WARM MIX ASPHALT in COLAS
OUTLINE

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4. SPECIFICATIONS
5. LATEST DEVELOPMENT
6. ENVIRONMENTAL ASPECT
7. CONCLUSION
- Greener solutions
- Cost of energy

New incentives
National agreement MEEDAT + road industry

<table>
<thead>
<tr>
<th>RAP</th>
<th>60%</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHG</td>
<td>33%</td>
<td>2020</td>
</tr>
</tbody>
</table>
DEFINITIONS

- HOT MIX: > 160°C
- WARM: > 100°C – 140°C
- HALF WARM: 60°C - 100°C
- COLD MIXES: UP to 60°C

Without H₂O or For a transient period
With H₂O
MORE THAN 8 SOLUTIONS

- WAM-Foam
- Sasobit
- Evotherm
- Aspha-Min
- Low Emission Asp
- Double barrel
- Rediset WMX
- Cecabase RT

- Sasol
- MEADWESTVACO
- Lea Co
- ASTEC Industries, Inc.
- AKZO NOBEL
- Arkema Group
WARM MIX - DEVELOPMENT FOR COLAS

- 2002: First Trial
- 2004: RN 157
- 2007: Colas Additive First trial
- 2008: FOAM trials North America
- 2010
SPECIFICATIONS FOR WARM MIXES

- Mechanical performances: Warm Mix ≥ Hot Mix
- Preference for solutions: without water
- Ability to produce and pave any kind of Mixes
- Suitability for all kind of mixing plants
- Temperature reduction: 30 - 40°C

SINCE 2008

Development to Pmb, RAP
FOAM  WMA  Colas NA

Existing Foam production systems evaluation in progress

ASTEC Double Green

MAXAM Aquablack

GENCOR Ultra foam
Principle

Foamed binders’ facilitates coating Mix Workability increased

But …

Behaviour of foam in the mix after mixing?

Cost: Investment.

No need for additives. But foaming ability differs from binders

US Market Mainly PG 64-22 (Pen 50/70 bitumen). Softer than France (Limits of this process?)
Chemical Additives

Used From 2005 to 2007

Principle: Reduction of the viscosity of the binder

- Performance of Mixes → ok
- Effect of the additives on binders: Increase of TBA and G*
- Limits of this process
  - Cost of the additive
  - Impact of the additive on the Environmental benefit of the process

Process stopped in 2007
Liquid Chemical Additives

Principle

Effect of the additive at the interface Bitumen/Aggregate

- Performance of Mixes → ok
- No modification of the binder
- Investment reduced
- Solution adapted for all kind of mixes
- Cost of the additive reduced compared to solid additives
- First trial in 2007. Now more than 1,000,000 t of Warm mix paved
<table>
<thead>
<tr>
<th></th>
<th>EME CCB</th>
<th>EME 3E CCB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binder Content</td>
<td>5.21 %</td>
<td></td>
</tr>
<tr>
<td>% RAP</td>
<td>20 %</td>
<td>20%</td>
</tr>
<tr>
<td>Temp (°C)</td>
<td>180°C</td>
<td>140°C</td>
</tr>
<tr>
<td>Complex modulus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% voids</td>
<td>3.3</td>
<td>3.4</td>
</tr>
<tr>
<td>$E^*_{15\degree C\ 10Hz\ (MPa)}$</td>
<td>16220</td>
<td>16436</td>
</tr>
<tr>
<td>fatigue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% voids</td>
<td>3.3</td>
<td>3.4</td>
</tr>
<tr>
<td>$\varepsilon_{6\ 10\degree C\ 25Hz}$</td>
<td>130</td>
<td>127</td>
</tr>
</tbody>
</table>

No difference between Warm and Hot
Liquid Chemical Additives

A 75 New Motorway

RAP 25 % in base course / 20 % in surface layer

Very Thin Asphalt Layer
Rugosoft on 225 000 m²

Warm High Modulus Asphalt
RAP 25 %
Liquid Chemical Additives

Last Trials: High RAP content. 2009 RN 2 LAON
Base course 40% RAP / Batch Plant

<table>
<thead>
<tr>
<th></th>
<th>Hot Mix RAP 40%</th>
<th>Hot Mix RAP 40%</th>
<th>Warm Mix RAP 40%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binder content (%)</td>
<td></td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>Temp (°C)</td>
<td>160</td>
<td>160</td>
<td>120</td>
</tr>
<tr>
<td>% voids at 100 gir.</td>
<td>4.1</td>
<td>5</td>
<td>4.8</td>
</tr>
<tr>
<td>Water Resistance</td>
<td>0.78</td>
<td>0.86</td>
<td>0.86</td>
</tr>
<tr>
<td>Rutting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% void content</td>
<td>7.3</td>
<td>7</td>
<td>8.7</td>
</tr>
<tr>
<td>% rut after 30000 cy.</td>
<td>4.5</td>
<td>3.1</td>
<td>4.1</td>
</tr>
<tr>
<td>Modulus 15°C10Hz(MPa)</td>
<td>10852</td>
<td>12114</td>
<td>12187</td>
</tr>
<tr>
<td>Fatigue resistance ε6 μdefs</td>
<td>89</td>
<td>95</td>
<td>91</td>
</tr>
</tbody>
</table>

On site: No difference in void content and in mechanical performances.
Liquid Chemical Additives

Racing track

Warm mixes in base and binder courses

RAP 20%

Energy saving and GHG reduction ~ 10%

Continuous warm mix production for 1 week
Liquid Chemical Additives  | Energy saving

Measurements 2007 - 2008

<table>
<thead>
<tr>
<th></th>
<th>Energy saving measured</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RD 906 Ecolastic M DB</td>
<td>17 %</td>
<td>50 MJ/t</td>
</tr>
<tr>
<td>Malauzat BBSG 0/10 3E</td>
<td>18 %</td>
<td>84 MJ/t</td>
</tr>
<tr>
<td>RN 333 BBMc 3E</td>
<td>- 15 à -20 %</td>
<td>31 à 40 MJ/t</td>
</tr>
<tr>
<td>A 75 GB 3E +R / GB</td>
<td>- 1.1 l/ton</td>
<td>61 MJ/t</td>
</tr>
</tbody>
</table>

Results coherent with previous ones and with Ecologiel
Environmental Aspect

Improvement of working conditions: significant fumes reduction

Temperature reduced - less steam

Also for inhabitants
Environmental Aspect

Campaigns conducted with external partners
Significants measurement point selected

Difficult to give a precise figure for reduction
• quantities detected extremely low on control mixes
  (sometimes under detection threshold of available equipment)
• sensitivity to environment
  (road traffic, influence of worksite, cigarette smoke)
International Development

- 2008 Romania, UK, Czech Republic, Belgium
- 2009 Poland, Denmark, Hungaria, Croatia, Canada (Alberta, Alaska..)
- 2009 Morocco, Réunion Island,

Other Benefit

mixes produced at «usual temperature »

- Improvement of workability - facilitate specific jobs (bridges)
- Ability to haul the mix on longer distances and still have workability to place and compact (exemple Nouvelle Calédonie)
Conclusion

• Now more than 1,500 000 t for COLAS
• Spreading of our solutions
  • All products
  • All kind of Jobs
  • All countries
• No failure up to now
  (Respect of manufacturing temperatures, compaction procedure,..)
• … But we still have a look to other possible solutions