M.E.'s ME Report

Newsletter on mechanistic-empirical pavement design implementation at the Michigan DOT November 2012

MEPDG…DARWin-ME…Are they the same? Yes…and no. MEPDG is sometimes used to generically indicate the mechanisitic-empirical pavement design method. It also refers to the first version of the software that was developed under the National Highway Cooperative Research Program (NCHRP) project 1-37A. When that software was turned over to AASHTO and developed into a commercially available version, it was called DARWin-ME. Very little changed with the mechanistic models from MEPDG to DARWin-ME, so they are essentially the same. To muddy the waters a little more, AASHTO has recently decided to change the name of their software over the next year and a half from DARWin-ME to AASHTOWare Pavement ME Design. So, when I refer to ME, I am talking about the design method in general. When I refer to MEPDG, I am talking about the original research project software. Until the name change is complete with AASHTO, I will continue to refer to the current software as DARWin-ME.

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Climate (Weather Considerations)

Many people who deal with pavements in some capacity believe weather has an impact on the performance of pavements, particularly here in Michigan. The opinion as to the level of impact may differ, but it is there nonetheless. How is weather accounted for in the pavement design process? In AASHTO 1993, the modulus of the subgrade and the modulus of subgrade reaction can be varied according to the season. But the base, subbase, and pavement layers can also have varying moduli based on temperatures and moisture contents. ME does a better job of taking climate into account. The material properties of all layers are varied throughout the year based on various weather parameters from the climate data.

DARWin-ME (as well as MEPDG before it) comes with weather station data that can be utilized for pavement design. DARWin-ME has 19 weather stations for Michigan (see Figure 1).

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Concrete Coefficient of Thermal Expansion

One of the key inputs for concrete design in ME is the coefficient of thermal expansion (CTE). CTE is defined as the change in unit length per change in unit temperature. It is typically expressed as microstrains/ºF or microstrains/ºC. Concrete cylinders are placed in a rigid support frame that is then placed in a temperature-controlled water bath. The temperature of the water bath is raised from 50 to 122ºF and then returned to 50ºF constituting one heating-cooling cycle. The length of the specimen is checked at specific time intervals during the cycle, and the CTE for that cycle is the average between the heating portion and cooling portion.

CTE is an input in the models for calculating joint movements and the curling stresses in concrete. It is one of the most sensitive inputs in concrete design (see Sensitivity Study summary on page 4). For this reason, MDOT initiated a study with Michigan State University in November 2005 to test the CTE of typical concrete mixtures used in Michigan. Seven aggregates representing different geologies were delivered to the same batch plant. Cylinders were made from concrete batches made using each of the aggregates. In addition, cylinders were made from concrete being delivered to a construction project that was active at the time of the research project.

Cylinders were cured and tested at 3, 7, 14, 28, 90, 180, and 365 days of age. Three heating-cooling cycles were run for each set of cylinders and length measurements were recorded every minute. Standard fresh and hardened concrete properties were tested as well. The CTE results are shown in the following table (average of heating-cooling cycles two and three):

Aggregate Type	CTE (microstrain/ºF)
2 limestones	4.49 to 4.54
3 dolomites	5.85 to 5.91
1 gravel	5.84
1 slag	5.71
1 trap rock (from Canada)	5.39

Higher values indicate a more thermally-active concrete and thus a higher potential for cracking predicted by ME.

Conclusions from the study:

- CTE is affected by aggregate geology.
- CTEs from samples 28 days old or less were statistically different from those 90 days old and older. However, cracking predictions in ME between the two age groups were not significantly different. So, measurement of CTE at 28 days was recommended.
- The variability in measured CTE was higher at higher CTEs
- CTE from the first heating-cooling cycle was statistically different from cycles two and three. Cycles two and three were statistically similar. So, the final CTE value should be the average of cycles two and three.

For further details on this study, the final report, *Quantifying Coefficient of Thermal Expansion Values of Typical Hydraulic Cement Concrete Paving Mixtures*, report # RC-1503 can be found on MDOT's public Web site. Along the left side of the screen, choose: Maps and Publications → Reports →Construction Field Services Research Reports. The report is listed under the Materials category.

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Figure 1. Michigan Weather Stations in DARWin-ME

Each weather station contains hourly measurements for air temperature, precipitation, percent sunshine, relative humidity, and wind speed. All stations have at least 65 months of continuous weather data (see Figure 2).

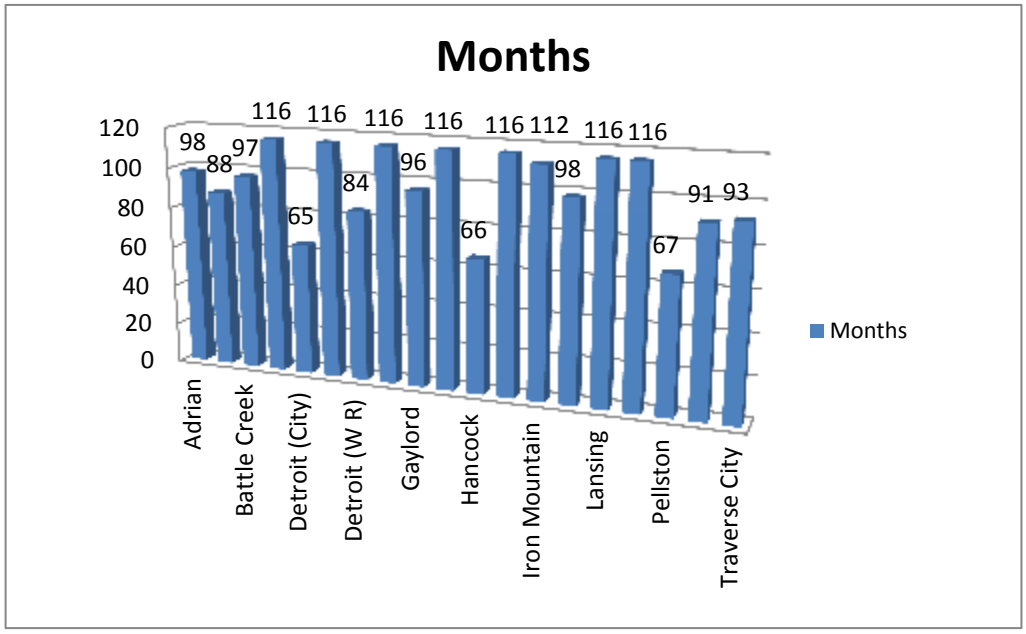

Figure 2. Months of weather data per station for Michigan weather stations in DARWin-ME

Designers can choose a single weather station or can create a virtual weather station for the project. A virtual weather station is one in which the weather data is interpolated from multiple weather stations. The designer chooses the weather stations to be used in the interpolation. In either case, DARWin-ME (and MEPDG) calculates several things from the weather data that will be utilized by various models within the software. It calculates:

- Mean annual air temperature
- Mean annual precipitation
- Number of wet days
- Freezing index
- Average number of annual freeze-thaw cycles
- Average air temperature for each of the months

In a future edition of this newsletter, we will discuss details of each of these calculated parameters including the values from each of the 19 weather stations. ❖

ME Sensitivity Study

In November 2005, MDOT initiated a research project with Michigan State University to check the sensitivity of the various inputs of the new design method and to check the validity of the predicted results. The first task was to run the MEPDG to see how the predicted distresses change with a change in each input. Each time, only one input was changed and the results were recorded. A reasonable range for each input was chosen before doing this. The change in each distress from each input change was examined separately to determine if that input was sensitive. The list of sensitive inputs from this task is provided below.

The next task was to do a more detailed sensitivity analysis of the interactions of changing two inputs at a time. The original list of sensitive variables was narrowed down to a set of practical inputs that realistically would be changed during a design. For example, MDOT determines dowel bar diameter for concrete pavements based on the slab thickness, so that input would not likely be varied in practice. Another example is surface shortwave absorptivity. We do not have any data to determine what this value should be, so it is highly likely the software default value would be used for all designs.

The end result of this second task was to determine where interactive effects between inputs occurred. For example, it was found that high air voids affect fatigue cracking more with thin hot mix asphalt (HMA) pavements than with thick HMA pavements. The practical conclusion from this is that thicker HMA pavements will reduce the fatigue cracking effects from having a higher air void content.

The third task was to check the validity of the predictions. Five concrete and five HMA in-service pavements were chosen to compare ME predicted distresses with actual observed distresses as recorded by MDOT's Pavement Management System (PMS). Construction records were examined to get as many materials inputs as possible to feed into MEPDG. The as-constructed cross section was input and run to see what distresses were predicted.

The predictions were extracted and compared with recorded distresses from MDOT's PMS database. Figure 3 gives an example of one such comparison (HMA fatigue cracking). In Figure 3, the lines with dots are the observed distresses, which are typically recorded every two years. The solid lines represent MEPDG's predictions. Each distress from MEPDG was then given one of three designations based on how well it was predicted: reasonable, over-predicted, or under-predicted. Overall, there was a mixed bag of all three. Many were reasonable, some were over-predicted, and some were under-predicted. The conclusion was that using the nationally calibrated models in MEPDG was giving reasonable results, but that calibration to Michigan's performance would significantly improve those predictions.

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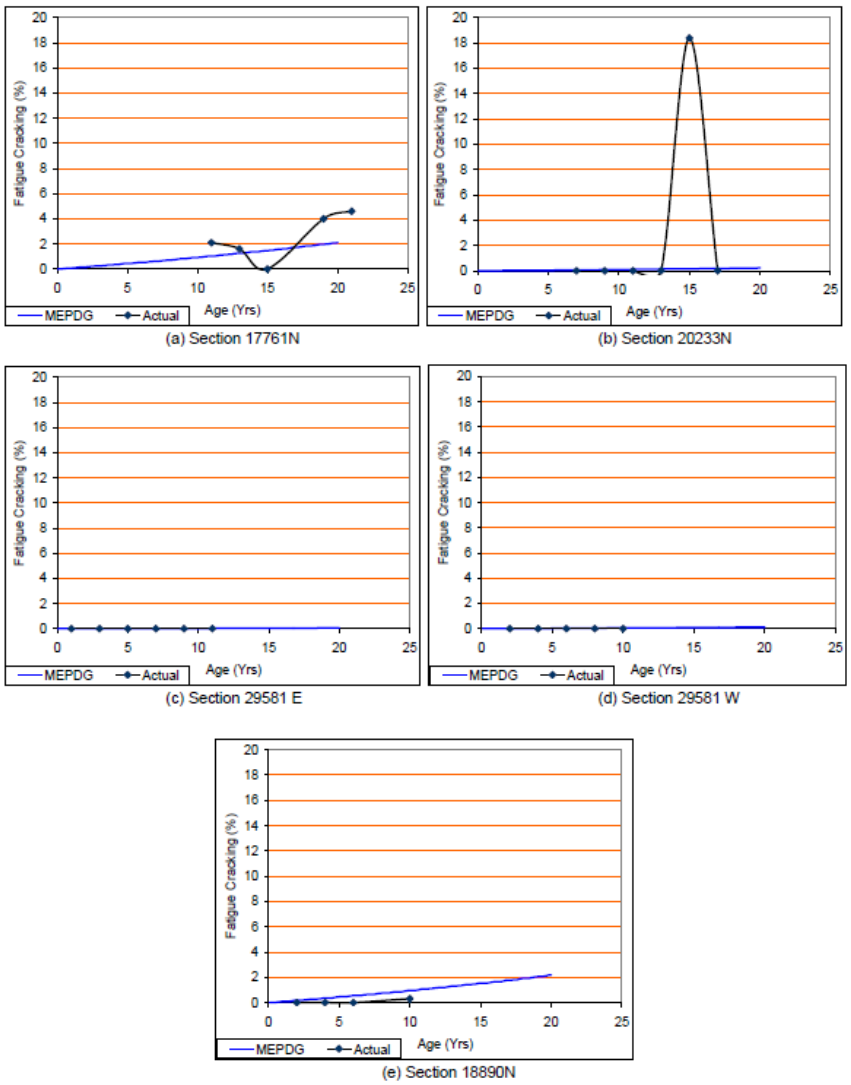

Figure 3. Comparison of MEPDG predicted fatigue cracking with recorded amounts for five in-service HMA pavement sections (from report RC-1516).

For further details on this study, the final report, *Evaluation of the 1-37A Design Process for New and Rehabilitated JPCP and HMA Pavements*, Report # RC-1516, can be found on MDOT's public Web site. Along the left side of the screen choose: Maps and Publications → Reports →Construction Field Services Research Reports. The report is listed under the Pavement Design category.

Sensitive Inputs

Traffic: Truck traffic, axle load spectra, monthly adjustment factors, hourly adjustment factors

JPCP: Permanent curl/warp temperature difference, joint spacing, edge support, dowel diameter and spacing, surface shortwave absorptivity, slab thickness, coefficient of thermal expansion, thermal conductivity, zero-stress temperature, compressive strength, modulus of rupture

HMA: thickness, mix gradation, dynamic modulus, effective binder content, air voids, Poisson's ratio, heat capacity, tensile strength, creep compliance

Base/subbase: base type, base thickness, gradation, plasticity index, resilient modulus, liquid limit

Subgrade: type, gradation, resilient modulus, plasticity index, liquid limit

Other: climatic region ❖

ME Resources

Some selected Web pages containing information on ME:

- FHWA's Design Guide Implementation Team Web page:

  http://www.fhwa.dot.gov/pavement/dgit/index.cfm

  This site has not been updated in a while, but it still contains recordings of a series of training classes conducted in 2004 to 2006. Click on "Workshops and Training" along the right side.

- NCHRP 1-37A report Web page:

  http://onlinepubs.trb.org/onlinepubs/archive/mepdg/home.htm

  This is the site for MEPDG. If you click on "Guide" under resources, you will be taken to the Web page containing the full series of pdf files representing the final report from the 1-37A project. It contains the details behind the development of the ME design method. Please note that the MEPDG software is no longer available.

- Pavement Interactive Web site:

  http://wiki.pavementinteractive.org/index.php?title=Main_Page

  This is a Wikipedia-style Web site for all things pavement. Use the search box to display articles related to your search terms. ❖

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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