HSE evaluation for the use of rejuvenators - BioRePavation case study
Emmanuel CHAILLEUX
Plan

- Main objectives
- Project outline
- Short feedback concerning lab and full-scale validation
- HSE evaluation (fume emission)
  - Motivation
  - Procedure
  - Results
- Conclusions
Main objectives

- Towards a more environmentally friendly pavement
  - Save natural resources
    - virgin petroleum bitumen
    - virgin aggregate from quarries

Increase recycling rate
rate targeted: 50 – 70%

Take most advantages from the old brittle bitumen remaining from reclaim materials

At least: same level of quality in comparison to conventional technics
Project outline

• Evaluation of 3 alternative bio-materials designed to help recycling (rejuvenators → full replacement)
• Comparison with conventional high performances mix (EME)

- **Sylvaroad™**
- **Biophalt®**
- **Epoxidized methyl soyate**

• Technical assessment
  • Demonstrator: IFSTTAR accelerated pavement testing facility
    • Distress mechanism monitoring
    • Innovative non-destructive method

• Environmental assessment
  • Life cycle assessment
  • Fume emission measurements
A new type of base course mix has been designed: GB5 type mix (50% RAP and 70% RAP) using aggregate packing concept (by maximizing their interlock)

- Designed according to:
  - Aggregate availability on the plant
  - Lab studies of blends with virgin binder and recovered RAP binder in order to determine optimal dosage

- Main mix properties:
  - Very dense mix
  - High modulus with a relatively equivalent « soft binder »
  - Low binder content 4.5%

### Table

<table>
<thead>
<tr>
<th>Fraction</th>
<th>10-14mm</th>
<th>0-2mm</th>
<th>Filler</th>
<th>8-12mm RAP</th>
<th>0-8mm RAP</th>
<th>Added Binder</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>37.2</td>
<td>7.7</td>
<td>2.3</td>
<td>34</td>
<td>16</td>
<td>2.8</td>
</tr>
<tr>
<td>MIX1:</td>
<td>0.1%BM1+2.7%FB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MIX2:</td>
<td>2.8%BM2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MIX3:</td>
<td>0.1%BM3+2.7%FB</td>
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<td></td>
<td></td>
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</tbody>
</table>
possible to produce, in plant, these materials with high RAP content and biobinders or bio-additives

Moderate performances in lab but high performance at full scale in comparison to the conventional mix
HSE evaluation (fume emission)

Motivation

Field studies
Organic emissions during construction generated by asphalt mix

Laboratory studies
Fumes generated by bitumen

Unrepresentative of ASPHALT FUMES

Laboratory studies
Fumes generated by asphalt mix

Fume potential
Emission of mix in controlled environment

NO relevant effects
**IFSTTAR experimental method**

**Objective**
Environmental Assessment and ranking of **bituminous mixes** in lab

**Functions**
- Generate fumes
- Collect / Sample
- Analyse

**Parameters studied**
- Formula
- Binder
- Process
Composition of bituminous fumes

- Hot Mix Asphalt HMA Manufacturing
  - Fumes
    - Particles
      - Inorganic Particles
      - Organic Aerosol
        - Benzene Soluble Matter BSM
          - PAH\textsubscript{particle}
          - Other organic compounds
    - Gas
      - Volatile & Semi-volatile Compounds: VOC & SVOC
        - PAH\textsubscript{gas}

Compounds emitted in our laboratory conditions
Sampling protocol

Continous TOC assessment

Sequenced mixing procedure

Temps

4 min

4 min

4 min

4 min

4 min

4 min

4 min
## Formula studied

<table>
<thead>
<tr>
<th>Formula</th>
<th>Name</th>
<th>Mix</th>
<th>RA content (%)</th>
<th>Fresh binder</th>
<th>Fresh Binder content (%)</th>
<th>Additive content (%)</th>
<th>Manufacturing temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>EME</td>
<td>A</td>
<td>20</td>
<td>20/30</td>
<td>4.8</td>
<td>-</td>
<td>175</td>
</tr>
<tr>
<td>BioRepavation</td>
<td>MIX2</td>
<td>B</td>
<td>50</td>
<td>Biophalt</td>
<td>2.8</td>
<td>-</td>
<td>120, 150, 180</td>
</tr>
<tr>
<td>MIX1</td>
<td>C</td>
<td>50</td>
<td>50/70</td>
<td></td>
<td>2.7</td>
<td>0.1</td>
<td>120, 150, 180</td>
</tr>
<tr>
<td>MIX3</td>
<td>D</td>
<td>50</td>
<td>50/70</td>
<td></td>
<td>2.7</td>
<td>0.1</td>
<td>120, 150, 180</td>
</tr>
</tbody>
</table>
**Experimental program (temperatures)**

<table>
<thead>
<tr>
<th>Mixing temperature (°C)</th>
<th>120</th>
<th>150</th>
<th>180</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mix</strong></td>
<td>Virgin aggregate (°C)</td>
<td>RA material (°C)</td>
<td>Virgin aggregate (°C)</td>
</tr>
<tr>
<td>A (EME)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>B (MIX2)</td>
<td>120</td>
<td>120</td>
<td>200</td>
</tr>
<tr>
<td>C (MIX1)</td>
<td>120</td>
<td>120</td>
<td>200</td>
</tr>
<tr>
<td>D (MIX3)</td>
<td>120</td>
<td>120</td>
<td>200</td>
</tr>
</tbody>
</table>
TCOS Results : EME

Courbes d'émission de COTE en fonction du temps

- COT émis EME essai 2
- COT émis ESSAI 1
- Masse cumulée (cinétique d'émission) ESSAI 1
- Masse cumulée (cinétique d'émission) EME ESSAI 2

COTE (mg d'éq C/kg de bitume) vs Temps (s)
TOCs Results: MIX3 (mix1 similar)
TOCs Results : MIX2

Low TOCe peak at short time

At 180°C, fumes increase with stirring sequence (unusual)
Temperature influence on fume
Regeneration versus conventional mix

MIX1

MIX3

TOC max (mg EqC/m3) vs Mix C Manufacturing temperature (°C)

Cumulated Mass (mg EqC) vs Mix D Manufacturing temperature (°C)

EME @ 175°C
Temperature influence on fume full replacement versus conventional mix

MIX2

Recommendation to no-overheated Biophalt higher than 150°C (lower TOC max and Cum mass is equal at 150°C)
Conclusions

• It is possible to manufacture (in conventional asphalt plant) and also to lay (at full scale) a road material with 50% of RA while reducing the amount of fresh bitumen (up to full replacement)
  – Durability: the 3 innovative materials behave better that the reference one which is largely used in Europe for base courses

• Measurements of fume emissions were performed on bituminous materials to characterize total organic compounds generated by asphalt material
  – Strong link between bituminous material composition and their emission potential
  – At the usual manufacturing temperature, 160°C, no additional fumes on mix with rejuvenators (MIX 1 and 3) are observed in comparison to the reference mix (EME)
  – Concerning mix with full binder replacement (Mix 2), the best emission performance in comparison to reference mix (EME) is below 150°C.
Thanks to the BioRePavation Consortium

- **IFSTTAR** (France - coordination – has evaluated durability at full scale)
- **EIFFAGE Infrastructures** (France – has produced an alternative binder & carried out mix design tests)
- **IOWA STATE UNIVERSITY** (USA – has produced a bioasphalt & carried out mix design tests)
- **KRATON chemical** (Netherlands – has produced a bio-based performance additive)
- **WESTERN RESEARCH INSTITUTE** (USA – has carried out non-destructive in-situ evaluation and binder tests)
- **UNIVERSITY OF NOTTINGHAM** (UK - has conducted life cycle and risk assessment, and binder tests)
Thank you for your attention

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lab and full-scale validation
high performance in comparison to the conventional mix

- Low rutting level
- After 1 million cycles: no cracks on the innovative materials, some cracks on the reference material (High modulus mix – EME)
- After 1.8 million equivalent loadings at 65 kN, no cracks on two innovative materials, 10% on one innovative material, 27% on the reference EME
- Results confirmed by FWD measurements and in-situ micro-sampling and testing

<table>
<thead>
<tr>
<th>MIXES</th>
<th>Air voids</th>
<th>Rutting estimates after initial consolidation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference: EME</td>
<td>3.4%</td>
<td>1%</td>
</tr>
<tr>
<td>Mix1</td>
<td>3.3%</td>
<td>2%</td>
</tr>
<tr>
<td>Mix2</td>
<td>1.6%</td>
<td>2%</td>
</tr>
<tr>
<td>Mix3</td>
<td>2.0%</td>
<td>1%</td>
</tr>
</tbody>
</table>

![Evolution of cracking graph](image)