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Accelerated Load Testing of Geosynthetic Base Reinforced/Stabilized Unpaved and Pavement Test Sections

INTRODUCTION

Figure 1
The accelerated wheel load test setup at the DOTD Pavement Research Facility

Roads in Louisiana are often built over weak subgrade soils due to the soft nature of subsurface soils and the presence of high water tables, which create many design and construction challenges. A common practice in Louisiana is to stabilize/treat the upper part of subgrade with cement or lime, depending on the subgrade soil type. This practice can help reduce the risks of excessive permanent deformations (rutting) by spreading the tire pressure into a wider area, thus reducing the vertical pressure on top of the untreated subgrade layer. However, the difficulty of stabilizing/treating very weak subgrade soil with cement or lime in certain conditions calls for an alternative solution. The use of geosynthetics to reinforce the base aggregate layer and/or stabilize the subgrade layer can offer a cost-effective alternative solution to this problem. The concept of using geosynthetics (geogrids and geotextiles) as reinforcement in roadway construction started in the 1970s. Since then, numerous studies have revealed that using geosynthetic reinforcement (mainly geogrids) in pavement structures can either extend the pavement service life and/or reduce the base course layer thickness. The geosynthetic type, geometry, location/noumber of geosynthetic layers, base thickness, and subgrade strength have significant effect on the performance of geosynthetic reinforced flexible pavement. However, no national method/specification for design of flexible pavements with geosynthetic reinforcement is agreed upon, and a universal design/analysis of pavement structures is still being investigated. With the pavement design moving toward Mechanistic-Empirical (M-E) based methods, quantifying the benefits of geosynthetics and incorporating these benefits into the Mechanistic-Empirical Pavement Design Guide (MEPDG) has recently received a lot of attention. However, the lack of understanding the mechanisms of geosynthetic reinforcement, especially in quantifying their benefits, has limited the effectiveness of attempts to change the engineering design practice. These limitations provide a motive for continual research on geosynthetic reinforced pavements to better understand the benefits of geosynthetics as reinforcement and incorporate their effects into future pavement designs within the M-E pavement design methods.

OBJECTIVES

- Evaluate the benefits of using triaxial geogrid and high strength woven geotextile to reinforce/stabilize base course aggregate layer and/or stabilize weak subgrade soils in flexible pavement applications.
- Quantify the benefits of using geosynthetics within the framework of the 1993 AASHTO pavement design guide and the AASHTO Pavement M-E design.

SCOPE

The objectives of this study were achieved through conducting an experimental testing program, which includes: (1) accelerated wheel load testing of instrumented geosynthetic-reinforced pavement test lanes built over weak subgrade soil; (2) full-scale cyclic plate load testing on the same field pavement test lanes; and (3) laboratory large-scale in-box cyclic plate load testing on instrumented geosynthetic-reinforced pavement test sections constructed inside a test box.

The benefits of using geosynthetics (triaxial geogrid and woven geotextile) in the pavement were quantified within the framework of the 1993 AASHTO pavement design guide and the AASHTO Pavement M-E design. Based on the results of this study, typical design parameters were recommended for the design of geosynthetics reinforced flexible pavement built over weak subgrade soils (CBR = 0.5-3). Additionally, the economic benefits of using geosynthetics in flexible pavement were demonstrated by a direct comparison with the unreinforced flexible pavement and the 12-in. cement/lime treated subgrade through a group of base thickness design scenarios and life-cycle cost analyses.

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PRINCIPAL INVESTIGATOR:
Murad Y. Abu-Farsakh, Ph.D., P.E.

LTRC CONTACT:
Zhongjie Zhang, Ph.D., P.E.
225.767.9162

FUNDING:
SPR: TT-Fed/TT-Reg

Louisiana Transportation Research Center

4101 Gourrier Ave
Baton Rouge, LA 70808-4443
www.ltrc.lsu.edu

METHODOLOGY

In this study, field and laboratory accelerated loading tests were conducted to evaluate the performance of geosynthetic reinforced/stabilized unpaved/paved roads under accelerated moving wheel and cyclic loads. The field pavement sections comprised of six test lane sections with different reinforcement configurations that constructed over weak subgrade soil. The test lanes were 80 ft. long and 13 ft. wide. Section 1 and Section 4 were the control sections without geosynthetic reinforcements; Section 1 was constructed over 1-ft. thick sand layer wrapped by nonwoven geotextile, and Section 4 was constructed with nonwoven geotextile on top of the subgrade layer. Section 2 and Section 3 were reinforced/stabilized by a triaxial geogrid placed at the base-subgrade interface, which are underlain by nonwoven geotextile for separation. An additional geogrid layer was installed at the upper one-third of the base layer thickness in Section 2. Section 5 and Section 6 were reinforced with geotextile of different base layer thicknesses. A 3-in. asphalt layer was constructed later on top of test lane sections.

The test sections were instrumented with earth pressure cells installed on top of subgrade to measure the vertical stresses. Piezometers were installed next to pressure cells to measure the excess pore water pressure. LVDTs attached to a 3-ft. rod were driven into the subgrade soil to measure deformation of the subgrade. Potentiometers were installed to measure the strain at the mid-height of the aggregate base layer.

The moving wheel load test was used to apply moving wheel loads on the test sections. The wheel applied unidirectional traffic load over a 40-ft. distance on the test sections with a speed of 10.5 mph. The magnitude applied wheel load was varied: 9750 lb., 12050 lb., and 14350 lb.

The cyclic plate load test was applied on a 1-in. thick, 12-in. diameter steel plate resting on the pavement surface. The maximum applied load in the plate load tests was 9,000 lb., which results in a loading pressure of 80 psi and simulates dual wheels under an equivalent 18,000-lb. single axle load. The setup for the cyclic plate load test was used in testing the field sections and laboratory sections for comparison.

The results from the three tests were compared and used to evaluate the benefits of using geosynthetics on pavement performance. The test results were used to estimate the equivalent resilient modulus for the reinforced sections in comparison to the unreinforced control section. The effect of geosynthetics on the life-cycle cost was evaluated using the traffic benefit ratio (TBR) and reduction in the base thickness (BCR) parameters. A cost-benefit analysis was performed to evaluate the savings in the pavement cost when geosynthetics are used.

CONCLUSIONS

- The test results demonstrate that both the triaxial geogrid and the high strength woven geotextile significantly improved the performance of pavement section in terms of reducing the surface permanent deformation and extending the service life of pavement sections. The adjusted traffic benefit ratio (TBR_{adj}) can be increased up to 2.12 for pavement constructed using 18-in. thick base layer on top weak subgrade soil and using two geogrid layers.
- The inclusion of geosynthetic reinforcement results on redistributing the applied load to a wider area, thus reducing the stress concentration on top of the subgrade layer.
- Geosynthetics placed at the base-subgrade interface are able to improve the performance of both the subgrade and base layers. However, by placing an additional geogrid layer at the upper one-third of the base layer, the performance of the base layer will be further increased.
- For geosynthetics functioning as base reinforcement within the context of AASHTO Ware Pavement ME Design, the effective resilient modulus of the base layer can be increased by 30% when using a single geosynthetic layer placed at the base-subgrade interface and 90% when using double geogrid layers.
- The life-cycle cost analysis (LCCA) demonstrated the potential cost savings of using geosynthetics in pavement as compared to the unreinforced/untreated sections. However, compared to the 12-in. treated subgrade with cement stabilized base pavement section, the LCCA showed it is more cost effective to use geosynthetics to reinforce the base layer of thickness < 12 in. For base thickness > 12 in., the cost benefit becomes close between using a single geosynthetic layer and 12-in. cement/lime treated subgrade with cement stabilized base. Moreover, the cost benefit of using double geogrid layers exceeds the cost savings of 12 in. treated subgrade with cement stabilized base.

RECOMMENDATIONS

- The pavement design engineers should consider stabilization/reinforcing the base layer with one geosynthetic layer placed at the base-subgrade interface or two geogrid layers for flexible pavements built over weak subgrade soils with resilient modulus $M_r < 4500$ psi (or CBR < 3).
- For design of geosynthetic reinforced flexible pavements built over weak subgrade (CBR = 0.5-3) using PavementME, the effective base resilient modulus for a single geosynthetic layer or double geogrid layers can be estimated using α values presented in the report.
- If long-term benefits of geosynthetics are considered, the extended service life of geosynthetics reinforced flexible pavements built over the weak subgrade (for CBR= 0.5-3) can be estimated according using the TBR values presented in the report.
- If short-term benefits of geosynthetics are considered, the reduced base thickness for geosynthetics reinforced flexible pavements built over weak subgrade (for CBR 0.5-3) can be estimated using the BCR factors presented in report.