Study on the effects of deformation control for embankment during liquefaction by using geosynthetics sandwiched between gravel

Ryo Hashimoto & Masaho Yoshida
Department of Civil Engineering, National Institute of Technology, Fukui College, Japan

Mikio Kubo, Hajime Kawasaki & Yoshinao Kurachi
Eternal Preserve Ltd., Japan

ABSTRACT: Road embankments are damaged due to settlements or deformations or both due to soil liquefaction from earthquakes. Due to these settlements and deformations, cracks and gaps form on the pavement and because of this, emergency vehicles cannot be driven at the time when they are most needed.
We are attempting a new construction method to reduce embankment deformation from soil liquefaction by laying a structure, which sandwich high strength geosynthetics fibers between layers of crushed stones, directly beneath an embankment. This method does not completely eliminate soil liquefaction and enable to some embankment deformations. However the road is at a restorable level even after an earthquake by limiting the settlement and the lateral deformations.
Small scale shaking table tests in a 1-g gravity field were carried out to evaluate effectiveness of a deformation mitigation method for road embankment during liquefaction by using gyosynthetics sandwiched between gravel. The gravel layer could dissipate an excess pore water pressure during liquefaction immediately, and restrained a shear deformation under the embankment because of its high permeability. Furthermore, the composite layer which consisted of the gravel with geosynthetics could perform as a rigid plate with high permeability. As a result, the improved layer could restrain the deformation of embankment, and this effect could keep shape of embankment.

Keywords: Liquefaction, Embankment, Gravel, Geosynthetics, Shaking table test)

1 INTRODUCTION

A settlement and deformation of road embankment were occurred due to soil liquefaction during earthquake. Because it brings a serious damage such as cracks and gap of road surface, even emergency vehicles could not pass the road after the earthquake. Photo 1 shows an example of road embankment damage during 2007 Noto-peninsula earthquake in Japan. It was considered that the damage was caused by liquefaction because the embankment consisted of loose consolidated sandy soil deposit with high water level. Ambulances and restoration work cars could not run through this road after earthquake.

A liquefaction countermeasure technique for embankment by using geosynthetics sandwiched between gravel had been proposed (Murakami et al., 2010). Because the gravel has high permeability, it will be able to dissipate excess pore water pressure rapidly. Furthermore, because the geosynthetics has high tension strength, the gravel layer with it will have high resistance against bending deformation due to overburden load of embankment. This method does not restrain the occurrence of liquefaction completely but mitigate the excessive deformation such as settlement and lateral movement. Its performance requirement is to secure a passable road for emergency car and repair the road rapidly just after earthquake.

Photo 1. Damage of road embankment during 2007 Noto-peninsula earthquake.

2 TEST PROCEDURE

formed under water by pouring silica sand No.7 (ρ =2.66g/cm3, D50=0.17mm, k=4.79x10-3cm) through 2mm sieve to reduce the dropping velocity and to maintain it in the loosest state as possible. The relative density of this liquefiable sand layer was about 50%. A base layer which consist of dense sand was made by shaking loose sand with acceleration of 100gal for 30 seconds, then it came to about 90% relative density and 100mm depth. A liquefiable loose sand layer above the base was also formed by above method and its relative density came about 60% by shaking as mentioned above.

A gravel layer below the embankment was 290mm x 390mm square and 30mm thickness, and a sheet of geosynthetics made by olefin was sandwiched between the gravel layer. No. 5 crushed stones (ρ =2.56g/cm3, D50=3.55mm, k=10.9cm) were used as the gravel. The embankment with 50mm height and 1:1.5 slopes was built of clay mixed with silicone, whose target unit weight was 15kN/m3.The size of model embankment was scaled down one seventy-fifth of real embankment whose height was 4m and crest was 10m.

A input wave used in tests was a sinusoidal wave with a frequency of 5 Hz and peak magnitude of 140gal as shown in Figure 2. The duration time of shaking was 6 second. Pore water pressure transducers, accelerometers and displacement meters were installed at the locations as shown in Figure 1. A vertical displacement of the embankment was measured along three lines by using a point gauge.

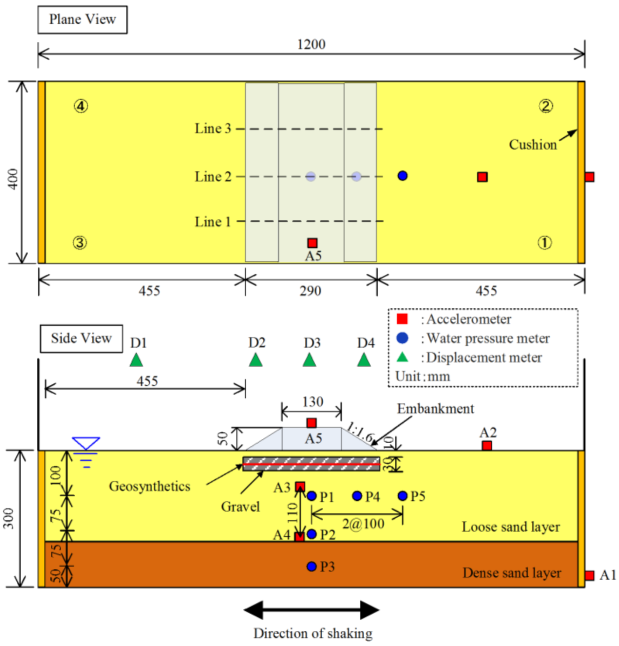


Figure 1. General view of model ground.

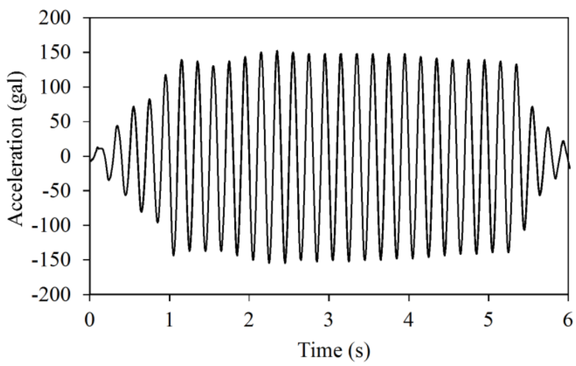
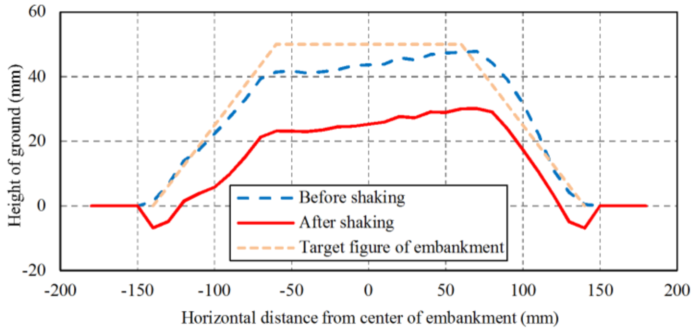


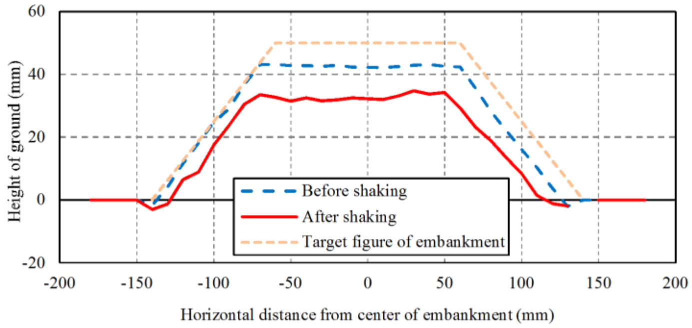
Figure 2. Time history of input acceleration.

3 TEST RESULTS AND DISCUSSIONS

Figure 3 shows a height of embankment from the surface of loose sand layer which were measured before and after shaking. It does not include the settlement of loose sand layer. It can be seen that the embankment over the gravel layer with geosynthetics sunk while keeping the shape of crest and slopes.



a) Unimproved ground



b) Improved ground

Figure 3. Deformation of embankment

Figure 4 shows a vertical displacement of embankment which was measured after shaking, that means settlement. These are average of three measurement lines. The displacement of improved ground was smaller than that of unimproved ground. The difference of settlement between the part of crest and slopes was rather small in that case of improved ground. It means that the embankment settled uniformly because the gravel layer with geosynthetics could behave like a rigid plate. This result indicates that this method might mitigate the excessive deformation of embankment such as settlement caused by liquefaction.

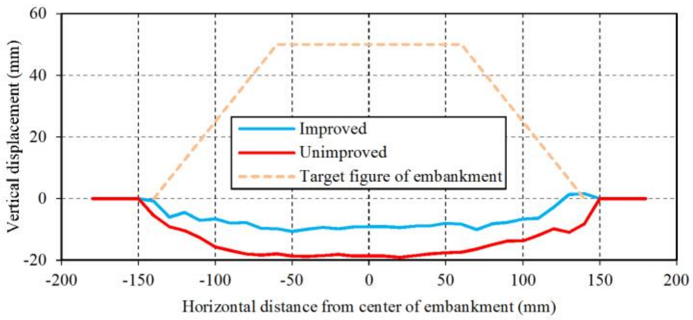


Figure 4. Vertical displacement of embankment.

Figure 5 shows time histories of excess pore water pressure ratio located at 100 mm depth from ground surface. It is clear that the pressure in case of improved ground was restrained during accumulation process of excess pore water pressure, and the time of dissipation were shortened. It is considered that this effect was caused by high permeability of gravel layer, and it related the mitigation of embankment deformation.

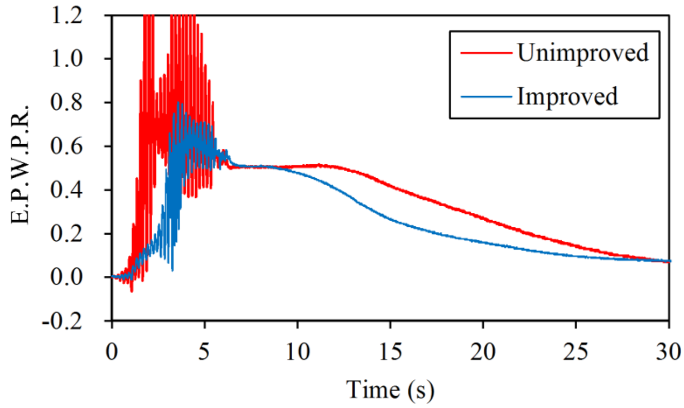
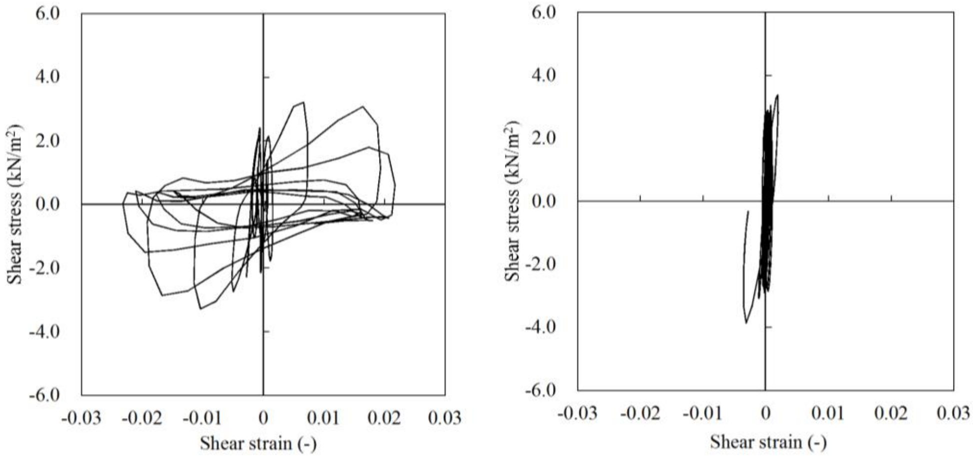


Figure 5. Time history of excess pore water pressure ratio at P1.

Figure 6 shows relationships between shear stress and shear strain of ground under the embankment during the generation process of excess pore water pressure which took three seconds after the beginning of shaking. Although the large shear strain occurred in the case of unimproved ground when the shear stress was small, it was small in the case of improved ground. It is confirmed that the gravel layer with geosynthetics restrained the shear deformation under the embankment.



a) Unimproved ground **b) Improved ground**

Figure 4. Relationship between shear stress and shear strain under embankment.

4 CONCLUSION

Shaking table tests were conducted in a 1-g gravity field in order to evaluate the effectiveness of gravel layer with geosynthetics under the embankment over liquefiable soil ground.

(1) The gravel layer could restrain the deformation of embankment, and this effect could keep shape of embankment.

(2) The composite layer which consisted of the gravel with geosynthetics could perform as a rigid plate with high permeability.

(3) The improved layer could dissipate the excess pore water pressure during liquefaction immediately, and restrained the shear deformation under the embankment because of its high permeability

REFERENCES

Nurakami, K., Kubo, M., Matsumoto, T. and Okochi, Y. 2010. Study on the effect of deformation control embankment during liquefaction by using geosynthetic sandwiched between gravel. *Geosynthetics Engineering Journal*, JGS, Vol.25, 133-140.