PUTTING RESEARCH TO WORK

BRIEF

Developing Critical Soil Design Inputs for the M-E Design Guide

Currently, Wisconsin DOT's pavement design procedures are based on the AASHTO 1972 Design Guide. Two inputs currently used in WisDOT's design procedures are the Soil Support Value and the resilient modulus model parameter *k*, which are parameters used to characterize subgrade soil support strength for pavement structures.

This practice will soon change. WisDOT is currently preparing to adopt the new AASHTO Mechanistic-Empirical Design Guide. The guide's design procedures base subgrade soil support assessments on several factors, including subgrade material, pavement material, seasonal variations in moisture, and repeated loading. The last is the most technical factor, requiring determination of a subgrade soil's resilient modulus—its response to frequent loading. Ultimately, M-E design is expected to reduce variations in a pavement's performance over its design life, prevent premature failure, and reduce the maintenance required over the life of the pavement.

What's the Problem?

Design based on the SSV and *k* parameters does not consider all possible failure mechanisms due to subgrade problems, and it doesn't consider repeated loading of the subgrade and pavement structure. The M-E Design Guide procedures would improve upon the existing soil strength characterization methods that use SSV and *k*, but WisDOT lacks the Wisconsin-specific design inputs necessary to implement the guide.

The critical missing inputs are the resilient modulus values of Wisconsin subgrade soils. Determining resilient modulus requires specialized, expensive equipment, considerable expertise, and time. As a result, this testing is expensive to conduct. If there were a way to estimate the resilient modulus of subgrade soils based on correlations with the basic soil properties WisDOT currently tests for, the department would not be required to use more conservative default design parameters, resulting in significant savings in time and money.

Research Objectives

The central goal of this study was to develop correlations between basic soil properties of Wisconsin subgrade soils and the tested resilient modulus for these soils. The researchers' specific goals included:

- Develop a database of both resilient modulus values and soil properties—including grain size, moisture content, and dry weight—for selected subgrades.
- Develop and validate correlations between resilient modulus and basic soil properties.
- Produce a database of Level 3 M-E design inputs for those pavement design projects in which testing of basic soil properties will not be conducted, and produce equations for Level 2 M-E design inputs for projects in which testing will be conducted.

Methodology

To determine correlations and recommend design procedures, investigators:

- Tested the physical and compaction properties of representative subgrade soil samples, including grain size, liquid and plastic limits, specific gravity, moisture content, and maximum dry unit weight. To ensure accuracy, each sample was tested two to three times.
- Conducted repeated load triaxial tests per AASHTO procedures to determine the resilient modulus of selected soils.
- Created a database including soil type, resilient modulus, standard soil properties test results, and environmental conditions.
- Developed and validated correlations between resilient modulus and soil properties through

Investigator

"We were able to develop a very high quality database of resilient modulus values for various Wisconsin soils."

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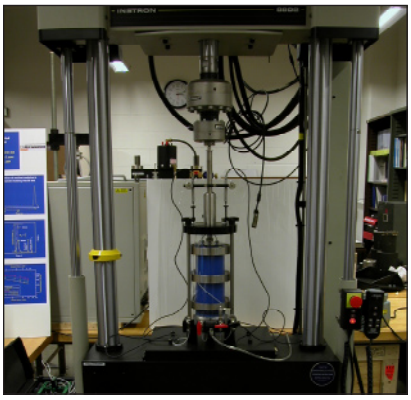

This state-of-the-art, servo-hydraulic materials test system gave investigators reliable resilient modulus values for several fine-grained and coarse-grained subgrade samples.

statistical analysis using the resilient modulus constitutive equation, per AASHTO procedures.

- Compared the models developed to Long-Term Pavement Performance program models.

Results

Investigators conducted testing and analysis of 19 selected subgrade soils, producing a high-quality, consistent test results database developed from repeatable results. Detailed results included:

- AASHTO procedures showed good results for fine- and coarse-grained soils when considered separately, with reasonably accurate correlations for estimating resilient modulus of compacted soils based on physical properties.
- The methods and models developed in this study were able to estimate resilient modulus better than the models developed in earlier research using the LTPP database. This was due to differences in the test procedures, test equipment, sample preparation, and other conditions.
- The researchers confirmed the impracticality of repeated load triaxial testing for Wisconsin.
- The investigators recommended that WisDOT use the database of resilient modulus inputs for Level 3 M-E design when testing of basic soil properties will not be conducted (a typical condition in the design of low-volume rural pavements, for example). They recommended that WisDOT use model equations to determine resilient modulus inputs for fine- and coarse-grained subgrade soils in Level 2 M-E design when testing of basic soil properties will be conducted (as in design of higher-volume pavements).

Implementation and Further Research

The researchers recommend that WisDOT convert this study's findings to tables and graphs that WisDOT designers can use in M-E design, and suggest that these research findings be added to the new design guide and WisDOT's Facilities Development Manual.

In addition, investigators and WisDOT engineers suggested two research directions to build upon this project's findings. First, future research should expand the subgrade soils database from the current 19 to 40 or 50 soil samples to increase the database's inclusiveness and effectiveness. This research would apply the testing methods used in this study to more samples.

Second, correlations with resilient modulus were tested on soils with limited physical conditions and properties. To expand and refine this project's findings, a study of the effect of freeze-thaw cycles on resilient modulus of Wisconsin subgrade soils could be conducted, as well as an investigation of new field devices that assess stiffness of compacted subgrade soils for quality control.

This brief summarizes Project 0092-03-11, "Determination of Typical Resilient Modulus Values for Selected Soils in Wisconsin," produced through the Wisconsin Highway Research Program for the Wisconsin Department of Transportation Research Program, 4802 Sheboygan Ave., Madison, WI 53707.

James McDonnell, WisDOT Research and Communication Services

Geotechnics TOC Representative

"This research has given WisDOT a method for determining resilient modulus for soils so that we can move toward use of the Mechanistic-Empirical Design Guide."

–Bruce Pfister
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