R&M Technology

EME / HSB / ETP-ENTPE-BP Fatigue Study

Gelsenkirchen, 19 June 2012

Bitumen
High modulus asphalt mixes

- Developed in France during the early eighties to reduce pavement thicknesses and later (in the nineties) to strengthen binder and wearing courses.
- EME = ‘Enrobes a Module Elevé’ for road bases
- BBME = “Betons Bitumineux a Module Elevé’ for surface and binder courses
Main EME & BBME performance requirements

- High stiffness and fatigue resistance at pavement design temperature
- High rutting resistance at high service temperature
- Sufficient resistance to thermal cracking (BBME)
- Good workability

⇒ Resulted in first set of performance driven specifications in 1992
⇒ Special hard bitumen grades are one of the key components
Hard bitumen grades

- Standard Bitumen:
  - NPG

- Special Bitumen:
  - Multigrades
  - Hard Bitumen Grades
  - Polymer Modified Bitumen

Performance of binder and asphalt mix

Added value
Hard bitumen grades

- For EME generally pure bitumen of very low Penetration (10/20 - 15/25))
- Required characteristics are compromise between optimised modulus, thermal susceptibility and ageing resistance
- Only achievable through tailor made refinery processes and formulations
- Manufactured by different refinery processes
  ⇒ Chemical composition and colloidal structure are strongly dependent on the manufacturing process
  ⇒ Rheological and ageing properties can vary widely
- For BBME often highly modified (hard) PMBs
Hard bitumen grades

Influence of PI and composition (i.e. colloidal instability) on behaviour

- PI and CI ↑
  - Resistance to low temperature cracking ↑
  - EME fatigue resistance ↑
  - EME rutting resistance ↑
  - Ageing resistance ↓
  - Healing capacity at ambient temperature ↓
  - EME stiffness ↓

Colloidal Instability Index:

\[
\text{Saturates + Asphaltenes} \over \text{Aromatics + Resins}
\]
Product Portfolio BP France

- Standard Bitumen
  - 20/30 - 160/220
  - 2,900 kT

- Special Bitumen
  - 10/20 - 15/25
  - 50-100 kT
  - 35/45 HIP
  - 100 kT
  - Polymer Modified Bitumen
  - 200 kT

Performance of binder and asphalt mix

Added value
BP Fatigue Database
Correlation between ε6 and initial stiffness

(± 180 mix evaluations)
BP Fatigue Database
Correlation between $\varepsilon_6$ and initial stiffness

Correlation between fatigue Epsilon 6 and Stiffness for EME2
Initial Stiffness has clear influence on Epsilon 6

The dependence is much more important for low stiffness values.

Almost no influence for mixes with conventional bitumen or HSB
**BP Fatigue Database**

Influence of binder type on $\varepsilon_6$

<table>
<thead>
<tr>
<th>BINDER TYPE</th>
<th>WAXY BITUMENS</th>
<th>PLASTOMERIC</th>
<th>MULTIGRADES</th>
<th>PLASTOMERIC PMBs</th>
<th>NPG</th>
<th>ELASTOMERIC PMBs</th>
<th>HSB</th>
<th>TOTAL</th>
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<td>2</td>
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<td>171</td>
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<tr>
<td>STD</td>
<td>33</td>
<td>17</td>
<td>31</td>
<td>13</td>
<td>44</td>
<td>16</td>
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</table>

**Diagram:**

- **WAXY**
- **HSB PLASTO**
- **MULTI**
- **PLASTO**
- **CONV**
- **ELASTO**
- **HSB**

**Epsilon 6 (\mu def)**
### BP Fatigue Database

**Influence of asphalt mix type on ε6**

<table>
<thead>
<tr>
<th>Binder Type</th>
<th>EME1</th>
<th>EME2</th>
<th>GB</th>
<th>BBMa</th>
<th>BBME</th>
<th>BBSG</th>
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<td>97</td>
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<tr>
<td><strong>Mean</strong></td>
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<td>145</td>
<td>101</td>
<td>172</td>
<td>147</td>
<td>169</td>
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<td><strong>Max</strong></td>
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<td>172</td>
<td>117</td>
<td>252</td>
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<tr>
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<td>16</td>
<td>10</td>
<td>42</td>
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**STATISTICS OF LCPC FATIGUE EPSILON6 (µdef) FOR THE GLOBAL DATA BASE**
BP Fatigue Database
Influence of binder and asphalt mix type

- The binder used is the most important factor
- Predominance of binder type over asphalt mix formulation
Two EME classes

EME class 2
- First generation applied since 1980
- Continuous aggregate grading (0/10, 0/14 or 0/20 mm)
- High binder content (typical 5.2 %)

EME class 1
- Introduced in 1988
- Still small percentage of the French EME market
- Continuous aggregate grading (0/10, 0/14 or 0/20 mm)
- Lower binder content (typical 3.9 %)
- Lower durability and resistance to fatigue than EME class 2
- Mainly used for layers that require a very high resistance to permanent deformation.
EME mixtures with high stiffness modulus and reasonable resistance to fatigue allow for thinner pavement thicknesses.
Experiences and developments EME technology

Experiences are generally positive:

- Various surveys of EME road projects have reported good performance
- Only one important cracking failure reported due to applying too hard HSB (Pen = 5). Product now excluded from the market
- Successful implementation of EME technology in Switzerland (HMT) in the early nineties with HSB imported from France
- Successful technology transfer to the Netherlands and the UK in the late nineties. No change versus French EME formulation and originally HSB imported from France

Developments

- Use of recycled asphalt in EME (requested by SANEF Motorways Agency)
- Trials with up to 50 % of recycled asphalt
EXPERIENCE WITH OPTIMISED HARD GRADE BITUMENS IN HIGH MODULUS ASPHALT MIXES

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ABSTRACT

In the early nineteen eighties, new generations of French asphalt mixes were developed to reduce roadbase thicknesses and subsequently to strengthen some binder/base courses and selected wearing courses. High modulus asphalt mixes "EME" and "BBME" were introduced. To achieve the required performance (high stiffness; fatigue resistance; high rutting resistance; resistance to brittle thermal cracking; ageing resistance; workability;...), appropriate asphalt mix designs were found which resulted in the first set of performance-based specifications in 1992. Among the key components were the hard special bitumen grades "HMB", mostly 10/20 and 15/25 penetration, with characteristics that resulted in compromises between optimised thermal susceptibility and ageing resistance. This is only achievable through tailor made refinery processes as illustrated with the evaluation of 2 extreme HMB with "SOL" and "GEL" type colloidal structures. A review and recommendations to interpret the draft CEN prEN 13924 specifications for HMB are provided. The example of a successful implementation of the "EME" technology from France to another European country is described, including the effect of recycled asphalt mix addition on "EME" performance.

Key words: Hard grade bitumens (10/20, 15/25), high modulus asphalt mixes (EME, BBME), performance testing, implementation of technology, recycling.
Fatigue Collaboration Project

Partners

Eiffage Travaux Publics (ETP)
- Main office in Paris
- Asphalt Lab in Ciry (North of France) and Bitumen lab in Lyon
- Contact Francois Olard

ENTPE in Lyon
- Contact Herve di Benedetto

BP France / GFT-Bitumen
- Contact Luc Planque

Duration

Mai 2010 – August 2013
Main objectives

- Better understanding of influence of recycled asphalt (RAP) on asphalt fatigue performance
- Better understanding of influence of bitumen/bitumen properties on asphalt fatigue performance
- Develop model to predict asphalt fatigue performance
Three themes

- Recycling
- Mix design
- Bitumen
Theme Recycling

- Asphalt mixture (EME 0/14) with two variables:
  - Bitumen type
  - Amount of RAP
Measuring bitumen fatigue performance
Measuring bitumen fatigue performance
Measuring bitumen fatigue performance

Fatigue tests at one strain level
Cycles to reach 50 % of initial stiffness
## Theme Mix Design

<table>
<thead>
<tr>
<th>N° Mélange</th>
<th>Nature granulat</th>
<th>Courbe granulaire</th>
<th>Nature filler</th>
<th>TL</th>
<th>Nature liant</th>
</tr>
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<tbody>
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<td>Chaux éteinte</td>
<td>4.30%</td>
<td>35/45 HIP</td>
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<td>35/50</td>
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<td>Chaux éteinte</td>
<td>5.30%</td>
<td>35/45 HIP</td>
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<td>Calcaire</td>
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<td>35/45 HIP</td>
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<td>35/45 HIP</td>
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<td>Chaux éteinte</td>
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<td>35/50</td>
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<td>CRB</td>
<td>Discontinue 6/10</td>
<td>Calcaire</td>
<td>5.30%</td>
<td>35/50</td>
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<td>Mélange 8</td>
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<td>Calcaire</td>
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<td>35/50</td>
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<td>35/50</td>
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<td>35/50</td>
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<td>Chaux éteinte</td>
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<td>35/50</td>
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<td>35/50</td>
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<td>35/45 HIP</td>
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<td>5.30%</td>
<td>35/45 HIP</td>
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</table>
Measuring asphalt fatigue performance

Constant temperature

25 Hz
Measuring asphalt fatigue performance

Cycles to reach 50% of initial stiffness
One asphalt mixture / 8 different binders:

- BP STRUCTUR 10/20 S
- 35/50
- 35/50 + 2.5 % SBS
- 35/50 + 4.5 % SBS (High Vinyl Type)
- 35/50 + 2.0 % PPA
- 35/45 HIP
- 35/45 HIP + 2.5 % SBS
- 100/150 GEL + 6.0 % SBS
...to discuss (first) results...

Stiffness Modulus

![Graph showing stiffness modulus with 14 GPa as a threshold]
...to discuss (first) results...

Fatigue
...and issues to solve

Definition of Fatigue Life Criteria

- Graph showing $E'/E_0$ vs. $N/N_{50\%}$
- Graph showing $\Sigma W_i/W_n$ vs. $N$ (cycles)
- Graph showing $\phi$ vs. $N$ [cycles]
...and issues to solve

Model does not fit the data

35-50 + 20% - Bitume - Modélisation 2S2P1D

Problème basse température/haute fréquence

<table>
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<tr>
<th>Temp. (°C)</th>
<th>Temp. (°C)</th>
<th>Φ (°)</th>
<th>Φ (°)</th>
<th>Real (E-2)</th>
<th>Real (E-2)</th>
<th>Imaginary (E-2)</th>
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<td>18</td>
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</table>
...and issues to solve

Assess equipment compliance errors...

Problème DSR basse temp./haute fréq. - ETP Corbas

\[
\begin{align*}
\gamma_0 &= \gamma_{\text{mat}} + \gamma_{\text{tor}} \\
\gamma_{\text{tor}} &= A \tau \\
G_{\text{mat}}^* &= \frac{\tau^*}{\gamma_{\text{mat}}} \\
G_0^* &= \frac{\tau^*}{\gamma_0^*} = \frac{\tau^*}{\gamma_{\text{mat}}^* + \gamma_{\text{tor}}^*} \\
G_{\text{mat}}^* &= \frac{\gamma_{\text{mat}}^*}{\gamma_{\text{mat}}^* + \gamma_{\text{tor}}^*} \\
G_0^* &= \frac{G_{\text{mat}}^*}{1 + \frac{\gamma_{\text{tor}}^*}{\gamma_{\text{mat}}^*}} \\
G_0^* (1 + AG_{\text{mat}}^*) &= G_{\text{mat}}^* \\
G_{\text{mat}}^* (1 - AG_0^*) &= G_0^* \\
G_{\text{mat}}^* &= \frac{G_0^*}{1 - AG_0^*}
\end{align*}
\]
...and issues to solve

...which appear to change with time!

Problème DSR basse temp./haute fréq. - ETP Corbas

Twee publications at E&E 2012

Viscoelastic properties of bitumen blends obtained from pure and RAP-extracted binders (presented)

Effect of Reclaimed Asphalt Pavement on complex modulus and fatigue resistance of bitumens and asphalts