Implementation of the MSCR Test and Specification: Questions, Clarifications, and Emphasis

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• Acknowledgments
  • Federal Highway Administration
      • Michael Arasteh, AOTR
      • John Bukowski, Tom Harman, Matt Corrigan, Jeff Withee, Tim Aschenbrener, Jason Dietz
  • Member Companies of the Asphalt Institute
    • Technical Advisory Committee
• MSCR Test
  • AASHTO T350

• Performance-Graded (PG) Specification using MSCR
  • AASHTO M332

• Practice for Evaluating the Elastic Behavior of Asphalt Binders Using the MSCR Test
  • Draft practice not yet sent to AASHTO for review
• Concerns/Questions/Challenges
  • Inconsistent implementation by specifying agencies
  • Grade names in AASHTO M332
  • Variability of MSCR test
  • Selection of appropriate test temperature
  • Leadership/champion
  • Use of recovery-Jnr curve for evaluating elastic response
• Concerns/Questions/Challenges
  • Use and relevance of Jnr-Diff as a specification requirement
  • Use and criterion for intermediate temperature binder parameter (G*sin δ)
  • Criterion for unmodified asphalt binders (“S” grades)
  • Original DSR criterion
  • Quick QC testing on original binder
• ASTM Standard
  • Standard Specification for Performance Graded Asphalt Binder Using the Multiple Stress Creep and Recovery Test
  • Bob Kluttz (Kraton), Chair

• Negative Votes (Summary of Key Points)
  • There’s some confusion on the language that a few folks are interpreting to mean binders must be modified. Action - reword Section 5.7.
  • There’s still fear of grade proliferation. Is there any solid data from any of the implementing states or UPGs to naysay this?
• Negative Votes (Summary of Key Points)
  • AASHTO T350 and ASTM D7405 are different (now fixed)
  • There’s still unhappiness with 5000 kPa for S and 6000 for all other grades.
  • And the one that drew the most flack—The R3.2 vs. Jnr3.2 curve for selecting R3.2 criteria. The implication from the language in the spec is that the figure is a yes/no determination on whether or not a binder is modified. Action – needs clarification (currently using M332 language).
• Negative Votes (Summary of Key Points)
• Use of recovery-Jnr curve for evaluating elastic response
  • Some agencies are using the curve as-is
  • Some agencies are specifying a minimum Rec-3.2 value
    • Kentucky has a requirement of Rec-3.2 ≥ 60% for their PG 76-22 asphalt binders (M320) when tested at 64°C
      • Replaces ER
  • Rec-3.2 is determining factor
  • Is curve even needed?
    • Replacement for PG Plus Tests
    • Maximum phase angle
• Use of recovery-Jnr curve for evaluating elastic response

\[ y = -64.872x^2 + 194.09x - 59.72 \]

\[ R^2 = 0.9946 \]
• Use of recovery-Jnr curve for evaluating elastic response
• Use of recovery-Jnr curve for evaluating elastic response
• Selection of appropriate test temperature
  • “Standard” environmental temperature
    • Selection of environmental temperature based on LTPPBind 3.1
    • Guidance on the appropriate assumptions needed
      • Similar to AMPT Flow Number
    • Locations that choose “standard” temperature that is different than environmental temperature
      • e.g., choosing 64°C when LTPPBind would suggest that the climate is 58°C
  • Southeastern states that use 67°C as standard temperature
• Selection of appropriate test temperature
  • Standard environmental temperature with grade bumping (higher traffic)

• Standard environmental temperature with grade dumping (RAP and RAS use)
  • Use of a softer grade due to RAP and/or RAS use
  • What temperature for testing?
    • i.e., PG 58-28 is used in a RAP-RAS mix in a 64°C climate
    • Test the PG 58-28 at environmental temperature (64°C)? If so what grade would this be ("R"?) Or test as PG 58S-28 (at 58°C)?
• Original DSR Criterion
  • Testing at environmental temperature with no change in criterion
  • H, V, and E grades will easily meet criterion at environmental grade
    • $G^*/\sin \delta \geq 1.00$ kPa
• Criterion for unmodified asphalt binders ("S" grades)
  • Original criterion was $J_{nr}$ at 3.2 kPa shear stress ($J_{nr}-3.2) \leq 4.0 \text{ kPa}^{-1}$
  • Changed to $\leq 4.5 \text{ kPa}^{-1}$ based on recommendation from Asphalt Binder ETG
    • Asphalt Institute report dated 26 April 2013
    • Presentation at Asphalt Binder ETG Meeting in May 2013 (Raleigh, NC)
  • Concern that change still allows some currently acceptable unmodified asphalt binders (M320) to fail M332.
• Criterion for unmodified asphalt binders (“S” grades)

Table 15: Calculated Values of Jnr-3.2 at AASHTO T315 $T_c$ and $G^*/\sin \delta$ at AASHTO TP70 $T_c$

<table>
<thead>
<tr>
<th></th>
<th>Figure 1 (Source A, PG 64-22)</th>
<th>Figure 2 (AI Miscellaneous)</th>
<th>Figure 4 (SHRP MRL)</th>
<th>Figure 31 (SHRP MRL, Multiple Labs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jnr-3.2 at AASHTO T315 $T_c$ (where $G^*/\sin \delta = 2.20$ kPa)</td>
<td>4.70 kPa$^{-1}$</td>
<td>4.65 kPa$^{-1}$</td>
<td>4.52 kPa$^{-1}$</td>
<td>4.65 kPa$^{-1}$</td>
</tr>
<tr>
<td>$G^*/\sin \delta$ at AASHTO TP70 $T_c$ (where Jnr-3.2 = 4.00 kPa$^{-1}$)</td>
<td>2.53 kPa</td>
<td>2.52 kPa</td>
<td>2.46 kPa</td>
<td>2.52 kPa</td>
</tr>
<tr>
<td>$G^*/\sin \delta$ at T350 $T_c$ (where Jnr-3.2 = 4.50 kPa$^{-1}$)</td>
<td>2.285 kPa</td>
<td>2.267 kPa</td>
<td>2.209 kPa</td>
<td>2.267 kPa</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.257 kPa</td>
<td></td>
</tr>
</tbody>
</table>
• Use and relevance of Jnr-Diff as a specification requirement
  • Indicative of stress-sensitive binders
  • Problem for some current formulations
  • Not a problem for the majority of modified binders
  • Is it needed?
Use and relevance of Jnr-Diff as a specification requirement

<table>
<thead>
<tr>
<th>ID</th>
<th>Grade</th>
<th>Temp. (°C)</th>
<th>Jnr-3.2 (kPa⁻¹)</th>
<th>Rec-3.2 (%)</th>
<th>Jnr-Diff (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>PG 76-28</td>
<td>64</td>
<td>0.748</td>
<td>32.6</td>
<td>1157</td>
</tr>
<tr>
<td>B</td>
<td>PG 70-22ER</td>
<td>64</td>
<td>0.311</td>
<td>59.7</td>
<td>20</td>
</tr>
<tr>
<td>C</td>
<td>PG 64-28NV</td>
<td>58</td>
<td>0.448</td>
<td>57.2</td>
<td>42</td>
</tr>
<tr>
<td>D</td>
<td>PG 64-28PM</td>
<td>58</td>
<td>0.227</td>
<td>73.1</td>
<td>14</td>
</tr>
<tr>
<td>E</td>
<td>PG 58-34PM</td>
<td>58</td>
<td>0.532</td>
<td>79.0</td>
<td>38</td>
</tr>
</tbody>
</table>
• Use and relevance of Jnr-Diff as a specification requirement

The curve stops at Jnr-3.2 = 2.00 kPa⁻¹ and 0.1 kPa⁻¹. Jnr-3.2 values greater than 2.00 kPa⁻¹ are not required to have any minimum Rec-3.2 value. Jnr-3.2 values less than 0.10 kPa⁻¹ are required to have a minimum Rec-3.2 value of 55%.
• Use and relevance of Jnr-Diff as a specification requirement
• Use and relevance of Jnr-Diff as a specification requirement
• Variability of MSCR test
  • Continued expressed concerns about variability in Jnr and Rec
• WCTG Data Set
  • Higher test temperature
  • Higher applied shear stress
• Variability of MSCR test
• WCTG Data Set

<table>
<thead>
<tr>
<th>Test</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Average</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ductility, Unaged</td>
<td>21.8%</td>
<td>6.3%</td>
<td>11.8%</td>
<td>10.8%</td>
</tr>
<tr>
<td>Ductility, RTFO</td>
<td>17.4%</td>
<td>8.2%</td>
<td>13.9%</td>
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</tr>
<tr>
<td>Toughness, Unaged</td>
<td>23.6%</td>
<td>4.6%</td>
<td>14.9%</td>
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</tr>
<tr>
<td>Tenacity, Unaged</td>
<td>49.0%</td>
<td>8.9%</td>
<td>21.9%</td>
<td>17.9%</td>
</tr>
<tr>
<td>Jnr, 3.2 kPa @ PG Temp.</td>
<td>57.0%</td>
<td>5.2%</td>
<td>27.5%</td>
<td>29.1%</td>
</tr>
<tr>
<td>Jnr, 3.2 kPa @ PG - 6 °C Temp.</td>
<td>51.1%</td>
<td>6.9%</td>
<td>24.3%</td>
<td>23.9%</td>
</tr>
<tr>
<td>Jnr, 10 kPa @ PG Temp.</td>
<td>878.4%</td>
<td>52.0%</td>
<td>137.1%</td>
<td>78.7%</td>
</tr>
<tr>
<td>Jnr, 10 kPa @ PG - 6 °C Temp.</td>
<td>237.3%</td>
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<tr>
<td>% Elastic Recovery, 25 °C</td>
<td>5.9%</td>
<td>1.0%</td>
<td>2.5%</td>
<td>2.0%</td>
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• Variability of MSCR test

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</tr>
<tr>
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<td>0.8%</td>
<td>2.5%</td>
<td>2.0%</td>
</tr>
</tbody>
</table>
• Variability of MSCR test
  • AI-Coordinated ILS
    • d2s% shown for between lab (reproducibility)

<table>
<thead>
<tr>
<th>ILS</th>
<th>Multi-Lab Rec-3.2</th>
<th>Multi-Lab Jnr-3.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETG 2009</td>
<td>18.1%</td>
<td>22.0-42.6%</td>
</tr>
<tr>
<td>NEAUPG 2010</td>
<td>18.7%</td>
<td>33.7%</td>
</tr>
<tr>
<td>SEAUPG 2011</td>
<td>9.8%</td>
<td>28.0%</td>
</tr>
<tr>
<td>NEAUPG 2012</td>
<td>7.6%</td>
<td>33.0%</td>
</tr>
<tr>
<td>PCCAS 2013</td>
<td>13.8%</td>
<td>36.8%</td>
</tr>
</tbody>
</table>
• Variability of MSCR test
  • AMRL PSP
• Variability of MSCR test
  • AMRL PSP
Implementation of the MSCR Test and Specification

- Variability of MSCR test
  - AMRL PSP

![Graph showing variability of MSCR test with AMRL PSP values](image)
• Variability of MSCR test
  • PCCAS ILS (2013)

<table>
<thead>
<tr>
<th>Test</th>
<th>Single Operator Precision</th>
<th>Acceptable Range of Two Test Results (d2s%)</th>
<th>Multilaboratory Precision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elastic Recovery (RTFO) at 25°C</td>
<td>5.6%</td>
<td>2013 PCCAS ILS</td>
<td>9.2%</td>
</tr>
<tr>
<td>R&amp;B Softening Point</td>
<td>2.8%</td>
<td></td>
<td>7.7%</td>
</tr>
<tr>
<td>Ductility (Original) at 4°C</td>
<td>17.9%</td>
<td></td>
<td>75.0%</td>
</tr>
<tr>
<td>Ductility (RTFO) at 4°C</td>
<td>19.5%</td>
<td></td>
<td>95.1%</td>
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<td>Tenacity at 25°C</td>
<td>17.9%</td>
<td></td>
<td>30.0%</td>
</tr>
</tbody>
</table>

MSCR Rec-3.2  8.0%  17.3%
• Use and criterion for intermediate temperature binder parameter \((G\sin \delta)\)
  
• Not specifically concern with MSCR
  
• Use of \(G\sin \delta\) as intermediate parameter
  
• Change to environmental temperature makes matters worse
  
  • PG 76-22 would be tested at 31°C and \(G\sin \delta\) would have to be \(\leq 5000\) kPa
  
  • PG 64V-22 would be tested at 25°C and \(G\sin \delta\) would have to be \(\leq 6000\) kPa
  
• Shouldn’t criterion change for each grade (H, V, and E)?
• Use and criterion for intermediate temperature binder parameter ($G \times \sin \delta$)

For PG 76-22 Grades

Maximum slope = 0.066

Maximum slope = -0.075

5000 kPa

2.2 kPa

76C 31C 25C
• Quick QC Testing on Original Binder
  • Terminal labs may not have RTFO oven
  • Need to validate presence of modifier and verify grade before shipping
  • MSCR testing on original binder?
  • Use of phase angle as surrogate?
Implementation of the MSCR Test and Specification

• Grade names in AASHTO M332
  • Acceptance of letter designation for traffic
  • Need high temperature (environmental) as part of the grade name to know appropriate test temperature
• PG designation is still appropriate
  • Still a Performance Graded asphalt binder
    • Even more so since Jnr is better correlated to rutting distress than G*/sin δ for both modified and unmodified binders
• Education for Designers, truck drivers
• Confusion of E and V (similar sounds) when ordering
  • Consider “X” instead of “E”?
• Inconsistent implementation by specifying agencies
  • We don’t have a rutting problem so why do we need a better high temperature parameter?
  • Every M320 grade may not equate to a distinct M332 grade
    • the current polymer loading in a PG 70-22 and PG 76-22 may be high enough that both grade to a PG 64V-22
### Implementation of the MSCR Test and Specification

#### MTE Rutting Study: Hamburg WI E10 Fine Mix

<table>
<thead>
<tr>
<th>PG Grade (M320)</th>
<th>PG Grade (MP19)</th>
<th>Test Temp, ℃</th>
<th>Jnr-3.2 at Test Temp, kPa^(-1)</th>
<th>Rec-3.2, %</th>
<th>HWT Rut Depth at 10,000 Passes, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>70-22</td>
<td>n/a</td>
<td>75</td>
<td>5.74</td>
<td>0.5</td>
<td>13.2</td>
</tr>
<tr>
<td>64-22</td>
<td>64-22S</td>
<td>64</td>
<td>3.40</td>
<td>3.4</td>
<td>7.1</td>
</tr>
<tr>
<td>70-22</td>
<td>70-22S</td>
<td>70</td>
<td>2.92</td>
<td>1.5</td>
<td>5.1</td>
</tr>
<tr>
<td>70-22</td>
<td>64-22H</td>
<td>64</td>
<td>1.35</td>
<td>4.4</td>
<td>3.6</td>
</tr>
<tr>
<td>76-22</td>
<td>64-22E</td>
<td>64</td>
<td>0.24</td>
<td>55.8</td>
<td>1.7</td>
</tr>
<tr>
<td>82-22</td>
<td>64-22E</td>
<td>64</td>
<td>0.08</td>
<td>78.5</td>
<td>1.6</td>
</tr>
</tbody>
</table>
• Leadership/champion
  • Implementation belongs to everyone
    • PG system had leaders in all areas
      • Researchers
        • Dr. Tom Kennedy, A-001 Research Program Leader
      • Users
        • FHWA (implementation funding and technology transfer)
        • Lead States
      • Industry
        • Expert Task Group
        • Suppliers
  • Need leaders in user agencies, industry
• **Suggestions for Path Forward**
  • Need to repackage message
    • What should have been done as PG system was implemented was to change high temperature criterion as grade was bumped (due to traffic)
    • Need to change criterion rather than test temperature
    • Recognize that this is a major specification change instead of just focusing on MSCR as a new test
      • Truer to concept of a performance-based specification
      • Next step in evolution of specification
Thanks!