SHAKING HISTORY EFFECT ON RELIQUEFACTION OF SANDY SOILS IN MODEL TEST

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1. INTRODUCTION

Sandy soils are prone to liquefy repeatedly even though the relative density of soil increases with recurring shakes. The shaking history plays an intrinsic role in repeated liquefaction. To observe the effects of shaking history on sandy soils' liquefaction repeatability, two tests on a level ground model of silica sand with grade number seven are performed in 1-G shake table apparatus. It has similar soil particle size distribution as Toyoura sand.

2. APPARATUS AND MATERIALS

For this study, 1-G Shake Table is chosen as model test apparatus. Numerous transducers and sensors are employed to study the real-time changes and effects in the soil model. In total 14 accelerometers, 14 pore pressure transducers, and 4 laser displacement sensors are installed. Fig. 1 shows the 1-G shake table with its transducers and sensors. Silica sand with grade number seven is selected for this study. Soil particle size distribution curve is shown in Fig. 2; along with its specific gravity, minimum and maximum void ratios.

3. METHODOLOGY

3.1. Model Preparation

The soil model in soil container is prepared by air pluviation method by using sand hopper. Sand is poured horizontally layer by layer with thickness of each to 0.1m and all transducers are installed systematically as shown in Fig. 1. For the sake of simplicity, sensors employed for analysis reported herein are shown in Fig. 1. The initial relative density of sand is controlled to be 50%~55%. After every 0.1m of air pluviation, black-colored silica sand with grade seven is poured to make a boundary line between two consecutive layers. Soil is fully saturated to 80% of the total height of sand model in the sand container. The water saturation is done at the completion of model and controlled by four piezometers attached to soil container. The water infiltration is started from the bottom of soil container by fixed-hose and pressure gauge assembly and pressure of water is kept below 1 kPa to avoid any change in relative density and fabric of soil. The 0.1m-thick top layer (denoted as Layer 1) is kept unsaturated and laser displacement sensors are installed on it to record the surface settlement after each shake.

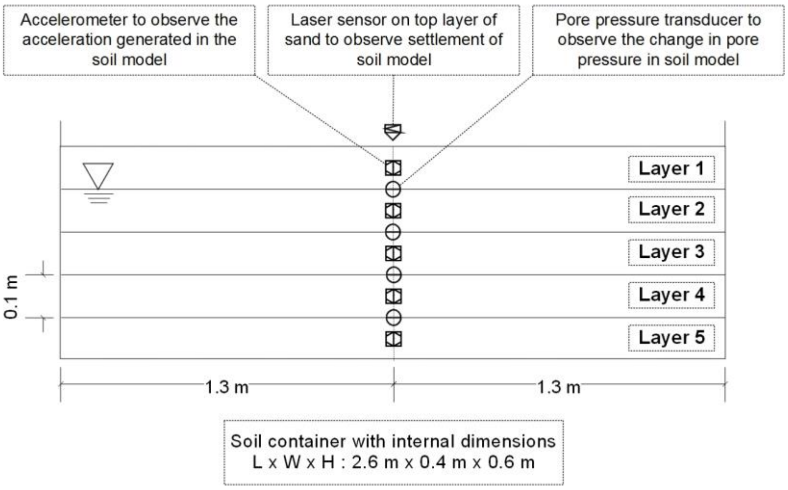

Fig. 1: Shake table with its transducers and sensors

3.2. Test Execution and Calculations of Stresses

To observe the shaking history on reliquefaction study, two tests are performed with the same methodology and test conditions. For both tests, shaking stages are started from 0.2g and terminated on 0.6g. Shaking stage is shifted to the next one with increment of 0.1g if the model does not liquefy on given shake. Every input acceleration has 20 cycles i.e. frequency of 5Hz for 4 seconds. The shear stress and shear strain of each layer is computed from data collected by accelerometer in each layer. The pore pressure transducers in each layer provide data to compute effective stress of that particular layer. Equations 1, 2, and 3 show shear stress, shear strain, and initial effective stress calculations respectively (Koga et. al., 1990).

$$\tau = \sum ma \qquad (1)$$

where τ is shear stress, m (kg) is mass of soil, and a (m/s^2) is response acceleration.

$$\gamma = \Delta d/\Delta h \qquad (2)$$

where γ is shear strain, Δd (m) is differential horizontal displacement between two accelerometers, and Δh (m) is vertical distance between two accelerometers. The horizontal displacement is computed by double integration of acceleration.

$$\sigma'_{V0} = \sum \rho' g\, h \qquad (3)$$

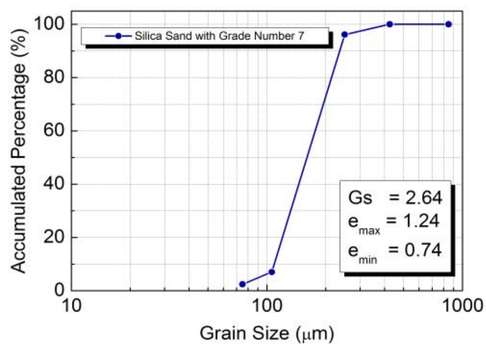

Fig. 2: Particle size distribution curve of silica sand with grade number 7

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where σ'_{V0} is initial vertical effective stress, ρ' (kg/m^3) is submerged density of sand, g (m/s^2) is gravity acceleration, and h (m) is depth from the model.

4. RESULTS AND DISCUSSIONS

In this study the liquefaction is defined when double amplitude (DA) shear stain attains or passes 1.5% for every shake. First test is stated as T1 and second test as T2. The DA shear strains of each layer of each test are mentioned in percentage (%) against shaking stages. Often 0.1g is enough to trigger liquefaction (Towhata, 2008) but in both tests liquefaction is not observed even on 0.2g. Referring to Fig. 3 and Fig. 4, liquefaction is seen on 0.3g with approximately equal number of cycles. Both tests have symmetrical pattern of DA shear strains fall with less number of cycles as shown in Fig. 3 and Fig. 4. Referring to Fig. 5, both tests show a similar trend of relative density increase with succeeding shaking stages when reliquefaction is occurred. By comparing T1 and T2 relative density trends, the 3rd stage of T2 shows abnormality but further rise of relative density of T2 is similar to T1. Reason for this abnormality is that the layer 1 of T2 does not liquefy on 2nd stage at 0.3g but starts to liquefy on 3rd stage at 0.3g. Referring to T1 (Fig. 3), 0.2g has no effect on liquefaction resistance to 2nd stage at 0.3g, however, in subsequent stages i.e. 7th, 8th at 0.3g, 9th at 0.4g, and 10th at 0.5g show no liquefaction at all. Layer 1 of T1 show reliquefaction on 13th stage at 0.5g. This may be due to previous shaking histories. The layer 1 of T2 (Fig. 4), shows the effect of pre-shake and liquefied on 3rd stage at 0.3g but with less DA shear strain as compared to T1 on same acceleration i.e. 0.3g. Moreover, the layer 2 of T2 re-liquefied on 11th stage at 0.5g with less number of cycles which shows mild effects of pre-shake histories.

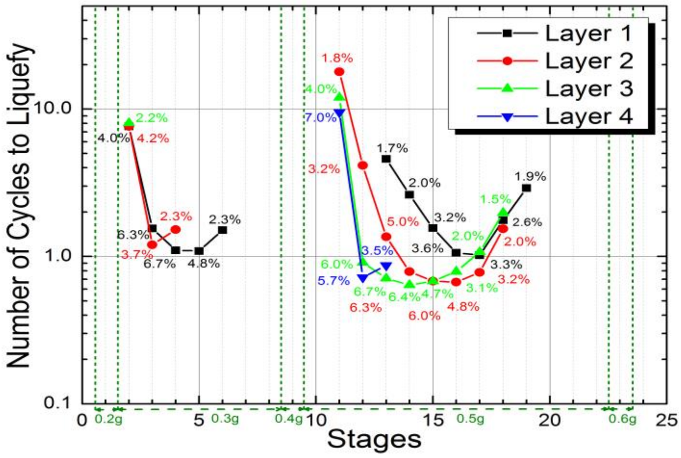

Fig. 3: Test 1 results, DA shear strain is mentioned in % of each layer against shaking stages

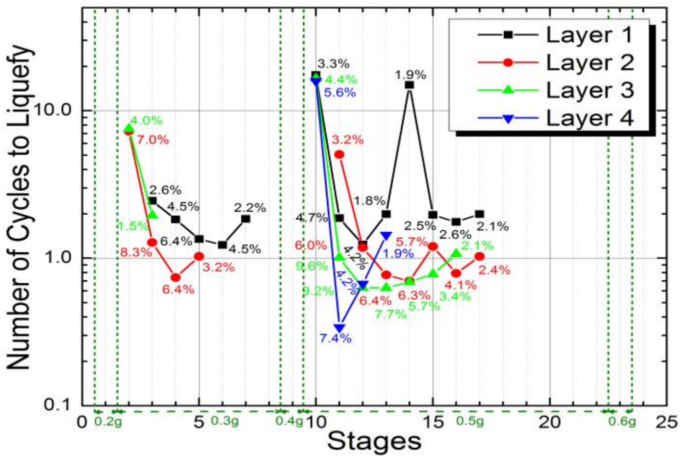

Fig. 4: Test 2 results, DA shear strain is mentioned in % of each layer against shaking stages

5. CONCLUSIONS

The objective of this study was to observe the effect of shaking history on re-liquefaction behaviour of sandy soils in 1-G shake table. By comparing Fig. 5 and Fig. 3, it is evident with no liquefaction, there is no change in relative density but the effect of accumulated shakes is prominent as number of cycles required for reliquefaction are increased (Fig. 3). This effect show some fabric change which enhanced the impedance of soil mass against reliquefaction. Same feature can be seen in layer 1 of T2 (Fig. 4) where soil layer liquefied on 3rd stage at 0.3g but with less number of cycles, may have less effect of fabric change. Possible reason for layer 1 of T2 is the shaking history has less recurrence as compared to T1 (see Fig. 3 and Fig. 4).

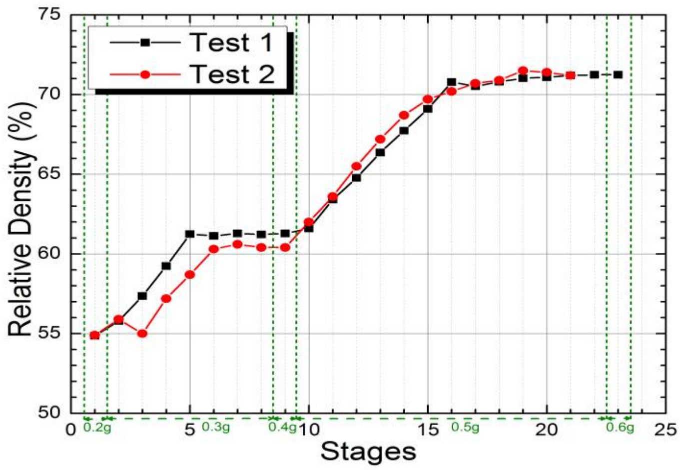

Fig. 5: Comparative relative density of both tests

6. REFERENCES

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