High performance asphalt and binders

Part 1
2012 Study Tour Key Topics

1. Long life pavements
   o Experience, design systems, use, durability & performance

2. High performance asphalt & binders
   o High modulus asphalt (EME, HiMA), modifiers

3. Sustainability
   o RAP/WMA, bitumen substitutes, carbon calculators & energy analysis
     climate change impacts, societal concerns

4. Health & Safety
   o Construction of road works, health considerations for bitumen
     and asphalt products

5. Procurement Systems
   o Proprietary products (Avis Technique, HAPAS, etc.), “green” procurement,
     REACH, responsible sourcing, PPP and contract models
Topic 2: High performance asphalt & binders

Overview of reasons

- Bituminous binders – key component in the performance and service life of bituminous surfacings & asphalt pavements
- About 90% of the Australian all weather road network length is surfaced with sprayed seals – about 50% of binder usage
- Need to ensure optimum asphalt and seals performance in the field, and to promote best practices suitable to be adapted and adopted in Australia. Seeking details on:
  - new developments and test methods in high performance asphalt and bituminous materials (e.g. HiMA /EME, PMB, Emulsion)
  - actions taken by European and others (e.g. binder manufacturers, asphalt producers and researchers) to overcome field problems (e.g. climate change)
  - correlation between laboratory test results and field trials
Topic 2: High performance asphalt & binders

What is High Performance Asphalt?

• What does it look like?
• How is this different to what we currently do?
• Isn’t what we do good enough?
• For Heavy Duty roads – what’s your pavement configuration?

<table>
<thead>
<tr>
<th>New Construction</th>
<th>Rehabilitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMA 10</td>
<td>AC10</td>
</tr>
<tr>
<td>AC 14</td>
<td>AC 10</td>
</tr>
<tr>
<td>AC 14</td>
<td>AC 14</td>
</tr>
<tr>
<td>AC 14</td>
<td>AC 20</td>
</tr>
<tr>
<td>AC 14 HB</td>
<td>AC20</td>
</tr>
</tbody>
</table>

Decreasing air voids
Topic 2: High performance asphalt & binders

High Performance Asphalt is essentially High Modulus Asphalt

French Catalogue:
Topic 2: High performance asphalt & binders

High Performance Asphalt is essentially High Modulus Asphalt

French Catalogue:

![High Performance Asphalt Chart](www.aapa.asn.au)
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Three French Methods of achieving High Modulus Asphalt:

- EME (Enrobésa Module Elevé)
- GB5
- GAB II

All methods move asphalt bases to Higher Modulus resulting in increase in load spreading and hence increased capacity.
**Topic 2: High performance asphalt & binders**

**EME: High Modulus Asphalt:**
- Standard Dense mix gradings
- 10/14/20 mix sizes
- Special **Hard Binder:** $\uparrow$ Stiffness
  $\uparrow$ Rut Resistance

- Increased binder content:
  $\uparrow$ Fatigue Resistance
  $\uparrow$ Density:
  $\uparrow$ Stiffness
  $\uparrow$ Moisture Resistance
**Topic 2: High performance asphalt & binders**

**GB5: High Modulus Asphalt:**

- Double Gap graded gradings (using packing theory):
  - Density: \( \uparrow \)
  - Stiffness: \( \uparrow \)
  - Moisture Resistance: \( \uparrow \)

- Standard binder content (4.0%):
  - Stiffness: \( \uparrow \)
  - Rut Resistance: \( \uparrow \)

- Modified Binder:
  - Fatigue Resistance: \( \uparrow \)
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GAB II: High Modulus Asphalt:

• 65% Sand (16/32 Aggregate acts as a filler):
  - Density:
  - Stiffness
  - Moisture Resistance
  - Fatigue Resistance

• Special Hard Binder:
  - Stiffness
  - Rut Resistance
## Topic 2: High performance asphalt & binders

### Hard Binders:

<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>10/20</td>
</tr>
<tr>
<td>Before RTFOT</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>After RTFOT</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>
Topic 2: High performance asphalt & binders

Hard Binders:

Key
- Vacuum Distillation
- Vacuum Distillation plus Air-rectification
- Severely oxidised bitumen
- Paving grade bitumen
- Oxidised bitumen

Temperature Sensitivity decreases

Penetration (dmm)

Softening Point (R&B °C)
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Hard Binders:

- EN 12591 paving grade
- EN 13924 hard paving grade
- BURA I, II, III, IV
- EN 13304 oxidised (examples)
- EN 13305 hard industrial (examples)
- prEN 13924-2:2011 Multigrade
### EME Binder Content:

<table>
<thead>
<tr>
<th></th>
<th>HiMA base course</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Class 1</td>
</tr>
<tr>
<td>$D$ (mm)</td>
<td>10, 14, 20</td>
</tr>
<tr>
<td>$P_{b,min} \rho = 2.65 \text{ g/cm}^3$</td>
<td>3.8</td>
</tr>
<tr>
<td>$P_{b,min} \rho = 2.75 \text{ g/cm}^3$</td>
<td>3.8</td>
</tr>
<tr>
<td>Richness modulus $K$</td>
<td>2.5</td>
</tr>
</tbody>
</table>
### Main specifications of HMA
(fundamental method, only one)

<table>
<thead>
<tr>
<th>Dénomination</th>
<th>Denomination</th>
<th>Norme NF EN de référence</th>
<th>Vmax</th>
<th>ESSR 70</th>
<th>ESSR 70</th>
<th>ESSR 70</th>
<th>ESSR 70</th>
<th>ESSR 70</th>
</tr>
</thead>
<tbody>
<tr>
<td>EB10-EME</td>
<td>Amine</td>
<td>NF EN 13108-1</td>
<td>80</td>
<td>30'000 cycles</td>
<td>$\nu = 3%$, $\nu_a = 6%$</td>
<td>$P_{2.5}$</td>
<td>$S_{min}=1000$</td>
<td>$\varepsilon_{25}$</td>
</tr>
<tr>
<td>EB14-EME</td>
<td>Amine</td>
<td>NF EN 13108-1</td>
<td>100</td>
<td>30'000 cycles</td>
<td>$\nu = 3%$, $\nu_a = 6%$</td>
<td>$P_{2.5}$</td>
<td>$S_{min}=1000$</td>
<td>$\varepsilon_{25}$</td>
</tr>
<tr>
<td>EB20-EME</td>
<td>Amine</td>
<td>NF EN 13108-1</td>
<td>120</td>
<td>30'000 cycles</td>
<td>$\nu = 3%$, $\nu_a = 6%$</td>
<td>$P_{2.5}$</td>
<td>$S_{min}=1000$</td>
<td>$\varepsilon_{25}$</td>
</tr>
</tbody>
</table>

- **General characteristics**
  - ESSR 70: 70
  - M: 7.5%
  - $P_{2.5}$: 14'000 MPa
  - $\varepsilon_{25}$: 130 µstrain
### Topic 2: High performance asphalt & binders

#### EME: main performances

<table>
<thead>
<tr>
<th>Type of mix</th>
<th>Giratory (Voids %)</th>
<th>Water sensitivity (nR ratio)</th>
<th>Rut depth (60°C-100 mm) * 10,000 cycles (%) ** 30,000 cycles (%)</th>
<th>Stiffness modulus (15°C-10Hz) in MPa</th>
<th>Fatigue – admissible strain (@ 1 million cycles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GB Class 2</td>
<td>≤ 11</td>
<td>≥ 0.65</td>
<td>≤ 10*</td>
<td>≥ 9,000</td>
<td>≥ 80.10⁻⁶</td>
</tr>
<tr>
<td>GB Class 3</td>
<td>≤ 10</td>
<td>≥ 0.7</td>
<td>≤ 10*</td>
<td>≥ 9,000</td>
<td>≥ 90.10⁻⁶</td>
</tr>
<tr>
<td>GB Class 4</td>
<td>≤ 9</td>
<td>≥ 0.7</td>
<td>≤ 10**</td>
<td>≥ 11,000</td>
<td>≥ 100.10⁻⁶</td>
</tr>
<tr>
<td>EME Class 1</td>
<td>≤ 10</td>
<td>≥ 0.7</td>
<td>≤ 7.5**</td>
<td>≥ 14,000</td>
<td>≥ 100.10⁻⁶</td>
</tr>
<tr>
<td>EME Class 2</td>
<td>≤ 6</td>
<td>≥ 0.75</td>
<td>≤ 7.5**</td>
<td>≥ 14,000</td>
<td>≥ 130.10⁻⁶</td>
</tr>
</tbody>
</table>
### Topic 2: High performance asphalt & binders

**New structure: national road (catalogue 1998)**

Guide des structures types de chaussées neuves (SETRA/LCPC)

RRN structurant TC6* / PF 3** - duration 30 years

<table>
<thead>
<tr>
<th>Fiche</th>
<th>Nº 1 GB 2</th>
<th>Nº 3 EME 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>VTAC</td>
<td>2.5 cm</td>
<td>2.5 cm</td>
</tr>
<tr>
<td>BBSG binder course</td>
<td>6.0 cm</td>
<td>6.0 cm</td>
</tr>
<tr>
<td>Base</td>
<td>14.0 cm</td>
<td>9.0 cm</td>
</tr>
<tr>
<td>Fondation</td>
<td>14.0 cm</td>
<td>10.0 cm EME 2</td>
</tr>
<tr>
<td>Total thickness</td>
<td>36.5 cm</td>
<td>27.5 cm</td>
</tr>
</tbody>
</table>

*Traffic 20 millions equivalent axle 130 KN, **capping layer PF 3 or $E=120$ MPa

-25%
### Topic 2: High performance asphalt & binders

#### Performances ranking of Asphalt mixes for base course

<table>
<thead>
<tr>
<th>Materials</th>
<th>Modulus at 15°C 10 Hz</th>
<th>Epsi 6 μdef 10°C, 25 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>GB2</td>
<td>9000</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>11000</td>
<td>90</td>
</tr>
<tr>
<td>GB3</td>
<td>9000</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>11000</td>
<td>100</td>
</tr>
<tr>
<td>GB4</td>
<td>11000</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>12500</td>
<td>110</td>
</tr>
<tr>
<td>EME2</td>
<td>14000</td>
<td>130</td>
</tr>
<tr>
<td></td>
<td>17000</td>
<td>140</td>
</tr>
</tbody>
</table>

Limits of performances determined in laboratory, used in pavement design.
GB5 Packing:
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Void Index evolution without any wall effect
\[ e = F(1-p) \]

Coarse aggregate void index

Experimental Curve

Wall Effect

Interference Effect

Void index evolution without any interference effect
\[ e = (C + 1)p - 1 \]
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- Mix with high fines content: $p < p_x$
  
  \[ e = F(1-p) + Dp \]

- Mix with medium fines content: $p_x < p < p_T$
  
  \[ e = Ep \]

- Mix with low fines content: $p > p_T$
  
  \[ e = (C+1)p - 1 \]
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GB5 Packing:
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Mix Design & Performance Testing:

- Selection and identification of components
- Choice: gradation & binder content
  - Compactability test (gyratory)
- Compaction
  - Water sensitivity
- Level 1
  - Duriez test
- Level 2
  - Rutting test
- Level 3
  - Modulus test
- Level 4
  - Fatigue test
  - Formulation selected
- Rutting
- Stiffness
- Fatigue
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Mix Design & Performance Testing:

- **Workability**
- **Water resistance**
- **Rutting resistance**

**Level 1**

**Level 2**

- **Modulus**

**Level 3**

- **Fatigue resistance**

**Level 4**

- **Fundamental Approach**
  - In EN 13108-1

**Level 3 + Level 4**

**General requirement**

- >14000 MPa
- 15° C -10Hz
- >130 μdefs (10° C 25Hz)
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Mix Design & Performance Testing:

EME2 specimen

0 50 100 (mm) 150 200 250
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High Modulus Asphalt

- Stiffness
- Fatigue
- Rut
### High Modulus Asphalt Production:

<table>
<thead>
<tr>
<th>Country</th>
<th>HiMA production (million tonnes)</th>
<th>RAP in HiMA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spain</td>
<td>39</td>
<td>3</td>
</tr>
<tr>
<td>France</td>
<td>39</td>
<td>7</td>
</tr>
<tr>
<td>Austria</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>USA</td>
<td>327</td>
<td>17</td>
</tr>
<tr>
<td>Germany</td>
<td>45</td>
<td>26</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>10</td>
<td>32</td>
</tr>
</tbody>
</table>
**Topic 2: High performance asphalt & binders**

*Questions*

• **Asphalt**
  o EME/ HiMA - specification, testing, field links, pavement & subgrade requirement, binder selection & processing
  o Performance & Construction
  o Reinforced, Modified Binders & SMA – design & composition, service life, pros & cons
  o Moisture Susceptibility: measures, tests & approaches
  o PGA/PA: maintenance & performance

• **Specifications and Test Methods**
  o Approaches to proprietary mix design, types of modifiers used, low temperature test methods, control of segregation & degradation, etc
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Questions

• Binders
  o concerns: climate change, quality & characteristic of imported material
  o testing level, lab-field correlation, stabilisation of unbound material

• Emulsions
  o test methods
  o types used in sprayed chip sealing
  o performance based specifications

• Surfacings
  o cost benefit of thin surfacings, reasons of application & modelling