Advancements in Characterization of Polymer Modified Asphalts

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The Fifth Mexican Asphalt Congress
Cancun, Mexico, August 27-31, 2007
Outline

- Need for Modified Asphalts
- Are modified asphalts better than conventional asphalts
- Limitations of ASTM and Superpave technologies
- New procedures for evaluating polymer modified asphalts
  - Rutting Resistance – MSCR test
  - Fatigue Resistance
- Final Remarks
The Need for Asphalt Modification

- Limitations of Oil Refining Practice
  - Asphalt is only one of many products
  - Little incentive to improve quality

- Physical Nature of Asphalt
  - Very sensitive to temperature
  - Soft at high temperature / Brittle at low temperatures

- Increased heavy traffic (trucks) volumes

- Some Premature Pavement Failures
The Need for Modified Asphalts

32 PG grades, 15 Widely used, 9 Modified
Expected growth of truck traffic on the National Highway System.
Source: FHWA office of asset management.

1993 - 2002
Truck Traffic Increased by 33%, Lane miles by 2%
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Enhanced Performance of HMA by Use of Polymer Modification

(H. Von Quintus – AMAP Meeting 2/2004)

3 times higher rut depth for unmodified
Enhanced Performance of HMA by Use of Polymer Modification

(H. Von Quintus – AMAP Meeting 2/2004)

Findings
Field & laboratory investigations of PMA mixes suggest:
- Enhanced Performance
  - 25 to 100 % increase in service life
  - 3 to 10 years increase in service life
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- Final Remarks
Specifications & Tests of Modified Bitumen / First Generation

- AASHTO-AGC-ARTBA-~ 1990- Task Force 31 - Polymer Modified Asphalts
- ASTM Standards:
  - Table 1 - Styrene Block Copolymers
  - Table 2 - Styrene Butadiene Rubber Latexes or Neoprene Latex
  - Table 3 - Ethylene Vinyl Acetate or Polyethylene
First Generation Specifications
Pre- PG grading

Task Force 31: Polymer Modified Asphalts-

Table 2

Styrene Butadiene Rubber Latexes or Neoprene Latex

<table>
<thead>
<tr>
<th>Property</th>
<th>2-A</th>
<th>2-B</th>
<th>2-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetration, 77 F, 100 g, 5 sec</td>
<td>min</td>
<td>100</td>
<td>70</td>
</tr>
<tr>
<td>Viscosity, 140 F, Poises</td>
<td>min</td>
<td>800</td>
<td>1600</td>
</tr>
<tr>
<td>Viscosity, 275 F, cSt</td>
<td>max</td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td>Ductility, 39.2, 5 cpm, cm</td>
<td>min</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Flash Point, F</td>
<td>min</td>
<td>450</td>
<td>450</td>
</tr>
<tr>
<td>Solubility, %</td>
<td>min</td>
<td>99.0</td>
<td>99.0</td>
</tr>
<tr>
<td>Toughness, 77 F, 20 ipm, in-lbs</td>
<td>min</td>
<td>75</td>
<td>110</td>
</tr>
<tr>
<td>Tenacity, 77 F, 20 ipm, in-lbs</td>
<td>min</td>
<td>50</td>
<td>75</td>
</tr>
</tbody>
</table>

**RTFOT or TFOT Residue:**

<table>
<thead>
<tr>
<th>Property</th>
<th>2-A</th>
<th>2-B</th>
<th>2-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity, 140 F, Poises</td>
<td>max</td>
<td>4000</td>
<td>8000</td>
</tr>
<tr>
<td>Ductility Retention, 39.2 F, 5cpm, cm</td>
<td>min</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Toughness, 77 F, 20 ipm, in-lbs</td>
<td>min</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tenacity, 77 F, 20 ipm, in-lbs</td>
<td>min</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Elastic Recovery - Questionable Value

USA Ductility & Australian Elastometer
Toughness and Tenacity
Not very scientific!

Calculation of Toughness and Tenacity
Typical Stress - Strain Curve for Rubberized Asphalt

TOUGHNESS = Area Under Curve ABCD
TENACITY = Area Under Curve CDE
Elastic Recovery – Many Different Methods (MD, NJ, NY, RI, PA & Port Authority)

<table>
<thead>
<tr>
<th>Specs</th>
<th>AASHTO T301</th>
<th>ASTM D6084</th>
<th>LC25-005 Quebec</th>
<th>ASTM D6084 PennDOT</th>
<th>ASTM D6084 NJDOT</th>
<th>ASTM D6084 Mod.AASHTO T301 - NY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Elongation</td>
<td>200 mm</td>
<td>100 mm +/- 25mm</td>
<td>200 mm</td>
<td>100 mm +/- 25mm</td>
<td>2 in/min</td>
<td>100 mm</td>
</tr>
<tr>
<td>Sample Hold Time</td>
<td>5 min</td>
<td>Immediately Cut</td>
<td>5 min</td>
<td>Immediately Cut</td>
<td>90 min</td>
<td>None</td>
</tr>
<tr>
<td>Relaxation Time</td>
<td>1 hour</td>
<td>1 hour</td>
<td>1 hour</td>
<td>1 hour</td>
<td>1 hour</td>
<td>1 hour</td>
</tr>
<tr>
<td>Min. ER</td>
<td></td>
<td>40% &amp; 60%</td>
<td>60%</td>
<td>50%</td>
<td>60%</td>
<td></td>
</tr>
<tr>
<td>Clips</td>
<td>Straight</td>
<td>Straight</td>
<td>Straight</td>
<td>Straight</td>
<td>As per ASTM</td>
<td>T301-95 or 99 (as noted)</td>
</tr>
</tbody>
</table>

Mooney – NEAUPG Meeting 2005
Second Generation – SHRP - Superpave Technology

Production

Rutting

Fatigue Cracking

Thermal Cracking

Time

RV

DSR

BBR

DTT

RTFO - aging

No aging

PAV - aging
Is Superpave Applicable to Modified Asphalts?

- Superpave Plus specifications
- NCHRP 9-10 – 1996-2000
  - $G^*$ & $\sin\delta$ do not accurately characterize the rutting and fatigue performance of modified binders
  - Creep and Recovery, binder fatigue were proposed for testing modified binders
Third Generation Measuring Damage Resistance

1. Binder Rutting Resistance Using Repeated Creep
2. Binder Fatigue Resistance Using Time Sweep

Thermal Cracking  Fatigue Cracking  Permanent Deformation  (mixing & compaction)

Pavement Temperature, C

-20  20  60  135
<table>
<thead>
<tr>
<th>Binder ID</th>
<th>PG Grade</th>
<th>Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5</td>
<td>PG 58-28</td>
<td>-</td>
</tr>
<tr>
<td>B9</td>
<td>PG 58-34</td>
<td>Elvaloy</td>
</tr>
<tr>
<td>D4</td>
<td>PG 58-34</td>
<td>SBS</td>
</tr>
<tr>
<td>B7</td>
<td>PG 58-40</td>
<td>Elvaloy</td>
</tr>
<tr>
<td>C4</td>
<td>PG 64-22</td>
<td>SBS</td>
</tr>
<tr>
<td>A3</td>
<td>PG 64-28</td>
<td>SBS</td>
</tr>
<tr>
<td>B2</td>
<td>PG 64-28</td>
<td>Elvaloy</td>
</tr>
<tr>
<td>D1</td>
<td>PG 64-28</td>
<td>SB</td>
</tr>
<tr>
<td>B5</td>
<td>PG 64-34</td>
<td>Elvaloy</td>
</tr>
<tr>
<td>D2</td>
<td>PG 64-34</td>
<td>SB</td>
</tr>
<tr>
<td>D5</td>
<td>PG 64-40</td>
<td>SB</td>
</tr>
<tr>
<td>A1</td>
<td>PG 70-28</td>
<td>SBS</td>
</tr>
<tr>
<td>B4</td>
<td>PG 70-28</td>
<td>Elvaloy</td>
</tr>
<tr>
<td>C2</td>
<td>PG 70-28</td>
<td>SBS</td>
</tr>
<tr>
<td>B8</td>
<td>PG 70-28</td>
<td>Elvaloy</td>
</tr>
<tr>
<td>D6</td>
<td>PG 70-34</td>
<td>SB</td>
</tr>
<tr>
<td>B3</td>
<td>PG 76-28</td>
<td>Elvaloy</td>
</tr>
<tr>
<td>C6</td>
<td>PG 76-28</td>
<td>SBS</td>
</tr>
<tr>
<td>B6</td>
<td>PG 76-34</td>
<td>Elvaloy</td>
</tr>
</tbody>
</table>

Study for WI-DOT included 19 Binders

1 no additive

4 With SB

6 With SBS

8 with Elvaloy
Effect of Additives

A,C = SBS, B = Elvaloy, D = SB

Higher $G_v$ = Better resistance to rutting
Binder Fatigue

Third Generation Tests

Modified And Conventional Binders
Effect of Polymers on Fatigue Life – Different Pavement Layers Results @ 25 C

![Graph showing the effect of polymers on fatigue life in different pavement layers at 25 C. The x-axis represents the Wi (in kPa) and the y-axis represents the fatigue life (in cycles). The graph includes lines for asphalt, Elvaloy, SBS, and SB, each indicating the varying effects on fatigue life.](image-url)
Effect of Additives
A, C = SBS, B = Elvaloy, D = SB

Higher Np20 = Better resistance to Fatigue

Test Temp.

Best are the Reactive Polymers
Concluding Remarks

- The results show that modification with SBS and Elvaloy additives can significantly improve resistance of binders to rutting and fatigue damage.
- The effects are not being accurately captured by simply measuring $G^*$ and $\sin\delta$.
- There is critical need to use damage resistance testing to accurately predict performance and select modifiers.
Acknowledgments / Disclaimer

- Thank you for the organizing committee of the 5th Mexican Asphalt Congress for accepting paper.
- The support of Dupont to the University of Wisconsin Asphalt Research Group is greatly appreciated.
- Opinions and Conclusions are those of the researchers. They are not necessarily those of sponsors.