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WisDOT Research Efforts That Support Implementation of the AASHTO Mechanistic-Empirical Pavement Design Guide

Prepared for
Wisconsin Highway Research Program

Prepared by
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Request for Report

The Wisconsin Highway Research Program asked for a report on research efforts funded or otherwise supported by Wisconsin Department of Transportation that support its adoption of the AASHTO Mechanistic-Empirical Pavement Design Guide.

Summary

Wisconsin DOT contributes to 15 studies and two pooled fund projects that will assist in implementing the MEPDG. The 11 WHRP projects are fully funded by WisDOT, as is the WisDOT implementation project. Total funding for the research projects as well as the WisDOT contribution to one of the two pooled fund projects is $1,162,848. WisDOT's efforts to implement the sophisticated new design procedures of the MEPDG, then, is benefiting from over $1.16 million in research funding.

Nine of the projects deal with flexible pavement design, six with geotechnics, and one each with rigid pavements and pavements generally.

Below we provide a summary table – **WisDOT Research Supporting Implementation of the AASHTO Mechanistic-Empirical Pavement Design Guide** – and then a **Project List** of all 17 efforts by topic area. We then provide detailed information on each project according to sponsorship in **WHRP Projects**, **MRUTC Projects**, **Wisconsin DOT Projects**, and **Wisconsin Pooled Fund Projects**. In each of these sections we detail projects according to topic area, providing information including contact information, funding, end dates, Web links when available, and detailed descriptions of project objectives with MEPDG applications highlighted, when possible.

WisDOT Research Supporting Implementation of the AASHTO Mechanistic-Empirical Pavement Design Guide					
Topic Area	**Project ID**	**Project Title**	**Done?**	**End**	**Commitment**
Flexible	TPF-5 (124)	Accelerated Performance Testing on the 2006 NCAT Pavement Test	N	12/09	n/a
Flexible	WHRP 0092-08-06	Wisconsin Mixture Characterization Using the SPT on Historical Aggregate Structures	N	10/08	$74,992
Flexible	MRUTC 08-08	Materials Characterization and Analysis of the Marquette Interchange HMA Perpetual Pavement	N	08/08	$60,000
Flexible	WHRP 0092-07-17	Development of Recommendations for Compaction Temperatures in the Field to Achieve Density and Limit As-Built Permeability	N	04/08	$60,000
Flexible	MRUTC 07-11	Database Development for an HMA-based Pavement Performance Analysis System	N	02/08	$50,000
Flexible	WHRP 0092-04-07	Testing Wisconsin Asphalt Mixtures for the AASHTO 2002 Mechanistic Design Procedure	Y	09/07	$125,000
Flexible	MRUTC 07-01	Development of Regional Pavement Performance Database for Validation and Local Calibration of the Predicted Models Used in the New AASHTO Pavement Design Guide	Y	05/07	$50,000
Flexible	WHRP 0092-05-07	Guidance, Parameters, and Recommendations for Rubblized Pavements	Y	11/06	$30,000
Flexible	WHRP 0092-03-14	Development of Modulus-to-Temperature Relations for HMA Mixtures in Wisconsin	Y	09/05	$63,891
General	WisDOT 1009-03-35	Mechanistic-Empirical Pavement Design Guide Implementation	N	03/08	$150,000
Geotechnics	TPF-5 (129)	Recycled Unbound Pavement Materials (MnROAD Study)	N	12/09	$75,000
Geotechnics	WHRP 0092-08-12	Determination of Resilient Modulus Values for Typical Plastic Soils in Wisconsin	N	04/09	$54,914
Geotechnics	WHRP 0092-07-05	Development of Testing Methods to Determine Interaction of Geogrid-Reinforced Granular Material for Mechanistic Pavement Analysis	N	10/08	$70,987
Geotechnics	WHRP 0092-06-05	Comparison of Basic Lab test Results with More Sophisticated Lab and In-Situ Test Methods on Soils in Southeastern Wisconsin	N	05/08	$35,043
Geotechnics	WHRP 0092-03-11	Determination of Typical Resilient Modulus Values for Selected Soils Representative of the Soils Distributions in Wisconsin	Y	06/06	$103,049
Geotechnics	WHRP 0092-02-01	Determination of Influences on Support Strength of Crushed Aggregate Base Course Due to Gradational, Regional, and Source Variations	Y	02/04	$99,972
Rigid	WHRP 0092-06-03	Investigation of Concrete Properties to Support Implementation of the New AASHTO Pavement Design Guide	Y	11/06	$60,000
Total Budget					**$1,162,848**

Project List

Following we list all the projects with which WisDOT is or has been involved that pertain to implementation of MEPDG procedures. Projects are arranged according to topic area.

Flexible Pavement Projects

- **Project Title:** Accelerated Performance Testing on the 2006 NCAT Pavement Test
  Project ID: TPF-5 (124) $ n/a **End Date:** 12/2009
- **Project Title:** Wisconsin Mixture Characterization Using the SPT on Historical Aggregate Structures
  Project ID: WHRP 0092-08-06 $74,992 **End Date:** 10/2008
- **Project Title:** Materials Characterization and Analysis of the Marquette Interchange HMA Perpetual Pavement
  Project ID: MRUTC 0092-08-08 $60,000 **End Date:** 08/2008
- **Project Title:** Development of Recommendations for Compaction Temperatures in the Field to Achieve Density and Limit As-Built Permeability
  Project ID: WHRP 0092-07-17 $60,000. **End Date:** 04/2008
- **Project Title:** Database Development for an HMA-based Pavement Performance Analysis System
  Project ID: MRUTC 07-11 $50,000 **End Date:** 02/2008

- **Completed Project:** Testing Wisconsin Asphalt Mixtures for the Mechanistic Design Procedure AASHTO 2002
  Project ID: WHRP 0092-04-07 $125,000 **Completed 09/2007**
- **Completed Project:** Development of Regional Pavement Performance Database for Validation and Local Calibration of the Predicted Models Used in the New AASHTO Pavement Design Guide
  Project ID: MRUTC 07-01 $50,000 **Completed 05/2007**
- **Completed Project:** Guidance, Parameters, and Recommendations for Rubblized Pavements
  Project ID: WHRP 0092-05-07 $30,000 **Completed 11/2006**
- **Completed Project:** Development of Modulus-to-Temperature Relations For HMA Mixtures in Wisconsin
  Project ID: WHRP 0092-03-14 $63,891 **Completed 09/2005**

General Pavement Project

- **Project Title:** Mechanistic-Empirical Pavement Design Guide Implementation
  Project ID: WisDOT 1009-03-3 $150,000 **End Date:** 03/08

Geotechnics Projects

- **Project Title:** Recycled Unbound Pavement Materials (MnROAD Study)
  Project ID: TPF-5 (129) $75,000 **End Date:** 12/2009
- **Project Title:** Determination of Resilient Modulus Values for Typical Plastic Soils in Wisconsin
  Project ID: WHRP 0092-08-12 $54,914 **End Date:** 04/2009
- **Project Title:** Development of Testing Methods to Determine Interaction of Geogrid-Reinforced Granular Material for Mechanistic Pavement Analysis
  Project ID: WHRP 0092-07-05 $70,987 **End Date:** 10/2008
- **Project Title:** Comparison of Basic Lab Test Results with More Sophisticated Lab and In-Situ Test Methods on Soils in Southeastern Wisconsin
  Project ID: WHRP 0092-06-05 $35,043 **End Date:** 05/2008
- **Completed Project:** Determination of Typical Resilient Modulus Values for Selected Soils Representative of the Soils Distributions of Wisconsin
  Project ID: WHRP 0092-03-11. $103,049 **Completed 06/2006**
- **Completed Project:** Determination of Influences on Support Strength of Crushed Aggregate Base Course Due to Gradational, Regional, and Source Variations.
  Project ID: WHRP 0092-02-01 $ 99,972 **Completed 02/2004**

Rigid Pavement Project

- **Completed Project** Investigation of Concrete Properties to Support Implementation of the New AASHTO Pavement Design Guide
  Project ID: WHRP 0092-06-03 $60,000 **Completed 11/2006**

WHRP Projects (11 Studies, $777,848)

Eleven studies pertinent to use by WisDOT of the new MEPDG have been completed or are in progress by WHRP through FFY 2008. Total expenditures for these studies are expected to total $777,848. Research entails work in flexible pavements, rigid pavements, and geotechnics.

Flexible Pavement Studies

The following WHRP studies pertain to flexible pavements and the MEPDG.

1. Project Title: Testing Wisconsin Asphalt Mixtures for the Mechanistic Design Procedure
Project ID: 0092-04-07 AASHTO 2002
Administrative Contact: Nikki Hatch
Sponsor: WHRP
Approved by Steering Committee: $125,000
Approved Ending Date: October 2005 ***Extension granted through September 2007***

Project Investigator (agency & contact): R. Christopher Williams
Michigan Technological University
301B Dillman Hall
1400 Townsend Dr.
Houghton MI 49931
906-487-1630
williams@mtu.edu
Percent Complete: 100 %
Final Report Date: July 2007
Final Report: http://www.whrp.org/Research/Flex/flex_0092-04-07/0092-04-07%20Final%20Report.pdf
Project Description: (From Work Plan)
The Wisconsin Department of Transportation (WisDOT) currently uses the AASHTO 1972 Interim Guide for the Design of Pavement Structures for hot mix asphalt. This pavement design procedure is a strictly empirical pavement design approach, however with the latest research and available computer capabilities, mechanistic pavement design procedures have become more feasible. The AASHTO 2002 Guide for Design of New and Rehabilitated Pavement Structures and associated software has been built on the mechanical properties of the pavement layers while still using functions to predict pavement life, thus making it a mechanistic-empirical pavement design approach. This pavement design procedure also allows for default values of the mechanical properties to be used, which is based on previous measurements of these properties.
The intent of this project is to examine typical hot mix asphalt (HMA) pavements that are constructed in the state of Wisconsin. **The analysis will compare the suggested pavement structures based on the current (1972) pavement design guide and that of the new (2002) pavement design guide. In order to develop the pavement structure as outlined by the AASHTO 2002 Pavement Design Guide the mechanical properties of the HMA layers must be measured.** These properties include Dynamic Modulus and Flow Number, which have been found to be significant predictors of rutting and fatigue by Witczak et. al. (2002). Properties of the other layers in the system have been obtained from the WisDOT pavement design inputs.
A cross-section of typical HMA pavements has been formulated into a research project matrix, for the greatest benefit for the WisDOT. Michigan Technological University (MTU) will sample these mixtures during the 2004 paving season. These mixtures will then tested in accordance with the AASHTO 2002
Design Guide for the aforementioned testing procedures and compiled into a library of values for the WisDOT.

2. Project Title: Guidance, Parameters, and Recommendations for Rubblized Pavements
Project ID: 0092-05-07
Administrative Contact: Nikki Hatch
Sponsor: WHRP
Approved by Steering Committee: $30,000
Approved Ending Date: October 2005 ***Extension granted through November 2006***
Project Investigator (agency & contact): Harold L. Von Quintus
Applied Research Associates
hvonquintus@ara.com
Percent Complete: 100%
Final Report Date: January 2007
Final Report: http://www.whrp.org/Research/Flex/flex_0092-05-07/Final%20Report_Rubblized%20Pavements_Wisconsin_December%202006.pdf
Project Description: (From Work Plan)
There are two objectives of this study, which are listed below.
1. Document historical information and data on the rubblization projects that have been built in Wisconsin.
2. Provide guidelines and recommendations for the selection, design, testing, and construction of rubblized PCC slabs, and determine the conditions for which rubblizing PCC pavements is a feasible rehabilitation strategy.
To achieve the above two objectives, the research activities planned for this project were envisioned and developed to generate answers to the following basic questions for the Wisconsin DOT:
• What parameters should be considered in determining if rubblization is a feasible alternative or rehabilitation strategy for PCC pavements?
• **What values of the design inputs should be used for determining HMA overlay thickness using the 1993 AASHTO Design Guide and M-E design procedures, such as the 2002 Design Guide?**

• What problems have been encountered and solutions applied during construction using this type of repair strategy of PCC pavements?
• What tests, and the frequency of tests, and inspection methods are needed during the rubblization and HMA overlay process, if different from current construction specifications and QA procedures?
• What data are needed to monitor and confirm the performance and design guidelines of this rehabilitation strategy?
• Is the rubblization of PCC pavements a cost-effective rehabilitation strategy (i.e., when compared to other rehabilitation strategies)?

3. Project Title: Development of Modulus-to-Temperature Relations For HMA Mixtures in Wisconsin
Project ID: 0092-03-14
Administrative Contact: Nikki Hatch
Sponsor: WHRP
Approved by Steering Committee: $63,891
Approved Ending Date: September 2005
Project Investigator (agency & contact): James A. Crovetti
Marquette University
Haggerty Hall 260
(414) 288-7382
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Percent Complete: 100%
Final Report Date: September 2005
Final Report: http://www.whrp.org/Research/publications/Final%20Reports/WHRP_05-11_Modulus_to_Temp_Relations.pdf
Project Description: (From Work Plan)
This project is investigating the relationships between **HMA Resilient modulus and mix temperature and considers a range of HMA mixture properties that may affect this relationship.** The project is utilizing both laboratory test results and field deflection data to quantify temperature-dependent changes in the HMA resilient modulus.

4. Project Title: Development of Recommendations for Compaction Temperatures in the Field to Achieve Density and Limit As-Built Permeability
Project ID: 0092-07-17
Administrative Contact: Nikki Hatch
Sponsor: WHRP
Approved by Steering Committee: $60,000
Approved Ending Date: April 2008
Project Investigator (agency & contact): Robert Schmitt
University of Wisconsin-Platteville
Percent Complete: 50%
Project Web Page: http://www.whrp.org/Research/Flex/flex_0092-07-17/index.html
Project Description: (From Quarterly Report)
The objectives of this study are to:
(1) Investigate the minimum limiting temperatures at which required density of HMA can be achieved with commonly used compaction effort;
(2) Investigate the effect of density achieved "as-built" on water and air permeability and measure how density and permeability (as-built) affect asphalt pavement performance in Wisconsin;
(3) Understand the inter-relations between HMA mixture properties (aggregate gradations and volumetrics), temperature and in-place density and permeability;
(4) Establish target minimum temperatures that are needed to achieve permeability and density values suitable for use within contract specifications;
(5) Develop temperature-stress profiles to provide guidelines for field compaction.
(6) Quantify the effects of Warm Mix additives on the minimum temperature and the temperature-stress profiles.
Tasks include:
Task 1. Literature Review. The objective of Task 1 is to conduct a comprehensive review of literature related to pavement densification and the relationship to performance.
Task 2 – Experimental Design. The objective of Task 2 is to design a field and lab experiment.

Task 3 – Field Data Collection. The objective of Task 3 is to implement the experimental design developed in Task 2 on 16 construction projects (32 layers) in the 2007 paving season and 24 construction projects (48 layers) in the 2008 paving season.

5. Project Title: Wisconsin Mixture Characterization Using the SPT on Historical Aggregate Structures
Project ID: 0092-08-06
Administrative Contact: Nikki Hatch
Sponsor: WHRP
Approved by Steering Committee: $74,992
Approved Ending Date: October 2008
Project Investigator (agency & contact): Ramon Bonaquist
Advanced Asphalt Technologies
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Sterling, VA 20166
(703) 444-4200
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Percent Complete: n/a
Project Web Page: http://www.whrp.org/Research/Flex/flex_0092-08-06/index.html
Project Description: (From Proposal)
Research Objectives: The objectives of the proposed research are to collect simple performance test properties on mixtures currently used by the Wisconsin Department of Transportation and to compare these properties to the observed performance of pavements built with similar mixtures. The project and the resulting database of simple performance test properties and observed performance will serve several purposes including:
• Provide typical simple performance test properties for mixtures used by the Wisconsin Department of Transportation classified by design traffic level, position in the pavement structure, and aggregate geology.
• Initial comparisons of simple performance test properties and pavement performance for selected Wisconsin projects.
• Local validation of criteria for rutting resistance developed in major national research efforts.
• Input data for evaluation and initial use of the MEPDG.
• Training of Wisconsin Department of Transportation staff in the use of the Simple Performance Test System for pavement and HMA design and evaluation.
Summary of Proposed Approach: Advanced Asphalt Technologies, LLC's (AAT's) proposed approach to this project is designed to achieve all project objectives, within the specified budget and schedule. The proposed project consists of five tasks:
Task 1: Select Mixtures and Assemble Performance Data
Task 2: Prepare Test Specimens
Task 3: Perform Simple Performance Tests
Task 4: Compare Simple Performance Test Properties and Performance
Task 5: Compile Final Report
Task 1 will involve selection of approximately 12 mixtures for characterization using the dynamic modulus and flow number tests from the Simple Performance Test System. The mixtures will be selected considering the design traffic level, position in the pavement structure, and aggregate type. Task 1 will also include assembling available performance data for the mixtures that are selected.
In Task 2, materials for the mixtures selected in Task 1 will be obtained and simple performance test specimens will be prepared at AAT's laboratory in Sterling, VA for subsequent testing at the Wisconsin Department of Transportation's Traux Laboratory. Task 2 will also include binder testing to obtain binder input data for various dynamic modulus and flow number predictive models.
In Task 3, the dynamic modulus and flow number tests will be conducted using the Simple Performance Test System in the Traux Laboratory by a graduate student from the Asphalt Research Group at the University of Wisconsin-Madison. The graduate student will receive training in the operation of Simple Performance Test System and analysis of the data from an experienced engineer from AAT. Wisconsin Department of Transportation staff will be encouraged to participate in this training.
The simple performance test properties collected in Task 3 and the performance data assembled in Task 1 will be analyzed in Task 4. The major analyses envisioned include:
• Comparison of dynamic modulus and flow number characteristics for various mixtures used by the Wisconsin Department of Transportation.

• Comparison of dynamic modulus and repeated load characteristics with the observed performance of Wisconsin pavements.
• Validation of criteria for rutting resistance developed in NCHRP Project 9-19 for the dynamic modulus test and NCHRP 9-33 for the flow number test.
• Evaluation of available predictive models for dynamic modulus and flow number for Wisconsin mixtures.
The final task, Task 5, consists of compiling a report that thoroughly documents the project. The report will be prepared in accordance with the Wisconsin Highway Research Program requirements. An electronic database of the simple performance test results will be included with the final report.

Rigid Pavement Studies
The following WHRP study pertains to rigid pavements and the MEPDG.

1. Project Title: Investigation of Concrete Properties to Support Implementation of the New AASHTO Pavement Design Guide
Project ID: 0092-06-03
Administrative Contact: Nikki Hatch
Sponsor: WHRP
Approved by Steering Committee: $ 60,000
Approved Ending Date: October 2006 ***Extension granted through December 1, 2006***
Project Investigator (agency & contact): Tarun Naik
UWM Center for By-Products Utilization
University of Wisconsin-Milwaukee
P.O. Box 784
Milwaukee, WI 53201
(414) 229-4105
tarun@uwm.edu
Percent Complete: 100%
Final Report Date: November 2006
Final Report: http://www.whrp.org/Research/Rigid/rigid_0092-06-03/06-03FR.pdf
Project Description: (From Research Problem Statement)
Background and Problem Statement: **The Wisconsin Department of Transportation (WisDOT) has received a copy of the new "2002 Design Guide, Design of New and Rehabilitated Pavement Structures." The Department is now reviewing the procedure, performing sensitivity analysis and determining the effort required to adopt and implement the procedure. The new concrete pavement design procedure contains two concrete properties not previously measured by WisDOT.** They are AASHTO T198 - Splitting Tensile Strength of Cylindrical Concrete Specimens and AASHTO TP 60 - Coefficient of Thermal Expansion of Hydraulic Cement Concrete. These two variables in the design process are very sensitive in determining the thickness design and predicted performance of the pavement. So, information on the relevant input variables for the procedure is required in order to assure successful implementation of this new mechanistic-empirical design procedure being proposed by AASHTO.
Scope: It is anticipated that there are two phases to this project. The first is a research and materials collection phase. The second is a laboratory study of representative concrete mixtures for the determination of split tensile strength and coefficient of thermal expansion.
The first phase entails researching the standard testing procedures, conducting a literature search to determine work done in this area to date in other states and universities and then setting up a testing matrix of representative concrete mixes for the State of Wisconsin.
Researcher will develop a testing matrix in Phase 1 for the prescribed testing for the spectrum of aggregates against a cross section of representative cementitious materials. WisDOT staff will work with the researcher in final selection of aggregate sources, and will assist the researcher as needed in gaining access to the selected aggregate sources.
Phase 2 of this project will include the mixing of concrete, development of test samples and the split tensile strength testing and coefficient of thermal expansion testing, reporting the results and recommending input values to be used by the Department in the AASHTO 2002 procedure.
Specific Results, Findings, Tool, etc.
1. Recommended values for split tensile strength testing and coefficient of thermal expansion to be used by the Department in the pavement design process.

2. Development of standard practice and recommendation for future work in this area by WisDOT.
3. Incorporation of results into WisDOT guidance and policy.

Geotechnical Studies
The following WHRP studies pertain to geotechnics and the MEPDG.

1. Project Title: Determination of Typical Resilient Modulus Values for Selected Soils Representative of the Soils Distributions of Wisconsin
Project ID: 0092-03-11
Administrative Contact: Nikki Hatch
Sponsor: WHRP
Approved by Steering Committee: $103,049
Approved Ending Date: September 2005 ***Extension granted through May 2006***
Project Investigator (agency & contact): Hani Titi
University of Wisconsin-Milwaukee
P.O. Box 784
Milwaukee, WI 53201
(414) 229-6893
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Percent Complete: 100%
Final Report Date: June 2006
Final Report: http://www.whrp.org/Research/Geotechnics/geo_0092-03-11/WHRP%2003-11%20Determination%20of%20Typical%20Resilient%20Modulus%20Values%20for%20Selected%20Soils%20in%20Wisconsin.pdf
Project Description: (From Work Plan)
The study will be conducted over 24 months, and be completed in 5 phases:
Task 1: Literature Review on Resilient Modulus of Subgrade Soils.
Task 2: Selection of a Wide Spectrum of Subgrade Soils that Comprise Core Soil Types in Wisconsin.
Task 3: Evaluate the Effects of Soil Properties and Stress Levels on the Resilient Modulus of Wisconsin Subgrade Soils.
Task 4: Analyses of Test Results and Development of Models to Predict Resilient Modulus. **Perform statistical analysis and obtained preliminary parameters for the AASHTO 200X resilient modulus universal model.**
Task 5: Final Report.

2. Project Title: Determination of Influences on Support Strength of Crushed Aggregate Base Course Due to Gradational, Regional, and Source Variations
Project ID: 0092-02-01
Administrative Contact: Nikki Hatch
Sponsor: WHRP
Approved by Steering Committee: $ 99,972
Approved Ending Date: February 2004
Project Investigator (agency & contact): Paul Eggen
OMNNI Associates
One Systems Drive
Appleton, WI 54914
(920) 735-6900
paul.eggen@omnni.com
Percent Complete: 100%
Final Report Date: February 2004
Final Report: http://www.whrp.org/Research/publications/Final Reports/WHRP 04 08 Determination of Influences on Support Strength of Crushed Aggregate Base Course Due to Gradual, Regional, and Source Variations.PDF
Project Description: (From Final Report Abstract)
This research investigates the range of load-carrying capability, in terms of resilient modulus (M_R), of crushed aggregate base course in Wisconsin and how variables, such as physical characteristics, material type, source lithology and regional factors influence M_R. Testing was conducted on 37 aggregate sources and the results statistically analyzed to look for correlations between M_R and these variables and to determine if they could be used to predict M_R. Results showed that M_R did not differ between and/gravel pit and quarry groups and that carbonate

quarries generally gave significantly higher M_R values than Precambrian, felsic-plutonic quarries. Changing gradation of base course from a given source affected M_R test results, but not consistently or predictably. Certain physical parameters, were found that influence M_R in some of the geologic subsets. However, none of the correlations were strong enough to predict M_R with sufficient confidence. **The test data will provide a base of information that will be useful when WisDOT adopts a mechanistic-empirical pavement design process.**

3. Project Title: Comparison of Basic Lab Test Results with More Sophisticated Lab and In-Situ Test Methods on Soils in Southeastern Wisconsin
Project ID: 0092-06-05
Administrative Contact: Nikki Hatch
Sponsor: WHRP
Approved by Steering Committee: $35,043
Approved Ending Date: May 2007 ***Extension granted through May 1, 2008***
Project Investigator (agency & contact): Tuncer B. Edil
University of Wisconsin-Madison
2226 Engineering Hall, 1415 Engineering Drive
Madison, WI 53706
(608) 262-3225
edil@engr.wisc.edu
Percent Complete: 35%
Project Web page: http://www.whrp.org/Research/Geotechnics/geo_0092-06-05/index.htm
Project Description: (From Quarterly Report)
The technical objective of the proposed study is to investigate all of the generated soils data in the Milwaukee Marquette Interchange project in an attempt to **correlate the more 'routine' laboratory tests to determine geotechnical design parameters (such as phi-angle, cohesion, unit weight, unconfined compression, consolidation characteristics, etc.) that are typically obtained from more sophisticated laboratory tests or in-situ field tests.** The range of values, variations, trends and correlation will be explored in terms of different types of soils and/or geological origin.

4. Project Title: Development of Testing Methods to Determine Interaction of Geogrid-Reinforced Granular Material for Mechanistic Pavement Analysis
Project ID: 0092-07-05
Administrative Contact: Nikki Hatch
Sponsor: WHRP
Approved by Steering Committee: $70,987
Approved Ending Date: October 2008
Project Investigator (agency & contact): Tuncer B. Edil
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edil@engr.wisc.edu
Percent Complete: 50%
Project Web page: http://www.whrp.org/Research/Geotechnics/geo_0092-07-05/index.htm
Project Description: (From RFP)
The overall objective of the proposed research is to resolve remaining questions relating to the interaction of geogrids with granular materials and the contribution of such a composite layer to pavement structure design. To obtain this objective, the project can be divided into three phases consisting of 1) a thorough review and analysis of the pertinent literature, 2) laboratory testing, analyses of the resultant data, and development of conclusions, and 3) assessment of full-scale field installations.
Phase 1 will consist of a literature search to obtain other research findings in the topic area. A thorough analysis of the obtained materials should then follow and all pertinent information should be summarized. The results of the literature search and the application to the work proposed for the remainder of the project should be presented to the Technical Oversight Committee (TOC) before proceeding to Phase 2.
Phase 2 will involve laboratory testing and modeling to determine the interaction of geogrids with specific granular materials and the resultant properties of these composite layers. The first objective will be to determine quantitatively the equivalent thickness of granular material sub-layers with a geogrid reinforcement element as

compared to a layer without the geogrid. In selecting granular materials, the researcher should focus on breaker run stone and pit run sand and gravel since these are the two materials cited in Section 5-10-15 of the Departmental Facilities Development Manual (FDM), as acceptable materials to be used with geogrids to improve subgrades. The Department will provide assistance to the researchers in locating representative samples of these granular materials. The geogrids used in this work should be representative of commonly used grids, but should include at least one rigid grid and one flexible grid of comparable strength at 5% elongation. These grids will be placed at the interface of the subgrade soils and the base of the granular materials. The second objective is to develop consistent and reasonably simple testing procedures that assess the enhanced modulus of specific geogrid reinforcement-granular material combinations. This would include identifying critical properties of both the granular materials and the geogrids. The third objective would be to develop the necessary charts, formulas, or other tools necessary to model the reinforced layer into mechanistic pavement design. A report of these activities should be made to the TOC before proceeding to the next project phase.
The objective of Phase 3 is to evaluate whether these procedures are representative of field conditions by comparing and analyzing the performance of representative full-scale test sections. There may be some existing field test data available from other research projects that may assist in this analysis. This existing data will be supplemented with test sections constructed on a WisDOT project. It is anticipated that this field test site will be located in the southern 1⁄2 of Wisconsin. These test sections should model several combinations of geogrids with the breaker run stone and the pit run sand and gravel and should also include comparative sections without the geogrid. Costs associated with these field tests should be included in the research project budget. The researcher will coordinate/contract directly with the contractor for this work. The results of the field test should then be used to make any necessary adjustments to the laboratory analyses and conclusions. Completion of the project will include submittal of a comprehensive report of all activities including final conclusions and recommendations.
This project will focus on improving the understanding of the interaction of geogrid with granular layers and how this composite layer can be factored into mechanistic pavement design and into appropriate geogrid/aggregate design procedures without extensive project-specific laboratory testing. The deliverables of this project will include methods for determining equivalent thicknesses of layers of breaker run stone and pit run sand and gravel reinforced with geogrid, methods for determining impacts of differing geogrids on layer properties, and methodology to incorporate such layers into mechanistic pavement design.

5. Project Title: Determination of Resilient Modulus Values for Typical Plastic Soils in Wisconsin
Project ID: 0092-08-12
Administrative Contact: Nikki Hatch
Sponsor: WHRP
Approved by Steering Committee: $54,914
Approved Ending Date: April 2009
Project Investigator (agency & contact): Hani Titi
University of Wisconsin-Milwaukee
P.O. Box 784
Milwaukee, WI 53201
(414) 229-6893
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Percent Complete: n/a
Project Web site: http://www.whrp.org/Research/Geotechnics/geo_0092-08-12/index.htm
Project Description: (From Proposal)
Research Objectives: The primary objective of this research project is to develop (and/or expand, improve) and validate a methodology for estimating the resilient modulus of various Wisconsin subgrade soils from basic soil properties (Level 2 input parameters in the mechanistic-empirical pavement design). The following specific objectives are identified for successful accomplishment of this research:
1. Conduct repeated load triaxial tests to determine the resilient modulus of Wisconsin soils selected by WisDOT engineers. These soils will also be subjected to different laboratory tests to obtain their physical and compaction properties. The obtained test results will augment and expand the test data conducted during Phase I of the resilient modulus research.
2. Develop/expand/modify resilient modulus correlations (models) that were proposed in Phase I between the resilient modulus constitutive model parameters (k1, k2, & k3) and basic soil properties. The new correlations will be validated for wide range of Wisconsin soils and conditions.
Benefits: **WisDOT is moving toward implementation of mechanistic-empirical design for pavements and has committed significant time and resources towards this effort. Resilient modulus of subgrade soils is required**

as input parameter in the mechanistic-empirical design process. To achieve accurate and efficient pavement designs, it is essential to accurately determine the resilient modulus of the subgrade soils. Without this study, WisDOT would use very conservative general values for soils input. This would significantly diminish the effectiveness and benefits on mechanistic-empirical pavement design.
The benefits of the mechanistic-empirical pavement design, which uses the resilient modulus to characterize subgrade soils, are widely recognized in the pavement community (e.g., NCHRP, FHWA, AASHTO). According to the research team of the NCHRP project 1-37A, the mechanistic-empirical design will reduce premature failure of pavements, which will result in $1.14 billion of annual savings in pavement rehabilitation cost. This estimation was based on probabilistic life cycle cost analysis under certain assumptions (e.g., 20 years design life).

MRUTC Projects (3 Studies, $160,000)

The following three studies by the Midwest Regional University Transportation Center pertain to the use by WisDOT of the MEPDG for flexible pavement applications. The studies have been budgeted at $160,000.

Flexible Pavement Studies

1. Project Title: Development of Regional Pavement Performance Database for Validation and Local Calibration of the Predicted Models Used in the New AASHTO Pavement Design Guide
Project ID: MRUTC 07-01
Administrative Contact: Jason Bittner
Sponsor: MRUTC
Approved Funding: $50,000
Approved Ending Date: March 31, 2007
Project Investigator (agency & contact): Hussain Bahia
3350 Engineering Hall, 1415 Engineering Drive
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Percent Complete: 100 %
Final Report Date: May 2007
Final Report: Part 1, http://www.mrutc.org/research/0701/FINAL_ME_PDG_Part_1.pdf; Part 2, http://www.mrutc.org/research/0701/FINAL_ME_PDG_Part_2.pdf.
Project Description: (From Part 1 abstract)
Optimization of transportation facilities for capacity and pavement condition could be achieved with mechanistic analysis of pavement structures. This report is focused on using the AASHTO M-E Design Guide (MEPDG) to show the results of quantitative sensitivity analyses of typical pavement structures (rigid and flexible pavements) to highlight the main factors that affect pavement performance in terms of critical distresses and smoothness. The sensitivity analyses were conducted using the Mechanistic – Empirical Pavement Design Guide software (version 8.1). Pavement performance included specifically faulting, transverse cracking, and smoothness for rigid pavements. It also included smoothness, longitudinal cracking, alligator cracking, transverse cracking, and permanent deformation for flexible pavements. The input parameters that were varied included traffic variables (AADTT, speed, and wander) and pavement structure for selected rigid and flexible pavements. In addition, the binder grade was varied for the flexible pavements. Based on the sensitivity results, the input parameters were ranked and categorized from those to which pavement performance is most sensitive to least sensitive (or insensitive). The ranking should help pavement designers identify the level of importance for each input parameter and also identify the input parameters that can be modified to satisfy the predetermined pavement performance criteria. It is expected that ranking could also help planners to determine how traffic of heavy vehicles could be directed to enhance the service life of various sections of pavement network and to develop better maintenance strategies.
(From Part 2 abstract)
This project identified two important calibration factors for a Midwest implementation of the Mechanistic-Empirical Pavement Design Guide (M-E PDG). The calibration factors are for the fatigue damage model in flexible pavements in Wisconsin. Pavement performance data was collected from Michigan, Ohio, Iowa and Wisconsin state transportation agencies using uniform data structures as spreadsheet templates specifically designed to manage the calibration data. Spreadsheets were developed for both flexible and rigid pavements. Calibration factors were derived by minimizing differences between observed and predicted pavement performance. The gathering of data required for calibration is labor intensive because the data resides in various and incongruent data

sets. Furthermore, some pavement performance observations include temporary effects of maintenance and those observations must be removed through a tedious data cleaning process. The scope of calibration factors is limited by these data impediments. For each state, the observed and predicted performances are compared for both flexible and rigid pavements. The predicted performance is computed using default and derived calibration factors. The project includes a case study design as an example for quantifying the benefits of the M-E PDG.

2. Project Title: Database Development for an HMA-based Pavement Performance Analysis System
Project ID: MRUTC 07-11
Administrative Contact: Jason Bittner
Sponsor: MRUTC
Approved Funding: $50,000
Approved Ending Date: February 29, 2008
Project Investigator (agency & contact): Robert Schmitt
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Platteville, WI 53818
(608) 342-1239
schmitro@uwplatt.edu
Percent Complete: 95%
Project Web page: http://www.mrutc.org/research/0711/
Project Description: (From Web page)
The first objective of this project is to develop a database template, using the existing WisDOT pavement management system, from which to perform pavement performance analysis using design, construction, traffic, environmental, and performance data for hot-mix asphaltic pavements. The second objective of this project is to investigate appropriate numerical or statistical methods that have the potential of quantifying and establishing relationships between design, construction, traffic, environmental, and performance data.
In-situ pavement performance can be considered a response variable to many project input variables, such as design (i.e., base type, soil support value, etc.), construction (i.e., selected materials, deviation from targets, etc.), and both environmental and traffic loading effects. **If WisDOT and Industry are to fully understand and realize the true components of in-situ pavement performance, and specify the necessary inputs through design and construction specifications to achieve that performance, quantitative relationships must be developed between the input variables and response variables through a scientific, fully integrated pavement performance analysis system.** System components are already in place, such as Meta Manager traffic data and Pavement Distress Index data, however, research is necessary to fully integrate the system and develop quantitative methods to understand the inter-relations of system components. The purpose of this project is to develop a comprehensive and fully integrated data acquisition, modeling, and analysis system to quantify the relationship between design, construction, environmental, and traffic inputs, and the resulting in-situ pavement performance output.

3. Project Title: Materials Characterization and Analysis of the Marquette Interchange HMA Perpetual Pavement
Project ID: MRUTC 08-08
Administrative Contact: Jason Bittner
Sponsor: MRUTC
Approved Funding: $60,000
Approved Ending Date: August 31, 2008
Project Investigator (agency & contact): James Crovetti
Marquette University
260 Haggerty Hall
Department of Civil and Environmental Engineering
Milwaukee, WI 53201
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Percent Complete: 25%
Project Web page: http://www.mrutc.org/research/0808/
Project Description: (From Web page)
The objectives of this study are to characterize the materials used to construct the HMA perpetual pavement and to analyze the collected pavement response data to investigate the interactions between materials, environment, and traffic loadings. **This study will require a detailed examination of the predictive equations and sub-routines**

which are part of the mechanistic-empirical design procedures developed under NCHRP Project 1-37A to determine how well these reflect the actual response measures. The conclusions of this study should provide guidance for the Wisconsin Department of Transportation to perform mechanistic-empirical pavement designs which are validated for local conditions.

The design and construction of perpetual pavements across the United States is gaining momentum as limited owner/agency budgets are facilitating longer lasting highways systems. The perpetual pavement design concept also provides an improved opportunity for asset management as this design concept represent an improved "life" cycle cost basis over traditional pavement designs. The Wisconsin Department of Transportation recently constructed their first perpetual pavement in the highly urbanized area of Milwaukee at the Marquette Interchange. Concurrent with the construction of this perpetual pavement was highly advanced instrumentation of the pavement system collecting climatic, loading characteristics, and loading responses. **The instrumentation combined with additional characterization of materials used to construct this perpetual pavement represents a unique opportunity to evaluate the newly completed Mechanistic-Empirical Pavement Design Guide and provide for local calibration of the guide to Wisconsin conditions.**

Wisconsin DOT Projects (1 Project, $150,000)

The following WisDOT project focuses specifically on MEPDG implementation for pavement design in Wisconsin, and is funded for $150,000.

General Pavement Study

1. Project Title: Mechanistic-Empirical Pavement Design Guide Implementation
Project ID: 1009-03-35
Administrative Contact: Laura L. Fenley
Sponsor: WisDOT
Approved: $150,000
Approved Ending Date: November 2007 *Extension granted through March 2008*
Project Investigator (agency & contact): Jagannath Mallela
Applied Research Associates, Inc. (ARA)
Suite 200
100 Trade Centre Drive
Champaign, IL 61820-7233
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Percent Complete: 80%
Project Web page: n/a
Project Description: (Excerpted from Technical Proposal)
The objective of this project is to implement or adapt the MEPDG procedure developed under NCHRP projects 1-37A and 1-40D, for use in Wisconsin. The scope of work includes identifying pavement test sections in Wisconsin with sufficient performance data, extracting pavement data from existing databases for those test sections, determining the appropriate inputs for the MEPDG to predict pavement distress and smoothness, compare the predicted to measured distress values, determine the magnitudes of the bias and standard error, and determine local adjustment or calibration factors to reduce any significant bias and standard errors of the prediction models for use in Wisconsin. Version 1.0 of the MEPDG was used.
The focus of this effort is centered on readily accessible data from pavement section in Wisconsin. The test sections are assumed to have a sufficient amount of traffic, climate, foundation, materials, structure, and performance data, and that data will be in a form needed to validate and, if need be, calibrate the MEPDG models. Examples of such sections include the Wisconsin Long-Term Pavement Performance (LTPP) sections and other Wisconsin local sections such as those considered in the MRUTC study *Regional Pavement Performance Database for Validation and Local Calibration of the Prediction Models Used in the New AASHTO Design Guide*. In other words, field and laboratory testing to establish the inputs is considered outside the scope of work for this project. Results of these initial efforts might suggest that additional sections be included, along with the necessary field and laboratory work, to improve the design process.

Wisconsin Pooled Fund Projects (2 Projects, over $75,000)

WisDOT contributes to four pooled fund projects administered by FHWA that will produce data or materials pertinent to implementation of the MEPDG. . Total contributions are not available, but it is believed that for three of the projects the Wisconsin total is $165,000. Two projects pertain to geotechnics and two to flexible pavements.

Flexible Pavement Project

WisDOT participates in one pooled fund study that will assist in implementation of MEPDG for flexible pavement applications.

1. Project Title: Accelerated Performance Testing on the 2006 NCAT Pavement Test Track
Project ID: TPF-5(124)
Administrative Contact: Tommy Nantung
Sponsor: FHWA; partners are Alabama, Florida, Georgia, Missouri, Mississippi, North Carolina, Nebraska, Oklahoma, South Carolina, Tennessee, Texas, Wisconsin
Committed Funding: $7,885,000 (WisDOT commitment not available)
Approved Ending Date: 2009
Lead Agency and Contact: Alabama Department of Transportation
Jeff Brown
(334) 353-6941
brownje@dot.state.al.us
Percent Complete: n/a
Project Web page: http://www.pooledfund.org/projectdetails.asp?id=374&status=4
Project Description: (From Web page)
The primary objectives of the pooled fund project described herein will be:
1. Constructing 200 ft test sections on the existing 1.7 mile NCAT test oval that are representative of in-service roadways on the open transportation infrastructure;
2. Applying a design lifetime of truck traffic in the 2 years following construction;
3. Assessing/comparing the functional and structural field performance of trafficked sections on a regular basis via surface and subsurface measures;
4. Validating the M-E approach to pavement analysis and design using both surface and subsurface measures;
5. Calibrating new and existing M-E approaches to pavement analysis and design using pavement surface condition, pavement load response, precise traffic and environmental logging, and cumulative damage;
6. Correlating field results with laboratory data; and
7. Answering practical questions posed by research sponsors. For example, can an innovative mix design utilized in one state be implemented in another sponsor's practice using locally available aggregates? Will a specific material source provide for a safe roadway surface if adopted for widespread use? If not, what maximum percentage will work?
The scope of work for the pooled fund project will include:
1. Hauling materials to the project from offsite locations. Material donations are typically secured by state sponsors, while reasonable hauling expenses are handled by the pooled fund;
2. Rebuilding sections in accordance with sponsors¿ directives via a competitively bid contract administered by ALDOT under the direction and oversight of NCAT;
3. Installing both environmental (i.e., multi-depth pavement temperature probes) and response instrumentation (i.e., high speed stress and strain gages) in new experimental sections;
4. Operating a 5-truck fleet for approximately 16 hours a day in order to apply a design lifetime of truck traffic in the 2 years following construction. Actual human drivers pilot the vehicles in order to best induce representative vehicle wander;
5. Measuring field performance each week when the fleet is parked to fully document the development of densification, rutting and cracking as a function of traffic and temperature. High-speed pavement response will also be measured on a weekly basis. Pavement deflection and surface friction will be measured on a monthly basis;
6. Conducting laboratory testing to quantify basic material and mix performance properties, which will serve as the basis of performance model development; and
7. Comparing predicted and measured pavement response as well as predicted and measured cumulative pavement damage in order to validate then calibrate prevailing M-E methodologies.

Geotechnical Project

WisDOT participates in the following pooled fund project that will assist in implementation of the MEPDG in base and subbase applications.

2. Project Title: Recycled Unbound Pavement Materials (MnROAD Study)
Project ID: TPF-5(129)
Administrative Contact: Ben Worel
Sponsor: FHWA; partners are California, Michigan, Minnesota, Ohio, Texas, Wisconsin
Committed Funding: $390,000 (WisDOT commitment, $75,000)
Approved Ending Date: 2011
Lead Agency and Contact: Minnesota Department of Transportation
Ben Worel
(651) 366-5522
ben.worel@dot.state.mn.us
Percent Complete: n/a
Project Web page: http://www.pooledfund.org/projectdetails.asp?id=361&status=4
Project Description: (From Web page)
The objective of this study is to monitor the performance of several test cells at the Minnesota Road Research Facility (MnROAD) constructed using recycled materials in the granular base layers, including blended with virgin materials and 100% recycled asphalt and concrete pavement materials. The material properties will be monitored during construction and throughout the pavement life in order to determine their effects on pavement performance. The properties will be used to verify mechanistic-empirical design inputs, especially their variation with changing seasons and moisture regimes.

This pooled fund study is strictly to perform the recycled materials research on newly built test sections at MnROAD, and its funding will come from Mn/DOT and other participating states. The funding for initial construction of the test sections will be obtained separately from Mn/DOT and other partners.This project is expected to consist of the following activities:

- Work Plan: The work plan for this pooled fund study will be developed by the participating organizations. This will include selecting recycled materials to construct the base layer for 3 cells at MnROAD. Possibilities include:
o 100% crushed concrete
o crushed concrete blended with virgin aggregate
o RAP blended with virgin aggregate

The pavement surface must also be carefully selected for these sections. Ideally, the same pavement will cover all three cells so as to minimize variables in the experiment.

- Instrumentation Design: Thermocouples, TDRs (moisture), strain gages, etc.
- General Testing & Monitoring: Monitor the pavement performance over time on each test section. Monitoring activities will include FWD tests, rutting measurements, distress surveys, ride measurements, and analysis of pavement sensor data.
- Special Testing & Monitoring: Unsaturated soil properties, resilient modulus, seasonal variation of material properties, etc.
- **Design Guide Modeling & Validation: The material properties for recycled unbound layers will be modeled in the new mechanistic-empirical design procedure.**
- Pooled Fund Travel: Money for each state to travel to discuss the progress of the study.
- Data Analysis & Reports: Work done under a research contract will develop interim and final reports that document the findings of this study.