High modulus asphalt understanding the performance requirements

For presentation at the AAPA 2012 Master Class on Premium Asphalt Bases 20 November 2012

By

Erik Denneman
Outline

• What is high modulus asphalt, and EME = HiMA?
• Performance of high modulus asphalt
• Translating performance specifications
• Performance based design of high modulus asphalt mixes
  – Process
  – Where to start?
  – Meeting the performance specs
• Exploratory work under Austroads TT1353
• Update on Durban trial (AAPA study tour 2011)
What is high modulus asphalt?

- Origin: France early 90s “Enrobés à Module Elevé” (EME)
- Typical characteristics:
  - High binder content \( \approx 6\% \) by mass of aggregate,
  - Hard binder: Pen 10-25,
  - Low air voids content,
  - High Modulus > 14 GPa at 15°C, 10 Hz,
  - High resistance against permanent deformation,
  - Good fatigue resistance,
  - Impermeable,
  - High mixing temperature.
EME = HiMA

- Enrobés à Module Elevé translates to High Modulus Asphalt
- Therefore these mixes are sometimes referred to as HiMA
- However, if you had just developed a Highly Modified Asphalt, an appropriate acronym would be...
- To avoid (further) confusion, recommend use of EME in Australia when referring to base mixes with a unmodified hard bitumen, designed using 'French' methodology
- This presentation is about EME
Performance of high modulus asphalt

- Slides on the performance of EME compared to ‘conventional mixes’
  - Modulus
  - Permanent deformation
  - Fatigue
- From South African EME T² project
- Based on work at CSIR for:
  - South African Road Authority Ltd (SANRAL)
  - Southern African Bitumen Association (Sabita)
Health warning:

- The data on the slides is for a limited number of mixes
- Test temperatures, sample conditioning, compaction, and materials (e.g. modifier content) differ from Australian situation
- Performance of the mixes cannot be meaningfully compared to local materials based on this data
- Local testing program required to rank the performance of EME
Modulus

![Modulus Graph]

- Master curve
- -5 °C
- 5 °C
- 20 °C
- 40 °C
- 55 °C

E* [MPa] vs Frequency [Hz]
Permanent deformation

![Graph showing permanent strain versus load repetitions for different materials at 55°C]

- BTB 1 55°C
- Coarse AE2 55°C
- Medium AE2 55°C
- HiMA 55°C
- Medium 60/70 55°C
- BRASO 55°C
Fatigue performance

All at 10 Degrees C

Number of load cycles

STRAIN (Microstrain)

- 40/50 dense
- SBS dense
- EME

Mix 1 (BTB)
Mix 3
Mix 4 (HiMA)
All at 10 Degrees C
SBS dense
40/50 dense
EME
Translating design requirements

- Select Australian equivalents for European specifications
- Aggregate selection & grading
- Bitumen properties & bitumen content selection
- Mix performance specification:
  - Workability
  - Durability
  - Modulus
  - Permanent deformation
  - Fatigue
### Aggregate selection

- **Filler**

<table>
<thead>
<tr>
<th>Requirements for fillers</th>
<th>EN test method</th>
<th>NF EN asphalt specification and EME requirement</th>
</tr>
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<tbody>
<tr>
<td><strong>Particle size distribution (PSD)</strong></td>
<td>EN 13043: 2002, Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas</td>
<td>2mm passing &gt; 100% 0.125 mm passing 85 to 100% 0.063 mm passing 70 to 100%</td>
</tr>
<tr>
<td><strong>Apparent particle density measurement</strong></td>
<td>EN 1097-7: 2008 Tests for mechanical and physical properties of aggregates, part 7: determination of the particle density of filler - pyknometer method</td>
<td>TBC</td>
</tr>
<tr>
<td><strong>Rigden voids</strong></td>
<td>EN 1097–4: 1999, Tests for mechanical and physical properties of aggregates: part 4: determination of the voids of dry compacted filler</td>
<td>28 to 38 ($V_{28/38}$)</td>
</tr>
<tr>
<td><strong>Harmful fines, methylene blue test (MBF)</strong></td>
<td>EN 933-9: 2009 Tests for geometrical properties of aggregates, part 9: assessment of fines - methylene blue test</td>
<td>$\leq 10$ (MBF-10)</td>
</tr>
</tbody>
</table>
| **Delta ring and ball test** | EN13179–1: 2000, Tests for filler aggregate used in bituminous mixtures: part 1: delta ring and ball test  
EN 1427: 2007, Bitumen and bituminous binders: determination of the softening point: ring and ball method | 8 to 16 ($D_{R&B8/16}$)  
Hydrated lime content of the filler should not exceed 1%                                                  |
## Aggregate selection

### Aggregate

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<td>EN 13043: 2002, Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas</td>
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</tr>
<tr>
<td>Crushed particles</td>
<td>EN 933, Tests for geometrical properties of aggregates, Part 5: Determination of percentage of crushed and broken surfaces in coarse aggregate particles Note: performed on 10/14 mm fraction</td>
<td>100% (C100/0)</td>
</tr>
<tr>
<td>Flakiness index</td>
<td>EN 933, Tests for geometrical properties of aggregates, Part 3: Determination of particle shape. Flakiness index</td>
<td>Maximum 25 (Fl25)</td>
</tr>
<tr>
<td>Impact value</td>
<td>EN 1097-2, Part 2: Methods for the determination of resistance to fragmentation Note: performed on 8/12.5 mm fraction</td>
<td>SZ18</td>
</tr>
<tr>
<td>Los-Angeles coefficient</td>
<td>EN 1097-2, Part 2: Methods for the determination of resistance to fragmentation</td>
<td>Not specified, usually LA20 for heavy duty asphalt applications</td>
</tr>
<tr>
<td>Flow coefficient, fine aggregate fully crushed</td>
<td>EN 933-6, Part 6: Assessment of surface characteristics - flow coefficient of aggregates</td>
<td>only for surface courses Ecs35-38 for base courses not specified</td>
</tr>
</tbody>
</table>
## Bitumen Properties

- **EN 13924 and EN 12591**

<table>
<thead>
<tr>
<th>Property</th>
<th>Test method</th>
<th>Unit</th>
<th>Penetration grade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>10/20</strong></td>
</tr>
<tr>
<td><strong>Before RTFOT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Penetration at 25 °C</td>
<td>EN 1426</td>
<td>0.1 mm</td>
<td>10-20</td>
</tr>
<tr>
<td>Softening point</td>
<td>EN 1427</td>
<td>°C</td>
<td>58-78</td>
</tr>
<tr>
<td>Viscosity at 60°C</td>
<td>EN12596</td>
<td>Pa.s</td>
<td>&gt;700</td>
</tr>
<tr>
<td><strong>After RTFOT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase in softening point</td>
<td>EN 1427</td>
<td>°C</td>
<td>&lt; 10</td>
</tr>
<tr>
<td>Retained penetration</td>
<td>EN 1426</td>
<td>%</td>
<td>-</td>
</tr>
<tr>
<td>Mass change</td>
<td></td>
<td>%</td>
<td>&lt; 0.5</td>
</tr>
</tbody>
</table>
## Mix performance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test method</th>
<th>EME 1</th>
<th>EME 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workability: air voids after 100 cycles</td>
<td>Gyratory compactor EN-12697-1</td>
<td>&lt; 6%</td>
<td>&lt; 6%</td>
</tr>
<tr>
<td>Durability retained strength ratio</td>
<td>Duriez test EN 12697-12</td>
<td>&gt; 70%</td>
<td>&gt; 70%</td>
</tr>
<tr>
<td>Modulus 15°C, 10Hz</td>
<td>2 point bending test EN 12697-26</td>
<td>&gt; 14 GPA</td>
<td>&gt; 14 GPA</td>
</tr>
<tr>
<td>Permanent deformation after 30k cycles</td>
<td>Wheel tracker EN 12697-22</td>
<td>&lt; 7.5%</td>
<td>&lt; 7.5%</td>
</tr>
<tr>
<td>Fatigue 2 point bending test, 10°C, 25Hz strain to 1E6 load reps</td>
<td>2 point bending test EN 12697-24</td>
<td>&gt;100 με</td>
<td>&gt;130 με</td>
</tr>
</tbody>
</table>
Translation challenges

- Centralised, national approach required
- EME working group formed under ARWG
Performance based design process

1. Select components
2. Formulate design grading
3. Select binder content
4. Compact gyratory specimens
5. Workability criteria met?
6. Durability criteria met?
7. Dynamic modulus criteria met?
8. Compact slab
9. Rut resistance criteria met?
10. Fatigue criteria met?

- Yes
- No

If Yes, proceed to the next step. If No, return to the previous step and adjust the selection accordingly.

Implement!
Selecting aggregate grading

- Guideline!

<table>
<thead>
<tr>
<th>Percent passing sieve size</th>
<th>D = 10 mm</th>
<th>D = 14 mm</th>
<th>D = 20 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min.</td>
<td>target</td>
<td>max.</td>
</tr>
<tr>
<td>6.3 mm</td>
<td>45</td>
<td>55</td>
<td>65</td>
</tr>
<tr>
<td>4.0 mm</td>
<td></td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>2.0 mm</td>
<td>28</td>
<td>33</td>
<td>38</td>
</tr>
<tr>
<td>0.063 mm</td>
<td>6.3</td>
<td>6.7</td>
<td>7.2</td>
</tr>
</tbody>
</table>
Design process

- Start by selecting a grading close to the target
# Binder content selection

## EME base course

<table>
<thead>
<tr>
<th></th>
<th>Class 1</th>
<th>Class 2</th>
</tr>
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<tbody>
<tr>
<td><strong>D (mm)</strong></td>
<td>10,14,20</td>
<td>10,14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>$P_{b_{\text{min}}} \rho = 2.65 \text{ g/cm}^3$</td>
<td>3.8</td>
<td>5.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.0</td>
</tr>
<tr>
<td>$P_{b_{\text{min}}} \rho = 2.75 \text{ g/cm}^3$</td>
<td>3.8</td>
<td>4.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.9</td>
</tr>
<tr>
<td>Richness modulus $K$</td>
<td>2.5</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.4</td>
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Design process

• Start by selecting a grading close to the target
• Select lowest binder content that satisfies richness modulus and min. binder content requirements
### Complete performance tests

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Design process

- Start by selecting a grading close to the target
- Select lowest binder content that satisfies richness modulus and min. binder content requirements
- Optimize mix design based on results from performance tests
  - Easiest way to increase workability is increasing compaction temperature
  - Increase binder content to meet fatigue requirements
  - Select harder binder if more binder is required, but rutting is also critical
  - Optimise aggregate packing, or change source if more VMA is required. E.g.: Bailey method (coming soon to an area near you!)
- Run performance tests again......
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Austroads TT1353

- Project leader: Laszlo Petho laszlo.petho@arrb.com.au
- Tasks 2012/13
  - Best practice review
  - Check local availability of EME type binders
  - Development of laboratory test plan: select Australian test methods for aggregate and performance testing
  - Laboratory testing incl. mix design
- Project for this financial year does not include the development of mix design guidelines for EME
- Report to Asphalt Research Working Group (ARWG)
- ARWG established a working group to organise demonstration of the technology
- A separate project will be proposed for integration of EME into the Austroads pavement design manual
Update on Durban trial

- Major access road for Durban harbour
- Estimated traffic: 8000 std axles per lane per day (60 msa in 20 years)
- Pavement and mix design performed by CSIR and industry partners
- 160 mm EME with SMA surfacing
- Constructed Sept 2011
- One year report:
  - SMA surfacing is suffering
  - No signs of deformation in EME
Thank you!