National Trends in Pavement Design

Southeastern States Pavement Management Association

Pavement Management and Design

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New Orleans, Louisiana

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First Engineered Road

Concrete
(Stone & other material with Lime)

Squared Stones

Fine Dry Soil (Well-compacted)
Roman Roads

- Roman Empire built over 3000 miles of roads in Britain alone by 200 A.D.
- Used ditches to aid in drainage
- Varied thickness over weaker soils
- Indicated that Romans had some understanding of basic soil mechanics
First Modern Roads

- 1764 France (Tresaguet)
- Labor costs too high; smaller stones, thinner sections
First Modern Roads

Use of Tar and Asphalt

- 1830’s USA - England (McAdam)
- Impervious surface; asphalt/tar mixed hot; sand added to fill voids
First Concrete Pavement

• 1891 George Bartholomew built first concrete pavement in Bellefontaine, Ohio
• 8-ft.-wide strip of Main Street
First Concrete Pavement

Rensselaer County, New York, 1908 -- farm-to-market thoroughfares.

Early dump truck hauls materials to paving site.
Concrete Design History

- 1916 – Typical Pavements 5 – 9”
- 1906/1918 – Patent for skewed joints
- 1920 – First CRCP in MD
- 1970 – 15 states had built CRCP sections
- <1922 - No jointed pavements, thickened center section to prevent cracking
- 1925-45 – Exp joints 50 – 120 ft, contraction joints 15-60 ft
Concrete Desing History

- 1940 to 1950 – Use of random jts.
- 1975 – 18 states using skewed jts.
First Asphalt Pavement

• Paris – 1854
• Used natural rock asphalt, i.e., limestone rock impregnated with asphalt.
• Pavement provided a quiet, easily cleaned surface, but the skid resistance was very low in wet weather.
First Asphalt Pavement in US

• 1870, Design by Edmund DeSmedt
• Sand Mix placed in front of City Hall in Newark, New Jersey
First asphalt concrete specifications appeared in the US in the 1890’s.
Concurrently, coal tar/aggregate mixtures were being used in Europe.
First hot-mix asphalt plants were developed in the late 1920’s.
Early Construction

- First modern asphalt paver introduced mid-1950’s
- Prior to 1950’s, asphalt was placed by form-riding finishers similar to PCC
Flexible Pavements

Conventional

- Asphalt
- Unbound Base
- Unbound Subbase
- Compacted
- Natural Subgrade

Deep Strength

- Asphalt
- Unbound Base
- Compacted
- Natural Subgrade

Full-Depth

- Asphalt
- Asphalt Base
- Compacted
- Natural Subgrade
AASHO Road Test
(late 1950’s)

AASHO, 1961)
AASHO Road Test Achievements

- Serviceability concept
- Traffic damage factors
- Structural number concept
- Empirical Process
- Simplified Pavement Design

(AASHO, 1961)
1950s Vehicle Loads...

Figure 23. Test vehicles, showing typical axle arrangements and loadings.

(AASHO, 1961)
History of the Current AASHTO Pavement Design Guide

- Empirical design methodology based on AASHO Road Test in the late 1950’s
- Several versions:
  - 1961 (Interim Guide), 1972
  - 1986 version
    - refined material characterization
  - 1993 revised version
    - More on rehabilitation
    - More consistency between flexible, rigid designs
    - Current version for flexible design procedures
  - 1998 Supplemental Guide for rigid pavement design
Why is pavement design SO HARD?

- Predicting the future
- Indecision on design
- Political influence
- Funds
- Materials
- Construction quality
Design Methodologies

- Experience
- Empirical
- Mechanistic-Empirical
- Mechanistic

Figure 57. Compacting subbase.
Current design traffic is far beyond road test limits.
The Concept of Mechanistic Design

- Fundamental engineering theories and material properties are used to calculate critical strains in the pavement due to traffic load.
Major Benefits of MEPDG over AASHTO

• More defensible design procedure
• More realistic pavement thickness at high ESAL’s = Cost Savings
• Ability to integrate with PRS, LCCA, warranty projects
• Not much different than AASHTO at lower ESAL ranges (<500,000)
Key Advantage of M-E Design

“Comprehensive” design procedure: Not Just Thickness!
M-E models directly consider true effects and interactions of inputs on structural distress and ride quality. Design optimization possible where all distress types are minimized!
Challenges of MEPDG Method

- Many inputs required
- Availability of models representing local conditions
- Availability of required material properties
- Predicting future traffic loads and climate
- What can not be addressed?
Why move to a ME based design procedure?

- Economics
- Deficiencies in current procedures
- Political climate
- Method based on sound engineering principles
Everyone is important in the MEPDG analysis process
• Balloted successfully in 2007
• AASHTO currently dev AASHTOWare version
What’s New in MEPDG

- Topics to be covered
  - Capabilities
  - Reliability
  - Compare AASHTO Guide to MEPDG
- Inputs
  - Climate
  - Traffic
  - ACP
  - PCCP
  - Unbound materials
- Calibration
- Testing
Capabilities

• Wide range of pavement structures
  ▪ New
  ▪ Rehabilitated
• Explicit treatment of major factors
  ▪ Traffic – Over-weight trucks
  ▪ Climate – Site specific and over time
  ▪ Materials – New and different
  ▪ Support – Foundation and existing pavement
Capabilities

- Models to predict change in distress over time
- User establishes acceptance criteria
  - Distresses and smoothness
What’s New in Design Reliability?

- Different than AASHTO 1986/93
- Based on predicted distress and IRI
- User selects reliability levels and performance criteria for distress and IRI
M-E Design Process

Climate

Materials

Structure

Iterations

Response

Damage Accumulation

Damage

Distress

Traffic
# What’s New About the Design Guide?

<table>
<thead>
<tr>
<th>Climate</th>
<th>1993 Guide</th>
<th>MEPDG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Seasonal Adjustments</td>
<td>Inputs for EICM</td>
</tr>
<tr>
<td></td>
<td>Drainage Coefficients</td>
<td>Thermal Properties</td>
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<tr>
<td></td>
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<td>Wind Speed</td>
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<tr>
<td></td>
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<td>Air Temperature</td>
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<td></td>
<td></td>
<td>Water Table Depth</td>
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<tr>
<td></td>
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<td>Sun Radiation</td>
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<td></td>
<td></td>
<td>Precipitation</td>
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</table>

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What’s New About the Design Guide?

1993 Guide
- ESALs
- Truck Equivalency Factors

MEPDG
- Axle Load Spectra
- Truck Speed
- Gear/Axle Configuration
- Axle/Tire Spacing
- Tire Pressure
- Traffic Wander
- Monthly, Daily Distribution Factors

Traffic
What’s New About the Design Guide?

1993 Guide
- Foundation
- Resilient Modulus
- “k” values

MEPDG
- Universal non-linear Resilient modulus Model
What’s New in Flexible Pavement Design?

<table>
<thead>
<tr>
<th>1993 Guide</th>
<th>MEPDG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layer Coefficient</td>
<td>Dynamic Modulus - SPT</td>
</tr>
<tr>
<td>Resilient Modulus (68°F)</td>
<td>(Level 1 &amp; Master curves)</td>
</tr>
<tr>
<td></td>
<td>Poisson’s ratio</td>
</tr>
</tbody>
</table>

HMA Materials
What’s New in Rigid Pavement Design?

**PCC Materials**

<table>
<thead>
<tr>
<th>1993 Guide</th>
<th>MEPDG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulus, Flex Strength, Tensile Strength (28-day)</td>
<td>Modulus of Elasticity (7, 14, 28 &amp; 90 day)</td>
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<tr>
<td></td>
<td>Flexural, Tensile Strength</td>
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<tr>
<td></td>
<td>Poisson’s ratio</td>
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<tr>
<td></td>
<td>PCC Thermal Props</td>
</tr>
<tr>
<td></td>
<td>Drying Shrinkage</td>
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<tr>
<td></td>
<td>Coefficient of Thermal Expansion</td>
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</table>
### What's New and Different

<table>
<thead>
<tr>
<th>Outputs</th>
<th>1993 Guide</th>
<th>MEPDG</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Structural Number</td>
<td>Time Series Distress and Smoothness Prediction</td>
</tr>
<tr>
<td></td>
<td>Rigid Pavement</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thickness</td>
<td></td>
</tr>
</tbody>
</table>
MEPDG Outputs – Flexible

Fatigue Cracking

Thermal Cracking

Longitudinal Cracking

Rut Depth

IRI
Joint Faulting

Transverse Cracking

Punchout

Joint Faulting

IRI
MEPDG is an Analysis Program

Trial design
### What's New and Different

<table>
<thead>
<tr>
<th>Input Levels</th>
<th>1993 Guide</th>
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<tbody>
<tr>
<td>Single Value</td>
<td>Level Three</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Level Two</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Level One</td>
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</table>
Input levels can be mixed and matched

Damage calculations are exactly the same regardless of design input level
Climatic Inputs

- Identify weather station
  - Pick from one of 800 sites
  - Create virtual by averaging surrounding or similar sites
- Create EICM file
- Depth to water table

<table>
<thead>
<tr>
<th>Input</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level</td>
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<td>✓</td>
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</tbody>
</table>
Climate Model (EICM)  
Asphalt Design

Adjustments:
- Unbound
  - Resilient modulus
  - Moisture content
- AC Hourly temperature profile
  - Thermal cracking
  - Rutting
Hourly Temperature Profile for AC Layers

-40 -30 -20 -10 0 10 20 30 40 50

6/15/94 6/15/95 6/14/96 6/14/97 6/14/98 6/14/99

Depth = 0 in.  Depth = 3 in.  Depth = 6 in.
• EICM used to predict
  ▪ Hourly temperature profile
  ▪ Monthly moisture gradient
Concrete Slab Temperature and Moisture Gradients

Curling

Warping

Slab wetter on top

Slab dryer on top
TRAFFIC INPUTS
Traffic Hierarchical Input
Levels

- **Level 3** – AADT & % trucks with TTC Classification Group
- **Level 2** – AADTT with Regional/Statewide AVC & WIM data
- **Levels 1** – AADTT with site specific AVC & WIM data
# Traffic Module Inputs - Overview

<table>
<thead>
<tr>
<th>Input Parameters</th>
<th>Input Level</th>
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<tbody>
<tr>
<td><strong>Inputs Required to Compute AADTT</strong></td>
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<tr>
<td>AADTT for Base Year</td>
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<tr>
<td>AADT and Percent Trucks for Base Year</td>
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<tr>
<td>Directional Distribution Factor</td>
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<tr>
<td>Lane Distribution Factor</td>
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</table>

**Truck Traffic Volume Adjustment Factors**

<table>
<thead>
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<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck Distribution Factors - Base Year</td>
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<tr>
<td>Truck Traffic Classification (TTC) Factor</td>
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<tr>
<td>Axle Load Distribution Factors</td>
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<tr>
<td>Monthly Distribution Factors</td>
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<td>1</td>
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<tr>
<td>Hourly Distribution Factors</td>
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<tr>
<td>Truck Traffic Growth Function/Factor</td>
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<tr>
<td>Axle Load Distribution Factors</td>
<td>✓</td>
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<tr>
<td>Axle Load Distribution Factors</td>
<td>✓</td>
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<tr>
<td>General Traffic Information</td>
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</tr>
<tr>
<td>No. of Axle Types per Truck Class</td>
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<tr>
<td>Axle Spacing</td>
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<tr>
<td>Axle Load Groups</td>
<td>✓</td>
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<tr>
<td>Tire Spacing/Axle Configuration</td>
<td>✓</td>
</tr>
<tr>
<td>Tire Pressure</td>
<td>✓</td>
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## Lateral Truck Traffic Wander

- Mean wheel location
- Traffic wander standard deviation
- Design lane width

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Unbound Materials (Aggregates and Subgrade)

- Resilient Modulus
  - Level 3 Defaults
  - Level 2 Correlations
  - Level 1 Materials specific testing

- Variability
  - None
  - Seasonal Values
  - EICM
Unbound Material General Properties

- Unbound Material Type - select from list of:
  - AASHTO Classification (AASHTO M 145)
  - Unified Soil Classification System (ASTM D 2487)
  - Other (e.g. crushed stone, cold recycled AC)

- Layer Thickness: thickness of the layer in inches
Subgrade resilient modulus is converted to a k-value that produces equivalent surface deflections for each month in year
ASPHALT MATERIAL PROPERTY AND DESIGN INPUTS
Mix Dynamic Modulus

• Level
  ▪ 3 – Predictive equation and binder class
  ▪ 2 – Predictive equation and binder tests
  ▪ 1 – Laboratory mix tests

• Predictive equation
  ▪ Gradation
  ▪ Air Voids
  ▪ Asphalt content
  ▪ Binder information
PCC MATERIAL PROPERTY AND DESIGN INPUTS
CRCP Design Features - Inputs

- **Reinforcement**
  - Bar diameter
  - Spacing
  - Percent steel
- **Base properties**
  - Base type
  - Erodibility
  - Base/slab friction coefficient
- **Crack spacing (optional)**

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JPCP Design Features - Inputs

- Joint Details
  - Joint spacing
  - Sealant type
  - Dowel diameter and spacing

- Edge Support
  - Shoulder type and LTE
  - Widened slab

- Base properties
  - Base type
  - Interface type, i.e. bonded or unbonded
  - Erodibility

<table>
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Three Step Process

• **Verification** – assuring general reasonableness

• **Calibration** – minimize difference between predicted and observed distress

• **Validation** – confirm accuracy of calibrated model
Performance Verification

- Procedure evaluates the trial design to determine if it meets the desired performance criteria at individually set reliability levels.
MEPDG Guide Calibration

• Done with national LTPP data
• Default values also from LTPP
• Confirm/change national defaults
Implementation – Calibration

• Requires extensive experimental studies, including:
  ▪ Field testing programs
  ▪ Laboratory testing
  ▪ Data analysis
Field Testing Programs

Select test sites in each agency (LTPP and others) that includes range of:

- Climate types and areas in the agency
- Pavement types
  - AC (all types), PCC (all types)
  - Types of overlays and rehab.
  - Base and subgrade types
  - Joint types in PCC
- Traffic characteristics
- Typical preservation techniques
Field Testing Programs, Cont.

- Obtain pavement performance data
  - Distress surveys
  - FWD and core testing
  - Pavement profile
  - Material related distresses
- Determine in-place material properties
Local calibration will involve recalibrating the distress models using data collected from the selected local sections.
Regional/Local Calibration Process

\[ \beta_s = \text{Agency Calibration Factor} \]

Actual Field Performance vs. Calibrated National Predicted Performance
MEPDG Survey Conducted in 2007

- 52 responses, 50 states plus DC & PR
- 65 questions on:
  - Current Design Procedures
  - MEPDG Knowledge
  - Implementation Activities
  - Partnering Activities
  - Training Needs
Asphalt Design Procedure

- AASHTO 1972: 63%
- AASHTO 1993: 13%
- State Design Procedure: 12%
- AASHTO/State Design Procedure: 8%
- Other: 4%
Concrete Design Procedure

- AASHTO 1972: 19%
- AASHTO 1981: 12%
- AASHTO 1993: 10%
- AASHTO 1998: 17%
- State Design Procedure: 36%
- AASHTO/State Design Procedure: 4%
- Other: 2%

AASHTO 1972
AASHTO 1981
AASHTO 1993
AASHTO 1998
State Design Procedure
AASHTO/State Design Procedure
Other
How does actual performance compare to design life?

- 45%: Similar to design life
- 33%: More than design life
- 12%: Less than design life
- 10%: Don't Know
Does SHA Use or Plan to Use MEPDG?

- N0 - 12
- YES - 40

Map showing states with blue for N0 - 12 and orange for YES - 40.
The MEPDG is not perfect…..BUT;

The MEPDG provides a reasonable and structured platform for continuous improvement.
Things to remember

• All pavement design systems need:
  ▪ Quality Materials Characterization
  ▪ Ties climate with design
  ▪ Quality Traffic Data
  ▪ Calibrated to local conditions

• The MEPDG is one tool for a designer
  ▪ Focused on the structural design aspects
  ▪ Has limitations
QUESTIONS

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