

# Research Record

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## Mechanistic Design for Flexible Pavements and Overlays

### MDOT Prepares for New Design Procedures

The Michigan Department of Transportation (MDOT) recently completed a study that may eventually help produce higher-quality road surfaces that not only last longer, but are also cheaper to build and maintain. The study was sponsored by MDOT and conducted through the Pavement Research Center of Excellence (PRCE) at Michigan State University (MSU).

MDOT currently uses an empirical, statistical-based design method that is based on the 1993 version of the American Association of State Highway and Transportation Officials (AASHTO) design guide. MDOT pavement engineers believed a change in design methodology and practice needed to be investigated to make more accurate predictions of design service life (DSL) and to better control the performance of the pavement in accordance with its design criteria. Although it was recognized that changes needed to be made in their design practices, determining which practices needed changing and the steps necessary to implement these changes posed a problem. This is where the PRCE entered the picture. The objective of the study was to have the PRCE review current MDOT flexible pavement and overlay design practices, make recommendations for improvements, and provide a formal, comprehensive implementation plan. The study's findings will help MDOT decide whether to adopt the mechanistic-based 2002 AASHTO Design Guide when it's completed.

#### Brief History of the PRCE

As reported in *Research Record* #76 (August, 1995), the Pavement Research Center of Excellence was established in 1995. The Center is a cooperative effort between MSU and the University of Michigan (U of M), with Michigan Technological University (MTU) involved as an in-

formal third arm. The PRCE benefits from the research strengths that each university provides, with MSU heading up research in flexible pavements, and U of M performing research in rigid pavement design. Due to the materials research involved in some of the PRCE projects, MTU serves as a subcontractor for materials research for both MSU and the U of M on many of the projects.

The PRCE is one of six current research centers that operate under the guidance of MDOT. The others include the Traffic and Safety Research Center at MSU, the Transit Research Center at MSU, the Intelligent Transportation Systems Center at the U of M, the Great Lakes Truck and Transit Research Center, which is a consortium of six universities led by the U of M, and the newly-founded Transportation Materials Research Center of Excellence at MTU.

#### Current MDOT Pavement Design Practices

Until the early 1970s, MDOT used standard cross sections for the design and construction of flexible and rigid pavements. These standard sections were adjusted to account for traffic volume and axle loads. In the early 1970s, MDOT changed its design methodology to the "AASHTO Interim Guide for the Design of Pavement Structures, 1972". The AASHTO method is based on empirical design methods, which are a statistically developed correlation between pavement layer thickness and traffic volume. All empirical design procedures are based on a set of pavement data that are limited to certain materials, environment, and traffic load factors. Empirical pavement design methods are often modified based upon experience and opinions. (Baladi, pg. 5)

In 1985, MDOT recognized the need to assess the advantages and disadvantages of changing its

flexible pavement and overlay design practices from the AASHTO method to a mechanistic-based method. Mechanistic-based design methods are used to determine the cross section layer thickness of asphalt pavements and/or thickness of asphalt overlays based on mechanical properties of the paving materials and the subgrade soil. (Baladi, pg. 5)

In 1996, MDOT began using the 1993 version of AASHTO's design guide, including the DARWin software. Although the current design procedures are providing more predictable results, there are still a number of shortcomings associated with the 1993 AASHTO design procedures. Foremost, the AASHTO procedure is almost entirely based on ride quality. Also, the DARWin software requires that a number of criteria related to material properties be assumed. These assumptions are due to the fact that MDOT currently lacks a procedure to effectively measure and verify the pavement's material properties.

To further complicate matters, projects with pavement costs exceeding \$1 million must follow MDOT's Life Cycle Cost Analysis (LCCA) policy to determine the most cost effective pavement type. Pavement costs are defined as those pavement structure items above the subgrade elevation. MDOT currently uses two procedures to determine the pavement's life/cycle costs. One refers to the method used when the pavement is newly designed or reconstructed, and the other is used when the pavement undergoes a major rehabilitation with a design service life of 10 years or more. Both of these procedures include an analysis period that equates to a prescribed "preventative maintenance schedule."

Since the LCCA procedures were initiated, an ongoing debate has existed about the proper prescription and timing for preventive maintenance treatments. Although MDOT is beginning to keep records to track specific maintenance activities with regards to the different construction and/or rehabilitation practices, it is still unclear when the service life of a pavement ends. The subjectivity of the current AASHTO design guidelines increases the inaccuracy of these estimates by requiring the engineer to make judgements on several input values. This contributes to the fragmentation of the current design procedure, as engineers' assumptions may greatly differ. Furthermore, different regions of the state must deal with totally different environmental factors including weather conditions and quality of pavement materials. When all of these factors are combined, it becomes more apparent that the use of a unified design procedure will enable MDOT to more objectively design and compare pavement performance from different regions of the state.

## **PRCE Recommendations**

After reviewing MDOT's procedures for existing pavement design, asphalt mix design, and material quality control, and after receiving input from their pavement engineers, technicians, and managers, the PRCE recommended the following:

"The various flexible pavement design procedures and the design of asphalt overlays used by MDOT be consolidated into a comprehensive and unified process. The main objective of the new process would be to optimize the life and performance of the pavement and to minimize life cycle costs." (Baladi, pg. 44)

The recommendation addresses several shortcomings with MDOT's current AASHTO-based design procedures:

- The design procedure is fragmented as it does not address a comprehensive design process.
- Material properties assumed during the design procedure are not verified after construction.
- The final as-built cross section is assumed to be equal to what was designed.
- Average Daily Traffic (ADT) information is converted to Equivalent Single Axle Load (ESAL) using standard truck factors. These factors have not been calibrated for new truck loads, tire pressures, and pavement condition.
- The current design procedure only addresses the functional performance of the pavement and not the structural performance of the pavement.

## **Implementation Plan Components**

To assure that the recommendation mentioned earlier is integrated as smoothly as possible, the PRCE formulated an Implementation Plan to gradually introduce the new design practices. The Implementation Plan consists of three primary interactive components: continuing education and training, information, and operation.

### **Continuing Education and Training**

This component consists of on-site training, periodic seminars, and short courses for participants from within MDOT's organizational structure. The training would disseminate the latest information on mechanistic-based design process, facilitate the development of a dialog between pavement designers across the state, and improve partnering between MDOT, industry, and academia.

### **Information**

This component will encompass material characterization data, standards and specifications, quality control/quality assurance (QC/QA), and utilize a total

pavement management system including a crucial feedback component. Overall, for a cost-effective design process to be implemented, the following key pieces of information are needed:

*Inventory Data*— This includes all data relative to the existing physical asset including the as-constructed cross sections, material properties, physical features, and age. These data should be arranged in an easy-to-use format in a PMS database.

*Material Characterization*— For existing pavements and for overlay design, a falling weight deflectometer (FWD) should be utilized on a routine basis to determine the in-situ engineering properties of the materials. During evaluation, the pavement's cross section is verified by coring, and the resulting data entered into the PMS database. This information could then be displayed on a state map to compare with state-wide performance data and help select timing for needed overlays.

*Standards and Specifications*— As mentioned earlier, current MDOT specifications only address the physical properties of asphalt mixtures. These specifications should be modified to reflect the engineering properties of the entire pavement system, including the properties of the asphalt mixtures and the as-constructed pavement. Included in the revised specifications would be the allowable maximum peak deflections for a particular pavement structure.

*Pavement Management System Implementation*— A complete PMS implementation will enable MDOT to achieve better and more cost-effective pavement management. A more consistent consideration of existing pavement conditions and the rate of deterioration, which is derived from a review and analysis of PMS data, will assure pavement engineers arrive at better and more balanced decisions.

*Feedback*— When feedback is properly performed, it becomes an invaluable calibrating system of checks and balances for the design process and the PMS.

*QC/QA*— An expanded QC/QA program would not only address the as-built pavement's physical components, but also include measurements to quantify the future performance of the pavement. This feature is an integral part of the checks and balances provided in the feedback component.

## Operation

The operational component of the plan consists of the mechanistic-based software that will be used in the design and analysis of the pavement structure and the QC/QA measures taken during the design and subsequent analysis of the as-constructed pavement.

*Software*— The new plan would use two software packages in the design and analysis of mechanistic-based pavements, MICHPAVE and MICHBACK.

MICHPAVE was first developed by MSU in 1990 to provide MDOT a linear and nonlinear finite element pavement design program. Although MICHPAVE was a step towards mechanistic-based design and was noticed both nationally and internationally, there were some functionality concerns that needed to be addressed. The software is currently being updated to address these concerns and to enable it to run within MDOT's Windows NT operating system. The new version of the software is expected in August of 1999. MSU developed the MICHBACK software in 1992 as part of a project that investigated causes and corrective measures for pavement rutting.

MICHBACK is a back-calculation program that calculates layer modulus values using FWD deflection data. Combined, these two software packages are the cornerstones for the computer-based design and analysis of asphalt pavements and overlays. (Baladi, pg. 4)

## Benefits

By implementing a mechanistic-based process for the design of flexible pavements and overlays, numerous benefits will be realized by MDOT, highways users, and to industry. (Baladi, pg. 57-60)

### Benefits to MDOT

*Increased Pavement Service Life*—By quantifying the engineering properties of the materials used, a much improved understanding of the root causes of pavement distress can be achieved. This should make PSL estimates more accurate. Other agencies that have switched to a mechanistic-based approach have shown promising results.

They report increased pavement life and decreasing costs. This coincides with the theory that designing and constructing pavements on the basis of an understanding of the material properties that affect pavement performance would lead to better performance at a reduced life/cycle cost.

*Optimizing Pavement Performance*— The project fix selections and timing will be based on historical distress data and on the causes and rate of pavement deterioration. This will likely optimize pavement performance for a given project cost.

*Reducing Life Cycle Cost*— The project's life/cycle cost is a function of the existing pavement condition, the type and timing of the fix, and the required future maintenance actions. As mentioned previously, reduced life/cycle costs are a beneficiary of an improved PSL.

*Establishing Comprehensive Pavement Performance Criteria*— Pavement performance is a function of pavement design, construction, quality control and the environment. Once performance criteria are developed and implemented, pavement performance can be optimized or perhaps even standardized.

*Augmenting Technical Capabilities*—The understanding of quantitative engineering properties of the paving materials and their responses to load enhance the technical capabilities of all engineers who are involved in the design process. This understanding would allow engineers to evaluate the effect of new materials on pavement performance.

*Continuing Improvement Using the Feedback System of the Pavement Management System*—The new design process includes the collection and computerization of the inventory data, material properties, and the design inputs, along with the historical pavement distress data. The collected data can help determine needed improvements in the design process and pavement performance.

*Enhancing Public and Legislative Communication*—The new design process should provide MDOT with a better understanding and tangible evidence of the causes of pavement distress. This factually-based information can help secure public and legislative support.

*Improving Total Quality and Teamwork*—A more unified MDOT design process should improve contract communication with its design consultants and construction contractors.

### Benefits to the Highway Users

The customer traveling on Michigan highways should realize the benefits of improved service and reduced need for tax increases. Costs should be reduced from increased PSL resulting from improved optimization on fix selection and timing that deal with the real causes of pavement deterioration. Improved pavement performance should result in improved service with fewer pavement closures, which means faster and safer driving conditions for motorists.

### Benefits to Industry

*Enhancing Partnering*—Communication between MDOT and the respective paving industries should improve by using more consistent and compatible terminology.

*Improving Technical Capability*—Due to the fact that the recommended pavement design process requires engineering of the pavement activities, the pave-

ment industry will most likely have to add engineers to their staff. This should enhance the technical capabilities of the industry.

### Future

The procedures described and recommended in the study are currently being reviewed by MDOT. Portions of the implementation plan have been addressed. Design software is being updated and a process for collecting and storing material data from as-constructed projects is being designed. MDOT's life/cycle cost procedures are being redone to better reflect actual performance data. An evaluation period to address the implied benefits is underway which is anticipated to end when the 2002 version of the AASHTO Guide is completed and presented to the states. During the interim period, review assessments will be made to judge MDOT's success toward self-improvement. One thing is for sure, the procedures and practices outlined in the PRCE study will help MDOT move more confidently into the new Millennium.

### Reference Material

*Mechanistic Design Implementation Plan for Flexible Pavements and Overlays*

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Gilbert Y. Baladi, Ph.D., P.E.

Michigan State University  
Pavement Research Center of Excellence  
East Lansing, MI.  
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*Implementation Issues in Mechanistic Flexible Pavement Design:*

*Michigan Experience*

David Smiley, P.E., MDOT

Neeraj Buch, Ph.D., MSU

Gilbert Baladi, Ph.D., P.E., MSU/PRCE

Ashok Gurjar, Ph.D., MSU

Michigan State University/Pavement Research Center of Excellence

Michigan Department of Transportation

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