Gravel-Tire Chips Mixture Drains in Mitigating Liquefaction Potential to Existing Residential Buildings

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1 INTRODUCTION

Liquefaction is known to build-up the pore water pressure over and above the hydrostatic values and therefore lead to a reduction of soil strength. A consequence of this is excessive settlement of structures located on such soils. Several mitigation techniques have been introduced to reduce the effects of liquefaction on structures, particularly to control the excessive settlements. However, very few of these mitigation techniques have been developed for existing buildings that rest on liquefiable soils. Sustainable techniques are also needed to address this, and such techniques should be implementable for existing structure.

Drainage method is one of effective liquefaction mitigation strategies, that is widely being used in practice. Seed and Booker (1977) have developed design guidelines for vertical drains to mitigate excess pore water pressures. The use of vertical drains, as a countermeasure, has the principal objective to relieve the excess pore pressure generated during the shaking before they reach high values that can finally cause damage and loss to infrastructures (Brennan & Madabhushi, 2006).

On the other hand, scrap tire-derived materials (STDMs) have rapidly been used in civil engineering in recent times. STDM and sand-STDM mixture are largely being used and investigated in literature. However, high compressibility and low elastic modulus of tire chips and sand and STDM mixture could result in high differential settlement and in-adequate bearing capacity of foundation. In order to solve the issues, gravel-tire chips mixture (GTCM) as an alternative geomaterial has been introduced by Hazarika et al. (2016). It is expected to be more practical and provide enough shear strength with higher permeability in comparison to that of sand-tire chips mixture.

Therefore, this study aims to investigate the performance of prefabricated geomaterial (gravel-tire chips mixture) drains constructed around the existing residential buildings in reducing liquefaction potential.

2 EXPERIMENTS AND METHODS

A series of 1g shaking table tests were conducted at the geo-disaster laboratory of Kyushu University to evaluate the effectiveness of GTCM drains in liquefiable soil (loose sandy soil) during earthquake. Two cases were conducted: Case 1, shallow foundation of heavy structure with bearing pressure of 3 kPa, which was represented by a rectangular block of brass material, located on liquefiable soil with improvement method of GTCM drains. Case 2, as a comparison, the same structure located on the same soil but without any improvement. The cross-sectional area of the structure is 230 mm×100 mm in model scale. The setup of Case 1 is shown in Fig. 1.

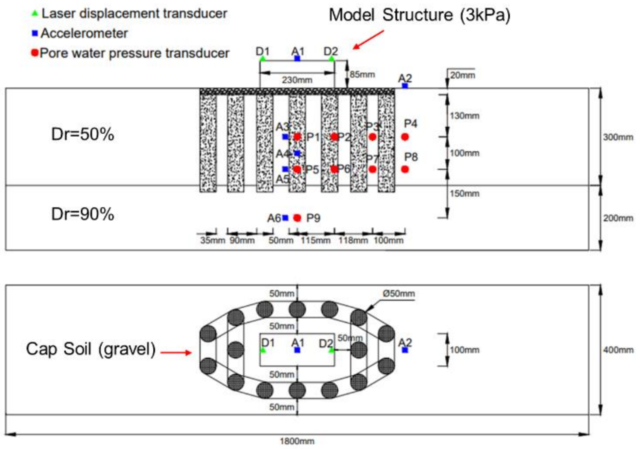
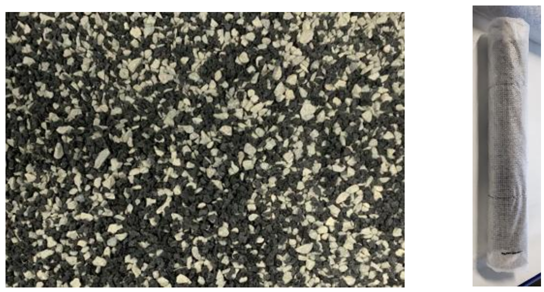


Fig. 1. Setup of the model.

Gravel and tire chips were mixed in the same volume, which means the volumetric gravel fraction GF=50% (Fig. 2(a)). This ratio was found to be the best mixing percentage, at which the rise in excess pore water pressure could be significantly restrained without compromising the stiffness of the reinforcing inclusion (Hazarika et al., 2020). Then the mixture was covered with wire mesh and geotextile to prevent sand falling into the drains, as shown in Fig. 2(b).



(a) (b)

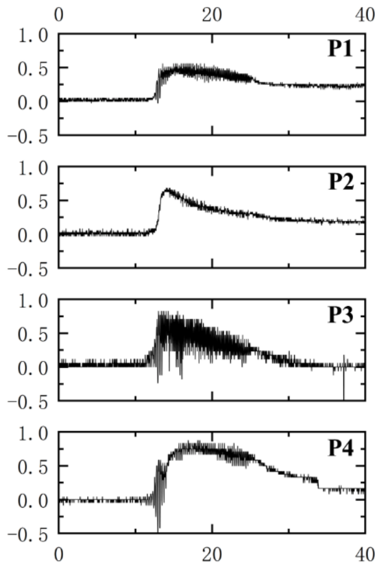
Fig. 2. (a) Gravel-tire chips mixture (GTCM); (b) GTCM drains.

Toyoura sand was used as foundation soil in these tests. A dense layer of this sand (D_r=90%) representing non-liquefiable ground was constructed using both dry deposition and tamping techniques. The upper liquefiable layer (D_r=50%) was constructed only using dry deposition technique. Once the foundation level was reached, the dummy model of foundation was positioned, leveled and embedded by 5 cm by further pouring the sand.

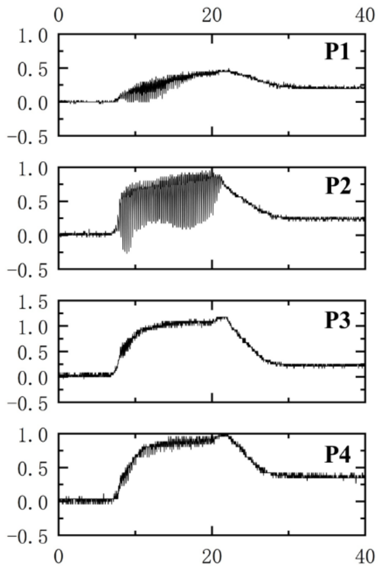
A sinusoidal acceleration of 200 Gal with frequency of 4 Hz and duration of 10s was applied to the model for both two cases. The responses of the model were recorded using accelerometers, pore water pressure transducers (PPTs) and displacement transducers installed at different locations of the model.

3 RESULTS

The development of excess pore water pressure inside the soil during the earthquake were recorded by PPTs. The time histories of excess pore water pressure ratio, which defined as $R_u = u_{expp}/\sigma'_{vo}$, are shown in Fig. 3 in the case of both cases for transducers located at the upper row (P1, P2, P3 and P4 shown in Fig. 1). In this figure, PPTs in Case 1 do not reach full liquefaction value of 1. However, the PPTs beneath the border of the building and in free field area (P2, P3 and P4 shown in Fig. 1) in Case 2 show values over 1 which means the liquefaction happened. The maximum R_u value in Case 2 is also higher than in Case 1, as shown in Fig.4. This is considered as the proof of effectiveness of GTCM drains in dissipating excess pore water pressure and reducing liquefaction potential.



(a)



(b)

Fig. 3. Time history of excess pore water pressure ratio in (a) Case 1; (b) Case2.

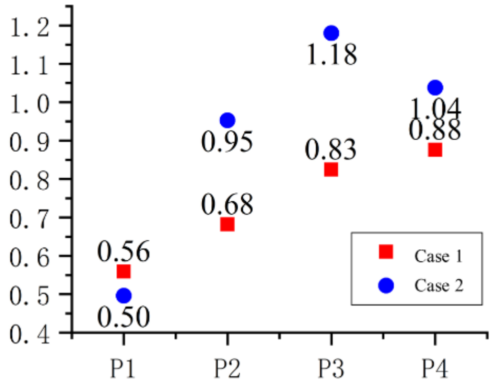


Fig. 4. Comparison of maximum *Ru* in two cases.

On the other hand, as shown in Fig. 1(a), the excess pore water pressure ratio reached the peak soon after the earthquake started and began to decrease in Case 1. In contrast, the R_u kept increasing during the shaking until the shaking stopped.

4 Conclusions

In this paper, a group of comparative tests was conducted based on whether GTCM drains have been applied or not. During the earthquake, GTCM drains installed around the existing buildings can dissipate the excess pore water pressure and reduce the potential of liquefaction. These experimental results form the benchmark for future testing to establish the efficiency of GTCM drains in reducing the liquefaction induced settlement.

REFERENCES

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