ESTABLISH PAVEMENT ME DESIGN INPUTS FOR NEW JOINTED PLAIN CONCRETE PAVEMENTS

June 22, 2016
AGENDA

Overview of Pavement ME inputs for New JPCP Designs

Identify the Inputs Users Need to Define for A New JPCP Design

• Analysis Parameters
• Traffic
• Climate
• Material
• Design features
• Calibration

Sensitivity of Cracking & Faulting Models to the Inputs

Conclusions
PAVEMENT ME REQUIRES COMPLEX INPUTS
Requires hundreds of design variables in six categories

Design Categories

1. General information
   • Site/project Identification
   • Analysis parameters
2. Climate (Globally available: MERRA)
3. Traffic
4. Material
5. Design features
   • Geometries, surface, & interface properties
6. Calibration

Inputs are based on a Hierarchical levels (Level 1, 2 or 3)

<table>
<thead>
<tr>
<th>Level</th>
<th>Input Values</th>
<th>Knowledge of Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Segment or Project Specific Data (AVC, WIM, vehicle counts, soil properties,</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>concrete and other material properties, etc)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Regional/Statewide Data</td>
<td>Fair</td>
</tr>
<tr>
<td>3</td>
<td>National Data, Educated Guess based on local experience</td>
<td>Poor</td>
</tr>
</tbody>
</table>

Only a handful of key inputs will significantly impact the predicted performance or design.
WAYS TO MINIMIZE THE EFFORT OF ESTABLISHING INPUTS
without loosing the accuracy of the design

1. Good default/semi-constant
   • Example: Poisson’s ratio, surface shortwave absorptivity, heat capacity

2. Correlations
   • Example: concrete strength vs stiffness; short-term strength vs long-term strength

3. Built-in grouped options
   • Example: Truck traffic classification groups, weather stations

4. Sensitivity
   • Each of the distress models is only sensitive to certain inputs

At the end, the user only needs to know a few key inputs to develop a reliable Pavement ME design.
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Conclusions
ANALYSIS PARAMETERS ARE KEY DESIGN INPUTS
but they are user defined and should be straightforward to establish

Distress threshold & Reliability (7)
KEY TRAFFIC INPUTS ARE DESIGN TRUCK TRAFFIC, GROWTH RATE AND TTC GROUPS

Design AADTT (3)

Vehicle Config. + Wheel wander (14)

Load spectrum details for single/tandem/tridem/quad over each month (16,800)

Vehicle class (10) × [VC% (1) + Growth rate (1) + Monthly adj. (12) + axles/truck (4)] + Hourly adj. (24) = 204
TRUCK FACTORS ARE DETERMINED FOR EACH TTC GROUP

<table>
<thead>
<tr>
<th>TTC Group</th>
<th>TTC Description</th>
<th>Vehicle/Truck Class Distribution (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Major single-trailer truck route (type I)</td>
<td>1.3 8.5 2.8 0.3 7.6 74.0 1.2 3.4 0.6 0.3</td>
</tr>
<tr>
<td>2</td>
<td>Major single-trailer truck route (Type II)</td>
<td>2.4 14.1 4.5 0.7 7.9 66.3 1.4 2.2 0.3 0.2</td>
</tr>
<tr>
<td>3</td>
<td>Major single- and multi-trailer truck route (Type I)</td>
<td>0.9 11.6 3.6 0.2 6.7 62.0 4.8 2.6 1.4 6.2</td>
</tr>
<tr>
<td>4</td>
<td>Major single-trailer truck route (Type III)</td>
<td>2.4 22.7 5.7 1.4 8.1 55.5 1.7 2.2 0.2 0.4</td>
</tr>
<tr>
<td>5</td>
<td>Major single- and multi-trailer truck route (Type II),</td>
<td>0.9 14.2 3.5 0.6 6.9 54.0 5.0 2.7 1.2 11.0</td>
</tr>
<tr>
<td>6</td>
<td>Intermediate light and single-trailer truck route (I)</td>
<td>2.8 31.0 7.3 0.8 9.3 44.8 2.3 1.0 0.4 0.3</td>
</tr>
<tr>
<td>7</td>
<td>Major mixed truck route (Type I)</td>
<td>1.0 23.8 4.2 0.5 10.2 42.2 5.8 2.6 1.3 8.4</td>
</tr>
<tr>
<td>8</td>
<td>Major multi-trailer truck route (Type I)</td>
<td>1.7 19.3 4.6 0.9 6.7 44.8 6.0 2.6 1.6 11.8</td>
</tr>
<tr>
<td>9</td>
<td>Intermediate light and single-trailer truck route (II)</td>
<td>3.3 34.0 11.7 1.6 9.9 36.2 1.0 1.8 0.2 0.3</td>
</tr>
<tr>
<td>10</td>
<td>Major mixed truck route (Type II)</td>
<td>0.8 30.8 6.9 0.1 7.8 37.5 3.7 1.2 4.5 6.7</td>
</tr>
<tr>
<td>11</td>
<td>Major multi-trailer truck route (Type II)</td>
<td>1.8 24.6 7.6 0.5 5.0 31.3 9.8 0.8 3.3 15.3</td>
</tr>
<tr>
<td>12</td>
<td>Intermediate light and single-trailer truck route (III)</td>
<td>3.9 40.8 11.7 1.5 12.2 25.0 2.7 0.6 0.3 1.3</td>
</tr>
<tr>
<td>13</td>
<td>Major mixed truck route (Type III)</td>
<td>0.8 33.6 6.2 0.1 7.9 26.0 10.5 1.4 3.2 10.3</td>
</tr>
<tr>
<td>14</td>
<td>Major light truck route (Type I)</td>
<td>2.9 56.9 10.4 3.7 9.2 15.3 0.6 0.3 0.4 0.3</td>
</tr>
<tr>
<td>15</td>
<td>Major light truck route (Type II)</td>
<td>1.8 56.5 8.5 1.8 6.2 14.1 5.4 0.0 0.0 5.7</td>
</tr>
<tr>
<td>16</td>
<td>Major light and multi-trailer truck route</td>
<td>1.3 48.4 10.8 1.9 6.7 13.4 4.3 0.5 0.1 12.6</td>
</tr>
<tr>
<td>17</td>
<td>Major bus route</td>
<td>36.2 14.6 13.4 0.5 14.6 17.8 0.5 0.8 0.1 1.5</td>
</tr>
</tbody>
</table>

ESALs/Truck

| TTC 1 | 1.69 |
| TTC 2 | 1.57 |
| TTC 3 | 1.82 |
| TTC 4 | 1.43 |
| TTC 5 | 1.90 |
| TTC 6 | 1.26 |
| TTC 7 | 1.63 |
| TTC 8 | 1.83 |
| TTC 9 | 1.16 |
| TTC 10| 1.46 |
| TTC 11| 1.85 |
| TTC 12| 1.05 |
| TTC 13| 1.55 |
| TTC 14| 0.83 |
| TTC 15| 1.04 |
| TTC 16| 1.33 |
| TTC 17| 1.03 |
REPLACING LOAD SPECTRUM WITH ESALS SHOWS NO LOSS OF ACCURACY IN DETERMINING SLAB THICKNESS


Constant ESALs, despite of different load spectrum, result in the same design thickness, if not overloaded.
REPLACING LOAD SPECTRUM WITH ESALS SHOWS NO LOSS OF ACCURACY IN DETERMINING SLAB THICKNESS

Overload Case

ESALs are much less accurate traffic inputs, when there is overloading.

Figure from Jeffery Roesler (2008) Characterizing Traffic for Rigid Pavements in Illinois, North Central MEPDG User’s Group meeting, Ames, IA.
### THREE OPTIONS FOR CLIMATIC INPUTS

1. Drop-down options for major US and Canadian cities

#### Hourly climatic parameters (6)

<table>
<thead>
<tr>
<th>Date/Time</th>
<th>Temperature (deg F)</th>
<th>Wind Speed (mph)</th>
<th>Sunshine (%)</th>
<th>Precipitation (in.)</th>
<th>Humidity (%)</th>
<th>Water Table (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 1/95</td>
<td>81</td>
<td>3</td>
<td>100</td>
<td>0</td>
<td>82</td>
<td>10</td>
</tr>
<tr>
<td>12:00 AM</td>
<td>81</td>
<td>3</td>
<td>100</td>
<td>0</td>
<td>82</td>
<td>10</td>
</tr>
<tr>
<td>1:00 AM</td>
<td>81</td>
<td>3</td>
<td>100</td>
<td>0</td>
<td>82</td>
<td>10</td>
</tr>
<tr>
<td>2:00 AM</td>
<td>81</td>
<td>3</td>
<td>100</td>
<td>0</td>
<td>82</td>
<td>10</td>
</tr>
<tr>
<td>3:00 AM</td>
<td>81</td>
<td>3</td>
<td>100</td>
<td>0</td>
<td>82</td>
<td>10</td>
</tr>
<tr>
<td>4:00 AM</td>
<td>81</td>
<td>3</td>
<td>100</td>
<td>0</td>
<td>82</td>
<td>10</td>
</tr>
<tr>
<td>5:00 AM</td>
<td>81</td>
<td>3</td>
<td>100</td>
<td>0</td>
<td>82</td>
<td>10</td>
</tr>
<tr>
<td>6:00 AM</td>
<td>81</td>
<td>3</td>
<td>100</td>
<td>0</td>
<td>82</td>
<td>10</td>
</tr>
<tr>
<td>7:00 AM</td>
<td>81</td>
<td>3</td>
<td>100</td>
<td>0</td>
<td>82</td>
<td>10</td>
</tr>
<tr>
<td>8:00 AM</td>
<td>81</td>
<td>3</td>
<td>100</td>
<td>0</td>
<td>82</td>
<td>10</td>
</tr>
</tbody>
</table>

#### Climate station

- Key West, FL (12936)

#### Error Log

- None
OPTION 2. WEATHER FILES FOR 2514 LTTP PROJECTS
From LTTP InfoPave (US and Canada only)
OPTION 3. MAKE WEATHER FILES BASED ON NASA MERRA DATA
Also from LTTP InfoPave (available soon worldwide)

Select Location in ~30 mile x ~40 mile grids

Download No-gap hourly Precipitation, Temperature, Wind, Sunshine, & Relative humidity since 1979

Select Date Range:
- From: 01/01/2005
- To: 12/31/2015

Fill the data in Pavement ME
ONLY SEVEN INPUTS ARE REQUIRED FOR PCC

The users only need to determine thickness, CTE, strength, mix properties, and curing method (7).
MATERIAL PROPERTIES UPDATE HOURLY WITH TIME AND CLIMATE

Typical unbound materials are provided in groups; the only user inputs are thickness and resilient modulus.

Semi-constants (2)

Good defaults or insensitive
Design features (5):
- Joint spacing
- Dowels
- Widen lanes
- Shoulder type
- Sealant type

These are not design features, but inherent property of the material or construction (4):
- Base friction
- Base erodibility
- Built-in gradient
- Surface shortwave absorptivity

There is no such thing as “bad” built-in gradient or CTE. We just have to design around them.
PAVEMENT ME ALLOWS AGENCIES TO DEVELOP AND USE LOCAL CALIBRATION COEFFICIENTS

You can save your local calibration coefficients as default or restore the national as default at one click
However, using Pavement ME result in ~2-3 in thinner JPCPs when compared to the AASHTO 93 guide.
THREE NATIONAL CALIBRATIONS FOR NEW JPCP SO FAR
Most JPCP designs have been done using the 2\textsuperscript{nd} Calibration

<table>
<thead>
<tr>
<th>Cal. 1</th>
<th>Cal. 2 (NCHRP 1-40D)</th>
<th>Cal. 2.5 (NCHRP 20-07 Task 288)</th>
<th>Cal. 3 (NCHRP 20-07 Task 327)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(NCHRP 1-37)</td>
<td>• Models updated</td>
<td>• To correct CTE testing</td>
<td>• To validate Task 288</td>
</tr>
<tr>
<td></td>
<td>• Cal. database expanded</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- MEPDG 0.7               - MEPDG 1.0 - Pavement ME 2.1
- 2004                   - 2007

Pavement ME 2.2          August, 2015
Impact of New Global Calibration

- Version 2.2 new global calibration for JPCP and CRCP should not result in significantly different designs on average since the same field sections with the same performance trends were used.
- Of course, some designs will be a little thicker and some thinner due to variations involved.
Therefore, Pavement ME 2.2 predicts more or less cracking/thicker or thinner design depending on whether T-D or B-U damage dominates.
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Conclusions
## DECREASE OF CTE IMPACTS TOP-DOWN AND BOTTOM-UP DAMAGE IN DIFFERENT AMOUNTS

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pit (Mu et al. 2011)</td>
<td>Climate, Jt spacing, Base type, Strength, Thickness, Traffic, Edge support, CTE</td>
<td>Thickness, Strength, CTE, Traffic</td>
<td>CTE, Strength, Asphalt base, Climate, Unit weight, Poisson's, Thermal conductivity</td>
<td>Strength, Thickness, Jt spacing, Width, CTE, Unit weight, Poisson's, Thermal conductivity</td>
</tr>
<tr>
<td>OK State (Ley et al. 2012)</td>
<td>Climate, Jt spacing, Base type, Strength, Thickness, Traffic, Edge support, CTE</td>
<td>CTE, Strength, Asphalt base, Climate</td>
<td>Strength, Thickness, Jt spacing, Width, CTE, Unit weight, Poisson's, Thermal conductivity</td>
<td>Strength, Thickness, Jt spacing, Slab width, CTE, Traffic, Edge support, Climate, Base support</td>
</tr>
<tr>
<td>Iowa State (Ceylan et al. 2013)</td>
<td>Climate, Jt spacing, Base type, Strength, Thickness, Traffic, Edge support, CTE</td>
<td>CTE, Thickness, Jt spacing, Traffic</td>
<td>Dowel Dia, CTE, Base, Subgrade, Climate</td>
<td>Dowel Dia, CTE, Base Erod, Traffic, Jt spacing, Temperature, Thickness, Climate</td>
</tr>
</tbody>
</table>

| Joint Faulting | Dowel Dia, Thickness, CTE, Base Erod, Traffic, Wet days, Jt spacing, CTE | CTE, Dowel Dia | Edge support, Dowel Dia, CTE, Thickness, Jt spacing | Dowel Dia, (-), CTE, (+), Base Erod, (+), Traffic, Jt spacing, Temperature, Thickness, Climate |

\[ \text{IRI} = \text{Function (cracking, faulting, spalling, site factor)} \]

**Notes:**
1. Grey indicates semi-constant values
2. (+)/(-) indicates the sign of the tangential slope of \( \Delta (\text{Distress}) / \Delta (\text{parameter}) \)
SUMMARY

1. Only a handful (10 or less) of design inputs greatly impact a new JPCP design, which includes:
   - Strength (-)
   - Thickness (-)
   - Jt spacing (+)
   - Slab width (-)
   - CTE (+)
   - Traffic (+)
   - Edge support (-)
   - Dowel diameter (-)
   - Climate (n/a)
   - Base type (n/a)

   (+)/(-) indicates the sign of the tangential slope of $\Delta$ (Distress) / $\Delta$ (parameter)

2. A Pavement ME run can be established without the loss of accuracy by only determining these most sensitive inputs and leaving the others as default.

3. The effort required to establish the inputs for a Pavement ME run is not significantly greater than that for a AASHTO 1993 design.
Thank You
& Any Questions?

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