SHAKING TABLE TESTS ON LIQUEFIABLE SANDY SOIL REINFORCED BY DIFFERENT LENGTH PILE

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ABSTRACT:
Small shaking table tests were carried out to study the liquefiability of the sandy soil by monitoring the pore pressure during and after the shaking in the model foundation strengthened by different length pile. The result shows that: strengthening the liquefiable sandy soil by sand pile, neither the longer piles produce better effect when same pile spacing; nor the closer piles produce better effect when same pile length. Under certain conditions, good anti-liquefaction result can not be reached by long pile densely placed.
KEY WORDS: sandy soil liquefaction, strengthening, shaking table test

1. INTRODUCTION

Soil liquefaction in the course of earthquake, causes the ground losing bearing capacity and appearing different settlement, accounting for a considerable proportion in the actual damages. The sand pile has been widely used to deal with the liquefiable soil in engineering because of its remarkable reinforcement effect, simple construction technique and inexpensive cost. The three effectiveness of sand pile processing liquefiable soil—compaction to liquefiable layer, drainage and seismic reducing is mutual connection and coupling, besides related to nature character of the foundation soil, but also related to the design of pile spacing, pile diameter, pile length and many other factors. At present, some knowledge about anti–liquefaction mechanism of granular material pile has been acquired, but it is quite limited. The anti-liquefaction design and judgement in practical engineering mainly focus on the effect of densification[1], it is either too conservative to reduce cost or not enough to eliminate the liquefaction risk completely. In order to determine exactly the validity of sand pile compound ground under certain earthquake resistance request, liquefied test theory which conforms to its characteristic must be established.The interrelated research is lack of experimental data.

In this paper, by monitoring the change of pore pressure and observing the macroscopic performance, the influence of different reinforcement parameter upon anti-liquefication effect was researched, to explore the mechanism of sand pile reinforcement and the anti-liquefication characteristic of compound ground furtherly, and provide scientific basis for reinforcing liquefiable soil in future actual projects.

2. EXPERIMENTAL DESIGN

2.1 Experiment Equipment and Test Requirements

This experiment was carried on in the Engineering Structure Laboratory of Taiyuan University of Technology, the major installation and instrument used present as follows: The shaking table was a small electromagnetic one, the frequency of the output sine wave can be controlled from 0.01 to 1000 HZ, the maximum amplitude is 5mm; The pore pressure gauge is DYS-resistance-strain produced by Sanda Test Instrument Factory in Dandong, Liaoning. Its measuring range is 0.02Mpa and resolution is 0.093% F · S.

This experiment simulateed the actual earthquake wave through inputting the sine wave. In view of the request of the earthquake intensity degrees, the simulation acceleration was 0.2g, the time of shaking was about 1min. According to the similarity rule [3] [4], the output acceleration should be 1g and the duration time should be 5.4s. Considering that the sine wave peak value input was more intense than actual earthquake wave, and the shaking table's modulation was manual, the require was unable to achieve in a short time, therefore the acceleration was adjusted to 0.75g, the time was expand to 10s, in addition the preliminary small fluctuation, the total time of shaking was 30s.

2.2 The Model Preparation

The model box was made of plexiglass with the internal dimension 250mm×200mm×400mm, and holes of 0.5mm in diameter were drilled at 20 mm interval in the four sidewalls, to satisfy certain drainage boundary condition [2]. Before test, three materials, sponge cushion [6] [7], polyfoam [8] [9] and the rubber [10],were used separately to examine the boundary simulation effect. Results showed that the polyfoam produced better effect, therefore, in this test polyfoam was sticked on both box sides, which is vertical in the shaking direction, to weaken the influence of rigid boundary.

The sandy soil of the model foundation, taken from five kilometers to the north of the Yifen Bridge,Taiyuan, and sieved with the sieve of 1mm in screen opening to remove coarse particles and impurities, was silty sand[5] according to its particle composition. Considering the boundary drainage holes, dry-filled method was used to make the model ground. When had filled up, saturated the soil by injecting water slow from the surface, and then left it to consolidate. Half a month later piles were inset with double tube method.

Three pore pressure gauge were placed in each model box along the vertical axis, the respective distance from the soil surface was 100mm, 200mm and 300mm, to recorded the pore water pressure in different depths. Its embedment was shown in Figure 1.

In this test, 10 kinds of model ground were prepared, including 1 non-reinforced model and 9 groups of reinforced model with different parameters (pile length, pile spacing). Each kind has three boxes to do parallel test.

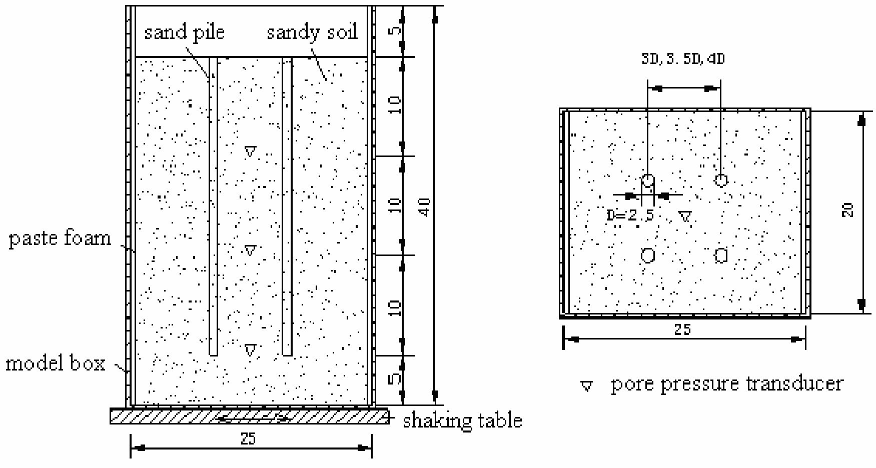

Fig. 1 Test model and pore pressure gauge embedment (unit: cm)

3. TEST DATA ANALYSIS

3.1 Pore Pressure-Time Curve in Non-reinforced Model

The fig. 2 shows the pore pressure ratio-time curve in non-improved soil: about 6s after the beginning of shaking, the pore pressure arised and increased, and about 16s later reached its peak, the soil body liquefied completely.

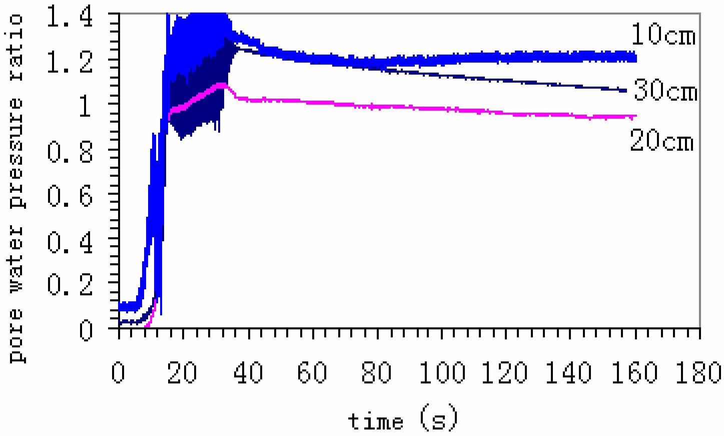

Fig. 2 Pore pressure ratio-time curve in non-improved soil

3.2 Pore pressure ratio-time curve when improved with different length pile

3.2.1 Pore pressure ratio-time curve when improved with pile of 100mm in length

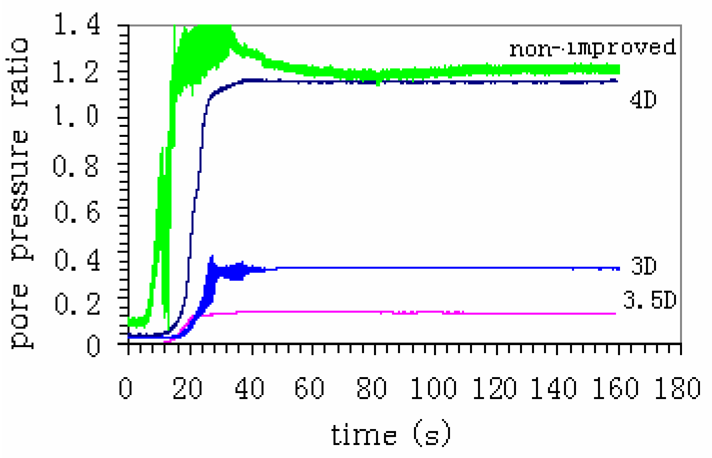

Fig.3　Variation of pore pressure ratio at the depth of 100mm（100mm in pile length）

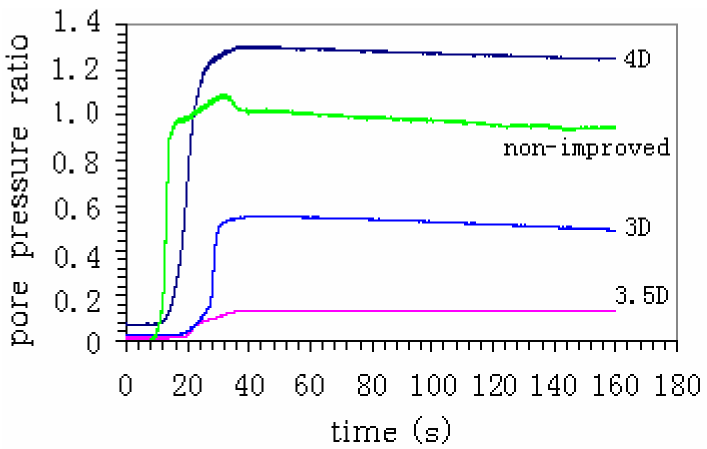

Fig.4　Variation of pore pressure ratio at the depth of 200mm（100mm in pile length）

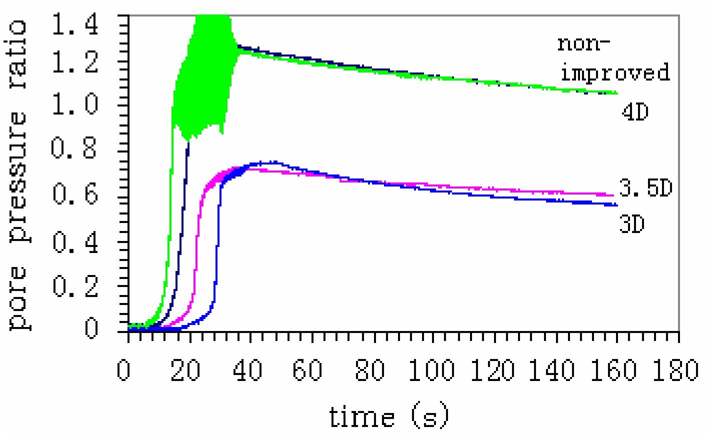

Fig.5　Variation of pore pressure ratio at the depth of 300mm（100mm in pile length）

The fig. 3~5 describe respectively that the change of pore pressure ratio with pile spacing in the depth of 100mm, 200mm, 300mm. It shows that: reforced with 3.5D in pile spacing produced best anti-liquefication effect, pore pressure ratio reached 0.73 in the death of 300mm, soil intenerated a certain extent, but did not liquefied; with 4D in pile spacing the pore pressure ratio in every layer surpasseed 1.0, the entire soil body liquefied, the effect was worst; with 3D in pile spacing the effect was in-between, the maximum pore pressure ratio 0.76 presented in the lower layer of 300mm, coming to the liquefacient scope of sandy soil, so it had liquefied.

3.2.2 Pore pressure ratio-time curve when improved with pile of 200mm in length

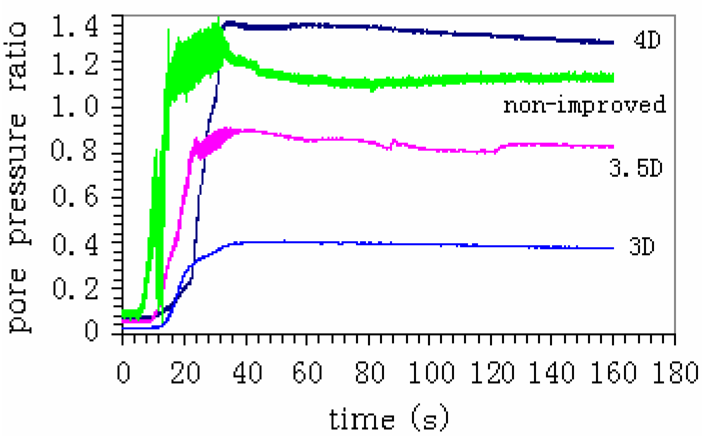

Fig.6 Variation of pore pressure ratio at the depth of 100mm（200mm in pile length）

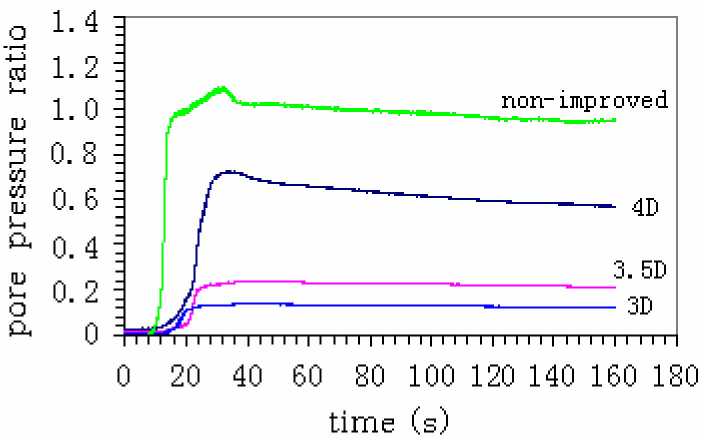

Fig.7 Variation of pore pressure ratio at the depth of 200mm（200mm in pile length）

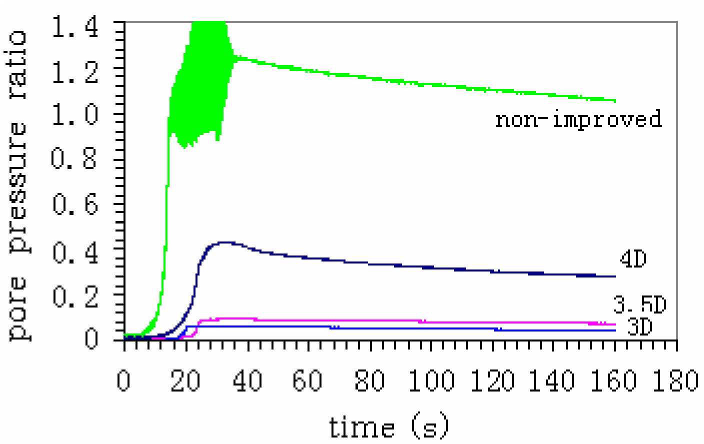

Fig.8 Variation of pore pressure ratio at the depth of 300mm（200mm in pile length）

The fig. 6~8 describe respectively that the change of pore pressure ratio with pile spacing in the depth of 100mm, 200mm, 300mm. It shows that: reforced with 3D in pile spacing produced best anti-liquefication effect, there was no liquefacient phenomena; with 4D in pile spacing the pore pressure ratio in upper layer surpasses 1.0 and serious liquefaction occurred, the effect was worst; with 3.5D in pile spacing the effect was in-between, the maximum pore pressure ratio 0.95 appeared in the upper layer, liquefaction took place.

3.2.3 Pore pressure ratio-time curve when improved with pile of 300mm in length

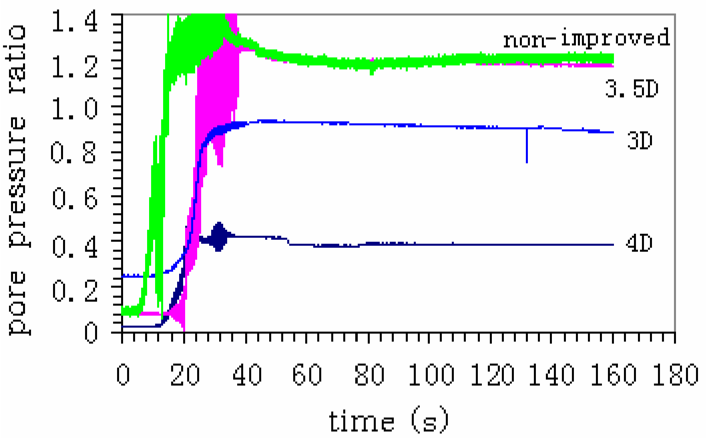

Fig.9 Variation of pore pressure ratio at the depth of 100mm（300mm in pile length）

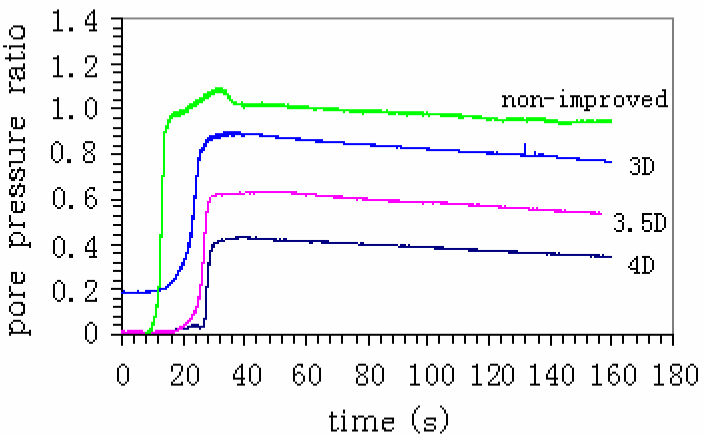

Fig.10 Variation of pore pressure ratio at the depth of 200mm（300mm in pile length）

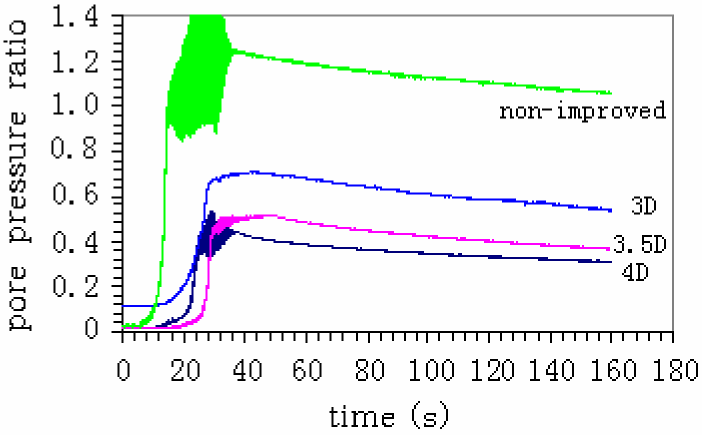

Fig.11 Variation of pore pressure ratio at the depth of 300mm（300mm in pile length）

The chart 9~11 describe respectively that the change of pore pressure ratio with pile spacing in the depth of 100mm, 200mm, 300mm. It shows that: reforced with 4D in pile spacing produced best anti-liquefication effect, in the upper layer the maximum pore pressure ratio was 0.48, soil appeard a little soft; with 3.5D in pile spacing the maximum pore pressure ratio in upper layer surpassed 1.0 and serious liquefaction occurred, the maximum pore pressure ratio in middle layer was 0.63, soil intenerated a certain extent; with 3D in pile spacing the maximum pore pressure ratio in upper layer was 0.93,combining the macroscopic performance, the upper soil body appeared liquefacient phenomenon.

4. CONCLUSION

In this paper, the effect of reinforcing the liquefiable sandy soil by different pile length is studied. Observing the test macroscopic phenomenon and analysing the data of pore pressure, the following conclusions were reached:

(1) In the strengthened soil with the pile of 100mm in length, the pore pressure in the shallow layer decreased because the pore water drained easily; while in the deeper layer increased because the pore water was hard to drain. The pore pressure increased with the depth increasing .The liquefaction region first appeared in the deeper soil, then spread to the shallow, and at last the entire layer liquefied.

(2) In the strengthened soil with the pile of 200mm in length, the pore pressure decreased with the depth increasing. Because the pile is useful to dissipate pore water in the deeper layer, and with the deeper water flowed towards the shallow, there the pore pressure increased. So the liquefaction region first appeared in the shallow layer.

(3) In the strengthened soil with pile of 100mm in length, 4D in pile spacing, the entire layer liquefied; with pile of 200mm in length, 3D in pile spacing, had the best effect, liquefaction did not occur; with pile of 100mm in length, 3.5D in pile spacing, and pile of 300mm in length, 4D in pile spacing, intenerated to a certain extent, but did not liquefied. With other combinations the effect was in-between, liquefaction occurred in either topsoil or subsoil.

It can be discovered that: strengthening the liquefiable sandy soil by sand pile, not the longer piles certainly produce better effect, when the same pile spacing; not the closer piles always produce better effect, when the same pile length, either. Under certain conditions, good anti-liquefaction result can not be reached by long pile densely placed.

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