Michigan Implementation of Mechanistic-Empirical Pavement Design

45th Annual Midwest Geotechnical Conference
East Lansing, Michigan
October 17-20, 2016

Mike Eacker, Pavement Management Engineer

Michigan DOT Mission

"Providing the highest quality integrated transportation services for economic benefit and improved quality of life"

Outline

- Michigan Pavement Design Background
- Implementation of ME
- Geotechnical Aspects

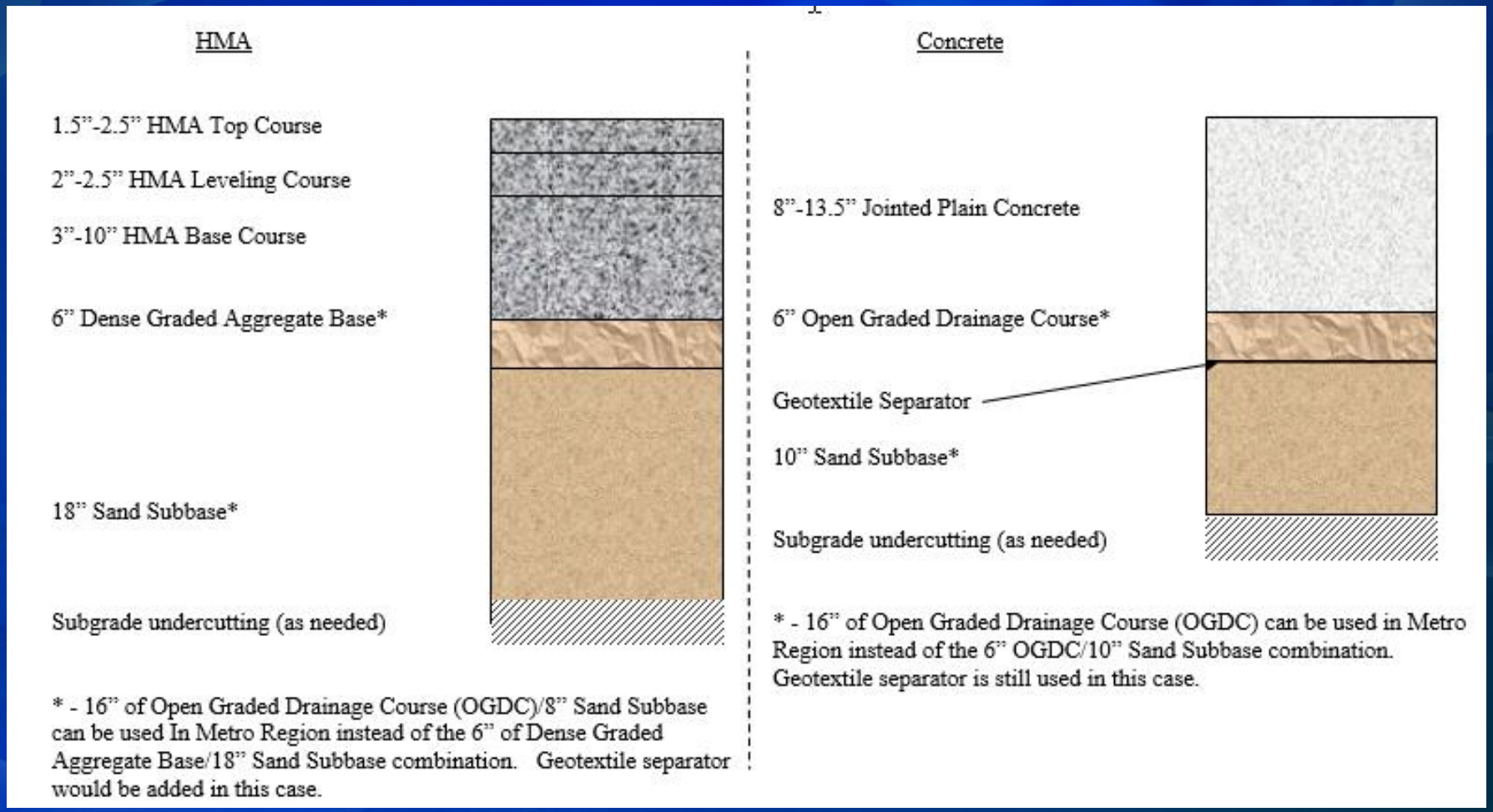
Michigan Pavement Design Background

Michigan Pavement Design Background

- Have been using AASHTO's 1993 Guide for Design of Pavement Structures
  - Software: Design and Rehabilitation for Windows (DARWin) 3.1
- Design duties
  - Central office designs: Projects with over $1 million in pavement costs which require a life-cycle cost analysis (LCCA) according to Michigan law
  - Region office designs: Non-LCCA projects

Michigan Pavement Design Background

- Typical Michigan Cross-Section



Michigan Pavement Design Background

- MDOT network breakdown
  - HMA – 10,800 lane miles
  - Concrete – 5600 lane miles
  - Composite – 11,000 lane miles
  - Freeway – 9,000 lane miles
  - Non-freeway – 18,400 lane miles
- Annual Construction Program
  - Road Reconstruction and Rehabilitation - $286 million growing to $591 million by 2022
  - Bridges - $176 million growing to $194 million by 2021
  - Road Preventive Maintenance - $90 million normally, $164 million for 2018, 2019, and 2020

Michigan Pavement Design Background

- Design life
  - Reconstructs – 20 years
  - Major Rehabs (rubblize, unbonded concrete overlay) – 20 years
  - Other Rehabs – 10 to 15 years
- Service life
  - HMA Reconstruct = 33 years
  - Concrete Reconstruct = 34 years
  - Rubblize/HMA Resurface = 26 years
  - Unbonded Concrete Overlays = 25 years

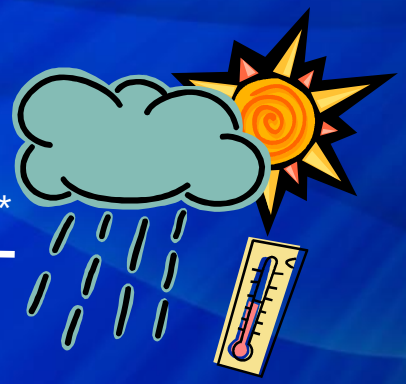
Implementation of ME

What Is ME?

Traffic

Structure & Materials

EICM*



* - Enhanced Integrated Climatic Model

Climate

Mechanistic Analysis

Transfer Functions

Predicted Performance

What Is ME?

	AASHTO 1993	Mechanistic-Empirical
Basis	Empirical observation from the 1958-59 AASHO Road Test	Theories of mechanics
Original Calibration	AASHO Road Test – Ottawa, Illinois	SHRP test sections from around the country
Traffic Characterization	Equivalent Single Axle Load	Axle load spectra
Materials Inputs	Very few	Many
Climatic Effects	Limited – can change inputs based on season	Integral – weather data from 600+ US weather stations included
Performance Parameter	Present Serviceability Index	Various distresses, IRI
Output	Thickness	Performance prediction (distress prediction)

What Is ME?

- Distresses (performance) predicted over time
  - HMA distresses
    - Transverse cracking
    - Longitudinal cracking
    - % fatigue cracking
    - Rutting
    - IRI
    - Reflective cracking
  - Concrete distresses (JPCP)
    - % slabs cracked
    - Faulting
    - IRI

Work Completed To Date

- "Evaluation of the 1-37A Design Process for New and Rehabilitated JPCP and HMA Pavements"
  - Sensitivity of the inputs
  - Comparison of in-service pavement performance with ME predicted performance
  - Michigan LTPP sections, 5 JPCP projects, 5 HMA projects
  - Reasonableness of model results
- "Quantifying Coefficient of Thermal Expansion Values for Typical Hydraulic Cement Concrete Paving Mixtures"
  - Utilized eight different aggregate geologies
  - Recommend CTE values for these different aggregate types

Work Completed To Date

- "Characterization of Truck Traffic in Michigan for the New Mechanistic Empirical Pavement Design Guide"
  - Sensitivity of traffic inputs
  - Used TrafLoad software
  - Used data from all permanent traffic recorders (WIM and classification sites)
  - Looked at one week per month vs. full data set – very little difference

Work Completed To Date

- "Characterization of Truck Traffic…" (cont.)
  - Grouped the WIM's into cluster of similar characteristics for most of the traffic inputs
  - Recommended input levels for each of the traffic inputs
  - Developed method for coming up with traffic inputs for areas not represented by a WIM

Work Completed To Date

- "Preparation for Implementation of the Mechanistic-Empirical Pavement Design Guide in Michigan"
  - Part 1 – HMA Characterization
    - Tested many different HMA mixes from around the state
    - Tried to decide how to categorize the different mixes into typical inputs
    - Used Artificial Neural Networks to build a model to predict the dynamic modulus master curve
    - 70+ total samples were collected representing 40+ different HMA mixes

Work Completed To Date

- "Preparation for Implementation…" (cont.)
  - Part 2 – Evaluate Rehab Designs
    - Evaluated whether ME rehab designs gave reasonable results
    - Sensitivity of rehab specific inputs
    - Compared in-service pavement performance with ME predicted performance – typically at least 10 projects for each fix type

Work Completed To Date

- "Preparation for Implementation…" (cont.)
  - Part 3 – Calibration and Validation
    - Evaluation of our PMS readiness to support ME
    - Compared in-service pavement performance with ME predicted performance
    - Adjusted calibration factors as needed
    - Checked the adjusted calibration factors on a different set of pavements

Work Completed To Date

- "Improvement of Michigan Climatic Files in Pavement ME Design"
  - Cleaned up the data
    - Filled in missing months
    - Corrected errors
  - Added additional years of data – now through 2014
  - Sensitivity to weather stations, weather data, and number of years of data
  - 15 new weather stations

Work Completed To Date

Work Completed To Date

- Other Research Projects
  - "Pavement Subgrade MR Design Values for Michigan's Seasonal Changes"
    - Utilized lab testing and falling weight deflectometer data
    - Subgrade resilient modulus values for AASHTO 1993 and ME
  - "Backcalculation of Unbound Granular Layer Moduli"
    - Utilized falling weight deflectometer data
    - Aggregate base, sand subbase resilient modulus values for AASHTO 1993 and ME

Current Work

- "Traffic and Data Preparation for AASHTO MEPDG Analysis and Design"
  - National pooled fund study: TPF-5(242)
  - Developing software (PrepME) for converting PTR data to ME inputs (replaces TrafLoad)
    - Runs quality checks on the traffic data and tools for repairing/improving the data
    - Can store material, climate, and FWD data for use with ME

Current Work

- "Updated Analysis of Michigan Traffic Inputs For Pavement ME Design"
  - Review of existing clustering methodology with recommendation on continuing or changing to new method
  - Utilize latest traffic data to update level I, II, and III traffic inputs
  - Check sensitivity to the number of years of data
  - Provide recommendations on improvements to the PrepME software
  - Recommend locations for permanent traffic recorders to fill in gaps

Implementation of ME

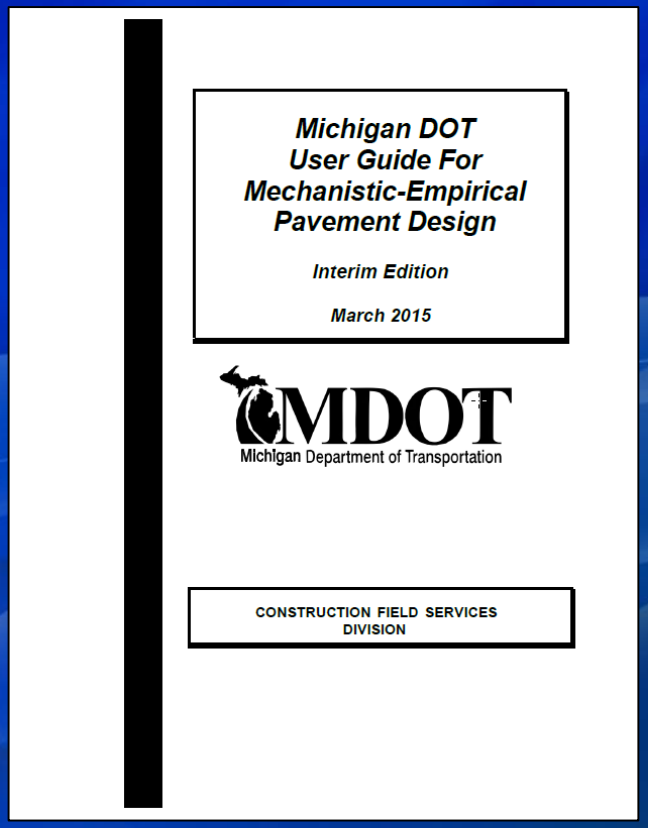
- ME Oversight Committee
  - Goal: Facilitate the implementation of ME as MDOT's standard design method
  - Facilitate business process changes for pavement design
  - Help with decisions on design criteria
  - Help with decisions on input values
  - Expand department knowledge of the software and the impacts of different inputs and design decisions
  - Explore research needs
  - Facilitate industry participation

Implementation of ME

- ME Oversight Committee (cont.)
  - Membership from various areas
    - Supervisors of the following general areas:
      - Pavement management
      - HMA materials
      - Concrete materials
      - Aggregate materials
      - Pavement evaluation
      - Traffic monitoring
    - Pavement Operations Engineer
    - Pavement Design Engineer (chair)
    - Region Soils Engineers (Region pavement designers)
    - Concrete and HMA paving industries

Implementation of ME

- ME User Guide
  - Developed 200+ document for software operation, inputs, calibration coefficients, etc.



Michigan DOT
User Guide For
Mechanistic-Empirical
Pavement Design

Interim Edition

March 2015

MDOT
Michigan Department of Transportation

CONSTRUCTION FIELD SERVICES
DIVISION

Implementation of ME

- Transition Phases:
  - Preliminary phase – ME designs of recent life-cycle projects (COMPLETED)
  - Phase 1 – newly submitted life-cycle and APB reconstruct projects (ON-GOING)
  - Phase 2 – Region-designed reconstruct projects
  - Phase 3 – newly submitted life-cycle rehab projects
  - Phase 4 – Region-designed rehab projects
  - Phase 5 – final recommendations for full implementation

Implementation of ME

- The Preliminary Transition Phase involves using the calibration results on recently life-cycled reconstruct projects to compare AASHTO 1993/ME results – completed Fall of 2014
- 13 life-cycled reconstruct projects from 2012 - 2014 were included
  - Projects from 6 of 7 Regions were included
  - Designs include ramps if they were included in the original life-cycle
  - Using inputs agreed upon by the ME Oversight Committee and Subcommittees and the final calibration coefficients
  - Original AASHTO 1993 design used as the starter cross-section in ME

Implementation of ME

- Average thickness change from AASHTO 1993 designs (without minimum thickness restrictions):
  - Concrete: -0.20”
  - HMA: -0.04”
- Individual projects saw -3.25” to +3” changes!
  - Instituted a restriction that final ME design cannot vary from the AASHTO 1993 initial design by more than ±1”. Existing minimum thicknesses still in place (6.5” HMA, 8” concrete).

Implementation of ME

- Phase 1 (life-cycled reconstructs) began March 2015
- Late 2015: began implementing Pavement ME Design version 2.2
  - Found a couple of concrete designs 2” thinner than from software version 2.0
  - Investigation revealed that errors in the concrete IRI model were corrected – re-calibration was needed

Geotechnical Aspects

Subgrade Modulus

- AASHTO 1993 – historically used a “worst case” value (i.e. spring thaw)
  - Range from 3000 psi (clays, silts) to 5000 psi (sand)
- ME – representative value for construction time frame
  - Software takes care of seasonal changes throughout the year
  - Range from 3700 psi to 8100 psi
  - Requires different mindset

Subgrade Modulus

- ME input – based on data from “Pavement Subgrade MR Design Values for Michigan's Seasonal Changes”
  - Clay – 3700 to 5100
  - Silt – 3700 to 5100
  - Clayey Sand – 3700 to 5100
  - Clayey Sand/Silty Sand – 4200 to 5800
  - Silty Sand – 4400 to 6000
  - Sand – 5500 to 7500
  - Sand/Silty Sand – 5900 to 8100

Subgrade Modulus

- How is modulus determined?
  - Hand augering → visual identification → correlation to accepted values for soil type

  OR

  - Falling weight deflectometer testing
    - Utilize AASHTO equation for subgrade modulus estimation using 0.25 correction factor

Subgrade Modulus

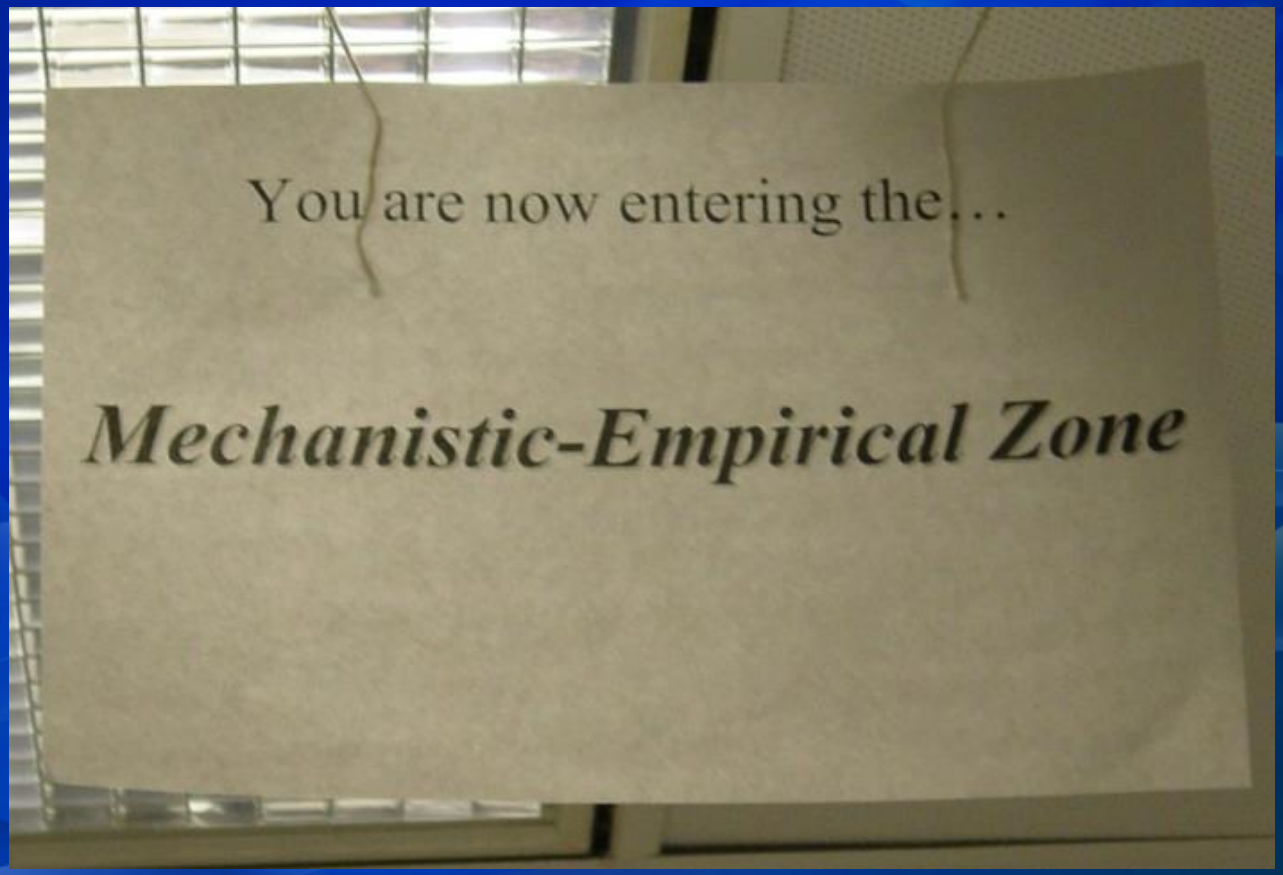
Michigan DOT Procedures for
In-situ Resilient Modulus Testing using the
Falling Weight Deflectometer (FWD)

Updated: 7/1/2015

Subgrade Modulus

- Poor subgrades
  - Normal procedure is to remove 12” to 24” of subgrade and replace with good quality granular material
  - Exploring use of stabilization in some cases
  - Demonstration projects using lime and cement kiln dust
  - Will need to consider ME inputs for stabilized subgrades
  - Recently completed research project “Performance Evaluation of Subgrade Stabilization with Recycled Materials”

Water Table

- Depth from top of subgrade to the water table
- ME results sensitive for depths less than 2 feet for concrete and 5 feet for HMA
- Recommended inputs:
  - Evidence of water within 5 foot of top of subgrade – use 2 feet
  - 5 feet for all other cases

Questions?