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Centrifuge model tests of geotextile-reinforced soil embankments during an earthquake

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A B S T R A C T

The behavior of geotextile-reinforced embankments during an earthquake was investigated using centrifuge model tests, considering a variety of factors such as gradient of slope, water content of soil, geotextile spacing, and input shaking wave. The geotextile-reinforcement mechanism was revealed on the basis of the observations with comparison of the unreinforced embankment. The geotextile significantly decreases the deformation of the embankment and restricts sliding failure that occurs in the unreinforced embankment during an earthquake. The displacement exhibits an evidently irreversible accumulation with a fluctuation during the earthquake which is significantly dependent on the magnitude of input shaking. The peak strain of the geotextile exhibits a nearly triangular distribution in the vertical direction. The embankment can be divided into two zones, a *restricting zone* and *restricted zone*, where the soil and geotextile, respectively, play an active restriction role in the soil-geotextile interaction. The soil restricts the geotextile in the *restricting zone*, and this restriction is transferred to the *restricted zone* through the geotextile. The strain magnitude of the geotextile and the horizontal displacement of the geotextile-reinforced embankment decrease with increasing geotextile layers, with decreasing water content of the soil, with decreasing gradient of the slope, and with decreasing amplitude of the earthquake wave.

1. Introduction

Geotextiles are an effective reinforcement for various soil structures such as slopes and containing walls (e.g., Schaefer, 1997). In recent years, geotextile has been used to increase the seismic stability level of a large quantity of small-size and medium-size earth embankments, which can be regarded as a kind of typical slope.

Field observation is an essential approach to obtain first-hand data for analyzing the behavior of the geotextile-reinforced slopes/embankments. For example, eleven reinforced soil structures were visually examined for evidence of distress resulting from an earthquake, and the results showed that these structures exhibited excellent seismic stability (Sandri, 1997). The seismic stability of an old earth-fill dam in Japan was significantly increased by constructing a counter-balance fill using geosynthetic reinforcement (Tatsuoka et al., 2007). A large number of field surveys were conducted on geosynthetic-reinforced embankments, and valuable understanding was obtained (e.g., Kelln et al., 2007; Indraratna et al., 2010). Nevertheless, the field observation cannot easily change the boundary conditions or loading styles, which means that this approach cannot be used in an investigation of the geosynthetic-reinforcement mechanism. The proper geosynthetic design of slopes/embankments is largely dependent upon systematic understanding of the behavior of such reinforced soil structures, which can be investigated by numerical simulations and model tests.

The limit equilibrium methods, which have been accepted in many engineering codes, were widely employed to evaluate the stability level of geosynthetic-reinforced slopes/embankments (e.g., Srbulov, 2001). A set of equations were formulated to determine the seismic stability and permanent displacement of cover soil in a solid-waste containment system (Ling and Leshchinsky, 1997). Diverse types of analysis methods, including theoretical and numerical methods, were used to investigate the behavior and influence parameters of the overall stability level of reinforced soil structures (e.g., Sawicki and Lesniewska, 1991; Qhaderi et al., 2005; Shukla and Kumar, 2008; Abusharar et al., 2009; Tolooiyan et al., 2009). The reliability analysis was also introduced to the safety assessment of reinforced soil structures (Genske et al., 1991). The effectiveness of numerical analysis is significantly dependent on the accurate modeling of the soil–geosynthetic interface, which has been investigated using a number of laboratory tests (e.g., Wu et al., 2008; Zhang and Zhang, 2009; Zhang et al., 2010).

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