M.E.'s ME Report

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

This edition focuses on some of the ME-related research in Michigan, past, present, and future. The past is represented by a summary of the work completed on characterizing the subgrade soils in Michigan. For the present, we have released the final report for Part 1 of the current project that Michigan State University (MSU) is conducting. Part 1 involved testing hot mix asphalt mixes collected from MDOT projects. Looking to the future, we are going to be moving forward this fall with a research project to improve the climatic files for ME. Michigan Technological University has been chosen to lead this project.

As always, I am happy to hear your feedback on this newsletter, and I am available to answer any questions you may have about the content. See the end of the newsletter for my contact information and a link to MDOT's ME Web page.

Mike Eacker

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Subgrade Inputs

For the AASHTO 1993 design method, the resilient modulus of the subgrade soil is a required input to characterize the support conditions of that layer. MDOT has traditionally used a single value to represent the resilient modulus throughout the year. It is generally believed that a majority of the damage to pavement is due to conditions present during the spring thaw period, so we use a subgrade resilient modulus value that is representative of these conditions. We know, however, the modulus of all layers varies throughout the year due to temperature and moisture variations. AASHTO 1993 does allow for some variation of modulus throughout the year by defining seasons (time periods of fairly consistent conditions–spring thaw, winter, etc.) and a representative modulus value for each season.

ME improves upon this by varying the material properties throughout the year based on the

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HMA Mix Characterization

Part 1 of MSU's ME research project involved testing of hot mix asphalt (HMA) mixes for several of the required materials inputs. The final report has been accepted and is available on the MDOT Web site. The inputs tested were dynamic modulus of the mix (also known as $|E^*|$), complex shear modulus of the binder (also known as $|G^*|$), and indirect tensile strength of the mix (IDT). In addition, the creep compliance (D(t)) input was calculated from the $|E^*|$ test results for each mix. $|G^*|$ was the only test MDOT had any experience with prior to this project.

A total of 64 loose HMA mix samples were collected representing 42 different mix designations (5E10, 4E1, ASCRL, etc.) and binder combinations. These samples were collected from a variety of projects in each of the seven MDOT regions. The samples were delivered to MSU, where test specimens were compacted using a gyratory compactor. Target air voids for the specimens were seven percent to match expected field compaction levels. Specimens were tested according to AASHTO T342 at five temperatures with six loading frequencies at each temperature. More information on the $|E^*|$ test is available online in the August 2012 edition of this newsletter on MDOT's ME Web page (see the link at the end of this newsletter).

For a majority of projects sampled, binder samples were also obtained on the same day that the loose mix was obtained. $|G^*|$ testing on the binder was conducted with the Dynamic Shear Rheometer device. A series of tests, at temperatures/frequencies similar to the $|E^*|$ testing, were completed. A sample test result is shown in Table 1. This table represents the average test results of seven PG 64-28 binders sampled from MDOT projects.

Test Temp. °F	$\|G^*\|$ (Pascals)	Phase Angle (degrees)
40	10,131,006	56.8
70	1,354,155	62.2
100	107,123.7	66.7
130	8824.3	70.1
168	834.1	72.9

Table 1. Average $|G^*|$ test results for PG 64-28 binders

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Larger $|G^*|$ values indicate a stiffer binder. As indicated in Table 1, the binder becomes stiffer at lower temperatures, which is expected. Higher phase angles are indicative of more viscous properties, which result in increased rutting potential. As Table 1 shows, the phase angle increases with increasing temperatures. This is expected since higher ambient temperatures increase the likelihood of rutting in HMA pavements.

The IDT tests were conducted on cores obtained from the area where loose mix was sampled or on specimens compacted in the lab. Testing was conducted in accordance with AASHTO T322. The load just prior to failure is used to calculate the IDT value.

The modified-Witczak model used in the ME software for predicting $|E^*|$ from other inputs was calibrated using test results from this project. Predictions from the calibrated model compared better with the test results than predictions from the nationally calibrated model. In addition, another $|E^*|$ predictive model, based on an artificial neural network (ANN), was developed as part of this research project. The ANN model's predictions agreed very well with laboratory test results. Both models were incorporated into the DYNAMOD software developed by MSU. DYNAMOD stores all the test results and allows the pavement designer to export the appropriate ME inputs by selecting the HMA mix and binder that will be used on the project. DYNAMOD was not fully complete at the conclusion of Part 1 of this project. MSU and MDOT will continue developing the DYNAMOD software.

For further details, please download final report RC-1593, *Preparation for Implementation of the Mechanistic-Empirical Pavement Design Guide in Michigan - Part 1: HMA Mixture Characterization*. The report is located on MDOT's Research Reports Web page under the Pavement Design subcategory at the following link:

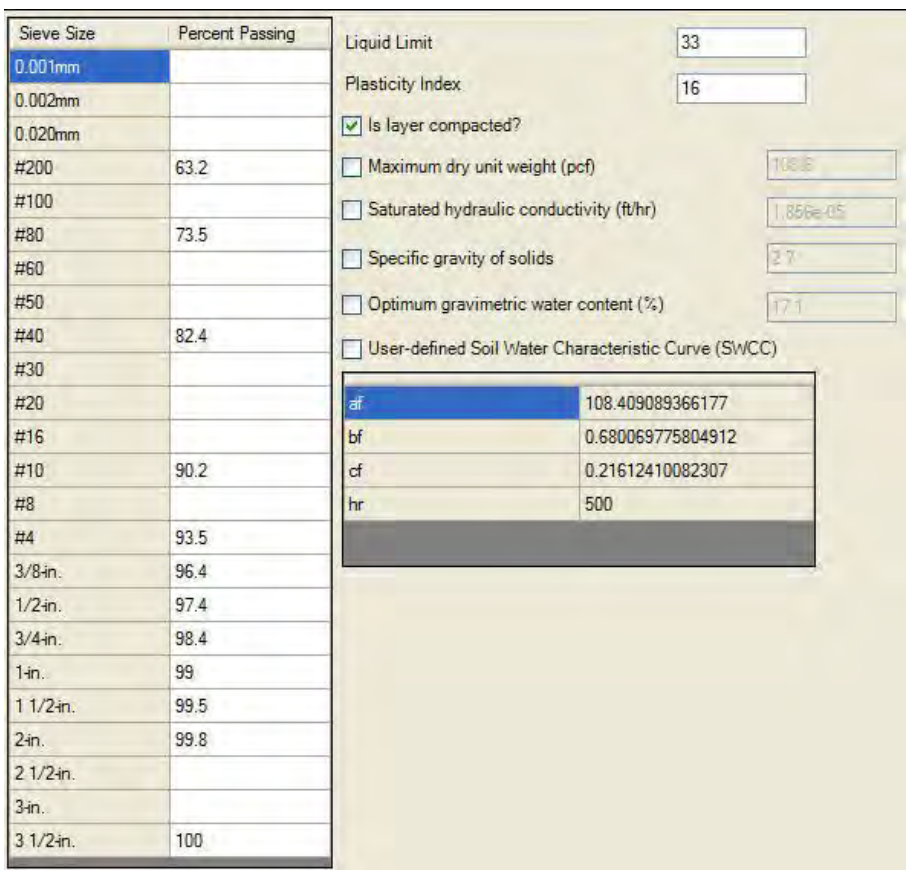
www.michigan.gov/mdot/0,4616,7-151-9622_11045_24249---,00.html

You can also use the link at the end of this newsletter to get to MDOT's ME Web page. ❖

moisture and temperature information in the climatic file that is an input. The climatic file contains historical hourly weather information (ambient temperature, precipitation, etc.) that allows the software to estimate the moisture content and temperature of each layer. These conditions are then compared to the resilient modulus that was input to estimate the modulus for any month of the year. The difference from AASHTO 1993 is the resilient modulus that is input is supposed to represent a value at optimum moisture content and maximum dry density.

Only input levels 2 and 3 are available for entering the resilient modulus value. At level 3, there are two options for treating the value that is entered: keep the modulus constant throughout the year or allow it to vary based on climatic conditions. At level 2, there is an additional option of entering values for each month of the year. Since climatic variation should be inherent when monthly values are entered, the modulus will not be changed based on the climatic file for this option. Additionally, level 2 allows the entry of a different measured value such as Dynamic Cone Penetrometer test results, California Bearing Ratio, etc. This value is then converted to resilient modulus via known correlations built into the software.

Other inputs required for the subgrade layer are Thickness (unless it is the last layer, in which case it is assumed to be semi-infinite), Poisson's Ratio, and Coefficient of Lateral Earth Pressure (horizontal pressure the soil exerts). There is also an area where gradation and other properties are to be entered. Figure 1 shows the ME default gradation and other properties for an A-6 (clayey) soil. Many of the properties seen in Figure 1 are used to calculate the moisture/temperature variations.



Sieve Size	Percent Passing
0.001mm	
0.002mm	
0.020mm	
#200	63.2
#100	
#80	73.5
#60	
#50	
#40	82.4
#30	
#20	
#16	
#10	90.2
#8	
#4	93.5
3/8-in.	96.4
1/2-in.	97.4
3/4-in.	98.4
1-in.	99
1 1/2-in.	99.5
2-in.	99.8
2 1/2-in.	
3-in.	
3 1/2-in.	100

Figure 1. A-6 soil ME default properties

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Subgrade Soil Characterization Research Project

In 2009, MSU completed a research project that characterized the subgrade soils found in Michigan. The state was divided into clusters with similar soil characteristics based on a Michigan Department of Environmental Quality geology map from 1982. Fifteen clusters were identified. Each cluster was further subdivided based on its percentage of that soil type. A 2007 Natural Resources Conservation Service Web Soil Survey was used to do this. A total of 99 sub-areas in the 15 clusters were identified.

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The main goal of this project was to determine resilient modulus values for the different subgrade soil types in Michigan. This was accomplished through laboratory triaxial testing and falling weight deflectometer (FWD) backcalculation. Of the 99 areas, 75 had samples taken for testing. Each sample was identified in the Unified Soil Classification System (USCS) and the AASHTO classification system.

Standard laboratory soil tests such as moisture content, Atterberg limits (where appropriate), gradation, etc., were conducted. Cyclic triaxial tests were conducted in accordance with AASHTO T307. A confining pressure of 7.5 psi and axial stresses of 10 psi and 15 psi were used for the triaxial tests. It was determined that these most closely match in-situ conditions of most subgrade soils under a pavement. Multivariate analysis was used to determine if any of the standard lab tests correlated to the measured resilient modulus values. If there was a correlation, those soil test parameters were included in a model for estimating the resilient modulus for that soil type. For example, the resilient modulus predictive equation for SC-SM soils (clayey sand - silty sand) is:

$$M_R = 39638 exp - 0.0037 * (SVSC - SM)$$

where,

$$SVSC - SM = C_u^{0.2} * (LL^{1.15} + MC^{1.3})$$

Cu is the coefficient of uniformity, LL is the liquid limit, and MC is the moisture content.

Historical FWD data collected from the previous 20+ years was utilized to backcalculate resilient modulus values. Additional FWD testing was conducted in clusters/areas under-represented by the existing FWD testing. Only tests where the existing cross-section at the time of testing could be determined were used for the backcalculation. No composite sections were backcalculated. MICHBACK software was utilized for all backcalculation. Backcalculated resilient modulus values closely match laboratory test values for most of the soil types. It is believed this is due to the confining and axial pressures applied during triaxial testing. Table 2 contains the recommended level 3 design values to use in ME, based on the USCS classification. The final report contains maps of different sections of the state with the predominant USCS soil type identified.

USCS Classification	Recommended Value, psi
SC, CL, and ML	4400
SC-SM	5000
SP-SM	7000
SM	5200
SP1	7000
SP2	6500

Table 2. Recommended ME level 3 resilient modulus values (Baladi, et. al.)

For further details, please download the final report for this project (report #RC-1531) from MDOT's Research Reports Web page under the Pavement Design subcategory using this link:

www.michigan.gov/mdot/0,4616,7-151-9622_11045_24249---,00.html

You can also use the link at the end of this newsletter to get to MDOT's ME Web page. ❖

ME Climate File Research Project

In October 2013, Michigan Technological University will begin a new research project that will enhance and improve the climatic data that is currently in the ME software. There are 19 weather stations for Michigan within the software (see the November 2012 edition of this newsletter for details on locations and number of months of data each one contains). The project will attempt to address several tasks:

1. **Check the quantity and quality of the data in the 19 weather stations**. This task will look for errors and outliers in the data. Five additional weather stations for Michigan in the original (MEPDG) version of the software were executed. They are currently excluded due to missing at least one month of data. This task will see if those missing months can be filled in so that these five stations can be utilized in the future.
2. **Learn about the sensitivity of the climatic data**. The sensitivity of designs to the different stations and to individual weather data items will be checked. In addition, sensitivity will be checked with regard to how many stations are chosen for interpolation when a virtual weather station is used.
3. **Determine sources of weather data that can be utilized to create additional stations and add to existing stations**. One source of data that will be investigated is the information being collected by MDOT's Intelligent Transportation System (ITS) area through their system of Road Weather Information System (RWIS) stations.
4. **Determine where additional stations would be beneficial**. There are gaps in the geographic coverage of the existing 19 stations across Michigan. This task will determine if the climatic conditions vary enough in these gaps from surrounding stations to require additional stations.
5. **Place data found in task #4 above in the correct format for use in ME**.
6. **Develop a procedure for choosing when a virtual weather station is to be used and how to choose the existing stations (number of stations, distance from project, etc.) that will be used**.

This $177,000 project is scheduled to be completed in the spring of 2015. ❖

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

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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