Performance: Neat & Modified Asphalt Mixtures

Follow up to “All PG 70-22s the Same?”, AAPT 1998

Phil Blankenship
Koch Pavement Solutions
We Are Going to Discuss...

• Project Description
• Mixture Results
  – Potential Rutting & Moisture Damage
• Project Performance as of November 2001
Cooperative Research

- Asphalt Institute
- Kentucky Transportation Cabinet
- Kentucky Transportation Center
- Various asphalt suppliers
- The Walker Company
- Koch Pavement Solutions
Question?

- Do all asphalt modification methods produce HMA mixtures that perform equally?
Research Goals

• Accomplish by...
  – Comparing the various mixtures according to potential performance
    – Rutting
    – Moisture damage
    – Low temperature (Asphalt Institute, TRR #1661)
  – Lab testing of asphalt binder & mix
  – Monitoring yearly performance
Project Description

- I-64 near Mount Sterling, KY
- 33 million ESAL’s (20-year design)
**Project Description**

- Milled & placed 38 mm (1.5 in.) dense-graded (coarse) HMA surface
- One variable (binder type)
  - PG 70-22’s with different modification methods with 64-22 (AC-20) control
98% Reliable PG at Surface

- Weather stations near project have these surface pavement temperatures:
  - 58.6 -20.8 (-20.1 air) → PG 76-22
  - 58.7 -22.9 (-21.5 air) → PG 76-28
- KY is in -22/-28 transition climate
Five Test Sections Placed in 1996

- The Walker Company constructed five, 1.5-mile PG 70-22 test sections
  - Straight-run (unmodified)
  - Chemically modified
  - SBR
  - SBS 1
  - SBS 2
- AC-20 (PG 64-22) control
Samples & Testing

- Sampled from contractor’s plant by Kentucky Transportation Cabinet
- Testing performed “blind” by:
  - Kentucky Transportation Cabinet
  - Asphalt Institute
  - Koch Pavement Solutions
Job-Mix Formula

- **Aggregate**
  - 45% Dolomite # 8’s, 35% Limestone sand, 20% Natural sand

- **Marshall design**
  - 5.5 % AC, 5.0 % voids at 75 blows
  - Similar to Superpave 9.5mm design with about 1% lower VMA

- **Evaluated in SGC at N-design = 109**
9.5-mm Nominal Mixture

Superpave Control Points

Mixture Gradation

Sieve Size (mm) Raised to 0.45 Power

% Passing

Gradation
<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Product</th>
<th>PG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AC-20 (Control)</td>
<td>64-22</td>
</tr>
<tr>
<td>2 - 3</td>
<td>Straight-Run (Crude)</td>
<td>70-22</td>
</tr>
<tr>
<td>4 - 5</td>
<td>Chemically modified</td>
<td>70-22</td>
</tr>
<tr>
<td>6 - 7</td>
<td>SBR-Latex</td>
<td>70-22</td>
</tr>
<tr>
<td>8 - 9</td>
<td>SBS 1</td>
<td>76-22</td>
</tr>
<tr>
<td>11 - 12</td>
<td>SBS 2</td>
<td>70-22</td>
</tr>
</tbody>
</table>
KY I-64, April 1997
Lab Mixture Results

Modulus & Rutting
Modulus and Rutting Tests
SST and APA
Repeated Shear Test - Frequency Sweep

Lab modulus testing
Repeated Shear Test - Frequency Sweep

Shear Frequency Sweep @ 0.01% Strain
Normalized at $T_{\text{eff}}$ (fatigue) = 28.0°C

Complex Shear Modulus ($G^*$), Pa

<table>
<thead>
<tr>
<th>Mixture</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - AC 20</td>
<td>2 - Straight Run</td>
</tr>
<tr>
<td>5 - Chemically Mod</td>
<td>7 - SBR</td>
</tr>
<tr>
<td>9 - SBS 1 (PG 76)</td>
<td>11 - SBS 2</td>
</tr>
</tbody>
</table>

Reduced Frequency, 28C, Hz
Repeated Shear Test - Constant Height

Lab rut testing
Repeated Shear Test - Constant Height

Mixture

- 1 - AC 20 (6.8% Voids)
- 2 - Straight Run (8.9% Voids)
- 5 - Chemically Mod (6.7% Voids)
- 7 - SBR (6.8% Voids)
- 9 - SBS 1 (7.0% Voids, PG 76)
- 11 - SBS 2 (5.6% Voids)

Plastic Shear Strain (rutting) vs. Cycle

$T_{\text{critical}} = 58^\circ C$

Maximum shear stress of 68 kPa
Repeated Shear Test - Constant Height

ESALs to 12.5mm Rutting

- 1 - AC 20 (6.8% Voids)
- 2 - Straight Run (8.9% Voids)
- 5 - Chemically Mod (6.7% Voids)
- 7 - SBR (6.8% Voids)
- 9 - SBS 1 (7.0% Voids, PG 76)
- 11 - SBS 2 (5.6% Voids)
<table>
<thead>
<tr>
<th>Least Potential Rutting</th>
<th>Shear Frequency Sweep mix m-value, 43°C</th>
<th>RST-Constant Height 58°C</th>
<th>RST-Constant Stress Ratio 58°C</th>
<th>GA Loaded Wheel dry at 49°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBS 1</td>
<td>SBS 2</td>
<td>SBS 2</td>
<td>SBS 1</td>
<td>SBS 1 - PASS</td>
</tr>
<tr>
<td>Chemically Modified</td>
<td>SBS 1</td>
<td>Chemically Modified</td>
<td>SBS 1</td>
<td>SBS 2 - PASS</td>
</tr>
<tr>
<td>SBS 2</td>
<td>Chemically Modified</td>
<td>Chemically Modified</td>
<td>Straight Run - PASS</td>
<td></td>
</tr>
<tr>
<td>SBR</td>
<td>AC 20</td>
<td>SBR</td>
<td>Chemically Mod. - PASS</td>
<td></td>
</tr>
<tr>
<td>AC 20</td>
<td>SBR</td>
<td>Straight Run</td>
<td>AC 20 - PASS</td>
<td></td>
</tr>
<tr>
<td>Straight Run</td>
<td>Straight Run</td>
<td>AC 20</td>
<td>SBR - FAIL</td>
<td></td>
</tr>
</tbody>
</table>
Lab Mixture Results

Moisture Damage
Moisture Damage Tests
APA, TSR, and HWT
Mixture Results
Hamburg Wheel Track Test

**Mixture**

1 - AC-20
2 - Straight Run
5 - Chemically Mod
7 - SBR
9 - SBS 1
11 - SBS 2

Deformation, mm

Wheel Passes

Stripping slope
Mixture Results
Hamburg and Asphalt Pavement Analyzer

Deformation, mm

HWT (wet, 50C)
APA (wet, 50C)

AC-20

1  2  5  7  9  11
# Mixture Results

## Summary of Lab Predicted Moisture Damage

<table>
<thead>
<tr>
<th>Asphalt</th>
<th>TSR</th>
<th>HWT wet, 50C</th>
<th>HWT Stripping Performance (passes)*</th>
<th>APA wet, 50C</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC20</td>
<td>Pass</td>
<td>Pass</td>
<td>Good</td>
<td>Pass</td>
</tr>
<tr>
<td>Straight Run</td>
<td>Pass</td>
<td>Pass</td>
<td>Good</td>
<td>Pass</td>
</tr>
<tr>
<td>Chemically Modified</td>
<td>Pass</td>
<td>4-mm max</td>
<td>Visual Stripping (Inflection Point)</td>
<td>4-mm max</td>
</tr>
<tr>
<td>SBR</td>
<td>Pass</td>
<td>Pass</td>
<td>Good</td>
<td>Fail</td>
</tr>
<tr>
<td>SBS 1</td>
<td>Pass</td>
<td>Pass</td>
<td>Good</td>
<td>Pass</td>
</tr>
<tr>
<td>SBS 2</td>
<td>Fail</td>
<td>Pass</td>
<td>Good</td>
<td>Pass</td>
</tr>
</tbody>
</table>
Conclusions in 1998
1998 Conclusions

• Did we expect all PG 70-22’s to perform the same? Not according to:
  – 4 rutting indicators show slight differences
  – 2 moisture damage tests show one mix with potential to strip

• Differences may take 5+ years to appear
1998 Conclusions

- In addition to PG testing & volumetric testing, performance related & based testing should be used to verify higher ESAL mixtures
I-64 Performance Update
I-64 Performance Update

• Project visited 1x per year
  – No differences in August 2000
  – No large lab performance differences in stripping & rutting (i.e. catastrophic failures) → no large field performance differences in stripping & rutting Last visit,
I-64 Performance Update

Cracking

• Last visit, November 2001
  – All sections but SBR has thermal cracks
  – 1 section with SBS has block & thermal cracking

• Cracking performance differences are from PG low differences, rather than modifier type
First…

Cracking Definitions

SHRP P-338 Distress Manual
What Is Transverse (Thermal) Cracking?

From SHRP P-338 Distress Manual
What Is Block Cracking?

FIGURE 9
ACP 2. Moderate Severity Block Cracking

FIGURE 10
ACP 2. High Severity Block Cracking

From SHRP P-338 Distress Manual
I-64 Section with No Cracks, Nov. 2001

No cracks: Typical of Sections 6-7 & 9-10
All sections cracked except 6-7 (SBR)
Low Severity Transverse Cracking
I-64 Block Cracking
Only Section 8-9, Nov. 2001

Section 8, SBS1
Moderate Severity Block Cracking
Why Cracking? Not expected & was not a major concern in KY...
The Midwestern region of the United States experienced its 2nd coldest December in 106 year record...”

“The December 2000 average temperature was 14.3°F (-10C)”

“... stations broke all-time cold records for December including South Bend, IN; Chicago-Midway, IL; and Louisville & Paducah, KY.”
December 2000 Low Temperature

- On December 16, 2000 the low was -17.2C near I-64 PG 70-22 project
### Results from AI Study

Asphalt Institute, TRR #1661

<table>
<thead>
<tr>
<th>Sample</th>
<th>Critical Pavement Temp, °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mixture IDT</td>
</tr>
<tr>
<td>A</td>
<td>-30.2</td>
</tr>
<tr>
<td>B</td>
<td>-31.7</td>
</tr>
<tr>
<td>C</td>
<td>-19.9</td>
</tr>
<tr>
<td>D</td>
<td>-23.1</td>
</tr>
<tr>
<td>E</td>
<td>-26.1</td>
</tr>
<tr>
<td>F</td>
<td>-22.5</td>
</tr>
<tr>
<td>G</td>
<td>-34.9</td>
</tr>
<tr>
<td>H</td>
<td>-29.9</td>
</tr>
<tr>
<td>I</td>
<td>-30.6</td>
</tr>
<tr>
<td>J</td>
<td>-30.8</td>
</tr>
<tr>
<td>K</td>
<td>-28.4</td>
</tr>
</tbody>
</table>

**Section 8-9:**
This field section has most cracks.

BBR m-value was limiting value on all binders.
# Observed Field Cracking

<table>
<thead>
<tr>
<th>Section (Modifier)</th>
<th>Low Transverse (Thermal) Cracking</th>
<th>Moderate Blocking Cracking</th>
<th>*BBR Predictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-7 (SBR)</td>
<td>No cracking</td>
<td>None</td>
<td>NA</td>
</tr>
<tr>
<td>11-12 (SBS2)</td>
<td>Few, 1-2 cracks</td>
<td>None</td>
<td>NA</td>
</tr>
<tr>
<td>4-5 (Chemically Modified)</td>
<td>Less cracks</td>
<td>None</td>
<td>NA</td>
</tr>
<tr>
<td>1 PG (64-22)</td>
<td>Several cracks</td>
<td>None</td>
<td>NA</td>
</tr>
<tr>
<td>2-3 (Neat)</td>
<td>Several cracks</td>
<td>None</td>
<td>NA</td>
</tr>
<tr>
<td>8-9 (SBS1)</td>
<td>Most cracking</td>
<td>Moderate</td>
<td>-15.1C Sample C in AI Study</td>
</tr>
</tbody>
</table>

*AI data key is not available on all samples.*
Comments from KYTC Materials Division

“The amount of cracking that occurred in the past year was very significant and highly undesirable on a 5-yr old project.”

What should suppliers & agencies learn from this project as of Nov. 2001?
Conclusions

• The 98% algorithms in LTPPBind continue to prove their validity in field performance

• Agencies should verify that they are specifying 98% reliable binders
Verify You Are Using 98% LTPPBind PG Binders

http://tfhrc.gov/pavement/ltpp/ltppbind.htm
Conclusions

• 98% temperatures occur less frequently than 50%, but can happen any year

• Dear Suppliers:
  – 1st recommend 98% reliable binder according to LTPPBind
  – …then discuss modifier advantages
Conclusions

• When 98% reliable binders are used, do not expect immediate performance differences between modifiers
  – Similar I-80 PennDOT study of 6 modifiers reported noticeable performance differences after 9-yrs (built 1989) when one section was removed
Other Similar Projects

• **Review reports on similar field studies:**
  – PennDOT I-80, CTAA 1996
  – TTI 187-22, Lewandowski’s LCC study
The American Road System
It Works!
Thank you