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Design of reinforced embankments on soft clay deposits considering the viscosity of both foundation and reinforcement☆

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ABSTRACT

The combined effects of the viscoplastic nature of foundation soil and viscoelastic behaviour of geosynthetic reinforcement (polyester, polypropylene and polyethylene) are investigated. A new method for defining the critical stage, with respect to embankment stability, and the operational field strain rate for use in assessing the undrained shear strength of rate-sensitive foundation soils similar to those examined is proposed. The effect of construction rate on the reinforcement stiffness at the critical stage is examined. The study shows that the selection of a design stiffness using the data obtained from a creep test provided reasonable and conservative results. The effects of the undrained shear strength profile, reinforcement stiffness and soil viscosity on embankment performance under working stress conditions are explored and a new limit equilibrium based design procedure is proposed. Finite Element analyses are used to examine the potential effectiveness of the proposed simplified design procedure.

1. Introduction

Geosynthetics reinforcement has gained wide acceptance as a means of allowing construction of embankments over soft foundation soils as highlighted by recently published papers (Basudhar et al., 2008; Bergado and Teerawattanasuk, 2008; Chen et al., 2008; Ghazavi and Lavasan, 2008; Li and Rowe, 2008; Rowe and Taechakumthorn, 2008; Abusharar et al., 2009; Huang and Han, 2009; Magnani et al., 2009; Subaida et al., 2009; Zheng et al., 2009; Indraratna et al., 2010; Jones et al., 2010; Karstunen and Yin, 2010; Taechakumthorn and Rowe, in press; Wang et al., 2011; Fan and Hsieh, 2011). Geosynthetic reinforcement can also be used in conjunction with techniques for acceleration pore pressure dissipation such as the use of prefabricated vertical drains, PVDs (Lorenzo et al., 2004; Chu et al., 2006; Rowe and Taechakumthorn, 2008; Sinha et al., 2009; Saowapakpiboon et al., 2010; Indraratna et al., 2011; Karunaratne, 2011) although this is beyond the scope of the present paper.

Reinforced embankment design typically focuses on consideration of stability with reinforcement providing the additional resistance required to provide confidence in the stability of the embankment. However for reinforced embankments on rate-sensitive soil, the serviceability limit state can be quite critical. Since geosynthetics are made of polymers, (typically; polyester (PET), polypropylene (PP) and polyethylene (PE)) that are susceptible to creep to a greater or lesser extent depending on the polymer (Allen et al., 1982; McGown et al., 1982; Christopher et al., 1986; Greenwood and Myles, 1986; Jewell and Greenwood, 1988; Bathurst and Cai, 1994; Leshchinsky et al., 1997; Shinoda and Bathurst, 2004; Jones and Clarke, 2007; Kongkitkul and Tatsuoka, 2007; Yeo and Hsuan, 2010), the time-dependant behaviour of the reinforcement has the potential to affect the long-term performance of a reinforced embankment. There is presently only very limited published research dealing with the potential effect of reinforcement creep on the performance of reinforced embankments on soft foundations (Li and Rowe, 2001, 2008; Rowe and Taechakumthorn 2008). Li and Rowe (2001) demonstrated that in some cases there can be a substantial decrease in the mobilized reinforcement stiffness after the end of construction and showed that the isochronous stiffness of the reinforcement can reasonably represent the stiffness of geosynthetic reinforcement at the critical stage (as will be discussed in the following section) for an embankment on a soft inviscous foundation.

For rate-sensitive soil deposits (i.e., soil deposits having strength/stiffness properties that substantially depend on the

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