Procds. of the 16th Asian Regional Conference on Soil Mechanics and Geotechnical Engineering,
October 14-18, 2019, Taipei, Taiwan

Dynamic centrifuge model test of liquefiable soils reinforced by soil-cement grid

Yuan Cao[1], Y.-G. Zhou[1*], Y. Kurimoto[2], A. Ishikawa[1,2], and Y. Shamoto[1,2]

[1]MOE Key Laboratory of Soft Soils and Geoenvironmental Engineering, Institute of Geotechnical Engineering, Center for Hypergravity Experimental and Interdisciplinary Research, Zhejiang University, Hangzhou 310058, P. R. China; [2]Institute of Technology, Shimizu Corporation, Tokyo 135-8530, Japan. *Corresponding author, E-mail: qzking@zju.edu.cn

Key Words: Liquefaction; Soil-cement grid; Ground improvement; Centrifuge model test

In the 1964 Niigata earthquake in Japan, it was found that the damage of a building using single diaphragm wall as enclosure foundation was slight, while the nearby building without enclosure was seriously damaged by soil liquefaction. Compared to single diaphragm wall, soil-cement grid has better effects for liquefaction mitigation. It has been well developed and gradually applied in engineering practices as a new liquefaction foundation (Sakai and Tazaki 2003). In addition, soil-cement grid is also a new remedial measure for earthquake-damaged foundations of high-rise buildings (JGS 1998). However, the mechanism of soil-cement grid against liquefaction and its performance during strong earthquake are still unclear. This paper describes a dynamic centrifuge model test to study the seismic response of liquefiable soils reinforced by soil-cement grid and evaluates the residual performance of the soil-cement grid after the previous strong earthquake.

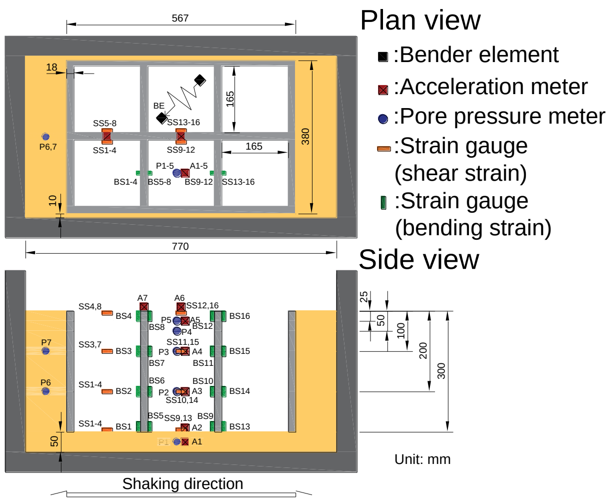


Fig.1. Model configuration

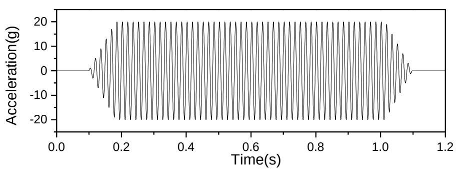
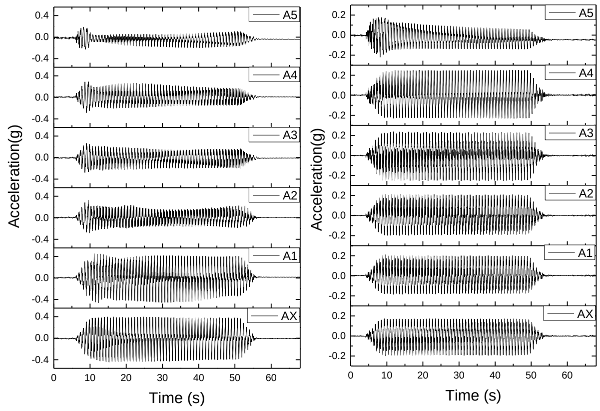


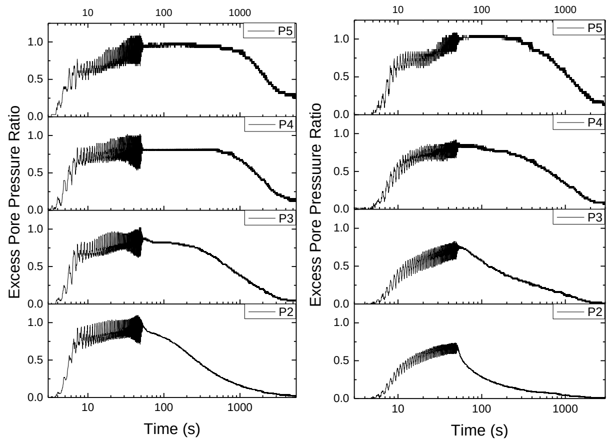
Fig.2. The input motion (Motion 1)

The centrifuge model ground was prepared in a rigid container with internal dimensions of 77cm × 40 cm × 50 cm, under a centrifugal acceleration of 50 g, which means the model scale is 1/50. The model soil-cement grid, surrounded by coarse sand, is made of a mixture of water, cement, Fujian sand and kaolin clay. And the clayey sand (i.e., Fujian sand with 10% of Kaolin clay) was dryly pluviated into the soil-cement grid to attain a relative density of 50%. The model configuration is shown in Fig. 1.



(a) (b)

Fig.3. Acceleration time histories: (a) Motion 1; (b) Motion 2.



(a) (b)

Fig.4. Time histories of excess pore pressure ratio: (a) Motion 1; (b) Motion 2.

In this case, the model was subjected to two subsequent sine sweep type of ground motions with the peak acceleration of 20g and 10g respectively. And the motion consists of the first 5 cycles with increasing amplitude, the middle 50 cycles with a constant amplitude at peak acceleration and the last 5 cycles with decreasing amplitude. The frequency of the earthquake motion is 60 Hz in model scale. Fig. 2 gives the first input motion as an example.

The main findings in this study are as follows:

(1) As shown in Fig. 3, during the first motion, liquefaction caused the de-amplification of soil acceleration inside the grid, while the acceleration increased to some extent after it comes to the nadir. It implies that the stiffness of the enclosed soil recovered during the long shaking and the concurrent pore water dissipation. During the second motion, the soil acceleration was considerably amplified except the top layer which is liquefied, which implies that the amplification response is input motion dependent and lower amplitude motion leads to higher amplification.

(2) Fig. 4 compares the excess pore pressure ratios of soils at different elevations inside the soil-cement grid, which indicates the fastened dissipation of the excess pore pressure and the reduced peak excess pore pressure ratio during the second motion especially at deeper depth.

(3) Large settlement of the soil inside the grid was observed after the first earthquake motion, which was also observed by other researchers (e.g., Olarte et al. (2018)). It implies that for improved ground by using soil-cement grid, the separation of the superstructure from the underlying soil may occur during and after strong earthquake, which will lead to the overloading-induced damage of soil-cement grid and even uneven settlement of the overlying foundation.

ACKNOWLEDGEMENTS

This study is supported by the National Natural Science Foundation of China (Nos. 51578501, 51778573), the Chinese Program of Introducing Talents of Discipline to University (the 111 Project, No. B18047), the Science Technology Department of Zhejiang Province (Centrifugal Hypergravity and Interdisciplinary Experiment Facility, CHIEF). The authors would thank Dr. Junchao Li and Mr. Zizhuang Yan for their kind help during the model tests.

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