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RESEARCH PROGRAMS

Project Summary Report 8193

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Field Investigation of Geosynthetics used for Subgrade Stabilization

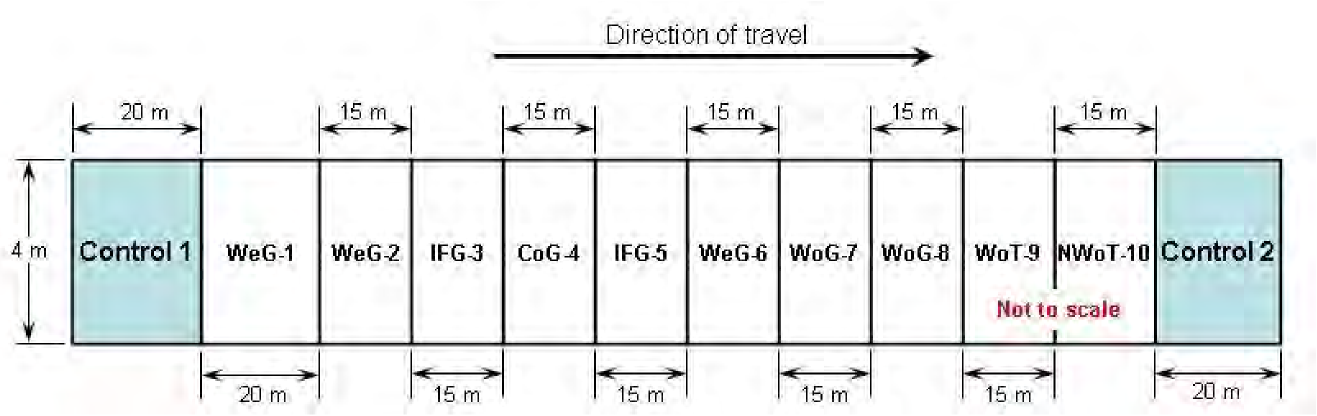
http://www.mdt.mt.gov/research/projects/geotech/subgrade.shtml

Introduction

Roadways are commonly constructed on weak native soil deposits. When excavation and replacement of these soils is not cost effective, soil stabilization may be necessary to provide a working platform so that the base course gravel layer can be properly constructed and overall rutting reduced. Geosynthetics are planar polymeric materials that have been extensively used in these situations (i.e., subgrade stabilization) to reinforce and/or separate the surrounding soils. Subgrade stabilization is typically applicable for unpaved temporary roads such as haul roads or construction platforms to support permanent roads. The Montana Department of Transportation (MDT) has used both geotextiles and geogrids for subgrade stabilization and supported this research because currently there is a lack of: 1) a universally accepted standard design technique that incorporates non-proprietary material properties of geosynthetics when used as subgrade stabilization, and 2) agreement as to which geosynthetic properties are most relevant in these cases for purposes of specification development. Therefore, this research was initiated to provide an understanding of which properties are most relevant as MDT seeks to update its specifications to more broadly encompass materials with which it has had good experience, as well as open up the application to other suitable materials. This is particularly important since new geosynthetics and manufacturing processes are regularly introduced into the market.

What we did

To achieve these objectives, a full-scale field test section was constructed, trafficked, and monitored at TRANSCEND, a full-scale transportation research facility managed by the Western Transportation Institute, to compare the relative performance of 12 test sections – ten with geosynthetics and two without geosynthetics (Figure 1). Existing pavement and base materials were excavated from the site to create a trench where an artificial subgrade (A-2-6 material) was placed in a weak condition. In-field measurements of vane shear, moisture content and DCP were primarily used to monitor subgrade strength during construction and after trafficking. Results from these tests showed that the subgrade soil was indeed weak and generally similar between test sections, especially for the upper layers which were primarily responsible for carrying the vehicle loads. After installation of the geosynthetics on top of the subgrade, displacement and pore water pressure sensors were installed at a single location along the length of each of the test sections. Approximately 20 centimeters of crushed base course aggregate (A-1-a material) was placed in a single lift as a structural layer and driving surface. The depth of the base course was determined using the FHWA U.S. Forest Service method (FHWA, 1995). Once the subgrade material was placed, all construction equipment was prevented from driving on the test area, and the base course layer was placed, leveled and graded from the side of the test area.



Acronym meanings: WeG = welded grid, IFG = integrally-formed grid, CoG = composite grid, WoG = woven grid, WoT = woven textile, NWoT = non-woven textile; numbers represent position along length of test site

Figure 1. General layout of test sections.

After construction, a fully loaded, three-axle dump truck was used to traffic the test sections. Measurements of longitudinal rut, transverse rut, displacement of the geosynthetic and pore pressures within the subgrade were taken during trafficking. Longitudinal ruts measurements were made within each of the two ruts at 1-meter increments along the entire length of the test sections for given truck passes, more frequently in the beginning and less frequently in the end. Live instrumentation was used to further understand the behavior of the geosynthetics during trafficking. Displacement and pore water pressure were collected at 200 Hz to capture dynamic responses due to the passage of the test vehicle.

Failure, defined as 100 mm of elevation rut, occurred in each of the test sections at or before 40 truck passes (88 traffic passes) of a fully-loaded, three-axle dump truck, which was much less than the 1000 design traffic passes expected from the geosynthetic-stabilized sections. An empirical approach was used to normalize small differences in subgrade strength and base course thickness so that a more direct comparison between test sections could be made. Soil subgrade strength values determined during the post-trafficking forensic evaluations were used in this analysis. The result of this procedure was the number of additional traffic passes (N_{add}) necessary to fail the test section as compared to what was needed to fail the control test sections. The relationship between N_{add} and mean rut depth, an indication of relative performance, is shown in Figure 2.

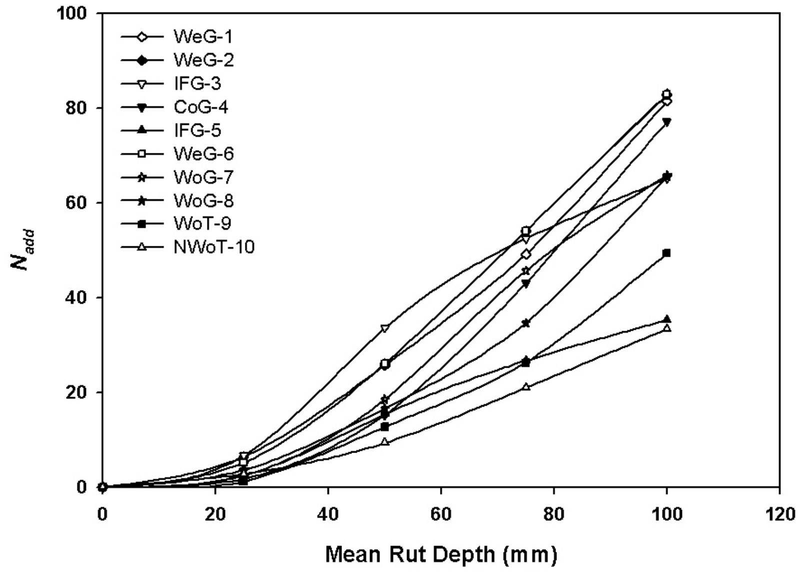


Figure 2. Relationship of N_{add} to mean rut depth at given rut depths.

Post-trafficking, forensic investigations were conducted to evaluate damage to the geosynthetic from trafficking, as well as, to re-evaluate pertinent soil strength characteristics (Figure 3). Forensic evaluations were located in areas that had experienced approximately the same rutting (i.e., 100 mm average rut) so that a direct comparison of damage between products could be made. An area 1.5 meters wide (in the direction of traffic) and 4 meters long was selected in each of the test sections, including the control test sections. Soils strength in the excavated areas was generally similar, yet according to the results of the vane shear, had lower strength than after construction; however, the DCP did not show significant difference in shear strength. Moisture contents collected during construction and after trafficking did not change significantly.

Figure 3. Air and vacuum removal of base course during forensic investigations.

What we found

The FHWA design method under predicts the depth of base aggregate needed to support the loads applied during this study as evidenced by the reduced number of traffic passes sustained by any of the test sections. Outside of inherent design limitations, two other possible reasons for premature failure may be the quality and/or in-place strength of the base course aggregate and the increased tire pressures in the test vehicle when compared to the tire pressures used to formulate the design methodology. Using the material properties of the actual test sections as inputs, the Giroud and Han (2004) design method also under predicted the depth of base material needed to support the loads applied during trafficking.

Tensile strength at 2 percent axial strain (indicative of the stiffness of the geosynthetic) in the cross-machine direction of the geogrids likely plays a significant role in suppressing rut formation under these conditions. It is unclear as to which material or interaction properties are most relevant for geotextiles; however, the function of separation likely aided the non-woven geotextile and composite welded geogrid stabilize the weak subgrade.

Using the displacement measurements, it was possible to perceive the primary reinforcement mechanism of the geosynthetics shift from lateral restraint of the base course to the membrane effect. This effect was perceptible in all of the test sections, regardless of their rate of failure.

The results generally showed that the welded, woven and the stronger integrally-formed geogrid products provided the best rutting performance, while the two geotextile products and the weaker integrally-formed geogrid provided significantly less stabilization benefit. This performance is likely directly related to the tensile strength of the materials in the cross-machine direction. Both of the integrally-formed grids sustained rupture damage during trafficking, which was seen to directly impact their ability to support the traffic loads. The majority of junction and rib damage occurred in the rutted area. Junction damage was greatest in the WeG-1 material (27.4 percent damage) and least in the WoG-7 material (6.8 percent). Rib damage was minimal in the welded and woven products.

What the researchers recommend

Overall, this research provides additional and much needed insight regarding which properties have a significant role on performance, as well as an assessment of two design methodologies' ability to predict rutting performance using the test section parameters as design inputs. Additional work is needed to more fully understand which geosynthetic material parameters are most relevant in these situations. Tensile stiffness appears to be the most pertinent material property (based on the results found during this research); therefore, additional properties such as cyclic tensile modulus and Poisson's ratio may be combined together to reflect a single indicator of tensile stiffness that relates well to field performance.

The test sections constructed in this project failed under a relatively small number of traffic passes. While this work provided useful information on performance of geosynthetics under loads producing gross failure, additional work is recommended to study conditions pertinent to operating conditions of a greater number of passes. These conditions will show differences in products for safe operating conditions, while the results from this project will provide information to help avoid gross and rapid failure. It is also recommended that new test sections constructed for operating conditions be used for a second stage of testing, which would involve regrading the rutted base layer and surfacing with asphalt concrete. This would mimic the entire process of subgrade stabilization and base reinforcement and would provide valuable information on how these two functions work together.

References

FHWA (1995) Geosynthetic Design and Construction Guidelines, Federal Highway Administration, Report No. FHWA-HI-95-038, 417pp.

Giroud, J.P. and Han, J. (2004) "Design Method for Geogrid-Reinforced Unpaved Roads. Parts I and II." Journal of Geotechnical and Geoenvironmental Engineering. vol 130, no. 8, pp.775-797.

For More Details . . .

The research is documented in Report FHWA/MT-09-003/8193, *Field Investigation of Geosynthetics used for Subgrade Stabilization*.

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MDT Implementation Status
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The results of the research have been used in conjunction with recent guidance and publications from FHWA, research into other state specifications, and other geogrid performance research to revise the MDT geogrid subgrade stabilization material specifications. The revised specifications for geogrid will enable more manufacturers to provide their products on MDT projects and thus increase competition and potentially decrease costs for these products without jeopardizing quality. The research results have provided some insight into what geogrid properties appear to be the most relevant for subgrade stabilization applications, however additional research is required to definitively determine which geosynthetic material properties most directly relate to stabilization of weak subgrade soils. Thus, MDT geogrid specifications will be continually evaluated as additional research and published information becomes available.

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