UPDATE: IMPLEMENTATION OF THE AASHTO MEPDG IN COLORADO

37th Annual Conference
Rocky Mountain Asphalt Conference and Equipment Show
February 25th, 2010

Jay Goldbaum, P.E., Colorado DOT

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Pavement Design Timeline & MEPDG Implementation in Colorado

- **Late 1950’s**
  - AASHO Road Test

- **1972, 1986, 1993**
  - AASHTO Guides

- **1999**
  - NCHRP 1-37A Launches

- **2004**
  - NCHRP Develops MEPDG

- **2007**
  - CDOT Updates Roadmaps

- **2008**
  - MEPDG is an AASHTO Standard

- **2009**
  - CDOT Begins Implementation

- **2011**
  - CDOT Adopts MEPDG

Sunday, March 28, 2010
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Pavement Design Timeline & MEPDG Implementation in Colorado

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<td>Diversity of Conditions</td>
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Implementation Programs Around the Country
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Objectives of CDOT’s MEPDG Implementation Project

- Identify resources needed to implement the MEPDG
- Confirm or adjust default values
- Confirm or adjust the calibration coefficients
- Recommend any changes in policy and procedure that will be needed
- Provide design document that can be used by CDOT
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M-E Guide Outputs for Flexible Pavement

- Fatigue Cracking
- Thermal Cracking
- Rut Depth
- IRI
M-E Guide Outputs for Flexible Pavement

Fatigue Cracking

Thermal Cracking

Rut Depth

IRI
Colorado’s MEPDG—The Plan

- 2009 to 2010: Data collection & input determination, 80+ test sections
  - Materials Testing and Characterization
  - Traffic Analyses
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- **2011: Documentation & Design Manual**

- **Continuous Training**
1. Conventional (HMA over ABC) Pavements
2. Full-Depth HMA Pavements
3. HMA Overlay
   • Simple overlay
   • Mill and fill
   • Full depth reclamation
   • Hot in-place recycled
   • Cold in-place recycled
   • SMA
4. HMA Overlay of PCC Pavements
   • Intact
HMA Experimental Factorials:

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2. Full-Depth HMA Pavements
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   - Simple overlay
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   - Intact
HMA Experimental Factorials (Continued):

A. HMA Thickness
   • Less than 4 inches
   • 4 to 8 inches
   • Greater than 8 inches

B. Base Course
   • Class 6
   • Class 7

C. Soil Foundation
   • Stabilized
   • Non-expansive
     i. Course grained
     ii. Fine grained

D. Climate Based on Elevation

LTPP test sections, pavement management sections, adjacent DOTs.

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Secondary Factors:
Neat and PMA mixes; with and w/o RAP; etc
Populating the Experimental Factorials

Long-Term Pavement Performance Data in Colorado
- 68 sections; 16 GPS and 52 SPS
- New Flexible Pavements
- HMA overlay of Flexible and Rigid Pavements

CDOT PMS Section Selection Criteria
- Representative roadway sections
- Availability of 3 condition surveys within 7-10 yr period (min)
- Consistency of distress measurements
- Availability of construction history data
- For Overlay Experiments: Number of overlays during the monitoring period is limited to one
- Availability of well-defined traffic data
- Availability of material properties from construction/ project
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## New Flexible Pavements

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<th>Binder Type</th>
<th>Elev.</th>
<th>Coarse-Grained Soil</th>
<th>Fine-Grained Soil, Non-Expansive</th>
<th>Fine-Grained, Expansive</th>
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CDOT PMS Roadway Sections

• 40 Asphalt Concrete Sections
  – 11 New Flexible Pavements
  – 19 Simple AC Overlays of Flexible Pavements
  – 6 AC Overlays with HIR
  – 2 AC Overlays with CIR
  – 2 AC Overlays of Rigid Pavements

• 11 Rigid Pavements
  – 5 New Rigid Pavements
  – 6 Concrete Overlays of

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CDOT PMS Roadway Sections

- **40 Asphalt Concrete Sections**
  - 11 New Flexible Pavements
  - 19 Simple AC Overlays of Flexible Pavements
  - 6 AC Overlays with HIR
  - 2 AC Overlays with CIR
  - 2 AC Overlays of Rigid Pavements

- **11 Rigid Pavements**
  - 5 New Rigid Pavements
  - 6 Concrete Overlays of...
1. Establish test segments.
2. Recover materials for testing.
3. Cores for crack propagation and layer rutting.
Data Collection – Forensic Investigations

1. Establish test segments.
2. Recover materials for testing.
3. Cores for crack propagation and layer rutting.

Sunday, March 28, 2010
HMA Sampling and Field Testing Plan

Layout

1000 ft sample unit

Start Station:

End Station:

LEGEND:
- X: Cores over Alligator or Wheelpath Long. Cracks
- (): Cores and Auger Samples for Moisture Content Tests of Unbound Materials and Soils
- (): Cores for HMA Air Void & other Laboratory Tests
- ( ): Location of Cores for HMA Rut Depth

Sunday, March 28, 2010
HMA Sampling and Field Testing Plan

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1000 ft sample unit

LEGEND:

- Cores over Alligator or Wheelpath Long. Cracks
- Cores and Auger Samples for Moisture Content Tests of Unbound Materials and Soils
- Cores for HMA Air Void & other Laboratory Tests
- Location of Cores for HMA Rut Depth

Start Station:

End Station:
# HMA Material Properties Required for the MEPDG Procedure

<table>
<thead>
<tr>
<th>Material Property</th>
<th>Input Level</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>HMA Dynamic Modulus</td>
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</tr>
<tr>
<td>HMA Repeated Load Permanent Deformation</td>
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<tr>
<td>HMA Indirect Tensile Creep Compliance</td>
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<tr>
<td>HMA Indirect Tensile Strength</td>
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<tr>
<td>HMA Maximum Specific Gravity</td>
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</tr>
<tr>
<td>Bulk Specific Gravity of Cores</td>
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</tr>
<tr>
<td>HMA Mixture Design Sheets</td>
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</tr>
<tr>
<td>Asphalt Specific Gravity</td>
<td>✓</td>
</tr>
<tr>
<td>Asphalt Content of HMA Mixture</td>
<td>✓</td>
</tr>
<tr>
<td>Asphalt Performance Grade</td>
<td>✓</td>
</tr>
<tr>
<td>Asphalt Penetration @ 25 °C</td>
<td>✓</td>
</tr>
<tr>
<td>Asphalt Viscosity @ 140 °C</td>
<td>✓</td>
</tr>
<tr>
<td>Asphalt Viscosity @ 275 °C</td>
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<tr>
<td>Asphalt Viscosity</td>
<td>✓</td>
</tr>
<tr>
<td>Asphalt Softening Point</td>
<td>✓</td>
</tr>
<tr>
<td>Fine aggregate specific gravity &amp; absorption</td>
<td>✓</td>
</tr>
<tr>
<td>Coarse aggregate specific gravity &amp; absorption</td>
<td>✓</td>
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<tr>
<td>Sieve analysis of fine &amp; coarse aggregate</td>
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</table>
Climate Data
Climate Data

= Cooperative Weather Station  = MEPDG Station
Rut Distress Prediction Equation for Flexible Pavements and HMA Overlays

\[ \Delta_{p(HMA)} = \varepsilon_{p(HMA)} h_{HMA} = \beta_{1r} k_2 \varepsilon_{r(HMA)} 10^{k_{1r}} n^{k_{2r}} \beta_{2r} T^{k_{3r}} \beta_{3r} \]

Where:
- \( \Delta_{p(HMA)} \) = Accumulated permanent or plastic vertical deformation in the HMA layer/sublayer, in.
- \( \varepsilon_{p(HMA)} \) = Accumulated permanent or plastic axial strain in the HMA layer/sublayer, in/in.
- \( \varepsilon_{r(HMA)} \) = Resilient or elastic strain calculated by the structural response model at the mid-depth of each HMA sublayer, in/in.
- \( h_{(HMA)} \) = Thickness of the HMA layer/sublayer, in.
- \( n \) = Number of axle load repetitions.
- \( T \) = Mix or pavement temperature, °F.
- \( k_2 \) = Depth confinement factor.
- \( k_{1r,2r,3r} \) = Global field calibration parameters (from the NCHRP 1-40D recalibration; \( k_{1r} = -3.35412, k_{2r} = 0.4791, k_{3r} = 1.5606 \)).
- \( \beta_{1r}, \beta_{2r}, \beta_{3r} \) = Local or mixture field calibration constants; for the global calibration, these constants were all set to 1.0.

\[ k_2 = (C_1 + C_2 D)0.328196^D \]
\[ C_1 = -0.1039(H_{HMA})^2 + 2.4868H_{HMA} - 17.342 \]
\[ C_2 = 0.0172(H_{HMA})^2 - 1.7331H_{HMA} + 27.428 \]

- \( D \) = Depth below the surface, in.
- \( H_{HMA} \) = Total HMA thickness, in.
Rut Distress Prediction Equation for Flexible Pavements and HMA Overlays

\[ \Delta_{p(HMA)} = \varepsilon_{p(HMA)} h_{HMA} = \beta_{1r} k_z \varepsilon_{r(HMA)} 10^{k_{1r} n^{k_{2r} T^{k_{3r} k_z}}} \]

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
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<tr>
<td>( \Delta_{p(HMA)} )</td>
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\( H_{HMA} \) = Total HMA thickness, in.
Example—Summary of Results; NCHRP Projects, **Rutting**

<table>
<thead>
<tr>
<th>Measured Rut Depth, inches</th>
<th>Total Predicted Rut Depth, inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.320</td>
<td>0.320</td>
</tr>
<tr>
<td>0.640</td>
<td>0.640</td>
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<tr>
<td>0.960</td>
<td>0.960</td>
</tr>
<tr>
<td>1.280</td>
<td>1.280</td>
</tr>
<tr>
<td>1.600</td>
<td>1.600</td>
</tr>
</tbody>
</table>

- Kansas; SPS-1 Mid-West
- Kansas; SPS-5 Mid-West
- Montana, New Construction
- Montana, Overlays
- SPS-1, General
- SPS-5, General
- MnRoads
- Test Tracks
- APT, Simulated Loads
- Line of Equality
- Kansas PM, New Construction
- Kansas PM, Overlays
Example—Summary of Results; NCHRP Projects, Rutting
Example — Rut Depth in Colorado

![Graph showing rut depth in inches vs. age in years for different locations in Colorado.]

- 08-1029, Craig
- 08-1053, Montrose
- 08-2008, La Junta
- 08-0502, RAP
- 08-0506, Virgin

Graph key:
- ○ 08-1029, Craig
- ● Line of Equality
- ● 08-1053, Montrose
- ● 08-2008, La Junta
- ▲ 08-0502, RAP
- ▲ 08-0506, Virgin

- Rut Depth, inches
- Age, years

Sunday, March 28, 2010
Example — Rut Depth in Colorado
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![Graph showing rut depth in inches versus age in years for different locations in Colorado.]

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The graph illustrates the relationship between age and rut depth, with predicted rut depths for each location shown as distinct markers. The line of equality is also depicted for reference.
Framework for Model Validation and Recalibration

- **Statistical Approach for Model Validation**
  - Determine Model Prediction Capability
    - Using coefficient of Variation, $R^2$
  - Estimate Model Accuracy
    - Using standard error estimate (SEE)
  - Determine Bias
    - Hypothesis testing of model intercept and slope for linear model fitting predicted and measured data
      - Slope = 1; Intercept = 0
    - Paired t-test for measured and predicted distress/IRI

- **Non-Statistical Approach for Model Validation**
  - Used when measured distress/IRI was mostly zero
  - Computation of diagnostic statistics not possible or meaningless

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Current Status

- **Task 0**: Project Kick-Off Meeting and Coordination
- **Task 1**: Database Development
- **Task 2**: Field Investigations and Lab Materials Testing
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Summary: Colorado’s MEPDG
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☑ Comprehensive tool for pavement design & analyses.
Summary: Colorado’s MEPDG

- Comprehensive tool for pavement design & analyses.
- Excellent forensic tool!
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- Optimize on design features – not just increase pavement thickness!
Comprehensive tool for pavement design & analyses.
Excellent forensic tool!
Optimize on design features – not just increase pavement thickness!
Accuracy can be quantified.
QUESTIONS?