Damage Assessment of Existing Asphalt Pavements for Mechanistic-Empirical Rehabilitation Design in Virginia: a Hybrid Approach

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Presentation Outline

• Introduction
• Problem Statement
• Objectives and Scope of Work
• Experimental Plan
• MEPDG Approach
• HYBRID Approach
• Pavement Rehabilitation Analysis
• Summary of Findings, Conclusions, & Recommendations
Introduction

• Many State Highway Agencies are currently in the process of implementing Pavement ME to design their flexible pavements.

• VDOT implemented Pavement ME for the design of new construction and reconstruction projects.

• Currently, on-going research is evaluating the use of Pavement ME for the design of rehabilitated flexible pavements in Virginia.
Introduction (Cont’d)

**Pavement ME Hierarchical System:**

- **Level 1:** most implementable procedure available; involves comprehensive laboratory and / or field tests.
- **Level 2:** inputs estimated through correlations with other material properties that are measured in the laboratory and / or the field.
- **Level 3:** estimates the most appropriate design input value of the material property based on experience with little or no testing.
Problem Statement

• Major step in the rehabilitation design using Pavement ME is the *damage assessment* in the existing AC pavement.

• Damage is computed as function of *undamaged dynamic modulus* (Witczak model) and *damaged dynamic modulus* (FWD Testing).

→ **Potential of damage overestimation !!!**
Problem Statement (Cont’d)

• **Limitations of the Pavement ME software:**

  → The *Witczak model* is mandated for the estimation of *undamaged dynamic modulus* of the existing layer.

  → The regression constants for the Witczak prediction model cannot be modified in the current version of the software.
Objectives and Scope of Work

• Assess the use of Level 1 analysis for M-E rehabilitation designs of deteriorated AC pavements in Virginia.

• Explore the possible implementation of a *HYBRID* approach for AC damage characterization to overcome the challenges of using Witczak prediction model.
Experimental Plan

Level 1 Pavement ME Rehabilitation Analysis

Damaged $|E^*|$ → FWD test in wheel path → Backcalculated $E_{\text{FWD}}$ at FWD testing temperature & frequency

Undamaged $|E^*|$ → Cores from between wheel path

In-place air voids
Asphalt binder content
Recovered aggregate gradation
A-VTS for recovered binder

Laboratory measured $|E^*|$ (AASHTO T378)

Undamaged dynamic modulus using Witczak predictive model

Damage characterization based on MEPDG approach

Damage characterization based on HYBRID approach

Pavement ME Rehabilitation Design & Analysis (AC Overlay over AC Pavement)
Case Study: Route 60

- From Red Rd (Rt 630E/W), Buckingham County to White Pine Ln, Cumberland County (L=5.42 mi)
- Two-way AADTT = 176 trucks
- Two lanes: 1 lane in design direction
- Operational speed = 55 mph
Undamaged Dynamic Modulus: **Witczak Model**
Undamaged Dynamic Modulus: *Witczak Model*

\[
\log |E^*| = 3.750063 + 0.02932 \rho_{200} - 0.001767 (\rho_{200})^2 - 0.002841 \rho_4 - 0.058097 V_a - 0.802208 \left( \frac{V_{b_{eff}}}{V_{b_{eff}} + V_a} \right) \\
+ 3.871977 - 0.0021 \rho_4 + 0.003958 \rho_{38} - 0.000017 (\rho_{38})^2 + 0.005470 \rho_{34} \\
+ \frac{1}{1 + e^{(-0.603313 - 0.313351 \log(f) - 0.393532 \log(\eta))}}
\]
Damaged Dynamic Modulus: **FWD Testing**

- Should existing AC layers be characterized separately?
- Can the AC layers be separated during the FWD analysis?
- How existing AC layers will be modeled in Pavement ME?

<table>
<thead>
<tr>
<th>Modulus of existing AC layer obtained from FWD testing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FWD Modulus (ksi)</strong></td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>750</td>
</tr>
</tbody>
</table>
Damage Characterization Based on MEPDG Approach (*Estimation of FC Damage*)

\[
E^*_{\text{dam}} = 10^{\delta} + \frac{E^* - 10^\delta}{1 + e^{-0.3 + 5 \times \log(d_{AC})}}
\]

- E* un-damaged (Witczak model) = 3,445 ksi
- E* damaged (NDT Testing) = 750 ksi
- \(d_{AC} = 2.07\)
Undamaged Dynamic Modulus: $E^*$ Testing of Cores
Damage Characterization Based on **HYBRID** Approach *(Estimation of FC Damage)*

$$E^*_{\text{dam}} = 10^\delta + \frac{E^* - 10^\delta}{1 + e^{-0.3 + 5 \times \log(d_{AC})}}$$

- $E^*_{\text{un-damaged (core testing)}} = 1,200$ ksi
- $E^*_{\text{damaged (NDT Testing)}} = 750$ ksi
- $d_{AC} = 0.9$
FC Damage Characterization: MEPDG vs. Hybrid Approach

- Estimated Damage $d_{AC}$:
  - Using Witczak model $E^*_{\text{(undamaged)}}$ & FWD $E^*_{\text{(damaged)}}$: $2.07$
  - Using $E^*_{\text{(undamaged)}}$ of cores tested in the lab & FWD $E^*_{\text{(damaged)}}$: $0.9$

<table>
<thead>
<tr>
<th>Category</th>
<th>Damage $d_{AC}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>0.00 – 0.20</td>
</tr>
<tr>
<td>Good</td>
<td>0.20 – 0.40</td>
</tr>
<tr>
<td>Fair</td>
<td>0.40 – 0.80</td>
</tr>
<tr>
<td>Poor</td>
<td>0.80 – 1.20</td>
</tr>
<tr>
<td>Very Poor</td>
<td>&gt; 1.20</td>
</tr>
</tbody>
</table>

![E* Master Curve @88°F (ksi)](image)

- E* Undamaged Master Curve - E* Testing of Cores
- E* Undamaged Master Curve - Witczak Model
- E* Damaged - FWD Testing

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→ PMS Data ????
Percent Alligator Cracking: **MEPDG vs. Hybrid Approach**

\[
FC_{Bottom} = \left( \frac{1}{60} \right) \times \left( \frac{C_4}{1 + e^{(C_1 C_1^* + C_2 C_2^*) \log(d_{AC-Bot} \times 100)}} \right)
\]

- \( FC_{Bottom} \) = Area of alligator cracking, % of total lane area;
- \( d_{AC-Bot} \) = cumulative damage index at the bottom of AC layer;
- \( C_1 = 0.8; C_2 = 0.8; \) and \( C_4 = 6000 \)
- \( C_1^* = -2 C_2^* \)
- \( C_2^* = -2.40874 - 39.748(1 + h_{AC})^{-2.856} \)

<table>
<thead>
<tr>
<th>Parameters / Approach</th>
<th>MEPDG</th>
<th>HYBRID</th>
<th>PMS Data (2014)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Damage ( d_{AC} )</strong></td>
<td>2.07</td>
<td>0.9</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Area of Alligator Cracking</strong></td>
<td><strong>65.2%</strong></td>
<td><strong>47.9%</strong></td>
<td><strong>42.2%</strong></td>
</tr>
</tbody>
</table>
Pavement Rehabilitation Analysis

- **Analysis 1:** MEPDG approach (Level 1)
- **Analysis 2:** HYBRID approach (Level 1 & 2)
- **Analysis 3:** MEPDG approach (Level 3)

**Data Inputs:**
- Witczak Model
- $E_{\text{Backcalculated}}$
- $E^*_{\text{Cores-Non-wheel path}}$

**Type of Analysis:**
- Pavement Condition Rating

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Findings & Conclusions

• *Higher damage characterization* was observed for the existing AC layer(s) when the Witczak model and FWD backcalculated data were used for undamaged and damaged E*, respectively.

• *Reasonable results for damage* were observed when estimated using the measured undamaged E* on cores combined with damaged E* from FWD backcalculation.

• The implementation of the *Hybrid* approach in the Pavement ME design software requires the use of a *combination of Level 1 and Level 2 data inputs*. 
Recommendations: **Hybrid Approach**

Step 1 – FWD Testing
*RWP Before Rehab*

Step 2 – Backcalculation Analysis
*Damaged AC Modulus $E_{FWD\_Damaged}$*

Step 3 – Core Sampling
*BWP Before Rehab*

Step 4 – Witczak $E^*$
*Undamaged Core properties (e.g., binder content, A-VTS, aggregate gradation, etc…)*

Step 5 – Lab $E^*$
*Undamaged Core Testing Following AASHTO TP79*

Step 6 – Damage Characterization
$E_{FWD\_Damaged} (Step 2)$ Vs. $E^*_{Lab\_Undamaged} (Step 5)$

Step 7 – %FC Calculation
*Using the damage in Step 6 & locally calibrated transfer function*

Step 8 – Pavement ME Analysis
*Existing AC layer(s), Level 2 (using outcomes of Step 4 & 6)*
Acknowledgments

• Virginia Department of Transportation (VDOT)
• Virginia Transportation Research Council (VTRC)
Thank You! Questions?!

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