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Reinforcement load and deformation mode of geosynthetic-reinforced soil walls subject to seismic loading during service life

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ABSTRACT

A Finite Element procedure was used to investigate the reinforcement load and the deformation mode for geosynthetic-reinforced soil (GRS) walls subject to seismic loading during their service life, focusing on those with marginal backfill soils. Marginal backfill soils are hereby defined as filled materials containing cohesive fines with plasticity index (PI) >6, which may exhibit substantial creep under constant static loading before subjected to earthquake. It was found that under strong seismic loading reinforced soil walls with marginal backfills exhibited a distinctive "two-wedge" deformation mode. The surface of maximum reinforcement load was the combined effect of the internal potential failure surface and the outer surface that extended into the retained earth. In the range investigated, which is believed to cover general backfill soils and geosynthetic reinforcements, the creep rates of soils and reinforcements had small influence on the reinforcement load and the "two-wedge" deformation mode, but reinforcement stiffness played a critical role on these two responses of GRS walls. It was also found that the "two-wedge" deformation mode could be restricted if sufficiently long reinforcement was used. The study shows that it is rational to investigate the reinforcement load of reinforced soil walls subject to seismic loading without considering the previous long-term creep.

1. Introduction

Using backfill soils with cohesive fine contents to build geosynthetic-reinforced soil (GRS) retaining walls for permanent purposes has attracted considerable attention in recent years (e.g., Farrag et al., 2004; Benjamim et al., 2007). Such backfills are considered to be marginal since they contain cohesive fines that have a plasticity index (PI) >6 and may or may not exceed 15% (Elias et al., 2001). If justified, this practice can increase the cost-effectiveness of GRS walls. However, unlike clean granular soils, soils with cohesive fine contents generally exhibit distinctive creep response under constant loading, and GRS walls with such backfills have time-dependent responses that are very different from those using clean granular backfills (Allen and Bathurst, 2002; Liu et al., 2009; Yang et al., 2009). Another important issue is the seismic performance of this type of GRS walls. Case histories (e.g., Sandri, 1997; Ling et al., 2001) and extensive investigations (e.g., Ling et al., 2005a,b; El-Emam and Bathurst, 2007; Madhavi Latha and Murali Krishna, 2008, 2009; Huang and Wu, 2009; Sabermahani et al., 2009) have shown that GRS walls with granular backfill soils exhibit good performance under strong earthquake loading. However, since earthquakes generally occur during the service life of earth structures, the seismic performance of GRS walls using marginal backfills and having experienced years of creep remains a concern. In particular, it is necessary to clarify the reinforcement load and deformation mode of this type of GRS walls subject to seismic loading during service life, so that the seismic design can be soundly founded.

In most practices of seismic design (e.g., Elias et al., 2001), the reinforcement load is obtained by analysis of limit equilibrium. The reinforced soil wedge bounded by a Rankine's or Coulomb's failure surface is used together with a maximum seismic acceleration in the horizontal direction to calculate the reinforcement load. Maximum load in each reinforcement layer is assumed to occur at the failure surface. It is necessary to check the validity of these assumptions on GRS walls using marginal backfills and subject to seismic loading during service life. Regarding the deformation mode, shaking table tests, either in a 1 g or ng condition, have demonstrated that a "two-wedge" mode exists for most GRS walls with granular backfills under strong seismic loading (e.g., Matsuo

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