STRUCTURAL IMPROVEMENT OF FLEXIBLE PAVEMENTS USING GEOSYNTHETICS FOR BASE-COURSE REINFORCEMENT

DEPARTMENT OF TRANSPORTATION
Maine

Proposal for a National Pooled-Fund Study

Structural Improvement of Flexible Pavements Using Geosynthetics for Base-Course Reinforcement: 2002 Update

By

The Maine Department of Transportation,
the Cold Regions Research and Engineering Laboratory,
and the University of Maine

STRUCTURAL IMPROVEMENT OF FLEXIBLE PAVEMENTS USING GEOSYNTHETICS FOR BASE-COURSE REINFORCEMENT

-- EXECUTIVE SUMMARY --

Geogrids and high-modulus geotextiles are being marketed as base-course reinforcement to increase the structural capacity of flexible pavement sections during the life of the pavement structure. (Figure 1). Although the benefits are very attractive to DOTs, there are few independent studies to support these claims.

Recently, the AASHTO Task Force on Geogrid/Geotextile Specification concluded that inadequate data exist to support the development of a specification for base-course reinforcement using geosynthetics and that additional research and field validation are needed. This study will provide, in a timely manner, missing data required for the determination of whether geosynthetic reinforcement is beneficial at conditions typically experienced in state highway construction.

To address the lack of comprehensive information about the performance of geosynthetic reinforcement of base courses, full-scale sections of pavement and underlying subgrade will be constructed and loaded to failure using a heavy vehicle simulator (HVS). The HVS will apply a moving dual-wheel load at the rate of 600 load repetitions per hour. Sections will be reinforced with geogrids or geotextiles. The effect of subgrade type, aggregate base course thickness, pavement thickness, and frost action will be investigated. Control sections without reinforcement will be used as a basis for comparison. In total, 32 sections will be tested. Each section will be instrumented to measure deformation, stresses, strains, temperature, and moisture. Study results will be presented in terms of stress and strain as related to pavement performance and will be compatible with the 2002 Pavement Guide.

Numerical modeling will be fully integrated into this work in order to help interpolate, and to a reasonable extent, extrapolate the influence (if any) of geosynthetic reinforcement on pavement behavior. This modeling approach will be much less computationally intensive than numerical modeling of pavements that has been done in the past. Therefore, it will be applied with relative ease to realistic traffic loadings.

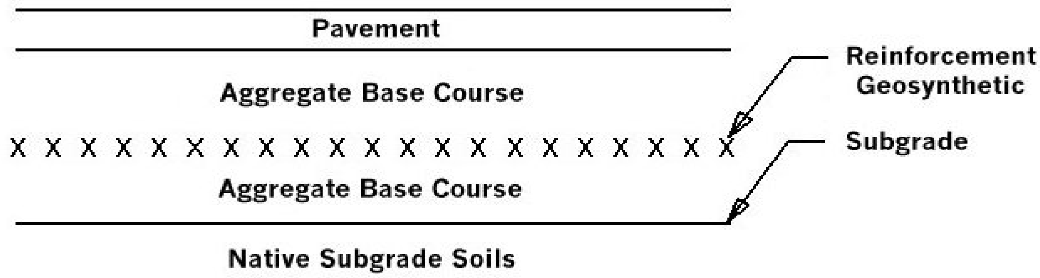

Figure 1: Base Course Reinforcement Using Geosynthetics

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PROBLEM

State department of transportation budgets for pavement rehabilitation and maintenance are under increasing demands, and it is difficult to obtain funds. To extend the value of pavement rehabilitation and maintenance, state DOTs are looking for design standards that will reduce rehabilitation costs and increase pavement longevity. The use of reinforcement geosynthetics to facilitate construction over weak subgrade soils (subgrade restraint) is well documented. However, their use to increase the structural capacity of a pavement system (base course reinforcement) is poorly understood. Geogrid and geotextile manufacturers claim that base course reinforcement will provide increased pavement service life and/or equivalent performance with a reduced structural section. These claims should be supported by independent studies using pavement designs and traffic capacities typical of DOTs. However, such studies are currently lacking.

Recently, the AASHTO Task Force on Geogrid/Geotextile Specification concluded that there are inadequate data to support the development of a specification for base course reinforcement using geosynthetics and that additional research and field validation are needed. This study will provide, in a timely manner, the critical missing data required for the successful development of an AASHTO specification for geosynthetic reinforcement of the aggregate base course of flexible pavement structures.

OBJECTIVES

The objectives of this study are:

1. To determine whether and under what conditions geosynthetics (geogrids and geotextiles) increase the structural capacity of pavements typically constructed by state DOTs.
2. To determine whether and under what conditions geosynthetics increase the service life of pavements typically constructed by state DOTs.
3. To measure in-situ stress/strain response of the reinforced material for use in current and future pavement design procedures, including mechanistic design.
4. To compare the performance of base–course-reinforced pavements subjected to traffic loading during periods of constant subgrade moisture with performance during seasonal weakening (thaw). Thus, the seasonal weakening of pavement layers will be assessed independently of the degree of traffic loading.

This work will be conducted independently of geosynthetic manufacturers, and geosynthetics for the project will be purchased outright.

BACKGROUND

Geosynthetics use is becoming common in many state department of transportation (DOT) construction/rehabilitation projects. They are routinely used as filters, separation layers, and subgrade restraint to facilitate construction on weak subgrades. More recently, they have been used in standard flexible pavement sections to reinforce the base course to support vehicular traffic during the life of the pavement structure (base-course reinforcement). When used as base-course reinforcement, according to the manufacturers, geosynthetics provide significant structural benefits, resulting in improved pavement life and/or equivalent performance with a reduced structural section. These benefits are very attractive to DOTs; however, there are few independent studies to support these claims. Most importantly, the traffic loading used in studies that have been conducted to date is much less than those typical of state highways. The issue of base-course reinforcement is of critical short-term and long-term importance.

Previous evaluations of the structural benefits of base-course reinforcement have been conducted on road sections that are designed to fail with a relatively low number of vehicle passes (Perkins and Ismeik, 1997a,b). Past work has utilized some combination of the following test parameters:

- Relatively weak subgrades (typically CBR 1-3, and M_r estimated at 2550 to 5200 psi)
- Thin base layers
- Thin asphalt layers designed to fail at a relatively low number of equivalent single-axle loads (ESALs).

These road sections do not adequately represent those commonly designed by state DOTs. Structural benefits documented for very weak subgrades overlain by thin bases and thin asphalt cannot be extrapolated to the thicker pavements typical of state highways. Thus, DOTs may be buying geosynthetics to provide base course reinforcement without achieving the expected performance.

In addition to load-induced damage, pavements are subjected to "environmentally induced" damage. Seasonal variations in soil temperature and moisture content can drastically change the mechanical properties affecting the support capacity of the base course and subgrade soils. Such seasonal variations will be considered in evaluations of the base reinforcement benefits of geosynthetics. Some evaluations will be achieved through the process of freeze/thaw. Results from the proposed work for thaw weakening can be applied to non-frost areas that experience seasonal changes in moisture content.

TEST PROGRAM

The experiments will employ a mechanistic approach to determine any structural benefits provided by geosynthetics used as base-course reinforcement for pavements typically designed by state DOTs. The following parameters will be methodically varied to examine their influence on pavement performance: asphalt thickness, base thickness, moisture conditions, subgrade type, and presence or absence and type (e.g., geogrid or geotextile) of base reinforcement. The results will be used to determine whether structural benefits (e.g., reduction in measured stresses and strains, increased resilient modulus) result from adding geosynthetics to the base course for the range of conditions tested. In conjunction with structural benefits, the cost effectiveness of using geosynthetics will be assessed.

The test program will be conducted at the Corps of Engineers Cold Regions Research and Engineering Laboratory (CRREL) in order to utilize their world-class facilities and state-of-the-art heavy vehicle simulator (HVS). All test sections will be subjected to a simulated 20 years of traffic loading. With accelerated traffic loading, controlled environments, and full-scale testing, results can be obtained in a matter of months, thereby providing this critical information to the transportation community in a timely matter.

The study will be conducted in four phases:

Phase 1 - Geogrids used in test sections with a constant subgrade moisture content

Phase 2 - Geogrids used in test sections with varied subgrade moisture content caused by freeze/thaw cycles.

Phase 3 - Geotextiles used in test sections with constant subgrade moisture content.

Phase 4 - Effect of subgrade strength on sections reinforced with geogrids and geotextiles.

An M_r of approximately 5000 psi (CBR of about 3) will be used for the subgrade soils in Phases 1, 2, and 3. In Phase 4, the subgrade will have an M_r of at least 8000 psi (CBR~6). A pavement structure will be designed as a typical state highway design to be the control section. Then three different pavement designs with reduced structural sections will be used, with and without reinforcement. An experimental control section of 24 in. of base and 6 in. asphalt will be utilized. Three additional sections include:

- 24 in. of base and 4 in. of asphalt (decreased asphalt layer thickness)
- 12 in. of base and 6 in. of asphalt (reduced base layer thickness)
- 12 in. of base and 4 in. of asphalt (reduced base and asphalt thickness).

A summary of the test sections for each phase is given in Tables 1 through 3. Please note that the experimental design can be modified based on the needs and interests of participating DOTs.

Each test section will be approximately 21 feet wide and 25 feet long. A subgrade soil with an AASHTO classification of A-4 will be utilized. Bank-run gravel using typical DOT specifications will be utilized. Each test section will be instrumented with temperature, moisture, stress, and strain sensors. Deformations in the base and subgrade will be measured using coil gauges or linear variable displacement transformers (LVDTs), and geosynthetic strain will be measured with strain gauges or LVDTs. Strain at the base of the asphalt layer will also be measured with strain gauges. In addition, surface rut depths, degree of pavement cracking, and falling weight deflectometer (FWD) response will be measured as a function of a number of prescribed passes. Level surveys will be conducted during freezing and thawing to quantify frost heave and settlement.

Accelerated loading will be conducted with the CRREL heavy vehicle simulator. The HVS can apply approximately 600 unidirectional load repetitions per hour. The loads can be varied from 5 to 25 kips. The tires planned for use in this study will be dual truck tires. Each of the eight test sections will be loaded until failure. The load will be allowed to wander from side to side for a width of 3 feet. Failure will be defined as a surface rut depth of ½ in. In Phase II, accelerated loading will be applied when thawing weakens the section.

Table 1: Test section design for Phases 1 and 2 using geogrid and subgrade M_r of 5000 psi.

Asphalt Thickness (in.)	Base Thickness (in.)	Reinforced
6	24	No
6	24	Yes*
6	12	No
6	12	Yes
4	24	No
4	24	Yes
4	12	No
4	12	Yes

*It may not be possible to load this section to failure within the time constraints of this project.

Table 2: Test section design for Phase 3 using geotextile and subgrade M_r of 5000 psi.

Asphalt Thickness (in.)	Base Thickness (in.)	Reinforced*
6	24	No
6	12	Yes
4	24	Yes
4	12	Yes
6	24	No / FT**
6	12	Yes / FT
4	24	Yes / FT
4	12	Yes / FT

*Unreinforced sections will have already been constructed in Phases 1 and 2. Thus, in this phase only a limited number of unreinforced sections will be constructed to provide verification of previous results.
**FT indicates sections will be subjected to freeze/thaw cycles.

Table 3: Test section design for Phase 4 using subgrade, minimum M_r of 8000 psi

Asphalt Thickness (in.)	Base Thickness (in.)	Reinforced
4	24	No
4	24	Yes – geogrid
4	24	Yes – geogrid/FT*
4	24	Yes - geotextile
4	12	No
4	12	Yes – geogrid
4	12	Yes – geogrid/FT*
4	12	Yes - geotextile

*FT indicates sections will be subjected to freeze/thaw cycles.

MODELING PROGRAM

Numerical modeling will be fully integrated into this work in order to help interpolate and, to a reasonable extent, extrapolate the influence (if any) of geosynthetic reinforcement on pavement behavior. This modeling approach will be much less computationally intensive than the numerical modeling of pavements that has been done in the past. Therefore, it will be applied with relative ease to realistic traffic loadings.

The finite-element modeling will be performed with EverFE, a finite-element program developed by Dr. William Davids, Assistant Professor at the University of Maine. Phenomenological models are currently being developed at the University of Maine to capture the critical behaviors of the asphalt, aggregate base, reinforcement, and subgrade. EverFE will be used to model these behaviors, and measured results from the tests will be used to calibrate the models.

The 3D finite-element code underlying EverFE has several unique features not available in commercial codes that are applicable for simulating reinforced flexible pavement structures. For example, EverFE's embedded reinforcement capabilities will permit the specific geometry of a geogrid to be modeled. This includes modeling relative slip between the geogrid and the base and subgrade. In addition, EverFE allows the treatment of spatially varying tire/pavement contact pressures, which can have a large effect on asphalt stresses. Finally, the state-of-the-art iterative solution strategies employed by the underlying FE code allow the rapid solution of large 3D models, which will permit the efficient completion of parametric studies that consider a large number and range of variables. EverFE also incorporates a K-θ model for granular layers, permits the consideration of thermal strains, and allows for the modeling of slip and de-bonding between layers. EverFE could potentially be extended to allow inclusion of plasticity-based material models to allow cumulative damage under repeated loading to be captured.

FIELD VERIFICATION

Maine DOT is constructing twelve instrumented field test sections in conjunction with this study. Six were completed in 2001, and the remaining six will be finished in 2002. The New England Transportation Consortium is providing funding for instrumentation and monitoring. Data will be collected periodically and will be used to validate and extend the model developed from the test sections constructed at CRREL.

DELIVERABLES

At the end of each phase, a detailed report will be issued to the DOTs. All analyses, conclusions, and recommendations will be presented in a practical manner, enabling the DOTs to fully utilize the critical data obtained from the research. These reports will provide design charts for a range of pavement designs. The following information will be included in the reports:

- In-situ stress/strain data as a function of load repetition and the following variables:
  - Subgrade type
  - Presence and type of reinforcement
  - Moisture content - Thaw weakening
  - Asphalt thickness
  - Base thickness
- Cost effectiveness analysis

The experimental portion of each phase will require about 12 months. An additional 6 months will be required to perform supporting analytical and numerical analyses and prepare the report for each phase.

BUDGET

The budget for each phase of the project is summarized in Table 4. The costs include construction and instrumentation of the test sections at CRREL, loading the sections to failure with the HVS, monitoring and data gathering during loading, and the analysis and numerical modeling of the test sections. The cost, for Phases 1 and 4 are higher than Phases 2 and 3 because of the need to construct the entire thickness of the subgrade soils. In addition, some instrumentation purchased for Phase 1 can be reused for subsequent phases.

Funding of this study has been developed in phases to provide state DOTs maximum funding flexibility. DOTs can fund any individual phase(s) or all four phases. Simply indicate which phases you are interested in funding when contacting Maine DOT.

Table 4. Summary of project costs by phase.

Phase	COST
1	$650,000
2	$500,000
3	$500,000
4	$600,000

It is recommended that an additional $35,000 be allocated over the course of the project for a DOT coordinator to oversee the project and for a DOT steering committee. It is anticipated that each phase will require approximately one year to complete.

POINTS OF CONTACT

Maine DOT:	Scott A. Hayden Maine Department of Transportation Geotechnical Section 219 Hogan Road Bangor, Maine 04401 207-941-4545 (Voice) 207-941-4533 (Fax) scott.hayden@state.me.us
University of Maine:	Prof. Dana Humphrey Department of Civil and Environmental Engineering University of Maine 5711 Boardman Hall Orono, ME 04469-5711 207-581-2170 (Voice) 207-581-3888 (Fax) dana.humphrey@umit.maine.edu
CRREL:	Dr. Karen Henry, P.E. ERDC-CRREL 72 Lyme Road Hanover. NH 03755 603 646-4188 (Voice) 603 646-4640 (Fax) Karen.S.Henry@erdc.usace.army.mil

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