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Technical note

Evaluation of geogrid reinforcement effects on unbound granular pavement base courses using loaded wheel tester

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ABSTRACT

Loaded wheel tester (LWT) was employed in this study to investigate the effect of geogrid reinforcement on unbound granular pavement base materials. In the LWT test, the compacted base course specimen was tested under the repeated wheel loading given by the LWT to simulate the actual service situation, and the rut depths of the base specimen were measured along the loading path. Four types of geogrids with different apertures and stiffness were tested with river sand and gravel base courses. In order to verify the effectiveness of the LWT tests, commonly applied cyclic plate loading tests were also performed on the same geogrids and base materials as comparisons. Three technical indices, the Traffic Benefit Ratio (TBR), the Rutting Reduction Ratio (RRR), and the Rate of Deflection (ROD), were employed in the study for the evaluation of the potential benefits of geogrid reinforcement. It was found that the results from LWT tests were generally in agreement with those from the cyclic plate loading tests, which indicates that the LWT test was an effective method to characterize the reinforcement effects of different combinations of geogrids and base courses. The corresponding technical indices proposed in the study were also valid to evaluate the reinforcement effects of geogrids on the specimens with or without geogrid reinforcement. From both LWT and cyclic plate loading tests, the geogrid-reinforced base courses exhibited significant improvement in rutting resistance comparing to the base courses without geogrid reinforcement.

1. Introduction

Due to the potential benefits of decreasing permanent vertical deformation, increasing lateral restraint ability, controlling crack propagation, and reducing base course thickness, geogrid has been widely used as a reinforcement material in pavement systems (Austin and Gilchrist, 1996; Perkins, 2001; Giroud and Han, 2004a, 2004b; Palmeira, 2009; Bhandari and Han, 2010; Dong et al., 2011; Zhou et al., 2012; Wang et al., 2014).

Currently, several experimental approaches have been developed to investigate the reinforcement effects of geosynthetics in pavement structures, which range from full-scale field tests to small-scale laboratory tests. Most of the results from previous studies indicated that incorporating geosynthetics in pavement base course can generally improve the overall performance of pavements and thus help them achieve a longer service life.

Field tests were carried out by Fannin and Sigurdsson (1996) on reinforced and unreinforced unpaved road sections through a test vehicle with standard axle loading. Large-scale single and multiple wheel tracking tests were carried out by Chan et al. (1989) at the Nottingham Pavement Test Facility (PTF) to study the reinforcement potential of geosynthetics in full-scale pavement sections. Perkins (2002) utilized a heavy vehicle simulator to apply traffic loads for characterizing the dynamic response of geosynthetic-reinforced flexible pavement in an environmental-controlled facility. More recently, a full-scale test track of unpaved road on soft

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subgrade was constructed by Hufenus et al. (2006) in order to evaluate its bearing capacity and performance with or without geosynthetic reinforcement. Al-Qadi et al. (2008) also proposed an accelerated test to characterize the reinforcement effects of geogrids in full-scale pavement sections. Field tests were conducted by Mekkawy et al. (2011) to evaluate the reinforcement of biaxial geogrids on stabilizing a severely rutted granular shoulder section supported on soft subgrade soils. Large or small scale cyclic plate loading tests have also been widely used to characterize geosynthetic-reinforced pavement systems in the laboratory. A series of cyclic plate load tests were carried out at the University of Waterloo to investigate the geosynthetics reinforcement to granular bases (Penner et al., 1985; Haas et al., 1988). Dynamic plate loading test was conducted by Ling and Liu (2001) to investigate the performance and various mechanical responses of geosynthetic-reinforced base courses in asphalt pavement under plane strain conditions. Full-scale cyclic plate loading tests were conducted by Chen et al. (2009) on pavement sections to evaluate the influences of modulus, aperture shape and location of geogrids on the reinforcement. Similar tests were also carried out by Al-Qadi et al. (1994) in a test pit and Perkins (1999) in a concrete test box on full-structured pavement sections. Large-scale unbound aggregate road sections were tested by cyclic loading to investigate geotextile and geogrid reinforcement in the aggregate bases over a soft subgrade in Tingle and Jersey (2005). Large scale field tests were performed by Demir et al. (2013) on the unbound granular fill layer above natural clay soil to understand how the bearing capacity and subgrade modulus was affected by footing size in unreinforced and granular fill with and without geogrid reinforcement. Similar large or small scale tests were also performed on base-subgrade structures in many other studies (Leng and Gabr, 2002; Moraci and Cardile, 2012; Nguyen et al., 2013; Abdi and Zandieh, 2014). Compared to field and full scale accelerated tests, small scale laboratory tests are more cost-effective in evaluating the reinforcement effects of geosynthetics on pavement bases. Zhang (2007) and Han et al. (2011) at the University of Kansas proposed the use of a commonly available type of loaded wheel tester (LWT), Asphalt Pavement Analyzer (APA), to characterize the reinforcement effects of geogrids on unbound granular base materials. They conducted a limited laboratory experiment on two geogrids and two types of granular materials. Their findings indicate that LWT is promising in evaluating geogrid reinforcement. However, due to the limited scope of their work, validation of LWT test method with more varieties of geogrids and a comparison between the LWT result and other conventional tests have not been completed yet.

2. Objective and scope

The objective of the present study was to validate the LWT test in evaluating geogrids reinforcement to unbound granular base materials.

In order to achieve the objective, three unbound granular materials were utilized to evaluate the reinforcement effects of four types of geogrids with different apertures and stiffness. The LWT results were also compared to those from a traditional cyclic axial load plate test on the same materials.

3. Experimental methods

3.1. Materials

River sand and gravel were used as the unbound pavement base materials. The river sand and original AB-3 gravel were the same as those used by Zhang (2007) and Han et al. (2011) at the University of Kansas. The fundamental properties of those base materials are presented in Table 1. In order to characterize the effect of the interactions between the grain size of aggregate and the aperture of geogrids, two different gradations of gravel were considered. One is the original AB-3 gravel and the other is the one adjusted to meet the Gradation D requirements in the Tennessee Department of Transportation (TDOT) specification. The grain size distribution of the river sand and the gravels are shown in Fig. 1. It is evident that the adjusted AB-3 gravel is coarser than the original AB-3 gravel.

Table 1
Fundamental properties of the base materials.

Base materials	Specific gravity, G_S	Minimum unit weight, γ_{dmin}, kN/m^3	Maximum unit weight, γ_{dmax}, kN/m^3	Minimum void ratio, e_{min}	Maximum void ratio, e_{max}
River sand	2.651	16.70	18.77	0.384	0.560
Gravel	2.640	17.01	21.64	–	–

Four types of geogrids, named GD1, GD2, GD3, and GD4, respectively, were tested in the study (Fig. 2). GD1 and GD2 are made of two and three layers of high strength extruded biaxial-oriented polypropylene. The layers are tied together without superimposing the grids, thus random-sized apertures are created to accommodate a variety of filling aggregates. GD3 and GD4 are punched-drawn biaxial polypropylene geogrids with a single layer, which possess relatively high modulus and large rib thickness and thus allowing strong mechanical interlock with aggregates being reinforced. The apertures of GD1 and GD2 are relatively smaller than those of GD3 and GD4 due to their multilayer structures, while the stiffness and tensile strength of GD4 are much higher than those of GD1, GD2 and GD3. The fundamental properties of the geogrids provided by the manufacturer are presented in Table 2. According to their physical and mechanical characteristics, GD1 and GD2 were applied in the river sand base course, while GD2, GD3 and GD4 were applied in gravel base courses.

3.2. LWT test

Both the LWT and the cyclic plate loading tests were conducted at The University of Tennessee, Knoxville. Prior to testing, the unbound base material was compacted in an aluminum testing box (600 mm × 400 mm × 100 mm) through manpower tamping and hammering efforts. Although 90% or higher relative density can be achieved in pavement constructions, 70% was chosen as the relative density for the compaction of the specimens, which is more applicable in the laboratory considering the manual compaction method. To control the density of the sample, the mass of the base materials for each layer were calculated in terms of the fundamental properties of the base materials given in Table 1. In addition, for testing the base materials with greater density, a greater

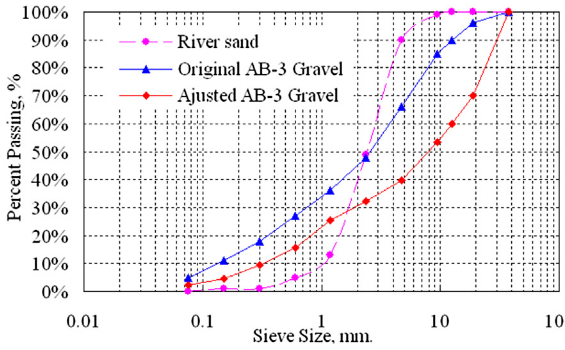

Fig. 1. Grain-size distribution of base course materials.