Verification of Desaturation Technique as a Liquefaction Countermeasure for Existing Embankments

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1 Introduction

Highways play a key role in providing not only normal but also emergency transportation facility during an earthquake disaster. In Shikoku area of Japan, a total of 10 km of highway embankments is expected to be severely damaged due to liquefaction of thick sandy foundation ground during an earthquake. Application of available liquefaction countermeasure techniques was considered for the foundation soil underneath the existing embankments, but the estimated cost was far beyond the available budget.

The main challenge the geotechnical engineers have been facing is the remediation works for the enormous length of the existing embankments in Japan that are highly susceptible to liquefaction-induced damage. In this paper, a newly developed and dramatically low-cost liquefaction countermeasure technique, known as ‘desaturation method by air injection’ and proposed by Okamura et al. (2011) is introduced. This technique has drawn a considerable research attention recently as an innovative technique, which can be applied in foundation soils just underneath existing structures (Fig. 1). In this paper, we examine the effect of this technique on seismic performance of embankments through a series of centrifuge tests.

2 Centrifuge Test

Three models, as shown in Fig. 2, were prepared: one was saturated foundation soil model (model 1) and the other two were foundation soil models desaturated by air injection technique (model 2 and model 3). All models consisted of a 2-m high well-compacted prototype embankment resting on a 5.4-m deep loose liquefiable sand bed. The models were shaken at 40g with input acceleration amplitude of 295 cm/s².

The input acceleration and observed excess pore pressure time histories are depicted in Fig. 3. At location B3, the excess pore pressure for model 1 reached the initial effective overburden stress, suggesting that the soil liquefied. On the other hand, for model 3, this location was within the desaturated zone and excess pore pressure was pretty low. For model 2, although this location was outside of the desaturated zone, excess pore pressure was apparently lower than that for model 1. This may be due to the migration of pore water from saturated to desaturated zone.

The distribution of maximum excess pore pressure (EPP) is shown in Fig. 4. The EPP for the benchmark model 1 at any location is close to the initial effective overburden stress, σ'v. On the other hand, the observed EPP in the desaturated zone is significantly low, which clearly indicates the effectiveness of desaturation on the excess pore pressures.
Settlement of the embankment crest is shown in Fig. 5. The crest settlements for the models 2 and 3 were less than one-seventh of the model 1. It can be concluded that the countermeasure applied in the soil underneath the embankment with the desaturation technique has a significant effect on reducing the embankment settlement.

Also shown in the figure is the crest settlement obtained from numerical residual deformation analysis, ALID (Yasuda et al., 1999). The simulated residual deformation is in a good agreement with the observed deformation in the tests.

Some photos of the post-test models are shown in Fig. 6. The foundation soil in model 1 liquefied and deformed significantly. Likewise in model 2, the deformation in the desaturated zone was quite limited, and the cracks were seen on the embankment slope near the boundary between saturated and desaturated zones. In model 3, however, the deformation of embankment was not distinctly observed.

References

