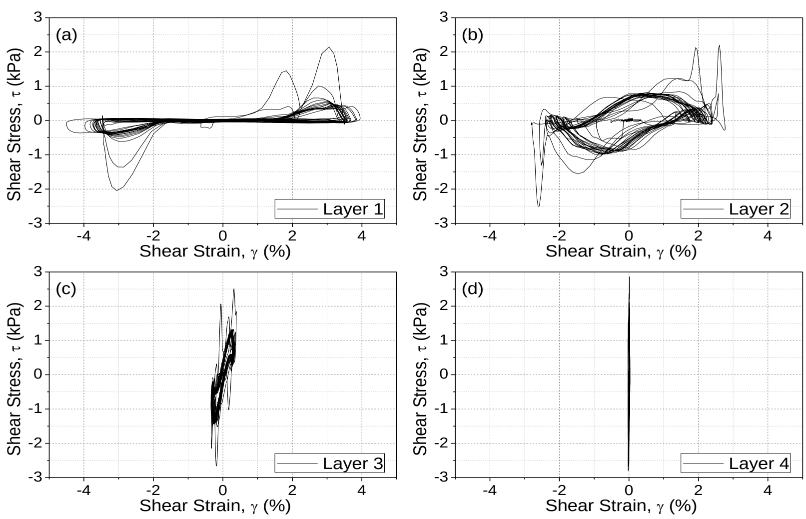

Fig. 4 Shear stress-strain relationship of layer 1(a), 2(b), 3(c) and 4(d)

3.2 Repeated Liquefaction Test

The input acceleration consisted of 20 sinusoidal cycles; i.e., frequency of 5 Hz and duration of 4 seconds. Acceleration amplitude started at 400gal (0.4g). If the soil model shows liquefaction, the same acceleration amplitude is repeated in the next shake stage. However, if the soil model does not liquefy, acceleration is

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raised by 100gal (0.1g) in the next stage. Number of loading cycle was kept the same throughout the repeated liquefaction test. The test ended at 1000gal (1g). It is noted that excess pore water pressure generated by previous shaking stage was dissipated and water level was adjusted to be as initial condition if needed before conducting the next shake stage.

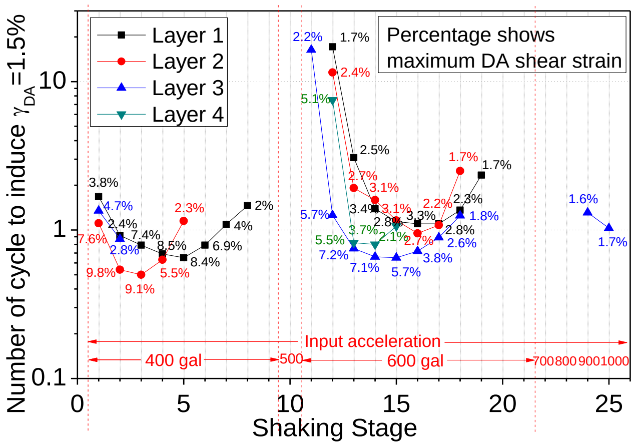

Fig. 5 Liquefaction resistance-shaking stage relationship

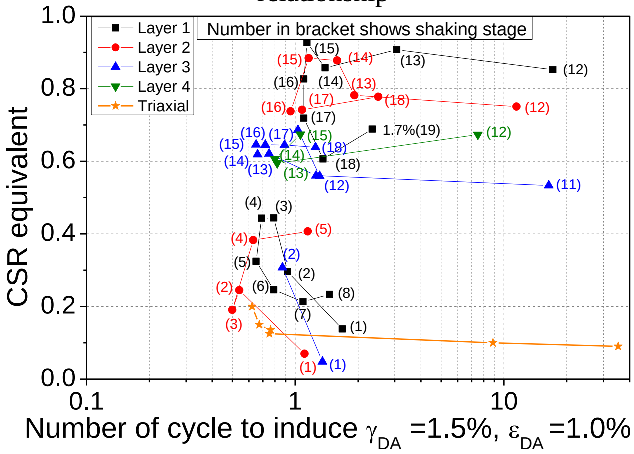

Fig. 6 CSR-Number of cycle to liquefy relationship

3. RESULTS AND DISCUSSIONS

4.1 Analysis

Shear stress generated on a horizontal plane at each layer can be computed as a summation of multiplied results of mass and acceleration and shear strain can be calculated from differential displacement (Δd) between two accelerometers (see Fig 3.). Displacements were obtained by double integration of acceleration data. Consequently, stress-strain relationship can be drawn. Figure 4 presents examples of shear stress-strain relationship of 4^{th} shaking stage at 400gal acceleration.

4.2 Results

In this study, liquefaction is defined as 1.5% double amplitude (DA) shear strain where number of cycle to liquefaction is calculated. Figure 5 shows relationship of number of cycle and shaking stage together with maximum DA shear strain and acceleration level. Liquefaction continuously occurred at the acceleration level of 400gal from the first shake to 9^{th} shake and from 11^{th} shake to 19^{th} shake at 0.6g acceleration. The number of cycle required to trigger liquefaction at the first shaking stage was relatively larger than the second stage. This behavior was also confirmed with five different sands (Ha et al., 2011). In addition, it can also be seen that if the maximum DA shear strain in the current stage is lower than that in previous stage, the number of cycle to liquefaction in the next stage can be expected to be larger compared to the current one and vice versa.

4.3 Comparison of shaking table and triaxial tests

Result of shaking table test in this research was compared with the result of repeated liquefaction test in triaxial apparatus done by Teparaksa and Koseki (2016). Because the cyclic shear stress amplitude changed during the shaking table test (see Fig 4.), in order to compare the results between these two tests, the cyclic shear stress was converted into an equivalent uniform cyclic shear stress by using cumulative damage concept described in Tatsuoka et al. (1986). Thus, equivalent cyclic stress ratio (CSR) can be computed. Figure 6 presents comparison of shaking table and triaxial tests in terms of CSR-number of cycle to liquefy relationship. It can be seen that at the initial shaking events (400gal), result of shaking table test are corresponding to that of triaxial test. However, at latter shaking events, shaking table result shows high value of CSR. This may due to high input acceleration (600gal) and larger relative density. It is noted that in this comparison, possible effects of differences in confining pressure and relative density are neglected.

4. CONCLUSIONS

In this research, repeated liquefaction behavior of silica sand with number seven grading is studied in shaking table apparatus and the result was compared with triaxial apparatus. In shake table test, it was found that the number of cycle required to trigger liquefaction at the first shaking stage was relatively larger than the second stage. Also, at the same acceleration level if the maximum DA shear strain in the current stage is lower than that in previous stage, the number of cycle to liquefaction in the next stage can be expected to be larger compared to the current one and vice versa. By comparing result between shaking table and triaxial test using cumulative damage concept, the shaking table data only corresponds to that of triaxial at the initial shaking stages (low input acceleration).

5. REFERENCES

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