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Performance of geosynthetic reinforced/stabilized paved roads built over soft soil under cyclic plate loads

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ABSTRACT

The benefits of using geosynthetics to enhance the performance of pavement constructed over soft subgrade was evaluated using cyclic plate load testing. A total of six test sections, with varying types and layers of geosynthetics and base thicknesses, were constructed inside a 2 m × 2 m × 1.7 m test box. A cyclic load at a frequency of 0.77 Hz was applied through a 305 mm-diameter steel plate. The test sections were instrumented by a variety of sensors to measure the load-associated pavement response and performance. The test results clearly showed the benefits of geosynthetics in significantly reducing the pavement rutting. The test section with double geosynthetics layers performs much better than all other sections studied in this paper. Geosynthetics placed at the base–subgrade interface function more as weak subgrade stabilization than as base layer reinforcement in this study. Finally, the benefits of geosynthetic reinforcement was quantified, within the context of the AASHTOWare Pavement ME Design guide, in terms of increasing the resilient modulus of base course layer and/or reducing the thickness of base aggregate layer in pavement structure. The results of analysis show that for geosynthetics functioning as base reinforcement alone, the value of resilient modulus of the base course layer can be increased by about one quarter and that the thickness of base layer can be reduced by about one third for the pavement sections, with 457 mm thick base and single layer of geosynthetic placed at the base–subgrade interface, tested in this study. For geosynthetics functioning as subgrade stabilization alone, the test results showed that the resilient modulus of subgrade can be almost doubled.

1. Introduction

Weak subgrade soil is a common problem in road construction. Whether it is a temporary access road or a permanent road built over a weak subgrade, a large deformation of the subgrade can lead to deterioration of the paved or unpaved surface. The use of cementitious materials to treat/stabilize the poor subgrade is a conventionally accepted practice by many state highway agencies. However, geosynthetics offer an environmental friendly and potentially economical alternative solution for reinforcing/stabilizing roads built over weak soil. The concept of using geosynthetics as reinforcement in roadway construction started in the 1970s. Since then many experimental, numerical, and analytical studies have thus been performed to evaluate the benefits of using geosynthetics in pavement application (Abu-Farsakh et al., 2014; Al-Qadi et al., 1994, 2008; Chen et al., 2009; Kwon et al., 2008; Perkins, 2001, 2002; Saghebfar, 2014; Tang et al., 2016; Tanyu et al., 2013; Vinod and Minu, 2010). Among various techniques in experimental studies, cyclic plate load test, due to its low cost and time savings, has been widely used by researchers to evaluate the performance of geosynthetic reinforced pavement (Abu-Farsakh and Chen, 2011; Al-Qadi et al., 1994; Berg et al., 2000; Cancelli et al., 1996; Chen et al., 2009; Haas et al., 1988; Leng and Gabr, 2002; Perkins, 1999, 2002; Tingle and Jersey, 2005). This type of test has also been proved to be a very good performance indicator test for the evaluation of pavement test sections (Chen and Abu-Farsakh, 2010).

Two types of geosynthetic products, geotextile and geogrid, are normally used in experimental studies in literature. The results revealed that geosynthetics can extend the service life of a pavement (Al-Qadi et al., 1997; Cancelli and Montanelli, 1999; Wasage et al., 2004), reduce the thickness of base course layer (Cancelli and Montanelli, 1999; Montanelli et al., 1997), and delay rutting development (Moghaddas-Nejad and Small, 1996; Kinney et al., 1998). The geosynthetic type, the location of geosynthetics, the

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base thickness, and the subgrade strength have significant effect on the performance of geosynthetic reinforced flexible pavement (e.g., Al-Qadi et al., 2008; Collin et al., 1996; Kinney et al., 1998; Perkins, 1999). Little improvement is obtained for pavement test sections constructed on subgrades with a high California bearing ratio (CBR) values (Perkins, 1999). For a thin base course layer, placing geogrid at the subgrade/base course interface gives better performance, while for a thicker course layer, placing the geogrid at the upper one third of the base course layer gives better performance (Al-Qadi et al., 2008; Haas et al., 1988; Abu-Farsakh and Chen, 2011). The benefit of a geosynthetic becomes insignificant if the base course layer is very thick (Collin et al., 1996; Kinney et al., 1998).

With pavement design moving toward mechanistic–empirical based methods, quantifying the benefits of geosynthetics and incorporating these benefits into Mechanistic–Empirical Pavement Design Guide (MEPDG) has recently received a lot of attention (Perkins et al., 2009; Chen and Abu-Farsakh, 2012). Nevertheless, a lack of understanding the mechanisms of geosynthetic reinforcement, especially rigorously quantifying the geosynthetic benefits, has limited the effectiveness of attempts to change the engineering design practice. These limitations provide a motivation for continual research on geosynthetic reinforced pavements to better understand the geosynthetic reinforcement benefits for incorporating into future pavement design involving mechanistic–empirical pavement design methods.

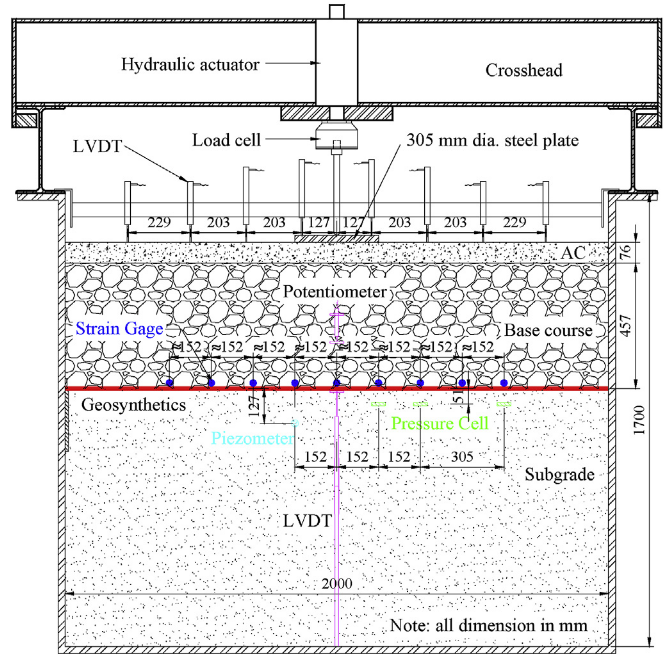

Fig. 1. The indoor test box and load actuator for cyclic load testing.

2. Objectives

The main objective of this research is to evaluate the benefits of using geogrid and high strength geotextile to reinforce base aggregate layer and/or stabilize weak subgrade soil in flexible pavement applications. For this purpose, six large-scale laboratory cyclic plate load tests were conducted to examine the effect of geosynthetic types, base course thickness, and number of geosynthetic layers on the performance of geosynthetic reinforced flexible pavement. A variety of sensors were installed for each section to measure the load-associated pavement response and performance, which could be used to quantify the benefits of geosynthetics within the framework of AASHTOWare Pavement ME Design guide.

3. Testing program

3.1. Pavement test sections

Six test sections were constructed in a steel test box with inside dimensions of 2.0 m (length) × 2.0 m (width) × 1.7 m (height). Fig. 1 shows a typical box pavement test section with the geometric dimensions and layout of instrumentations used in this study.

Each test section was constructed with 1.06 m of very wet high plasticity clay to represent the weak natural subgrade soil. The subgrade layer was constructed by first mixing the soil with a certain amount of water to achieve the target moisture content with lift thickness of 152 mm. Then, the clay was raked level and compacted using a 203-mm × 203-mm plate adapted to a vibratory jack hammer to the predetermined height to achieve the desired density. A 305 mm thick non-woven geotextile-wrapped sand embankment was then constructed for section 1. Sections 2 and 3, which have same base layer thickness of 457 mm, were reinforced by triaxial geogrid. While both sections 2 and 3 have one geogrid layer placed above a nonwoven geotextile at the base–subgrade interface, there is an additional geogrid layer installed at the upper one-third of the base layer for section 2. Section 4 is a control section with 457 mm thick base layer and a layer of non-woven geotextile at the base–subgrade interface, a typical practice in Louisiana. The high-strength woven geotextile, placed at the base–subgrade interface, was used to reinforce sections 5 and 6, which have base layer thickness of 457 mm and 254 mm, respectively. The preparation details of test sections can be found in Abu-Farsakh and Chen (2011). The summary of configurations of each test section is shown in Fig. 2.

Various types of instruments were installed at different locations within the pavement layers to measure the load-associated pavement response and performance. These include pressure cells to measure the total vertical stress at the top of subgrade layer, piezometer to measure the possible excess pore water pressure in the subgrade, customized potentiometer to measure the compressive strain at the mid-height of the base course layer, customized LVDT to measure the total deformation of subgrade layer, strain gauges to measure the strain distribution along the geosynthetics, and LVDTs to measure the surface deformation of pavement test sections. Installation procedures of different instruments can be found in Chen et al. (2009) and Tang et al. (2015).

3.2. Pavement layer materials

3.2.1. Subgrade

The subgrade soil consisted of a high plasticity clay, having a liquid limit of 88 and a plastic index of 53 with 96.6% passing # 200 and organic content of 9.2%. It is classified as CH per Unified Soil Classification System (USCS) or A-7-6 according to the American Association of State Highway and Transportation Officials (AASHTO) classification system. The clay has an optimum moisture content of 35% and a maximum dry density of 1250 kg/m^3 according to the standard Proctor test. To simulate weak subgrade condition (CBR = 0.5), the target moisture content and dry density of subgrade were set as 48% and 1114 kg/m^3, respectively, during construction.

3.2.2. Base course material

Mexican crushed limestone material was used in the base course layer for all test sections. The crushed limestone had 1.56%