Iowa State University
Institute for Transportation

Investigation of AASHTOWare Pavement ME Design/DARWin-ME Performance Prediction Models for Iowa Pavement Analysis and Design

tech transfer summary

The proposed local calibration factors resulting from this project are expected to improve the accuracy of pavement performance predictions for Iowa pavement systems and help implement the use of AASHTOWare Pavement ME Design software in Iowa.

DECEMBER 2015

RESEARCH PROJECT TITLE
Investigation of AASHTOWare Pavement ME Design/DARWin-ME Performance Prediction Models for Iowa Pavement Analysis and Design

SPONSORS
Iowa Department of Transportation
(InTrans Project 14-496)

PRINCIPAL INVESTIGATOR
Halil Ceylan, Director
Program for Sustainable Pavement Engineering and Research (ProSPER)
Institute for Transportation
Iowa State University
515-294-8051
hceylan@iastate.edu

CO-PRINCIPAL INVESTIGATORS
Kasthurirangan Gopalakrishnan, Research Associate Professor, and
Sunghwan Kim, Research Scientist
Iowa State University

MORE INFORMATION
www.intrans.iastate.edu

Institute for Transportation
Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
515-294-8103

The mission of the Institute for Transportation (InTrans) at Iowa State University is to develop and implement innovative methods, materials, and technologies for improving transportation efficiency, safety, reliability, and sustainability while improving the learning environment of students, faculty, and staff in transportation-related fields.

Background and Problem Statement

The Mechanistic-Empirical Pavement Design Guide (MEPDG) was developed under National Cooperative Highway Research Program (NCHRP) Project 1-37A as a novel mechanistic-empirical procedure for the analysis and design of pavements. The MEPDG, published in 2008, was subsequently supported by AASHTO's DARWin-ME pavement design software (starting in April 2011) and AASHTOWare Pavement ME Design was the next generation of pavement design software (as of February 2013).

Although the core design process and computational engine have remained the same over the years, some enhancements to the pavement performance prediction models have been implemented along with other documented changes as the MEPDG transitioned to AASHTOWare Pavement ME Design software.

Preliminary studies were carried out to determine possible differences between the AASHTOWare Pavement ME Design, MEPDG (version 1.1), and DARWin-ME (version 1.1) performance predictions for new jointed plain concrete pavement (JPCP), new hot-mix asphalt (HMA), and HMA over JPCP systems. Differences were indeed observed between the pavement performance predictions produced by these different software versions.

Further investigation was needed to verify these differences and evaluate whether identified local calibration factors from the latest MEPDG (version 1.1) were acceptable for use with the latest version of AASHTOWare Pavement ME Design (version 2.1.24 at the time this research was conducted).

Project Objectives

- Evaluate the accuracy of nationally calibrated and MEPDG locally calibrated pavement performance prediction models obtained through previous Iowa Calibration of MEPDG Performance Prediction Models project
- Examine AASHTOWare Pavement ME Design performance predictions using previously identified MEPDG calibration factors
- Refine the local calibration coefficients of the AASHTOWare Pavement ME Design pavement performance predictions for Iowa pavement systems using linear and nonlinear optimization procedures

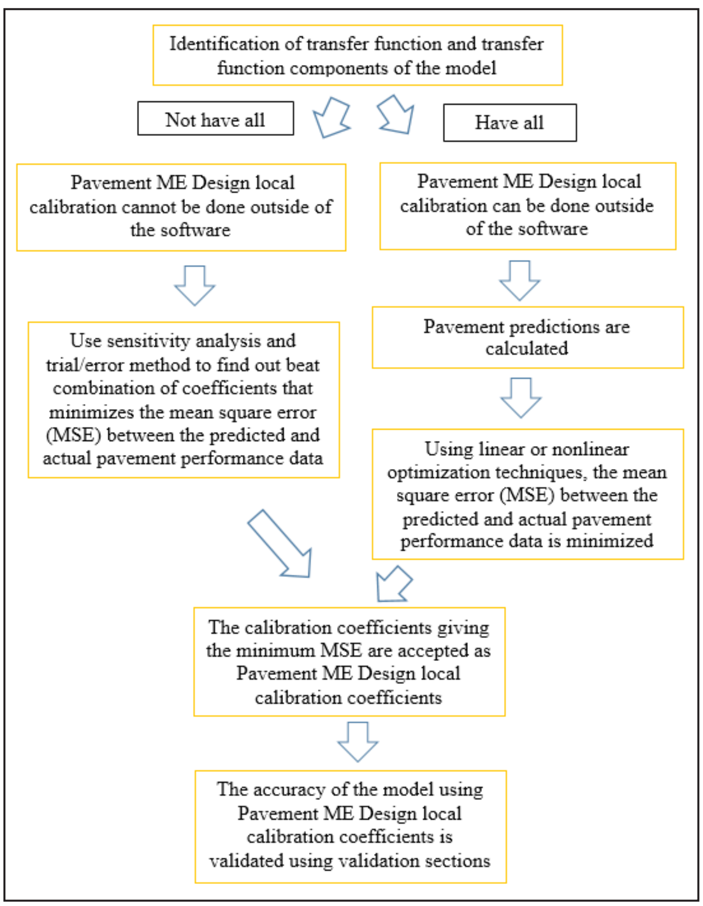
Research Description

Two optimization approaches (nonlinear and linear) were investigated in this study depending on the form of the AASHTOWare Pavement ME Design JPCP performance prediction models and the availability of the required equation inputs.

Most nonlinear optimization techniques require an objective function, constraints, and increments to search optimized values. The objective function used by the nonlinear optimization technique to obtain local calibration coefficients (LCC) minimizes the bias (ε) and the root mean square error (RMSE) between the actual distress measurements and the AASHTOWare Pavement ME Design predictions.

Three different optimization tools, MS Excel solver, a brute force method, and Lingo 15.0 software, were utilized to ensure that the optimum calibration coefficients obtained by any one of these tools were close to those determined by the other tools.

The linear optimization approach was utilized in this study via a trial-and-error procedure as the alternative approach for optimization of LCC.



Optimization procedures used to obtain local calibration coefficients

The database developed in the previous MEPDG local calibration study for Iowa pavement systems was updated and utilized in this study. This database includes detailed information required in AASHTOWare Pavement ME Design runs for the representative pavement sections in Iowa considered in this study.

The required design inputs for the selected sections were collected primarily from the Iowa DOT pavement management information system (PMIS) database, material testing records, and previous project reports relevant to MEPDG implementation in Iowa.

A total of 35 sections for new JPCPs (rigid pavements), 35 sections for new HMA pavements (flexible pavements), and 60 sections for HMA over JPCPs (composite pavements) were selected. Among the selected new JPCP and new HMA roadway segments, 25 sections were used for calibration and 10 sections were used for verification of the identified calibration coefficients. In the selected HMA over JPCP roadway segments, 45 sections were used for calibration and 15 sections were used for verification of the identified calibration coefficients.

Key Findings

- The mean joint faulting, transverse cracking, and International roughness index (IRI) models for Iowa JPCPs were significantly improved as a result of AASHTOWare Pavement ME Design local calibration when compared to the nationally calibrated and MEPDG locally calibrated counterparts.
- The identified AASHTOWare Pavement ME Design local calibration factors significantly increased the accuracy of the rutting model for Iowa HMA pavements compared to the nationally calibrated and MEPDG locally calibrated counterparts.
- The identified AASHTOWare Pavement ME Design local calibration factors increased the accuracy of the IRI model for Iowa HMA pavements when compared to the nationally calibrated and MEPDG locally calibrated models, although the nationally calibrated and MEPDG locally calibrated IRI models also provided acceptable predictions.
- The nationally calibrated longitudinal (top-down) cracking model underpredicted this distress while the MEPDG locally calibrated model overpredicted this distress for Iowa HMA pavements. The accuracy of this model was improved as a result of AASHTOWare Pavement ME Design local calibration.

- All of the nationally calibrated, MEPDG locally calibrated, and AASHTOWare Pavement ME Design locally calibrated alligator (bottom-up) and thermal cracking models provided acceptable predictions for Iowa HMA pavements.

- The identified AASHTOWare Pavement ME Design local calibration factors significantly increased the accuracy of IRI predictions for Iowa HMA over JPCPs.

- The identified AASHTOWare Pavement ME Design local calibration factors increased the accuracy of the rutting model to a quite noticeable extent for Iowa HMA over JPCPs compared to the nationally calibrated and MEPDG locally calibrated models, although the nationally calibrated and MEPDG locally calibrated IRI models also provided acceptable predictions for this model.

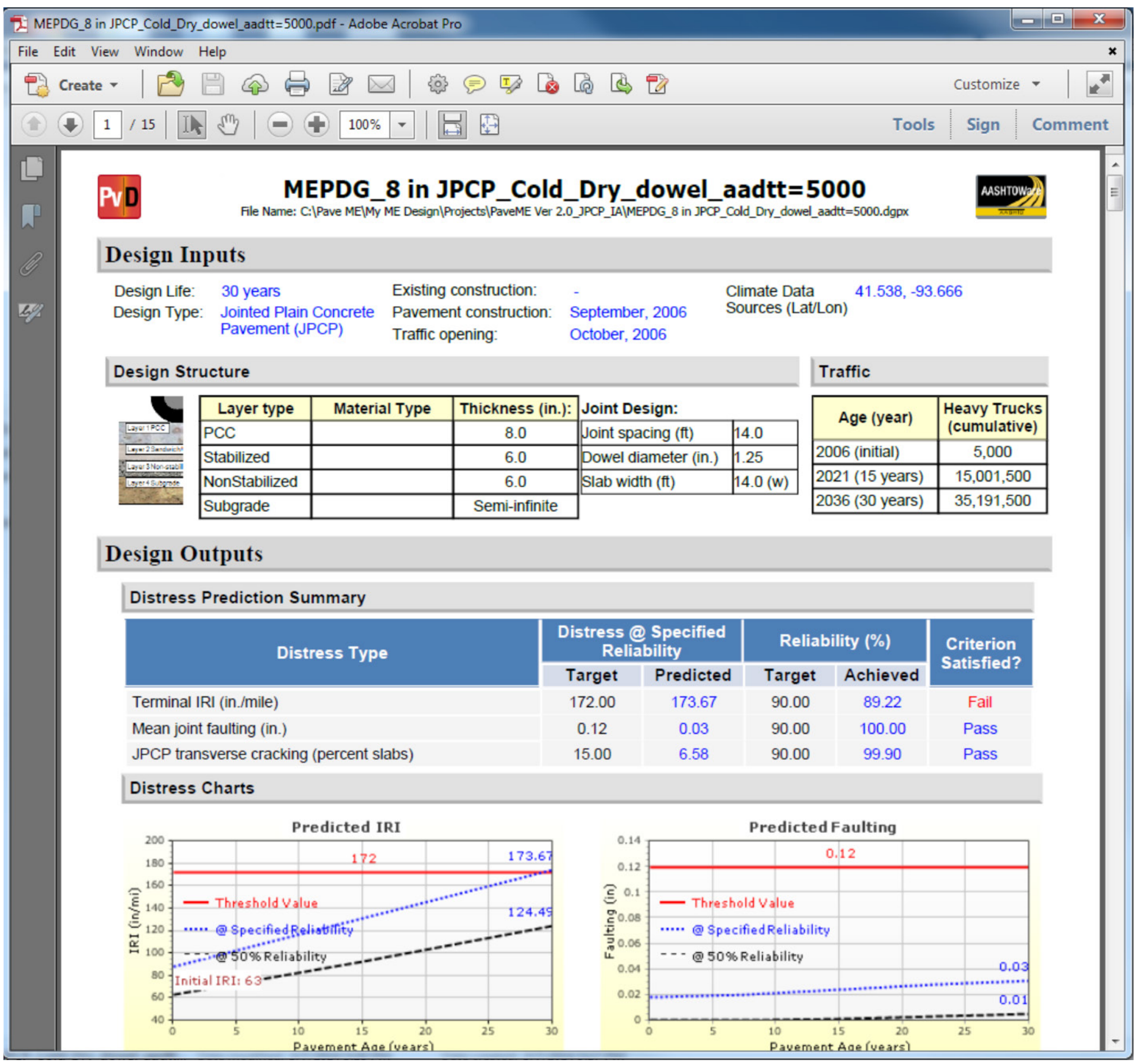
- All of the nationally calibrated, MEPDG locally calibrated, and AASHTOWare Pavement ME Design locally calibrated alligator (bottom-up) cracking models provided acceptable predictions for Iowa HMA over JPCPs.

- The nationally calibrated models underpredicted longitudinal (top-down) cracking while the MEPDG locally calibrated model exhibited excessive standard error for Iowa HMA over JPCPs. The accuracy of this model was improved as a result of AASHTOWare Pavement ME Design local calibration.

- The nationally calibrated and MEPDG locally calibrated thermal cracking models underpredicted this distress. The accuracy of this model was improved as a result of AASHTOWare Pavement ME Design local calibration.

Recommendations

- The locally calibrated JPCP performance models (faulting, transverse cracking, and IRI) identified in this study are recommended for use with Iowa JPCPs as alternatives to the nationally calibrated models.


MEPDG_8 in JPCP_Cold_Dry_dowel_aadtt=5000.pdf - Adobe Acrobat Pro

File Edit View Window Help

Create Customize 1 / 15 100% Tools Sign Comment

MEPDG_8 in JPCP_Cold_Dry_dowel_aadtt=5000

File Name: C:\Pave ME\My ME Design\Projects\PaveME Ver 2.0_JPCP_IA\MEPDG_8 in JPCP_Cold_Dry_dowel_aadtt=5000.dgpx

Design Inputs

Design Life: 30 years
Design Type: Jointed Plain Concrete Pavement (JPCP)
Existing construction: -
Pavement construction: September, 2006
Traffic opening: October, 2006
Climate Data Sources (Lat/Lon) 41.538, -93.666

Design Structure

Layer type	Material Type	Thickness (in.):
PCC		8.0
Stabilized		6.0
NonStabilized		6.0
Subgrade		Semi-infinite

Joint Design:	
Joint spacing (ft)	14.0
Dowel diameter (in.)	1.25
Slab width (ft)	14.0 (w)

Traffic

Age (year)	Heavy Trucks (cumulative)
2006 (initial)	5,000
2021 (15 years)	15,001,500
2036 (30 years)	35,191,500

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	172.00	173.67	90.00	89.22	Fail
Mean joint faulting (in.)	0.12	0.03	90.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	6.58	90.00	99.90	Pass

Distress Charts

Sample PDF output from AASHTOWare Pavement ME Design software run

- The locally calibrated rutting, longitudinal (top-down) cracking, and IRI prediction models identified in this study are recommended for use with Iowa HMA pavements as alternatives to the nationally calibrated models.

- The locally calibrated rutting, longitudinal (top-down) cracking, and IRI prediction models identified in this study are recommended for use with HMA over JPCPs as alternatives to the nationally calibrated models.

- The nationally calibrated alligator (bottom-up) and transverse (thermal) cracking prediction models are recommended for use with Iowa HMA systems, because even though the accuracy of these models was improved, the improvement was insignificant.

Future Research

- Reflective cracking is one of the most common types of distresses that occur in Iowa composite pavements (HMA over JPCP), which constitute over 50% of the entire Iowa highway system. Recently, the reflective cracking model developed through NCHRP 1-41 has been successfully integrated into the new version of AASHTOWare Pavement ME Design (version 2.2, released on August 12, 2015). Because the Iowa DOT is one of the few SHAs at the forefront of implementing AASHTOWare Pavement ME Design and has a significant percentage of composite pavements (more than 50%) in its highway network, it is expected to significantly benefit from the local calibration of the recently integrated reflective cracking prediction model in AASHTOWare Pavement ME Design.

- Material properties are important design inputs affecting AASHTOWare Pavement ME Design predictions, but the characterization of these properties requires time and considerable resources. High-accuracy surrogate material models for Iowa construction materials similar to the models developed by the Iowa State University (ISU) Program for Sustainable Pavement Engineering and Research (PROSPER) team (e.g., an artificial neural network [ANN]-based HMA dynamic modulus prediction model) will be greatly beneficial to the Iowa DOT, not only in the use of AASHTOWare Pavement ME Design, but also for the quality control and quality assurance of paving materials.

- The AASHTOWare Pavement ME Design performance criteria for different classes of Iowa roads are recommended for future investigation. As part of this investigation, highly accurate models to predict Iowa distress history should be developed by using various conventional regression methods and computational intelligence tools.

- It is recommended that the Iowa DOT develop a satellite pavement management/pavement design database for each project being designed and constructed using AASHTOWare Pavement ME Design as part of the current PMIS. This database should be in a format comparable to that of the AASHTOWare Pavement ME Design inputs and outputs.

  The database could be utilized to identify the causes of specific pavement failures for each project and to recalibrate the AASHTOWare Pavement ME Design performance prediction models for nontraditional paving materials such as recycled materials or warm-mix asphalt (WMA).

- As of 2015, new pavement performance prediction models (e.g., a top-down cracking model) are under development to be incorporated into AASHTOWare Pavement ME Design in future releases. Similarly to these models, the recently developed bonded concrete overlay of asphalt pavement mechanistic-empirical (BCOA-ME) model is under consideration to be implemented in AASHTOWare Pavement ME Design in the future.

  As such new models are added to the software or the existing models are refined/modified, the verification and calibration of these new models to Iowa pavement systems are recommended to increase the versatility of the use of AASHTOWare Pavement ME Design and incorporate advanced pavement design methodologies.

Implementation Readiness and Benefits

The results of this research are immediately implementable by the Iowa DOT. The recommendations summarized above have the potential to improve the accuracy of pavement performance predictions for Iowa pavement systems and to implement AASHTOWare Pavement ME Design in Iowa with the proposed local calibration factors.

A properly designed pavement structure (not over designed) can save costs in pavement construction and provide a longer service life.

Program for Sustainable Pavement Engineering and Research (ProSPER)