Performance of Gravel-Tire Chips Drains in Mitigating Liquefaction

Yutao Hu[1*], Hemanta Hazarika[1], Stuart Kenneth Haigh[2], Gopal Santana Phani Madabhushi[2]

1: Kyushu University, 744 Motoka, Nishi-ku, Fukuoka 819-0395, Japan

2: University of Cambridge, Cambridge CB2 1PZ, UK

*corresponding author: hu.yutao.594@s.kyushu-u.ac.jp

Keywords: GTCM drains, liquefaction, 1g shaking table test

INTRODUCTION

Liquefaction is well known as an earthquake-induced hazard due to the build-up of the excess pore water pressure over and above the hydrostatic values and therefore result in the reduction of soil strength. This hazard has been responsible for tremendous damage in historical earthquakes which resulted in high economic loses and associated social costs.

Drainage method is one of effective liquefaction countermeasures, that has been widely used in practice. The principal objective of using vertical drains is to relieve the excess pore water pressure generated during the shaking before they reach high values that can finally cause damage and loss to infrastructures (Brennan and Madabhushi, 2006). More recently, Garcia-Torres and Madabhushi (2019) have investigated performance of the drains underneath structures.

On the other hand, gravel-tire chips mixture (GTCM) as an alternative geomaterial, has been introduced by Hazarika et al. (2019). Hazarika *et al.* (2020) also introduced the concept of horizontal drain technique for preventing liquefaction-induced damage of buildings. The main objective of this study is to evaluate the performance of GTCM drains as a new liquefaction countermeasure for existing residential buildings.

METHODS AND MATERIALS

A series of 1g shaking table tests were conducted at geo-disaster laboratory of Kyushu University to investigate the effects of GTCM drains in liquefiable soil. Two cases were conducted: Case 1, shallow foundation of 3 kPa, represented by a rectangular block of brass material with cross-section area of 230mm × 100mm in model scale, located on loose sandy soil with GTCM drains installed, as shown in Figure 1. For Case 2, the same structure located on loose sandy soil with no improvement was tested for comparison. Toyoura sand was used as foundation soil in these tests. A sinusoidal acceleration of 200 Gal with frequency of 4Hz and duration

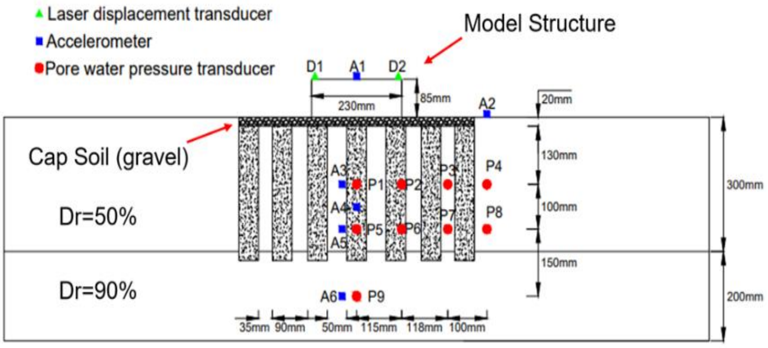

Figure 1 Setup of 1g shaking table

of 10s was applied to the models for both two cases. The responses of the model were recorded using accelerometers, pore water pressure transducers (PPTs) and displacement transducers installed at different locations of the model.

RESULTS AND DISCUSSION

Figure 2 shows the time history of excess pore water pressure ratio, defined as $R_u = u_{expp}/\sigma'_{vo}$, for PPTs in shallow layer of loose sand (P1, P2, P3 and P4 shown in Figure 1). Compared to Case 2, the Ru values were controlled to extremely low level in Case 1. As liquefaction happened in unimproved soil, the effects of GTCM drains could be the main reason that prevented liquefaction.

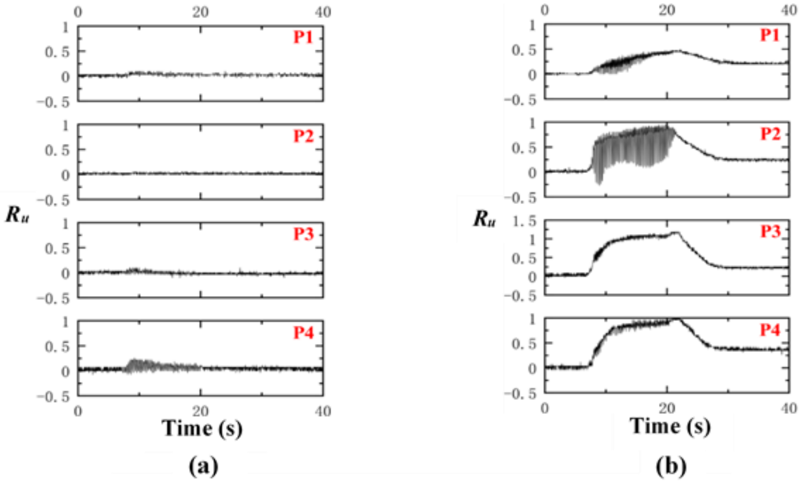

Figure 2 Time History of R_u in: (a) Case 1; (b) Case 2

CONCLUSION

This study aimed to evaluate the performance of GTCM drains in mitigating liquefaction. As the results of 1g shaking table tests proved the effectiveness of such improvement, GTCM drains have the potential to be a new liquefaction mitigation technique. In this sense, we should continue to investigate the characteristics of GTCM drains and try to develop the design guidelines for application in practice.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to Kyushu University for the financial grant under Progress 100 project. Special thanks go to Mr. Yuichi Yahiro, technical assistant of Geo-disaster Laboratory of Kyushu University, for his help and support while conducting shaking table tests.

REFERENCES

Brennan, A.J. and Madabhushi, S.P.G., Liquefaction remediation by vertical drains with varying penetration depths. Soil Dynamics and Earthquake Engineering, 26(5), 469–475, 2006.

Garcia-Torres, S. and Madabhushi, S.P.G., Performance of vertical drains in liquefaction mitigation under structures, Bulletin of Earthquake Engineering, 17(11), 5849–5866, 2019.

Hazarika, H., Pasha, S.M.K. et al., Tire chip reinforced foundation as liquefaction countermeasure for residential buildings, Soils and Foundations, 60(2), 315-226, 2020.

Hazarika, H., Pasha, S.M.K. et al., Sustainable geo-materials in construction towards climate change adaptation, Reference Module in Materials Science and Materials Engineering, 2019.