An Overview of the New AASHTO MEPDG Pavement Design Guide

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AMEC E&I
FEATURES OF THE AASHTO M-E PAVEMENT DESIGN GUIDE

- Developed under the US NAS (National Academy of Sciences)–NCHRP (National Cooperative Highway Research program)

- $10,000,000 – 7 Year Effort (Largest Single US Transportation Research Project in the History of the US)

- Project Team Leaders
  - AC/Flexible Pavements: Dr. M.W. Witczak
  - Rigid Pavements: Dr. M. Darter
Introduction

- Road and Highways are a very significant cost for agencies to construct, maintain and rehabilitate (US Infrastructure worth $1,000,000,000,000)

- Pavement design is a very complex process that involves many variables as well as the variation of each variable. It is one of the most complex Civil Engineering structures to design because we demand a FS=1.0

- Mechanistic concepts provide a more rational and realistic methodology for pavement design; however, pavement response models are mathematically very complex and do not have a single closed form equation solution.

- The M-E PDG provides a consistent and practical method to design a pavement for a desired level of reliability.
The MEPDG considers a wide range of AC Flexible pavement structural sections for:

- New pavement systems
- Overlay pavement systems
NEW PAVEMENTS OPTIONS

- Conventional Flexible Pavements
- Deep Strength HMA Pavements
- Full-Depth HMA Pavements
- "Semi-Rigid" Pavements
REHABILITATION OPTIONS

- **HMA Overlay over Existing HMA:**
  
  **New**       **Existing**
  - AC       Conventional AC
  - AC       Deep strength HMA pavements
  - AC       Full depth asphalt
  - AC       Semi-rigid pavements

- **HMA over JPCP**

- **HMA over CRCP**
REHABILITATION OPTIONS (CONT’D)

- **HMA over Fractured JPCP**
  - Crack and Seat
  - Rubbilization

- **HMA over Fractured CRCP**
  - Rubbilization
The primary distresses considered in the MEPDG for flexible pavements are:

- **Permanent Deformation (rutting)**
  - AC Layers
  - Unbound Base/Subbase/Subgrade Layers
  - Total Rut Depth
- **Fatigue Cracking**
  - Top Down-Longitudinal Cracking
  - Bottom Up- Alligator Cracking
- **Thermal Cracking**

In addition, pavement smoothness (IRI) is predicted based on these primary distresses and other factors.
Major Asphalt Pavement Distresses

- Major pavement distresses
  - Permanent deformation
  - Fatigue cracking
  - Transverse (Thermal) cracking

• How can we simulate these problems in the lab?
Dynamic Modulus Test
Construction of E* Master Curve

Dynamic Modulus Test (Level 1)

✓ AASHTO TP62-03

✓ 5 Temperatures: 14, 40, 70, 100 and 130 °F

✓ 6 Frequencies: 25, 10, 5, 1, 0.5 and 0.1 Hz

<table>
<thead>
<tr>
<th>Spec ID</th>
<th>Temp. (°F)</th>
<th>Freq. (Hz)</th>
<th>E* (ksi)</th>
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<td>333</td>
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Construction of E* Master Curve

- **Time-Temp. Superposition**
  - Use any arbitrary temperature value as a reference
  - Normally this value is set to be at 70°F
  - Shift E* test results at other temp. to reference temp. by time-temp superposition
  - E* results are not changed
  - Can calculate E* values at any temp. and freq. from master curve
Dynamic Modulus ($E^*$)

Advantages:

- $E^*$ allows hierarchical characterization
- takes care of aging
- takes care of vehicle speed
- can be linked to PG Binder
- $E^*$ approximates FWD back-calculated modulus
- provides rational mechanistic material property for distress prediction
- FHWA – AASHTO test protocols available
- Distress predictive models available
Indirect Tension Creep Test
Beam Fatigue Test
Rotational Viscometer

torque

sample

spindle

sample chamber
**Dynamic Shear Rheometer**

- torque (T)
- deflection angle (\(\Theta\))
- height (h)
- radius (r)
Assessment of Reliability

- $F_C$
- $F_{C_{failure}}$
- $F_{C_{Ave}}$
- $F_{C_o}$

- probability of failure ($\alpha$)
- reliability $R = 1 - \alpha$

Month $i$, Time
Hierarchical Input Process

- **Level 1 (High Reliability)**
  Analysis of special problems
  Usually will incorporate Testing
  High Visibility/Risk/Cost Projects

- **Level 2 (Medium Reliability)**
  Standard Design - Most Cases
  (Rigorous but practical)

- **Level 3 (Lower Reliability)**
  Lower impact/risk projects
### HIERARCHICAL APPROACH  
(AC MODULUS)

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>MIX</th>
<th>BINDER</th>
<th>RELIABILITY</th>
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<tr>
<td>1</td>
<td>$E^*$ Lab Test</td>
<td>$G^*,\delta$ Lab Test</td>
<td>$f(\psi)$</td>
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<tr>
<td>2</td>
<td>$E^*$ Predictive equation</td>
<td>$G^*,\delta$ Lab Test</td>
<td>$f(\psi)$</td>
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<tr>
<td>3</td>
<td>$E^*$ Predictive equation</td>
<td>AC Grade to properties</td>
<td>$f(\psi)$</td>
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Hierarchical Approach in NCHRP 1-37A

- Major Reasons for Presence in M-E PDG
  - Allows for a Quantifiable Decision to be Made, Based on Benefit / Costs Regarding the Utility of Using Detailed Engineering Tests and Data Collection / Analysis Techniques Relative to Simple, Empirical Correlations or Engineering Guesses
Hierarchical Approach in MEPDG

- **Major Reasons for Presence in M-E PDG**

  - *Provide Quantifiable Methodology for Agency to Prove Certain High Profile, High Importance and High Cost Projects Justified*

    - "Most Advanced State of the Art Technology is Mandated to Save Significant Cost Benefits"
Hierarchical Approach in MEPDG

- Major Reasons for Presence in M-E PDG
  - Collary is also True
    - “Many Projects do not Require Sophisticated, Advanced Engineering Approaches”
EXAMPLES OF THE FLEXIBLE PAVEMENT DESIGN PROCESS
INFLUENCE OF TRAFFIC ANALYSIS METHOD UPON AC RUTTING

![Graph showing the relationship between Total Number of ESALs and AC Rutting (in)]
Actual Traffic load spectra yields higher levels of rutting and cracking compared to the classical E18KSAL’s.

Traffic repetitions is a significant parameter influencing pavement distress.
INFLUENCE OF BINDER GRADE UPON AC RUTTING

Binder Grade

AC Rutting (in)

PG 82-22  PG 70-22  PG 64-22

0.25
0.20
0.15
0.10
0.05
0.00
INFLUENCE OF BINDER GRADE UPON AC RUTTING (SUMMARY)

- Binder stiffness has a significant influence upon AC rutting.

- As the binder stiffness increases, AC rutting decreases.

- In fact, as the entire HMA mix stiffness increases, AC rutting decreases.
INFLUENCE OF TRAFFIC SPEED UPON AC RUTTING

![Graph showing the relationship between traffic speed and AC rutting. The x-axis represents traffic speed in mph, ranging from 0 to 70. The y-axis represents AC rutting in inches, ranging from 0 to 0.7. The graph shows a decreasing trend as traffic speed increases.]
Traffic Speed Influences The AC Rutting.

Creep Speed (Parking Lot, Intersection Analysis) Causes Much More Damage To The Pavement Compared To Faster Highway Speeds.
INFLUENCE OF ENVIRONMENTAL LOCATION UPON AC RUTTING

Environmental Location

MAAT (75.1°F)
MAAT (66.5°F)
MAAT (62.1°F)
MAAT (47.2°F)
For all variables being the same, the higher the temperature of an environmental location, the higher the AC rutting becomes.
INFLUENCE OF AC THICKNESS UPON AC ALLIGATOR FATIGUE CRACKING

Use of M-E PDG Analysis as a Design Tool

Criteria

Design

AC Thickness (in)
AC thickness has a significant influence upon Alligator fatigue cracking. As the AC thickness increases, the amount of alligator (bottom-up) fatigue cracking decreases.
INFLUENCE OF TRAFFIC WANDER UPON AC RUTTING
INFLUENCE OF TRAFFIC WANDER UPON BASE LAYER RUTTING

Distance (in)

Base Rutting (in)

-0.40
-0.35
-0.30
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
-50 -40 -30 -20 -10 0 10 20 30 40 50

Wander = 0
Wander = 10 in
Wander = 24 in
INFLUENCE OF TRAFFIC WANDER UPON SUBGRADE LAYER RUTTING
The more channelized that the vehicular traffic becomes, the more severe the pavement rutting becomes.

The severity of the rutting is magnified for layers near the surface.
INFLUENCE OF GWT DEPTH UPON SUBGRADE LAYER MODULUS

GWT Depth (ft) vs. Modulus of Subgrade (psi)

- Green line: Compacted Subgrade
- Pink line: Natural Subgrade

Depth标记:
- AC: 1 ft
- Base: 3 ft
- Compacted SG: 5 ft
- Natural SG: 10 ft

Depth范围:
- 1 ft to 11 ft
Presence of GWT near / within unbound material layers can significantly alter the material moduli and hence increase pavement damage.
INFLUENCE OF BINDER GRADE UPON AC THERMAL FRACTURE (FARGO, ND)
Binder stiffness has the greatest influence upon Thermal Fracture within a cold environment.

As the binder stiffness (or surface layer stiffness) increases, the AC Thermal Fracture increases.
INFLUENCE OF ENVIRONMENTAL LOCATION UPON AC THERMAL FRACTURE

<table>
<thead>
<tr>
<th>Environmental Location</th>
<th>Thermal Cracking Amount (ft/mile)</th>
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<tbody>
<tr>
<td>Barrow</td>
<td>2500</td>
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<tr>
<td>Fargo</td>
<td>2000</td>
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<tr>
<td>Billings</td>
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INFLUENCE OF TIME AND VARIOUS AC VOLUMETRIC PROPERTIES UPON AC THERMAL FRACTURE (SUMMARY)

- **Thermal Cracking cumulatively increases over time.**
- **Combined property of binder content and air void has an influence upon the Thermal Fracture.**
- **In general, AC Thermal Fracture decreases with an increase of binder content and a decrease in air void.**
OVERALL M-E PDG SUMMARY

- **M-E PDG** is the most powerful Pavement-Material Analysis-Design Tool ever developed.
- **M-E PDG** will lead to a more fundamental analysis of the consequences associated with the material-structure - environmental interaction.
- **M-E PDG** has the potential for increasing pavement performance and life while decreasing life cycle costs associated with new and rehab scenarios.
Implementation Considerations

- Be careful of blind application of Modified asphalts in MEPDG.

- $E^*$ value may be okay
  - Distress performance prediction models (ac rutting, fatigue cracking and thermal fracture) generally calibrated with conventional asphalt mixtures
  - Performance prediction of Modified AC Mixtures questionable
  - Suggest local calibration
Implementation Considerations

MEPDG is an excellent product and major enhancement to current technology; however the technology is still evolving:

- Do not expect perfect predictions
  - Need to locally calibrate to actual field performance
    - Must be prepared to Conduct Trench Sections!!!!!!
  - Need to have a well defined nationally coordinated approach to develop planned model enhancements
    - Reflective cracking
    - Rutting and fatigue cracking model enhancements
    - Chemically Stabilized Materials Calibration
    - Performance of modified mixtures
    - Refinement of level standard deviations for use in reliability models