M.E.'s ME Report

Newsletter on mechanistic-empirical pavement design implementation at the Michigan DOT October 2013

The featured article in this edition is the first part of a two-part article introducing the typical inputs for the new paved surface layers. Part 1 covers jointed plain concrete. Part 2 will cover asphalt and will appear in the next newsletter. Also included in this edition is a summary of the final report for Part 2 of the ongoing ME research project with Michigan State University, which has been published. Part 2 involved an evaluation of the ME methods for rehabilitation designs we typically use in Michigan. The last article details a September meeting of the AASHTO Region 3 States. They met in Wisconsin to discuss implementation efforts with ME.

Mike Eacker

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Evaluation of ME Rehabilitation Designs

The second part of the three part on-going research project *Preparation for Implementation of the Mechanistic-Empirical Pavement Design Guide in Michigan* is now complete. This part of the project involved an evaluation of the rehabilitation designs available in the Pavement ME Design software. In 2008, Michigan State University completed the first ME evaluation project for MDOT. However, that project only evaluated new and reconstruct designs.

The evaluation process involved three levels of sensitivity analysis and then verification of the predictive models using Michigan inputs. The first level of sensitivity involved the typical one-at-a-time analysis. Rehabilitation designs use many of the same inputs for the new overlay layer as those used for new and reconstruct designs. Since these inputs were already run through a sensitivity analysis in the previous ME evaluation project, they were not included this time. Only those inputs unique to the rehabilitation designs were included. Next, the sensitive inputs from the one-at-a-time analysis were paired with the known sensitive inputs from the overlay. This provided the interactive effects between overlay and existing pavement inputs. Lastly, a global sensitivity analysis was conducted. In global sensitivity, all of the sensitive inputs are randomly varied over a range of values. This is significantly different from the one-at-a-time and interactive analysis that used only the minimum and maximum values for each input. By randomly varying each of the inputs being analyzed, each design run is theoretically a unique design. After hundreds of design runs, the results were fed into an artificial neural network to create 3-D plots of how distresses vary over the input range. An example of one of these plots is shown in Figure 3. This plot shows how alligator cracking significantly increases when an overlay with high air voids is over a thin existing HMA pavement.

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Paved Surface Layer Inputs
Part 1 of 2: Jointed Plain Concrete

When referring to layer inputs, what we are really talking about are the material properties of a layer. The number of materials inputs required by ME represents a large increase over the AASHTO 1993 method. In this article, we will discuss the layer inputs for the new paved surface layer (concrete or asphalt). In a rehabilitation design, there are layer inputs for the existing concrete or asphalt as well, but those inputs are not discussed here.

In the AASHTO 1993 design method, there are relatively few inputs overall and only a couple of materials inputs for the pavement layers. For concrete, the 28-day flexural strength and 28-day elastic modulus are required inputs. Each asphalt layer is characterized by an elastic modulus and structural number.

So, why is there a need to expand on the number of materials inputs with the ME design procedure? Research over the years has demonstrated there are many other materials properties beside those noted above that affect the performance of pavements. For example, it has been established that the concrete coefficient of thermal expansion significantly impacts transverse cracking. For asphalt, the dynamic modulus is a stronger indicator of how the pavement will handle the load (stresses and strains from loading) than elastic modulus. Neither one of these properties is found in the AASHTO 1993 design. Following is a summary of the inputs needed for the new concrete layer. The asphalt layer inputs (Part 2 of this article) will be discussed in the next newsletter. Figure 1 shows the inputs required for the new concrete pavement layer with example values.

The values listed are those proposed to be used on MDOT projects by the ME Concrete Subcommittee.

The number of materials inputs required by ME represents a large increase over the AASHTO 1993 method.

This subcommittee is a collection of MDOT concrete materials experts, pavement management staff, region pavement designers, and the concrete industry. After a series of meetings, the above inputs were proposed and are currently being reviewed by the ME Oversight Committee (see the August 2012 newsletter for a description of this committee).

As indicated, there are quite a few more inputs than are currently used for the AASHTO 1993 design method. Those that may vary from project to project, or were determined to be different than the defaults in the ME software, are:

Thickness: This will vary from project to project.

Unit Weight: Based on typical values from MDOT projects.

Portland Concrete Cement (PCC) Coefficient of Thermal Expansion (CTE): It was determined that there are two dominant aggregate types used in MDOT projects: limestone and dolomite. Testing conducted by Michigan State University determined the CTE of limestone to be 4.5 x 10-6 in./in./˚F, while that of dolomite is 5.8 x 10-6 in./in./˚F. It was further determined that dolomite is generally the aggregate used in MDOT's University and Metro Regions. Therefore, the 5.8 value would be used in these two regions, while the 4.5 value would be used in the other five MDOT regions.

Cementitious Content: Typical concrete mixes used on MDOT projects have 500 pounds/cubic yard of cement and other supplementary materials.

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PCC	
Thickness (in.)	10
Unit weight (pcf)	145
Poisson's ratio	0.2
Thermal	
PCC coefficient of thermal expansion (in./in./deg F x 10^-6)	4.5
PCC thermal conductivity (BTU/hr-ft-deg F)	1.25
PCC heat capacity (BTU/lb-deg F)	0.28
Mix	
Cement type	Type I (1)
Cementitious material content (lb/yd^3)	500
Water to cement ratio	0.42
Aggregate type	Limestone (1)
PCC zero-stress temperature (deg F)	Calculated
Calculated internally?	True
User-specified PCC set temperature	
Ultimate shrinkage (microstrain)	530.8 (calculated)
Calculated internally?	True
User-specified PCC ultimate shrinkage	
Reversible shrinkage (%)	50
Time to develop 50% of ultimate shrinkage (days)	35
Curing method	Curing Compound
Strength	
PCC strength and modulus	Level:3 Compressive(5600)

Figure 1. Concrete Layer Inputs.

Water to Cement Ratio: The value of 0.42 matches the ME default. However, it was also determined from some limited data, and subcommittee members' experience, that this is a reasonable value for MDOT projects.

Aggregate Type: It was determined that roughly 70 to 80 percent of the lane miles of concrete placed in the last four years used a limestone coarse aggregate.

PCC Strength and Modulus: Data from four regions indicated that 5600 psi was an average value for 28-day compressive strength. Level 3 was chosen for this input because Levels 1 and 2 require compressive strength values at ages other than 28-day, including a 28-day to 20-year ratio. Test data at these other ages is not available.

This concrete layer is used for both jointed plain concrete pavement (JPCP) and continuously reinforced concrete pavement (CRCP). Some additional inputs are specific to both JPCP and CRCP that do not appear in the concrete layer. The inputs for JPCP can be seen in Figure 2. Since Michigan does not use CRCP, the specific inputs for it are not discussed here.

JPCP Design	
PCC surface shortwave absorptivity	0.85
PCC joint spacing (ft)	14
Is joint spacing random ?	False
Joint spacing (ft)	14
Spacing of Joint 1	
Spacing of Joint 2	
Spacing of Joint 3	
Spacing of Joint 4	
Sealant type	Other(Including No Sealant... Liquid... Silicone)
Doweled joints	Spacing(12), Diameter(1.25)
Is joint doweled ?	True
Dowel diameter (in.)	1.25
Dowel spacing (in.)	12
Widened slab	Not widened
Is slab widened ?	False
Slab width (ft)	
Tied shoulders	Tied with long term load transfer efficiency of 50
Tied shoulders	True
Load transfer efficiency (%)	50
Erodibility index	Fairly erodible (4)
PCC-base contact friction	Full friction with friction loss at (60) months
PCC-Base full friction contact	True
Months until friction loss	60
Permanent curl/warp effective temperature difference (deg F)	-10

Figure 2. JPCP Design Inputs.

Similar to the concrete layer inputs, Figure 2 contains example inputs as proposed by the ME Concrete Subcommittee. Of these, the following will vary or were determined to be different from the defaults in the ME software:

PCC Joint Spacing: 12', 14', or 16' depending on the pavement thickness per the chart in MDOT Standard Plan R-43.

Sealant Type: Since the standard joint sealant is hot-pour rubber, “Other” will be used.

Dowel Diameter: 1", 1.25", or 1.5" depending on the pavement thickness per the chart in MDOT Standard Plan R-40.

Is Slab Widened?: In situations where the outside lane is widened, this input will be “True.”

Slab Width: 14' when a widened lane is used.

Tied Shoulders: This should be set to “True” when tied concrete shoulder or tied curb and gutter are used. This is the majority of the time since asphalt shoulders are rarely used.

Erodibility Index: For typical unbound open-graded drainage course, “Fairly Erodible” will be used. For stabilized bases, “Extremely Erosion Resistant” will be used. These are both based on the recommendations from the NCHRP 1-37 project, which developed the ME design method.

Months until Friction Loss: The recommendation from the NCHRP 1-37 project was to set this at 60 months because this was the value used for the national calibration. The software default is 240 months.

Part 2 of this article will be in the next newsletter and will explore inputs for the new asphalt layers.

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Another way to look at the plot is that obtaining good compaction (signified by lower air voids) increases in importance the thinner the existing pavement is.

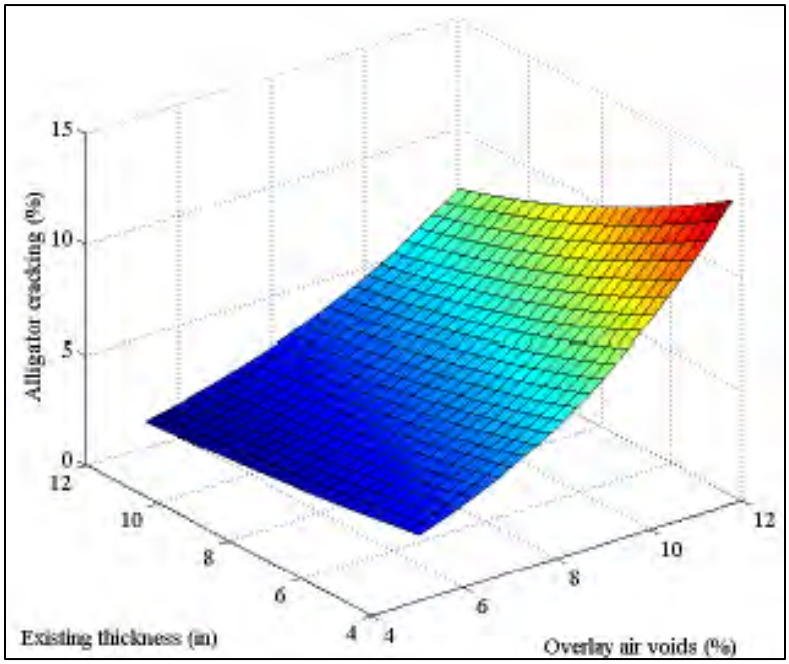

Figure 3. Alligator cracking predictions for varied existing pavement thicknesses and overlay air void contents.

To measure whether the distress predictions are sensitive to an input, the Normalized Sensitivity Index (NSI) was used. The NSI is a measure first used in the recently completed NCHRP 1-47 project, *Sensitivity Evaluation of MEPDG Performance Prediction*. The NSI represents the percentage change of the distress relative to the design limit caused by a percentage change in the design inputs. Following is the form of the equation:

$$NSI = (\Delta Y/\Delta X) * (X/DL)$$

Where,

S = Sensitivity index
ΔY = change in distress
ΔX = change in input around value at X
X = value of input
DL = design limit for the distress

Four types of rehabilitation designs typically found in Michigan were run through the above analysis with the following results (inputs resulting in sensitive results):

- HMA over HMA
  - Overlay air voids, overlay thickness, existing pavement thickness, effective binder content, base modulus, and existing pavement condition.

- HMA over JPCP
  - Overlay thickness, overlay air voids, and existing PCC thickness.
- Rubblization
  - Overlay air voids, overlay thickness, effective binder content, and PCC modulus.
- Unbonded concrete overlay
  - Overlay CTE, overlay thickness, overlay modulus of rupture, and overlay joint spacing.

For each of the rehabilitation types noted above, the as-constructed information for several in-service pavements were run through ME to see what it predicts for distresses. These predictions were compared with the actual observed distresses to see how well the nationally calibrated models predict. Figures 4 and 5 are examples of this comparison. Figure 4 shows the comparison for a single unbonded concrete overlay, while Figure 5 shows the comparison for all unbonded overlays used in this study. All models showed some level of over or under prediction. So, local calibration of all models for the four rehabilitation designs is recommended. This calibration is currently ongoing with Part 3 of the research project.

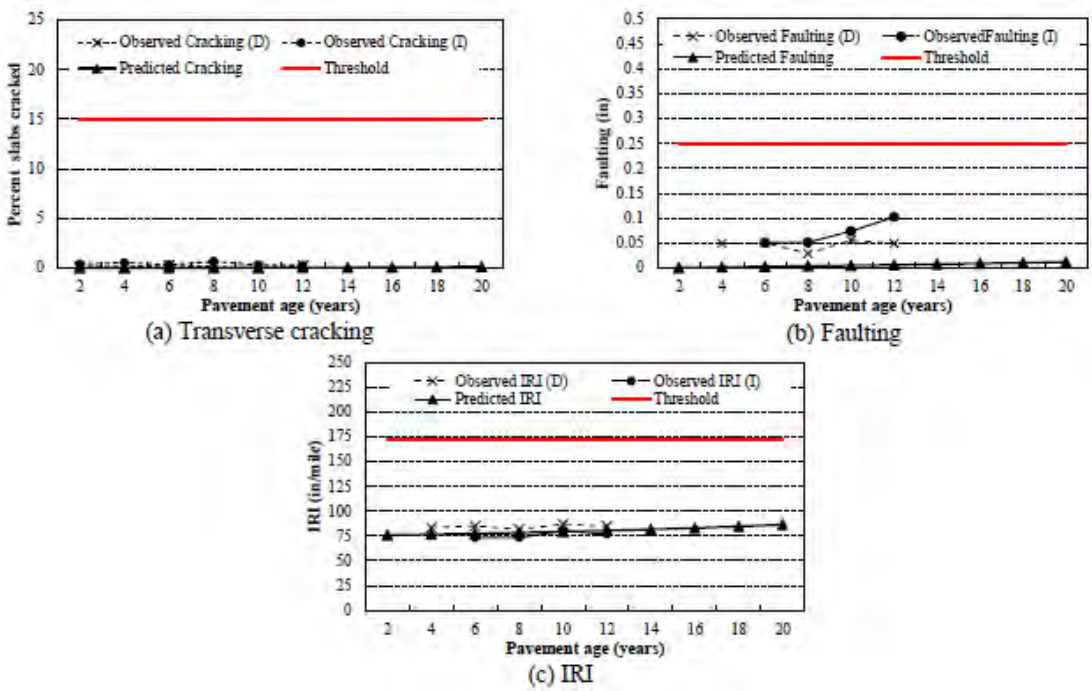

Figure 4. ME predictions versus measured distresses for a single unbonded overlay project. This example is a divided roadway so D or I are used to indicate the direction based on decreasing or increasing milepoints.

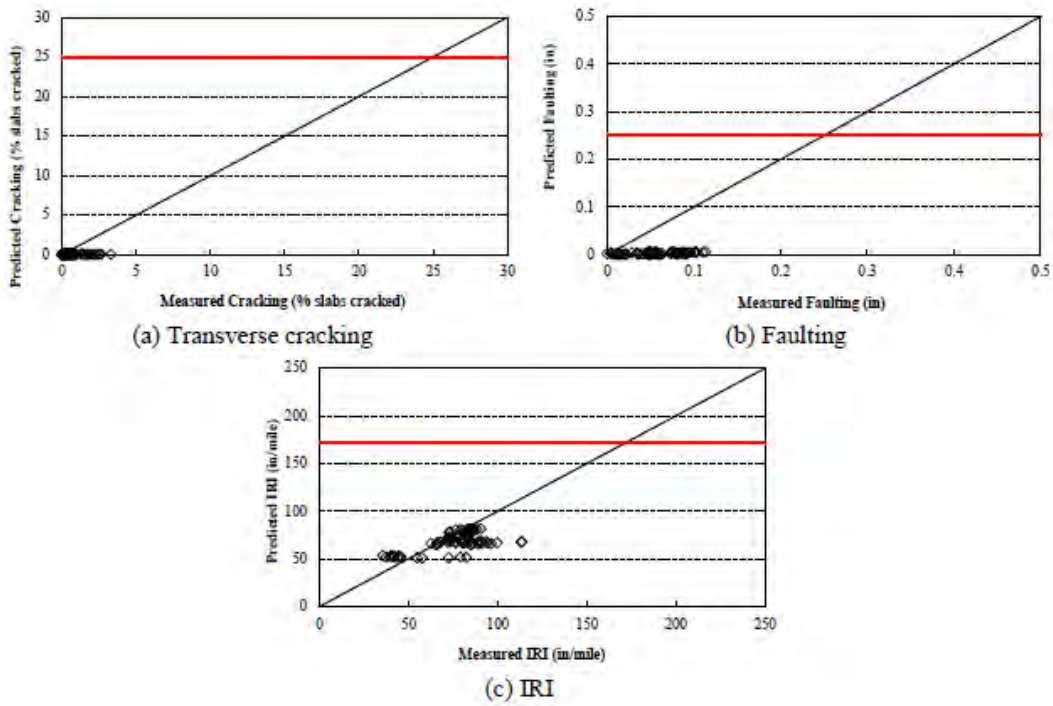

Figure 5. ME predictions versus measured distresses for unbonded overlay projects.

For further details, the final report is on the MDOT ME Web page (the link is provided at the end of this newsletter). The report is in the ME-related research reports drop-down menu and is titled *Evaluation of Rehab Fixes in ME*. ❖

Pavement Designers Attend ME Peer Exchange in Wisconsin

On September 10 through 12, 2013, the Wisconsin Department of Transportation (DOT) hosted the AASHTO Region 3 States at a peer exchange meeting about ME implementation. Held in Madison, all 10 states had representatives in attendance to discuss their ME efforts. Also in attendance were a representative from the FHWA Resource Center in Atlanta, Georgia, and one from ARA, the consultant who created and maintains the Pavement ME Design software for AASHTO. The following five topics were on the agenda:

- Calibration
- Materials Testing
- Traffic
- Design Acceptance
- Moving From Development To Deployment

For each topic, the goal was to answer four questions:

1. What is working well?
2. What are the implementation steps to emulate?
3. What elements in ME could cause problems, concerns, etc.?
4. What questions could be addressed by other agencies such as FHWA, AASHTO, etc.?

There was a lot of good discussion and it was helpful to see where the other states are with implementation, what is working well for them, and problems they are struggling with. It is interesting to point out that two states, Illinois and Kentucky, have been using their own mechanistic-based design procedure since the 1980s. During the meeting, Wisconsin announced that, as of January 2014, it will begin to create official designs with ME. Missouri has been using ME since 2004 (approximately $2 billion worth of pavements since then), and Indiana has been using ME since 2009. Minnesota has its own mechanistic procedure for HMA, which it will begin using as soon as the equivalent concrete procedure is completed. The remaining states are in various stages of implementation.

Michigan had three representatives at the meeting: Mike Eacker and Justin Schenkel from the Construction Field Services Division/Pavement Management Section, and Larry Dropiewski, Metro Region Geotechnical Unit Leader. See Justin and Larry's comments in the highlighted box.

Jag Mallela from ARA gave a presentation about what ARA is working on to improve the Pavement ME Design software. ARA is planning new releases of the software in July and December each year for the foreseeable future. They are considering a series of Webinars that will go deeper into the theory of ME design. These will build on the series they conducted earlier this year that reviewed operation of the software. (The series is available on AASHTO's Pavement ME Design Web page at www.aashtoware.org/Pavement/Pages/default.aspx). ARA is also looking into allowing different design lives for each of the distresses predicted for a design and incorporation of a new reflective cracking model for HMA overlays. Currently, users can only select one overall design life for each design. ARA is planning to release a new version of the software this December that will include the following enhancements:

- Layer-specific calibration coefficients for rutting.
- Special axle loading module for HMA pavements. This would be similar to the module that was in the original MEPDG software but was removed when it became a commercial product.
- Ability to run the software in virtual environments such as Citrix. This will allow users to run the software from a server rather than from their computers.
- The help file will move from Adobe PDF format to HTML format (Internet browser-based).

Chris Wagner from FHWA noted that this was the first of the AASHTO regions to have a meeting like this. Similar meetings are in the works

I thought that the discussion on Deployment was the most interesting considering that MDOT is nearing the Deployment stage of the ME design process. Tommy Nantung of the Indiana DOT led the discussion on this topic. His information highlighted the importance of training pavement designers who will be using ME. I appreciated Tommy's information and the discussion of this topic.

— Justin Schenkel

Attending this meeting helped me to better understand some of the ME specific dialect and get a clearer understanding of the many advantages of transitioning to this new pavement design software. One thing that stood out to me was the time and effort that goes into the calibration process. I now appreciate the effort necessary to provide the ME program the best possible inputs, to achieve the most accurate predictions for Michigan pavement designs.

— Larry Dropiewski

for the other regions. Attendees readily agreed that this meeting was very beneficial and that it should be continued on an annual basis.

The Wisconsin DOT is writing a report summarizing the meeting. When completed, the report will be posted on the Wisconsin DOT Web page. The link to that report will be provided in the next ME newsletter.

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For questions about information in this newsletter, further details on mechanistic-empirical pavement design implementation in Michigan, or to submit an idea for an article in a future newsletter, please contact:

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Link to MDOT's ME Web page: http://www.michigan.gov/mdot/0,4616,7-151-9623_26663_27303_27336_63969---,00.html