Performance control of bituminous mixtures with a high RAP content

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For saving bitumen, aggregate and energy resources, during the last ten years companies:

- Increased the RAP content
- Developed new processes to reduce the temperature

The main parameters to ensure the sustainability and mechanical performances of the bituminous mixtures with high RAP content:

- The homogeneity between the new binder and the binder coming from the RAP
- The binder properties resulting from the mixing: low temperature, ageing,...
Bituminous mixtures with high RAP content

Parameters:

- Industrial:
  - ✓ Batch or continuous plant
  - ✓ Homogeneity of the RAP in the stockpile
  - ✓ RAP incorporation method: Temperature (ambient temperature or preheating), Mixing time...

- Laboratory: European Manufacturing procedure: NF EN 12697-35
  - ✓ RAP is heated to 110 °C for 2H 30 or to the target mixing temperature to simulate the industrial manufacturing
  - ✓ Mixing time:

<table>
<thead>
<tr>
<th>Mixture type</th>
<th>Binder</th>
<th>Reclaimed asphalt</th>
<th>Mechanical mixing</th>
<th>Hand mixing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone mastic asphalt</td>
<td>Paving grade</td>
<td>Not included</td>
<td>4 min</td>
<td>5 min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Included</td>
<td></td>
<td>As appropriate</td>
</tr>
<tr>
<td>Modified</td>
<td>Included or not included</td>
<td>5 min</td>
<td></td>
<td>As appropriate</td>
</tr>
<tr>
<td>Other than stone mastic asphalt</td>
<td>Paving grade</td>
<td>Not included</td>
<td>3 min</td>
<td>5 min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Included</td>
<td></td>
<td>As appropriate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Included or not included</td>
<td>5 min</td>
<td></td>
</tr>
</tbody>
</table>
Bituminous mixtures with high RAP content

Correlation laboratory/ plant manufacturing

- RAP content 35 to 50%

Eurovia procedure:
- 40 s aggregates + RAP (110 °C – 2 H30) : 150 to 180 °C (according to the bitumen grade)
- 140 s after the binder adding. Before moulding the mixture we wait one hour.
Two tests were set up in the research centre:

- Experimental extraction system by leaching *
- Rheological model based on Hirsh model

*Navaro. J, Drouadaine. I, Proteau M., Pouteau B.,Mendez. S. (2012b), New methodology to qualify the binder in the production of warm mix asphalt with a high rate of recycling, CTAA

* Drouadaine. I, Faucon Dumont S., Proteau M., Mc Keon B., Girard M., Mendez. S. (2013), New methodology to qualify the binder in the production of warm mix asphalt with a high rate of recycling, IRF
Experimental extraction system

By progressive leaching

**Objective:**
- Define a tool to predict the homogeneity of a mixture

**Test description:**
- Progressive extraction * with a solvant and analysis of samples by infrared.

* ZEARLEY, 1979, CARPENTER et WOLOSICK, 1980, BICHERON, 1992, HUANG, 2005
Experimental extraction system

By progressive leaching

1) An air atomising nozzle with a conical screen to protect the user. Solvent flow from this nozzle is controlled by means of a needle gauge (2), a single piston pump (3) which draws liquid solvent into a tank (5). A discharge valve (4) and an expansion tank (6) ensure the correct load behind the nozzle and a properly adjusted and regular flow rate. The leaching cell consists of a vertical tube (7), closed at the bottom in a funnel shape which channels the leach, and covered above by the spray system (1) and a steel woven wire mesh screen (8) placed on a supporting grid (9). The reclaimed asphalt concrete sample (10) is placed on this screen. The system for sampling the channelled leach consists of a vacuum pump (11) which creates a depression under the screen and draws the collected leach to a sampling station with two storage units (12 and 13); filling is controlled by two 3-way valves (14, 15) so that the flasks can be filled in situ. Each flask is associated with a vent-valve device (16, 17) to return it to atmospheric pressure so that it can be easily replaced during the leaching process. A container (18) upstream from the vacuum pump acts as a safety device in case the leach should be drawn up accidentally.
Experimental extraction system

Evaluation of the blending degree

- Analysis of the CO (1700 cm\(^{-1}\)) and/or SO (1067 cm\(^{-1}\)) pics

- Example to determine a new index to qualify the homogeneity:
  
  ▶ From the CO pic:

\[
\text{Oxydation index} = \frac{a_i - a_{Ap}}{a_{AE} - a_{Ap}}
\]

- ai = slope with the sample n after leaching,
- aAp = slope with the new binder
- aAE = slope with the recovered binder from the RAP
Experimental extraction system

Evaluation of the blending degree

- **Examples**

Blending degree

Homogeneous mixture

Heterogeneous mixture

\[ y = 0.10x + 0.31 \]

\[ y = 0.36x + 0.46 \]
Rheological Model

Hirsch Model *

\[ |E|_m = P_c \left[ 4,200,000 \left( 1 - \frac{VMA}{100} \right) + 3 |G^*|_b \left( \frac{VFA \times VMA}{10,000} \right) \right] + \frac{(1 - P_c)}{\left( 1 - \frac{VMA}{100} \right) + \frac{VMA}{4,200,000} + \frac{3 |G^*|_b (VFA)}{1000}} \]

\[ P_c = \frac{\left( 20 + 3 |G^*|_b \left( \frac{VFA}{(VMA)} \right) \right)^{0.58}}{650 + \left( 3 |G^*|_b \left( \frac{VFA}{(VMA)} \right) \right)^{0.58}} \]

VMA : Voids in mineral aggregates

VFA : Voids filled by binder

*Christensen, D., Pellinen, T., Bonaquist, RF. (2003), Hirsch model for estimating the modulus of asphalt concrete, Journal of the association of asphalt paving technologists, vol. 72 p 97-121
For different bituminous mixtures we determined:

- VMA,
- VFA,
- Recovered G*
- E* (HMA)

=> Significant difference for HMA with a modulus > 14000 MPa
### Rheological Model

#### « Correlation » PG / Penetrability

<table>
<thead>
<tr>
<th>PG</th>
<th>82-4</th>
<th>76-16</th>
<th>70-16</th>
<th>70-22</th>
<th>64-22</th>
<th>64-28</th>
<th>58-28</th>
<th>52-34</th>
</tr>
</thead>
<tbody>
<tr>
<td>82-10</td>
<td>76-10</td>
<td>70-16</td>
<td>70-22</td>
<td>64-22</td>
<td>64-28</td>
<td>58-28</td>
<td>52-34</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Penetrability (1/10 mm)</th>
<th>10/20</th>
<th>20/30</th>
<th>35/50</th>
<th>50/70</th>
<th>70/90</th>
<th>90/100</th>
<th>120/140</th>
<th>160/220</th>
</tr>
</thead>
</table>

- **Surface course**
- **Base course**
Modification of the Hirsh model parameters for a larger bitumen grade range
**Bituminous mixture with high RAP content**

**Example 1: Qualification of a blending**

<table>
<thead>
<tr>
<th>Blending degree</th>
<th>G* recovered 15 °C, 10 Hz (MPa)</th>
<th>E* measured 15°C, 0.02 s (MPa)</th>
<th>E* calculated 15°C, 10Hz (MPa)</th>
<th>Δ (E* mea.- E<em>cal)/E</em> mea.) *100 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA (40% RAP + PmB)</td>
<td>0.03</td>
<td>41.4</td>
<td>13300</td>
<td>13890</td>
</tr>
<tr>
<td>HMA (10% RAP + 35/50)</td>
<td>0.04</td>
<td>30</td>
<td>12500</td>
<td>12760</td>
</tr>
<tr>
<td>WMA (10% RAP + 35/50)</td>
<td>0.03</td>
<td>30</td>
<td>11500</td>
<td>11380</td>
</tr>
<tr>
<td>HMA (40% RAP + PmB)</td>
<td>0.04</td>
<td>44</td>
<td>15070</td>
<td>14440</td>
</tr>
<tr>
<td>WMA (70% RAP + 35/50)</td>
<td>0.16</td>
<td>59</td>
<td>10025</td>
<td>14700</td>
</tr>
<tr>
<td>WMA (20% RAP + 35/50)</td>
<td>0.11</td>
<td>63</td>
<td>13500</td>
<td>14700</td>
</tr>
<tr>
<td>WMA (20% RAP + 35/50)</td>
<td>0.25</td>
<td>53</td>
<td>10100</td>
<td>13730</td>
</tr>
<tr>
<td>HMA (20% RAP + 35/50)</td>
<td>0.02</td>
<td>65</td>
<td>15300</td>
<td>15480</td>
</tr>
<tr>
<td>WMA (50% RAP + 2.9% 50/70)</td>
<td>0.03</td>
<td>56</td>
<td>12280</td>
<td>12600</td>
</tr>
</tbody>
</table>
Bituminous mixture with high RAP content

Analysis

- With a blending degree inferior to 0.1 (homogeneous mix), the difference between the calculated $E^*$ and the measured $E^*$ on the asphalt concrete is inferior to 10%.

- With a blending degree superior to 0.15 (heterogeneous mix), the difference between the calculated $E^*$ and the measured $E^*$ on the asphalt concrete is superior to 20%.
Example 2: Evaluation of the new binder characteristics on the asphalt mixtures according to the RAP content

- Evaluation of the HMA modulus for different RAP content (pen. = 14 1/10 mm, TBA= 73°C) by adjusting the new binder to reach a theoretical penetrability of 31.
  - The different bitumen grade come from the same refinery
  - Lab procedure:
    - RAP is preheated 2 H 30 at 110°C
    - The mixing time : 140 s
    - Four mixtures : 0, 20, 45 and 70%
    - Total binder content is fixed
  - The blending degree for all the mixture is between 0.02 and 0.08.
Example 2: Evaluation of the new binder characteristics on the asphalt mixtures according to the RAP content

For the same theoretical binder grade the impact of the ratio between aged binder coming from the RAP / new binder affects significantly the HMA modulus.
Eurovia developed 2 complementary tests to qualify the bituminous mixtures with RAP and adjust the lab manufacturing to the industrial plant

- Extraction system by a progressive leaching followed by infrared (chemical analysis)
- Rheological model to calculate $E^* = f(\text{VMA}, \text{VFA}, \text{Recovered G}^*)$ up to 20,000 MPa

Further tests are in progress:

- To characterize the leachate by rheological tests to define a gradient dynamic modulus in the asphalt concrete
- To determine new oxidation index based on CO, SO pics ... to compare for example the impact of the plant type ...
All these tests are not sufficient to ensure the sustainability.

- Measurements of the mechanical properties of the binder (after RTFOT or RTFOT + PAV) in comparison to pure bitumen are necessary.
  - BBR, ABCD tests...
  - Rheological measurements (DSR, MSCR, LAS...)

Conclusion

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THANK YOU FOR YOUR ATTENTION