Moisture Susceptibility in Asphalt Mixes in Alberta

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City of Edmonton, Transportation Services
Presentation Outline

• What is Moisture Susceptibility?
• Tests for Moisture Susceptibility?
• What has been done?
• Conclusions
• Specifications
• Products in Use
Stripping
Moisture Susceptibility/Stripping
Three Basic Mechanisms of Stripping:

• Physical – Chemical Reactions
• Surface Coatings
• Smooth Surface Texture
Stripping Process
Significant Factors Affecting Moisture Susceptibility in Asphalt

- **Aggregate Composition** - aggregates with a **high silica content** and **low calcium content** are more moisture susceptible, angularity & roughness are also important
- **Voids/Compaction**
- **Design & Construction Practices**
Tests for determining stripping potential

• Lottman
• Root -Tunnicliff (ASTM D 4867)
• Modified Lottman (TSR test) (AASHTO T283)
• Marshall retained stability (ASTM D 1075)
• Hamburg Wheel Tracking Test (AASHTO TP-324 & Tex-242-F)
• Boiling Test (ASTM D 3625)
• Static Immersion Test (AASHTO T 182)
Modified Lottman (TSR test)
AASHTO T283

• Two sample sets;
• Conditioned –
  - Saturated;
  - Frozen;
  - Placed in water bath;
  - Placed in an oven
• The two sets are then tested for their Tensile Strength;
• TSR value is calculated:

\[
\text{TSR} (\%) = \frac{\text{Avg. wet tensile strength}}{\text{Avg. dry tensile strength}}
\]
Hamburg Test
AASHTO T-324

• Three sets of two specimens;
• Conditioned – in water tank for 30 minutes at 50 °C prior to testing
• Test is run and the deformation caused by wheel loading is measured
Hamburg Test Results

• City of Edmonton does not have a Hamburg Specification

• TxDOT recommends a max. allowable rut depth of 12.5 mm at
  
  ➢ 20,000 passes for PG-76 or higher,
  ➢ at 15,000 passes for PG-70 and
  ➢ at 10,000 passes for PG-64 or lower

• Our mixes are generally PG 58-28 mixes
Moisture Susceptibility Issue

• 2009 during lab testing on a new asphalt mix;
• Not identified in the Field as moisture susceptibility;
• Extensive TSR and Hamburg testing on all mixes
• Questions:
  - Why is there increased moisture susceptibility?;
  - When did it start??
  - What has changed??
City of Edmonton Mix

Background

• Depleting aggregate resources have led to research on the economic feasibility of obtaining aggregates from greater distances

• Today, obtaining virgin aggregate from elsewhere in the province is a reality

• Were the changes in aggregate Source causing the stripping problem???

• Changes to the actual mix components and gradations.
Approximate City of Edmonton Aggregate Source Radius: 1970's & Current
2013/14 Gravel pits
Aggregate Origins

Sand and gravel deposit classification:
1) preglacial deposits
2) glacial deposits
3) recent/postglacial alluvial deposits
**Aggregate Composition**

<table>
<thead>
<tr>
<th>Component</th>
<th>Composition Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>87% to 99%</td>
</tr>
<tr>
<td>SiO₂</td>
<td></td>
</tr>
<tr>
<td>Plagioclase Feldspar</td>
<td>0% to 6%</td>
</tr>
<tr>
<td>NaAlSi₃O₈ to CaAl₂Si₂O₈</td>
<td></td>
</tr>
<tr>
<td>Potassium Feldspar</td>
<td>0% to 6%</td>
</tr>
<tr>
<td>KAlSi₃O₈</td>
<td></td>
</tr>
<tr>
<td>Clay (Illite, trace</td>
<td>0.8% to 2.5%</td>
</tr>
<tr>
<td>kaolinite &amp; smectite)</td>
<td></td>
</tr>
<tr>
<td>Calcite</td>
<td>0% to 2%</td>
</tr>
<tr>
<td>CaCO₃</td>
<td></td>
</tr>
</tbody>
</table>
Other factors……. % voids, binder content, film thickness

• % Air Voids;
• Binder content;
• Film thickness;
• Voids Filled;
• TSR Values;
• Mineral Aggregate Gradation
Anti-strip

• In August of 2009 - addition of a min. of 0.3% anti-strip.

• This spec. is performance based:
  ✓ a min. TSR of 75% must be met
  ✓ no product has been specified
  ✓ more anti-strip may be required
ACR Without Anti-strip
TSR = 52%

ACR With 0.3% Anti-strip
TSR = 89%
ACO without Anti-strip
TSR = 49%

ACO with 0.3% Anti-strip
TSR = 79%
ACB without Anti-strip
TSR = 58%

.....with 0.3% Anti-strip
TSR = 94%
Conclusions

- Anti-strip is now a virtual requirement in Edmonton to meet the TSR requirements of our various specifications;

- All locally used aggregates (regardless of geological origin) are composed mainly of quartz (87%+);

- Bitumen Content, Void Ratio, Film Thickness & Gradation were fairly consistent in the mixes examined;

- Bitumen Content, Void Ratio, Film Thickness & Gradation do not seem to play a major role in stripping of our mixes if the parameters are within specification tolerances;

- For samples that did not meet the specification tolerances for these properties significant variation in stripping was noticed.
Specifications
Alberta Transportation’s Requirements

- Tensile Strength Ratio (TSR) of mix shall be 75%;
- Mixes meeting or > 75% do not require anti-strip additive;
- Contractor may still use an anti-strip additive.

If TSR value of 75% is not met:
- Mix shall be treated with liquid Anti-strip additive;
- Not <0.4% nor >0.8% by weight of binder and retested;
- If Treated TSR value ≥ 60% and it is improved over the untreated mix, Mix is suitable for use;
- If the treated value is < 60% or < the untreated value the mix shall not be used.
# Alberta Transportation Mix Requirements

<table>
<thead>
<tr>
<th>Mix Type</th>
<th>Aggregate Criteria</th>
<th>Marshall Mix Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Top Size (mm)</td>
<td>% MF. -5000 (min)</td>
</tr>
<tr>
<td>H1</td>
<td>16</td>
<td>75</td>
</tr>
<tr>
<td>H2</td>
<td>12.5</td>
<td>70</td>
</tr>
<tr>
<td>M1</td>
<td>12.5</td>
<td>50</td>
</tr>
<tr>
<td>L1</td>
<td>12.5</td>
<td>50</td>
</tr>
<tr>
<td>S1</td>
<td>10.0</td>
<td>60</td>
</tr>
<tr>
<td>S2</td>
<td>10.0</td>
<td>75</td>
</tr>
<tr>
<td>S3</td>
<td>25</td>
<td>40</td>
</tr>
</tbody>
</table>

**Notes:**

1. The Percentage of Manufactured Fines in the -5000 Portion of the Combined Aggregate.
2. Use the same number of blows as for the surface course.
3. The Design Air Voids shall be chosen as the lowest value, within the range of 3.5 to 4.0% inclusive, such that all other mix design criteria are met.
4. Air Void limits listed in Note 3 shall be reduced by 0.5% for community airports. VMA at 2.5% Air Void shall be a minimum of 12.5%.

<table>
<thead>
<tr>
<th>Design Air Voids</th>
<th>Minimum Theoretical Film Thickness Requirements (μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0 and 3.9</td>
<td>Mix Types H1, H2, M1, S2</td>
</tr>
<tr>
<td>3.7 and 3.8</td>
<td>6.0</td>
</tr>
<tr>
<td>3.5 and 3.6</td>
<td>6.1</td>
</tr>
<tr>
<td>3.3 and 3.4</td>
<td>6.2</td>
</tr>
<tr>
<td>3.0, 3.1 and 3.2</td>
<td>Community Airports only, L1</td>
</tr>
<tr>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>
## City of Calgary Mix Requirements

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>Mix Type A</th>
<th>Mix Type B</th>
<th>Mix Type C</th>
<th>Mix Type M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marshall Stability (kN)</td>
<td>10 min.</td>
<td>8 min.</td>
<td>12 min.</td>
<td>6 min.</td>
</tr>
<tr>
<td>Marshall Flow (0.25 mm Units)</td>
<td>8 – 15</td>
<td>2.0 – 4.0</td>
<td>2.0 – 4.0</td>
<td>2.0 – 4.0</td>
</tr>
<tr>
<td>Air Voids (%)</td>
<td>4.3 – 4.7</td>
<td>3.3 – 3.7</td>
<td>3.8 – 4.2</td>
<td>2.8 – 3.2</td>
</tr>
<tr>
<td>Voids in Mineral Aggregate (%)</td>
<td>12 min.</td>
<td>14 min.</td>
<td>13.5 min.</td>
<td>15 min.</td>
</tr>
<tr>
<td>Voids Filled With Asphalt (%)</td>
<td>60 – 70</td>
<td>70 – 80</td>
<td>65 – 80</td>
<td>70 – 85</td>
</tr>
<tr>
<td>Film Thickness (μm)</td>
<td>6.0 min.</td>
<td>7.0 min.</td>
<td>7.0 min.</td>
<td>7.0 min.</td>
</tr>
<tr>
<td>Tensile Strength Ratio (%) *</td>
<td>75 min.</td>
<td>75 min.</td>
<td>75 min.</td>
<td>75 min.</td>
</tr>
</tbody>
</table>

* Tested in accordance with AASHTO T283 including the optional freeze cycle
# City of Edmonton
## Mix Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>10mm - HT</th>
<th>10 mm - LT</th>
<th>20mm - B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mix Type</strong></td>
<td>10mm - HT</td>
<td>10 mm - LT</td>
<td>20mm - B</td>
</tr>
<tr>
<td><strong>Selected Parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Gyrations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gyrations $N_{\text{design}}$</td>
<td>100</td>
<td>75</td>
<td>100</td>
</tr>
<tr>
<td>Gyrations $N_{\text{maximum}}$</td>
<td>160</td>
<td>115</td>
<td>160</td>
</tr>
<tr>
<td>Density at $N_{\text{maximum}}$ (%$G_{\text{mm}}$)</td>
<td>98.0 Max</td>
<td>98.0 Max</td>
<td>98.0 Max</td>
</tr>
<tr>
<td>Bailey CA-CUW</td>
<td>60 to 85 Max - Fine Graded</td>
<td>60 to 85 Max</td>
<td>60 to 85 Max</td>
</tr>
<tr>
<td>Air Voids, % of total mix (virgin mix)$^1$</td>
<td>4.0 +/- 0.4%</td>
<td>3.0 +/- 0.4%</td>
<td>3.5 +/- 0.4%</td>
</tr>
<tr>
<td>VMA, %</td>
<td>13 Minimum</td>
<td>14 Minimum</td>
<td>12 Minimum</td>
</tr>
<tr>
<td>Voids filled, %</td>
<td>70 - 80</td>
<td>73 - 85</td>
<td>65 - 75</td>
</tr>
<tr>
<td>Tensile Strength Ratio % (AASHTO T283)$^2$</td>
<td>80 Minimum</td>
<td>80 Minimum</td>
<td>80 Minimum</td>
</tr>
<tr>
<td>Minimum Film Thickness$^3$, mm</td>
<td>7.5 min.</td>
<td>7.5 min.</td>
<td>6.5 min.</td>
</tr>
<tr>
<td>APA (mm, 52°C, 8,000 cycles)</td>
<td>5.0 max.</td>
<td>7.0 max.</td>
<td>5.0 max.</td>
</tr>
</tbody>
</table>

Note 1: The mix design air voids shall be selected at the mid point of the specified range or the lowest value within the range in which all the other mix design criterion are met.

Note 2: Minimum Tensile Strength Ratio to be determined in accordance with AASHTO T283, with optional freeze-thaw, at air void content of 7.0 +/- 0.5 percent.

Note 3: Minimum film thickness to be determined to Appendix 02066.A
Anti-Strip Products

- Products currently utilized by our contractors:
  - ADHere – Amine
  - Redicote – Amine
  - Pavegrip – Amine
  - Zero Grind – Limestone dust
Questions?