Sensitivity to Pavement ME Input Values
(Version 2.5.4)

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Major Pavement Design Input Factors – A lot of moving parts in pavement performance prediction

- Traffic
- Subgrade
- Climate Effects
- Material Properties
Understanding the Impact of Input Variability on Pavement Design

• Many design input factors are estimated
  • Traffic
  • Climatic factors
• Others are measured, but may not be comprehensively representative of site conditions
  • Subgrade support, per CBR, Mr, or other location specific sampling technique
  • Material properties
• The accuracy of estimates are often not verified
Background for Information Presented

• Study Objective: Assessment of feasibility of using a single 50 gyration asphalt base course for all PennDOT projects

• Utilized asphalt mix E* values from Table 9.5 of PennDOT Pavement ME Design User Input Guide

• Considered the range of E* values for mixes available for other layers in asphalt pavement designs

• Considered the range of traffic levels, in-state climate conditions, and subgrade conditions
Primary Factors in ‘86 and ‘93 Guides

• Traffic
• Subgrade support
• Selection of reliability
Additional ME Factors

- More detailed input information, including
  - Improved climate modeling
  - Improved subgrade and aggregate characterization
- Viscoelastic asphalt material characterization
  - Temperature effects
  - Load Speed (test frequency)
  - Mixture properties
## Study Traffic Levels Considered

<table>
<thead>
<tr>
<th>Traffic</th>
<th>Category</th>
<th>Two-Directional AADTT</th>
<th>Vehicle Class Distribution</th>
<th>Axle Load Distribution Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low</td>
<td>700</td>
<td>Minor Arterials, Collectors, and Recreational (PA TPG5 to 10)</td>
<td>PA Statewide Typical</td>
</tr>
<tr>
<td>2</td>
<td>Medium</td>
<td>2,308</td>
<td>Other Principal Arterial (PA TPG 3 &amp; 4)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Heavy</td>
<td>14,020</td>
<td>Urban Principal Arterial-Interstate (PA TPG 1)</td>
<td></td>
</tr>
<tr>
<td>Subgrade</td>
<td>Type</td>
<td>$M_r$ (psi)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>---------------</td>
<td>-------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>RMS014-A6</td>
<td>6,200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>RMS025-A24</td>
<td>20,400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Stabilized</td>
<td>50,000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ME Analysis Parameters @ 90% Reliability, for example

• Roughness, IRI - 172 in./mile
• Total Rut Depth - 0.5”
• Fatigue Cracking - 25% of lane area
• Low Temperature Cracking - 1,000’ per lane mile
• Top Down and Longitudinal Cracking - is not used at this time
Pavement Section Variation Used, High Traffic Level

PE 2019
## Range of Pavement Thickness

<table>
<thead>
<tr>
<th>Traffic Level</th>
<th>Wearing</th>
<th>Binder</th>
<th>25mm AC Base</th>
<th>Agg. Subbase</th>
<th>Total AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>2”</td>
<td>2.5 – 3.5”</td>
<td>3 – 4”</td>
<td>6”</td>
<td>7.5 – 9.5”</td>
</tr>
<tr>
<td>Medium</td>
<td>2”</td>
<td>3 – 4”</td>
<td>3.5 – 4.5”</td>
<td>6”</td>
<td>8.5 – 10.5”</td>
</tr>
<tr>
<td>High</td>
<td>4 – 5”</td>
<td>5 – 6”</td>
<td>6”</td>
<td>11 – 13”</td>
<td></td>
</tr>
</tbody>
</table>
So, what is evident?

• How is a pavement design recommendation sensitive to input selection?

• Typical Relationships
  • Traffic volume
  • Subgrade support

• Additional material property different from AASHTO “93
  • Specific material properties, ie. Visoelastic behavior
    • Climate as it affects AC stiffness
    • Load Speed
Effect of Subgrade on Fatigue Prediction

![Fatigue cracking graph](image.png)

- Low Traffic, Subgrade MR 6,200 psi
- Low Traffic, Subgrade MR 50,000 psi
- Medium Traffic, Subgrade MR 20,400 psi
- Heavy Traffic, Subgrade MR 6,200 psi
- Low Traffic, Subgrade MR 20,400 psi
- Medium Traffic, Subgrade MR 6,200 psi
- Medium Traffic, Subgrade MR 50,000 psi
- Heavy Traffic, Subgrade MR 20,400 psi
Viscoelastic Asphalt Material Properties

- PA asphalt mix stiffness
Excerpt from Table 9.5 for 25 mm Base Mixes

<table>
<thead>
<tr>
<th>Mix ID</th>
<th>Temperature (°F)</th>
<th>Dynamic Modulus ($E^*$) in psi at Different Testing Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.1 Hz</td>
</tr>
<tr>
<td>Mix6 25mm WMA Base</td>
<td>14</td>
<td>2,483,674</td>
</tr>
<tr>
<td>PG 64-22 ESAL Range (0.3 to &lt;3M) Ndesign = 75</td>
<td>40</td>
<td>1,384,881</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>352,626</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>79,064</td>
</tr>
<tr>
<td></td>
<td>130</td>
<td>32,324</td>
</tr>
<tr>
<td>Mix17 25mm HMA Base</td>
<td>14</td>
<td>1,863,151</td>
</tr>
<tr>
<td>PG 64-22 ESAL Range (&lt;0.3M) Ndesign = 50</td>
<td>40</td>
<td>865,581</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>225,734</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>64,406</td>
</tr>
<tr>
<td></td>
<td>130</td>
<td>29,739</td>
</tr>
</tbody>
</table>
Master Curves of Dynamic Modulus for 25 mm PennDOT Base Mixes
E* for Base Mixes in PennDOT Materials Catalog as a Function of Loading Frequency
PA Climate Effect on Asphalt Properties

• Coldest in state vs. Warmest in state
  • Bradford
    • Low temperature - Typically 10 to -10
    • high temperature - Typically 90-95 degrees F
  • Reading
    • Low temperature - 0 to-20 degrees F
    • high temperature - Typically 80-85 degrees F

• Reflected as Impact on material properties
  • Low temperature increases AC stiffness
  • High temperature decreases AC stiffness
PA Climate Effect on Asphalt Properties

• Bradford

![Diagram](image1)

• Reading

![Diagram](image2)
E* values: Reading #4, Bradford # 5
• Traffic Level has a significant affect on pavement thickness!
Example Sensitivity of Fatigue Crack Prediction for a Single Mix at High Traffic Level
Medium Traffic Level, Fatigue Cracking Sensitivity

Medium Traffic, Mix 17 N=50, gpy 75%
Medium Traffic, Mix 17 N=50, gpy 90%
Medium Traffic, Level 3 75%
Medium Traffic, Level 3 90%
Performance Limit

PE 2019
At low traffic level, fatigue cracking is relatively insensitive, even though the tolerance level is higher.
Take a look at IRI affect on thickness at three traffic levels
Example IRI Prediction for a single mix at High traffic level

![Graph showing the relationship between Total AC Thickness (in) and Terminal IRI (in/mile). The graph includes lines representing different traffic conditions and mixtures, with a performance limit indicated by a red line.](image-url)
Medium traffic level IRI prediction
Contrast predictions for low traffic level
Reliability Impact on thickness at High Traffic Level
Significance to Design Thickness

• At lowest thickness level (7.5”), the fatigue cracking threshold is distinguished by reliability level (90 vs 75)
  • R=75% is below threshold,
  • R=90% does comply

• For R=90% one additional inch is required to comply with the fatigue cracking threshold - equates to about 130% increase in traffic loading

• At 2 additional inches (9.5”) the fatigue cracking performance is clustered below the threshold value - 270% increase in traffic loading
Traffic Impact on Rutting, Low - High
AC Rutting at Warm and Cold Temperature Extremes in PA
Thermal cracking predicted at Bradford (cold) vs. Reading (warm) climates, not sensitive to mix E*
Effect of Reliability
Example, 50 gyration mix effect on fatigue
Reliability effect on IRI

![Graph showing the effect of reliability on IRI]
Reliability effect on Rutting
Observation Regarding the Impact of Reliability

• Reliability has a significant influence on the recommended pavement thickness
• There is no distinction for reliability by data input level, even though:
  • Level 1 includes greater detail, which should improve the reliability of the model
  • vs. Level 3 uses generic input with no specific refinement of the model
• Lower level reliability (50%) is recommended for lower volume roads, although investment cycles for these roads is typically longer than for higher volume roads
Observations

- Traffic and subgrade support are still significant,
- At hi traffic level, predicted differences in performance are significant
- Climate effect can have significant impact on AC material properties
- Specific AC mix properties can have significant impact
  - Loading rate
  - AC binder stiffness
  - Effect of aggregate and binder sources for the same class of material, i.e., 25 mm base
- Impact of Reliability associated with data input level, detailed vs. national average
- Reliability impact on predicted pavement performance
- Other relationships between other project specific factors
Questions?