Structural Improvement of Flexible Pavements Using Geosynthetics for Base Course Reinforcement: Test Plan

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PURPOSE

The purpose of this test plan is to ensure that the tests being conducted for this project serve the purpose of this project—specifically, to provide stresses, strains and resilient modulus values of geogrid-reinforced and un-reinforced test sections such that this work can eventually be used with future modifications to the AASHTO 2002 Design Guide. We will present the results of testing and modeling in terms of stress and strain as related to pavement performance. The executive summary of the research proposal (as updates in 2002) is attached as an appendix for readers' reference.

OBJECTIVES & PROJECT HISTORY

The original objectives of this study were to:

1. Determine whether geosynthetics (geogrids and geotextiles) can be used to increase the structural capacity of pavements typically constructed by state DOTs.
2. Measure in-situ stress/strain response of the reinforced material for use in current or future pavement design processes.
3. Determine whether geosynthetics can be used to increase the service life of pavements typically constructed by state DOTs.
4. Compare the performance of base course reinforced pavements subjected to traffic loading during non-frost periods with performance during thaw. Thus, the influence of thaw weakening on pavement performance will be assessed independently of the degree of traffic loading.

The original proposed phases of the work were:

Phase 1 - Geogrids in test sections, 'constant' climatic conditions.

Phase 2 - Geogrids on test sections subjected to freeze/thaw cycles.

Phase 3 - Geotextiles on test sections not subjected to freeze/thaw as well as test sections subjected to freeze/thaw.

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

In the summer of 2002, the Pooled Fund Project had a large portion of funding committed to the various phases of the project such that when combined became enough to complete all or most of what was originally termed 'Phase 1' of the work—that of constructing ONE series of test sections to contain four test sections that had base reinforcement and four identical sections without base reinforcement. We convened the contributing states in October 2003, and proceeded to begin Phase1 with a budget of $480,000 for the ERDC-CRREL portion of the work. Hence, the original project objectives numbered 1 through 3 above still apply to our efforts; however, the project is reduced in scope to include only one subgrade strength and freezing and thawing of the test sections is also not be included in the scope of work.

In the original plan, we wanted to use a subgrade M_r of 5000 psi (CBR~3) in Phases 1, 2, and 3, and in Phase 4 the subgrade would have a M_r of at least 8000 psi. (CBR~6). Therefore, this was the target subgrade modulus for the current ('Phase 1') project.

As planned, an experimental control section of 24 in. of base and 6 in. asphalt was designed, and three additional sections are:

- 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).

Each of these sections is constructed with and without geogrid at the base/ subgrade interface.

Construction of test section

There is a detailed construction report to which interested readers are referred. The purpose of this section is to highlight where the construction met and differed from the original proposed construction of the test sections for Phase 1 work.

<u>Asphalt, subgrade and base layers:</u> The proposal included using a subgrade soil with an AASHTO classification of A-4 and a base course of bank-run gravel using typical DOT specifications. When the test sections were built, we used the A-4 subgrade and an AASHTO type A-1 (USCS type GP-GM--mix of poorly graded gravel and silty gravel) base that meets New Hampshire specification 301.4 for base course materials.

As mentioned above, the original plan was to use a subgrade M_r of 5000 psi. However, the method of construction chosen, which included compaction of the subgrade to maximum density and optimum water content, produced a subgrade with estimated stiffness of approximately 12000 psi. We subsequently softened the subgrade by adding water gradually, over a period of months, to the base course/ subgrade interface in attempt to saturate the subgrade. We monitored the softening of the subgrade via FWD tests while carefully adding water once or twice a week so as not to 'flood' the base course. We assured that the base course remained as dry as possible by installing monitoring wells in the center of the test sections to the top of the subgrade and checking water levels during the watering process.

Through this process of adding water to the subgrade, we were able to achieve fwd-measured subgrade stiffness reductions of almost 50% in most of the test sections over time. In the first two test sections trafficked in the summer of 2006, the estimated subgrade modulus was approximately 6000 psi.

Finally, and noteworthy, is that the water content measurements with time indicate relatively constant moisture content. However, FWD analyses indicate that the subgrade has regained stiffness from July 2006 to February 2007. The University of Maine-and ERDC-CRREL team may have to decide whether and how much water to add and when to add it with respect to the remaining test program.

<u>Instrumentation and initial readings of strain gages:</u> The proposal included instrumentation of test sections for temperature, moisture, stress, and strain, including geosynthetic strain measurement and measurement of strain at the base of the asphalt layer. Instrumentation has been installed to measure all of these parameters. However, the proposal indicated that strain gages would be placed at the base of the asphalt, and they were not. Asphalt strains are being measured by emu coil gages instead.

Geogrid strain gages should have been read both pre-construction and post-construction. However, the pre-construction readings were improperly made, and there are no un-tensioned geogrid strain gage readings. Further, several of the strain gages attached to the geogrid on Test Section 4 were lost when the strain gages were connected to the computer. However, the post-construction readings can be made prior to trafficking of the remaining test sections that contain geogrid. Provisions will be made for a final reading of the geogrid strain gages after testing, in an unloaded state which will serve to provide the missing baseline data missed during the construction phase. Specifically, as part of final forensic excavation at end of the project, we will carefully excavate all soil off of grid and then get the strain readings with the grid un-tensioned. This will be necessary in order to determine the force in the geogrid, since the force is determined from the change in strain reading from the un-tensioned to the tensioned state, although creep and stress relaxation will have to be accounted for. Previous field and laboratory testing results will be used to make the appropriate adjustments.

TEST PROGRAM

This section provides a detailed test protocol, agreed upon by ERDC-CRREL and the University of Maine. This testing plan serves the objectives of the project; however, details were not provided in the proposal. Any differences between proposal contents and the test protocol are noted.

The results of the test program will be used to determine the structural benefits (e.g., reduction in measured stresses and strains, increased modulus) of adding the geosynthetic reinforcement to the base course for the subgrade conditions tested. The testing utilizes ERDC-CRREL's Heavy Vehicle Simulator (HVS), and non-frost climatic conditions are being simulated. The original proposal stated that each test section will be subjected to a simulated 20 years of traffic loading, and (in a later paragraph) that each test section will be trafficked to failure. We have chosen to traffic each test section to failure, defined by the formation of a ½-in. deep rut. We will then determine the equivalent applied axle loads to failure.

The original proposal indicated that we would measure surface rut depths, degree of pavement cracking, and Falling Weight Deflectometer (FWD) response as a function of a number of prescribed passes. We have agreed upon a schedule of prescribed passes to determine surface rut depths with a profilometer, and any cracking will be documented on the same schedule. FWD measurements can only be made before and after HVS trafficking, due to the need to move the HVS prior to positioning the FWD. This FWD testing schedule meets the objectives of the project.

The HVS applies approximately 600 uni-directional load repetitions per hour, and the initial load applied during testing is 11 kips, which represents half of a 22 kip axle-load. This is the maximum axle load permitted in several states. For initial loading of the control test section, Test Section 2, with four inches of asphalt and 12 inches of base, the wheel load was increased from 11 kips to 16 kips at 164,000 passes. For the ‘matching’ geogrid test section, Test Section 4, the wheel load was increased from 11 kips to 16 kips at 163,000 passes. This increase in the wheel load is made upon the recommendation of the University of Maine, who tracks the development of ruts over time as the test section is loaded, and estimates when to increase the wheel load such that rutting failure will occur within project deadlines.

The load ‘wanders’ from side to side for a width of 3 feet, in a pattern that concentrates loading in the center. The tires used in this study are dual truck tires inflated to a pressure of 100 psi. Once failure (1/2 inch rut depth) is reached, loading ceases.

<u>Tests required prior to loading a geogrid test section.</u>

1. Initial readings of geogrid strain gages should be made, or verified prior to being recorded. These readings should be sent immediately to University of Maine for validation before any further testing occurs. (This can be done a day or two before testing begins.)
2. FWD tests should be performed as immediately as possible prior to loading to establish the modulus values of the pavement layers.
3. Water contents and temperature files should be obtained to assure that this information is available for the FWD test date.
4. A level survey of pins placed along the sides of each test section is done to establish the elevations of the surface of the test section. (These can be used to determine whether any large movements of the entire test section occur.)
5. An initial profilometer survey is done to establish the contours of the paved surface prior to loading.
6. All emu and Geokon stress cell readings throughout the pavement system must be recorded with no load applied to the test section immediately before applying any traffic load to that section. This should be done for static and dynamic readings.
7. A static, 11 kip load is then applied to the static load test points, designated by the following local coordinates [x (in) y (in)], which are defined in the CRREL report

"Construction and Instrumentation of Full-Scale Geogrid Reinforced Pavement Test Sections":

1) [-72, 0] – Directly over a pair of transversely mounted strain gages on the geogrid.
2) [-60, 0] – Directly over a pair of longitudinally mounted strain gages on the geogrid.
3) [-48, 0] – Directly over a pair of transversely mounted strain gages on the geogrid.
4) [18, 0] – Directly over Z-direction soil/AC strain gage stack.
5) [24, 0] – Directly over X-direction soil/AC strain gage stack.

It is important to note that points (1) – (3) are subject to change based on the survivability of the geogrid strain gages (step 1).

Record all gages with the wheel at each location. Take readings approximately 10 sec. after final positioning of wheel in each case. This time can be increased somewhat if necessary, but should be constant for all tests.

Tests required prior to loading a control (un-reinforced) test section.

1. FWD tests should be performed as immediately as possible prior to loading to establish the modulus values of the pavement layers.
2. Water contents and temperature files should be obtained to assure that this information is available for the FWD test date.
3. A level survey of pins placed along the sides of each test section is done to establish the elevations of the surface of the test section. (These can be used to whether any large movements of the entire test section occur.)
4. An initial profilometer survey is done to establish the contours of the paved surface prior to loading.
5. All emu and Geokon stress cell readings throughout the pavement system must be recorded with no load applied to the test section immediately before applying any traffic load to that section. This should be done for static and dynamic readings.
6. A static, 11 kip load is then applied to the points, designated by the following local coordinates [x (in) y (in)], which are defined in the CRREL report "Construction and Instrumentation of Full-Scale Geogrid Reinforced Pavement Test Sections":

4) [18, 0] – Directly over Z-direction soil/AC strain gage stack.
5) [24, 0] – Directly over X-direction soil/AC strain gage stack.

Record all gages with the wheel at each location. Take readings approximately 10 sec. after final positioning of wheel in each case. This time can be increased somewhat if necessary, but should be constant for all tests.

Intermediate and Final Static Load Tests

Repeat the complete process described above (either geogrid or un-reinforced test section, as appropriate) for the static load test at 250 and 12000 passes, and at other intermediate loading levels, as requested by the University of Maine. Using the results of the first three static loading tests, they will estimate when it will be best to conduct the remaining static load tests.   For Test Sections 2 and 4, these tests were conducted at 24000, 74000, 163000 (or 164000), 213000 (or 214000) and 263000 passes. It is expected that static load tests may be required at larger numbers of cycles for the remaining test sections since they all have thicker AC and/or base layers.

<u>Tests required immediately after loading a geogrid test section.</u>

1. A final profilometer survey is done to establish the contours of the paved surface prior to loading.
2. All emu and Geokon stress cell readings throughout the pavement system must be recorded with no load applied to the test section immediately after applying any traffic load to that section. This should be done for static and dynamic readings.
3. Final, unloaded readings of geogrid strain gages should be made, or verified prior to be being recorded. These readings should be sent immediately to University of Maine for validation before the electronic leads are disconnected and re-connected to another test section's strain gages.
4. FWD tests performed as immediately as possible after loading should be performed to establish the modulus values of the pavement layers.
5. Water contents and temperature files should be obtained to assure that this information is available for the FWD test date.
6. A level survey of pins placed along the sides of each test section is done to establish the elevations of the surface of the test section.

<u>Tests required immediately after loading a control (un-reinforced) test section.</u>

1. A final profilometer survey is done to establish the contours of the paved surface prior to loading.
2. All emu and Geokon stress cell readings throughout the pavement system must be recorded with no load applied to the test section immediately after applying any traffic load to that section. This should be done for static and dynamic readings.
3. Final, unloaded readings of geogrid strain gages should be made, or verified prior to be being recorded. These readings should be sent immediately to University of Maine for validation before the electronic leads are disconnected and re-connected to another test section's strain gages.
4. FWD tests performed as immediately as possible after loading should be performed to establish the modulus values of the pavement layers.
5. Water contents and temperature files should be obtained to assure that this information is available for the FWD test date.
6. A level survey of pins placed along the sides of each test section is done to establish the elevations of the surface of the test section.

Appendix:

EXECUTIVE SUMMARY OF RESEARCH PROPOSAL (AS UPDATED IN 2002)

High-modulus geogrids and geotextiles are being marketed as base course reinforcement to increase the structural capacity of flexible pavement sections constructed on weak subgrades (Figure 1). This is seen as a cost-saving measure that can increase pavement life or reduce aggregate base course thickness. Base course reinforcement is distinct from other uses of geosynthetics, such as separation or as an expedient means to facilitate construction operations on weak ground, which are already well established.

To address this critical lack of data, 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 high-modulus geogrids or geotextiles. The effect of subgrade strength, 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. The full-scale tests will be supplemented by three-dimensional finite element modeling. The test program will consist of four phases, with each phase taking approximately 1 year to complete at an average cost of $530,000 per phase. As an illustration of the potential payoff of this research project, DOTs could realize as much as a 50% cost reduction using a reduced structural pavement section while maintaining equivalent performance.

Recently, the AASHTO Task Force on Geogrid/Geotextile Specification has 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. The Task Force disbanded for an indefinite period of time in 2001. This research will provide critical data and validation, which can lead towards the eventual creation of an AASHTO specification for base course reinforcement. The results will be published in a format to conform with future modifications to the AASHTO Pavement Design Guide.

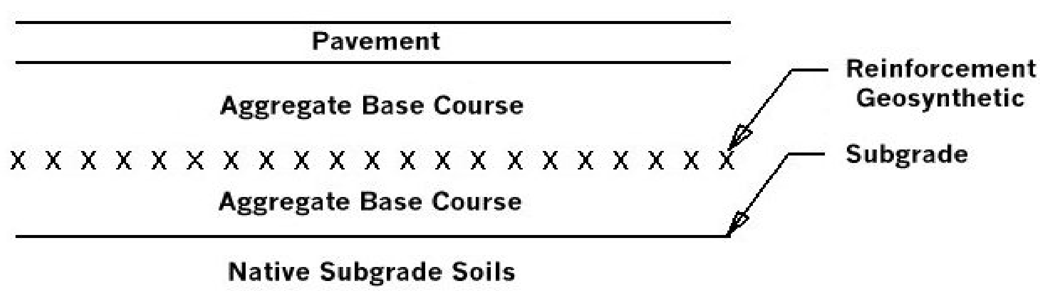

Figure 1: Base Course Reinforcement Using Geosynthetics