DEVELOPING TEST PROTOCOLS TO DETERMINE GEOSYNTHETIC MATERIAL PROPERTIES THAT BETTER REPRESENT TRAFFIC LOADING CONDITIONS

Final Report

by

Eli Cuelho

&

Suresh Ganeshan

of the

Western Transportation Institute
College of Engineering
Montana State University - Bozeman

November 2004

1 INTRODUCTION

Geosynthetics have been successfully used for filtration, separation, drainage, moisture barriers and reinforcement in flexible pavements. Using them to reinforce the base layer of flexible pavements may provide savings either by reducing the thickness of the base or extending the life of the road. To quantify their potential benefit, it is essential to evaluate their intrinsic material properties under conditions pertinent to pavements. Standard tension tests, such as ASTM D 4595 and D 6637 (used for conducting tension tests on geotextiles and geogrids, respectively – ASTM, 2003) apply monotonic loads to the materials to determine elastic moduli in their two principal directions. However, the types of loading conditions prescribed by these tests do not reflect conditions experienced by geosynthetics used to reinforce flexible pavements. Even though multiple research studies have been carried out to determine the effects of load rate, type of load, temperature, sample size and configuration, and normal confinement on geosynthetic material properties, results to-date are either limited, not applicable, or conflicting. Therefore, the first objective of this project was to investigate test protocols that better describe the intrinsic material properties of geosynthetics pertinent to reinforced pavement design applications. To accomplish this, an extensive literature of past research was reviewed and summarized to evaluate the effect of temperature, strain rate, confinement, and load type (i.e., monotonic or cyclic) on geosynthetic material properties.

A new mechanistic-empirical design guide for flexible pavements is currently under development and review by American Association of State Highway and Transportation Officials (AASHTO) through the National Cooperative Highway Research Program (NCHRP) Project 1-37A (NCHRP, 2003). This new method, however, does not address geosynthetic reinforcement of the base layer. Perkins et al. (2004) has developed a design method for geosynthetic-reinforced pavements that is compatible with the methods developed in NCHRP Project 1-37A (NCHRP, 2003). A finite element model (FEM), developed by Perkins et al. (2004), uses structural membrane elements for the reinforcement. Mechanistic material models are an essential component; therefore, material models that describe the geosynthetic reinforcement layer needed to be developed. Therefore, the second objective of this research was to conduct laboratory tests that appropriately describe the constitutive material properties of geosynthetics to reinforce pavement structures, as input parameters into a FEM. Available time and resources permitted only load type and, to some extent, various strain rates to be conducted and studied with regard to their effect on geosynthetic material parameters. A side study of the effect of sample size was also conducted.

1.1 Background

It is well known that geosynthetic reinforcement materials exhibit direction dependent properties. Most notably, the elastic modulus differs between the machine and cross-machine direction of the material. An orthotropic material model best describes the direction dependent properties of reinforcement materials but cannot be used directly in a 2-D axisymmetric finite element model. An orthotropic linear elastic material model contains nine independent elastic constants, four of which describe the behavior within the plane of the material (E_{xm}, E_m, $\nu_{xm\text{-}m}$, $G_{xm\text{-}m}$) and are pertinent to a reinforcement sheet modeled by membrane elements. These parameters are defined as follows:

- E_{xm} is the elastic modulus in the cross-machine direction
- E_m is the elastic modulus in the machine direction
- $\nu_{xm\text{-}m}$ is the Poisson's ratio in the cross-machine/machine plane
- $G_{xm\text{-}m}$ is the shear modulus in the cross-machine/machine plane

The elastic moduli in the two principal directions are generally determined from tension tests, the in-plane Poisson's ratio can be determined from biaxial tension tests, and there is no current test to directly determine the in-plane shear modulus. Kinney and Xiaolin (1995) developed a test to determine a parameter called the aperture stability modulus, which can be related to the in-plane shear modulus of the material.

The response model used by Perkins et al. (2004) was a two-dimensional axisymmetric finite element model based on models contained in NCHRP Project 1-37A (NCHRP, 2003). Axisymmetric response models require that the reinforcement be described by an isotropic material model, which is incapable of distinguishing direction dependent material properties (i.e., machine versus cross-machine direction). Since the material models for the remaining pavement layers are elastic, a model of similar complexity was chosen for the reinforcement. Even though many reinforcement materials exhibit non-linear behavior, this behavior is ignored for the sake of simplicity when attempting to select properties pertinent to the stress or strain range anticipated for the material. Hence, an isotropic linear elastic model is used for the reinforcement within the finite element response model, where required input parameters consist of an elastic modulus, E, and a Poisson's ratio, ν. Equivalent isotropic elastic constants are calculated from orthotropic constants using a relationship derived from a work-energy approach described by Perkins et al. (2004). The work described in this report focuses on determining the elastic modulus in both principal strength directions, that is, E_m and E_{xm}, the elastic moduli in the machine and cross-machine directions, respectively.

1.2 Organization of This Report

Chapter 2 provides the results of an extensive literature review of various factors affecting geosynthetics testing. Load type, specimen size and aspect ratio, strain rate, and temperature are all considered. In addition, various strain measuring devices are discussed.

Chapter 3 describes the laboratory equipment used to test the various geosynthetics. Specifically, the loading system, gripping mechanism, and instrumentation are described. The seven geosynthetics used in this research are described in this section, as well as how individual samples were prepared for testing.

Chapter 4 details the two main test protocols used to test the geosynthetics. Monotonic tests were conducted to determine effects due to strain rate and specimen size. Cyclic tests were compared to standard monotonic tests.

Chapter 5 summarizes the analysis of the test results. Comparisons are made between cyclic and tangent modulus, and the effects of strain rate and specimen size on secant modulus are summarized.

Finally, **Chapter 6** summarizes and concludes all the work conducted as part of this research project, as well as provides suggestions for future research.