EXPERIMENTAL STUDY OF LOOSENED SAND DUE TO PIPING

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1. INTRODUCTION

Erosion of soil due to piping, seepage or overtopping causes serious hydraulic work failure (Lachouette et. Al., 2007). It was found that 46% of dam failures were attributed at least in part to piping (Foster et al., 2000). Internal erosion due to piping is especially dangerous because only subtle evidence could be observed from the external even when severe migration of soil particles has already taken place. At present, piping propagation, extents of loosening due to piping effect and mechanical properties of soil with internal pipes are not well understood.

In laboratory experiments, the concept of forming ground loosening by water soluble material was realized by glucose (Renuka&Kuwano, 2011). In this research, glucose powder was filled in a slim plastic tube to simulate piping effect. Triaxial tests under different densities were conducted, representing loose and dense ground respectively. The pipe number for each density varies from 1 to 2. For comparison purpose, specimens without internal pipe were also conducted under similar densities.

2. TEST PROCEDURE

2.1 Test Material

Toyoura sand was used in this study, which is clean, fine-grained and uniformly graded sand with angular and sub-angular particle shapes. Its specific gravity is 2.64, and the maximum and minimum void ratios are 0.992 and 0.678 respectively.

2.2 Triaxial test

A strain controlled triaxial apparatus for specimen of 75 mm in diameter and 150 mm in height was used. High Capacity Differential Pressure Transducer (HCDPT) was used to record the effective confining pressure, and internal load cell was employed to measure the axial load. Four LDTs (70mm×3mm×0.2mm) and three Clip Gauges were fixed in the specimen with the support of the hinges and aluminum blocks glued outside the membrane. Arrangement and location of sensors are shown in Fig.1. LDT1&3 are used to measure the axial strain at upper half of the specimen and LDT2&4 for the lower half. As for radial strain, the results recorded by two relevant clip gauges were averaged separately for upper and lower part.

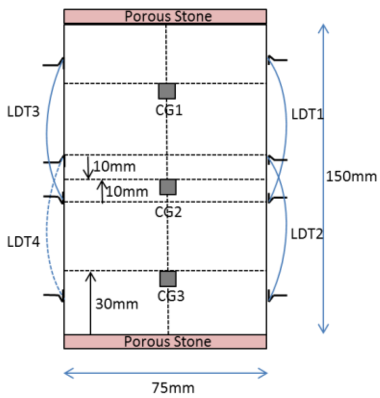

Fig.1 Arrangement of local sensors

The specimen was prepared by air pluviation. For experiments which represent the ground loosening by piping, a plastic pipe of 6mm in diameter and 0.15mm in thickness was placed in advance and glucose powder was poured into the pipe after sand pluviation was completed. Then the pipe was removed with the glucose left inside the specimen. Specimens of two relative densities (D_r=42% and 70%) were tested, both with the inside pipe number of 0,1 and 2.

Specimens were erected at isotropic stress of 25kPa and then the confining pressure was increased to 50kPa. After around 20 hours dissipating the creep effect, small cyclic loading, which has peak to peak strain amplitude of 0.001%, was applied axially with 11 cycles. Then 1500ml of water was penetrated from bottom cap with rate of 12-16ml/min to completely dissolve the glucose powder, and drainage was allowed from top cap. Second small cyclic loading was applied after 20 hours from the 1st water inflow to examine the variation of mechanic properties of loosened sand. After that, the second water cycle (300ml) started in the same way, and again the third cyclic loading was conducted. The objective of the 2nd water cycle is to observe the properties of already loosened soil when it is undergone through another water infiltration. Finally, the LDTs and Clip Gauges were all detached from the specimen and shearing took place with strain rate of 0.1% per minute.

3 TEST RESULTS

The volumetric strains shown in Fig.2 were calculated by using the average of radial strains from three Clip Gauges and average axial strains from four LDTs. NP stands for the specimen without internal pipe, which is controlled specimen. Large deformations were observed in all the specimens with pipes, especially for the loose specimen with 2 pipes inside. $\Delta\varepsilon_{vol}$ of the loose sand group caused by 1st water cycle were 0.058%, 0.77% and 3.10% for the controlled specimen, 1-pipe-specimen and 2-pipe-specimen respectively, and the results were 0.051%, 0.46% and 2.26% for the dense cases. Such obvious difference between specimens with 2 pipes and 1 pipe lies in the local deformation perceived by the Clip Gauges was much larger in 2-pipe-specimen, on which the clip gauges were fixed closer to the glucose pipes.

Keywords: Soil pipe, Internal erosion, Triaxial test
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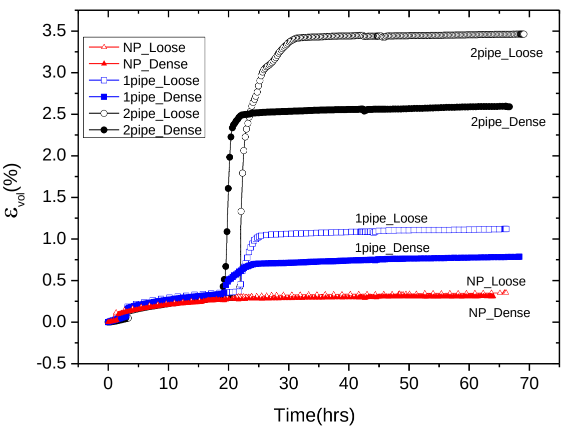

Fig.2 Volumetric strain variation

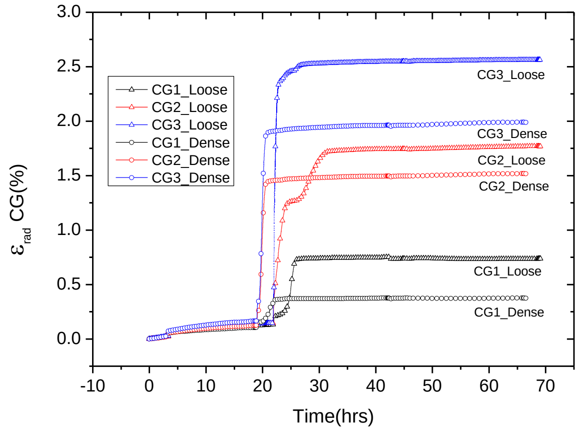

Fig.3 Variation of CGs' results

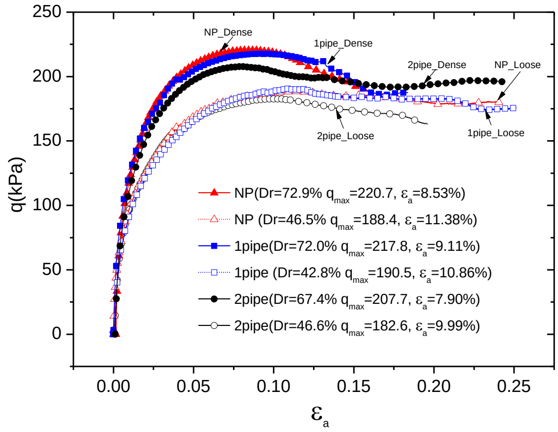

Fig.4 Deviator stress vs. axial strain

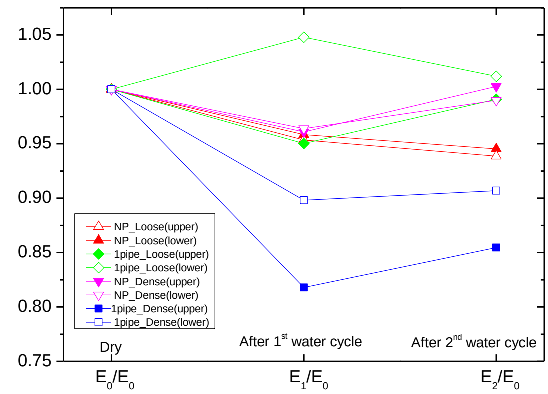

Fig.5 Variation of Young’s Modulus with water path

Fig.3 shows the tendency and variation of radial strain along the specimen, which depicts that the Clip Gauge at the bottom of the specimen undergoes largest deformation. The possible reason may lies in the water inflow direction. As water infiltration starts from the bottom cap, the lower part of the specimen begins to deform as a result of glucose dissolving. Such deformation continues and expands to the region near initial pipes throughout the whole period of water cycle. Meanwhile, the sand particles begin to rearrange, resulting in a renewal structure. This will bring a stable support for the upper part of specimen. The relationship between deviator stress and axial strain during triaxial shearing of all six experiments are shown in Fig.4. The peak shear strength is larger in dense specimen than loose one, while for each density the differences are not so significant for the specimen with and without pipe. Still it can be seen that loosened soil shows lower stiffness compared with the controlled specimen, especially for the cases of 2-pipe-specimen. Fig.5 shows the changing ratio of Young’s modulus evaluated by the axial and radial strains at small cyclic loading. E_0, E_1 and E_2 stand for Young’s modulus before the first water cycle (dry state), after the first water cycle and after the second water cycle respectively. Young’s modulus reduction in specimens with internal pipe is obvious, although some inconsistent behavior can be found, which is possibly due to non-uniform particle arrangement.

4 CONCLUSIONS

The deformation and mechanical properties of sand with internal pipes under different density were studied in this research. It was found that loose sand shows nearly 1.5 times larger axial, radial and volumetric strain than dense sand during the first water infiltration. Direction of water infiltrations plays an important role in loosening formation and propagation. Young’s modulus tends to decrease due to piping effect, while a clear tendency is different to identify because of the non-uniform particle arrangement.

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