High Modulus Asphalt: the French Experience

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CONTENT

- Background
- Mix design
- Pavement design: road pavements
- Pavement design: airport pavements
- Manufacturing and placing
- Developments
- Conclusions
BACKGROUND

- 1980
- A COLAS invention
- GBTHP
- Very high performance road base asphalt
- $E^* = 16000 \text{ Mpa (15°C 10 Hz)}$
- $\varepsilon_6 = 160 \times 10^{-6} \mu\text{s (10°C 25 Hz)}$
BACKGROUND

- 1988
- Technical advice
- GBTHP
- Very high performance road base asphalt
- $E^* = 16000$ Mpa (15°C 10 Hz)
- $\varepsilon_6 = 160 \times 10^{-6}$ µs (10°C 25 Hz)
BACKGROUND

- Oct. 1992
- French Standard
- NF P 98140
- Updated in Nov. 1999

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BACKGROUND

- Oct. 1992
- French Standard
- NF P 98140
- Updated in Nov. 1999
- 2 types of EME
- Focus on EME2:
  - \( E^* > 14000 \text{ Mpa} \) (15°C 10 Hz)
  - \( \varepsilon_6 > 130 \times 10^{-6} \text{ } \mu \text{s} \) (10°C 25 Hz)
BACKGROUND

- A few words about the French asphalt mix design method
- 4 levels of performance based tests
  - Water resistance
  - Resistance to permanent deformation
  - Stiffness modulus $E^*$
  - Fatigue resistance $\varepsilon_6$
A few words about the French asphalt mix design method

- **4 Levels of Performance Based Tests**
  - Water resistance
  - Resistance to permanent deformation
  - Stiffness modulus $E^*$
  - Fatigue resistance

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BACKGROUND

- A few words about the French asphalt mix design method.
- 4 levels of performance-based tests:
  - Water resistance
  - Resistance to permanent deformation
  - Stiffness modulus $E^*$
  - Fatigue resistance

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BACKGROUND

- Water resistance EN 12697-12
- Compressive strength on core after 8 days of immersion
BACKGROUND

- Resistance to permanent deformation: EN 12697-22
- Determination of rut depth
BACKGROUND

- Stiffness modulus $E^*$ EN 12697-26
- Sinusoidal dynamic deflexion 15°C 10 Hz
- Direct tension 15°C 0.02 s
BACKGROUND

- Fatigue resistance (EN 12697-24)
- Determination of strain level for 1 million cycles $\varepsilon_6$ (10°C 25 Hz)
BACKGROUND

- 1994
- The French Design Manual for Pavement Structures
BACKGROUND

- 1994
- The French Design Manual for Pavement Structures
- English version in 1997
BACKGROUND

- 1997
- An updated Avis Technique
- COLBASE S

- \( E^* = 16000 \, \text{Mpa (15°C 10 Hz)} \)
- \( \varepsilon_6 = 145 \times 10^{-6} \, \mu\text{s (10°C 25 Hz)} \)
BACKGROUND

- 1998
- The French guide for new pavement structure (SETRA/LCPC)
BACKGROUND

- 1998
- The French guide for new pavement structure (SETRA/LCPC)

Road base asphalt: 21 cm
EME: 15 cm
- 29%
BACKGROUND

- 2008
- European Standard EN 13108-1
- EME2

- AC Ø base binder
  \[ S_{min} = 14000 \, \varepsilon_{6-130} \quad \text{Vi} = 3\% \quad \text{and} \quad \text{Vs} = 6\% \]
MIX DESIGN

- An appropriate combination of
  - Aggregates
  - Bitumen

- An appropriate gradation
  - The standard does not provide with any specification
  - The main aim is to reach a dense mix: void content between 3 & 6% when tested with the gyratory compactor (80 to 120 revolutions depending on the maximum aggregate size)

- An appropriate bitumen
  - A « hard » bitumen
  - A high bitumen content
Mix design

- The characteristics of the bitumen will provide the mix with its modulus (and rutting resistance).
- The bitumen content will provide the mix with its fatigue properties (and water resistance).
Mix design

- Basically, the stiffness $E^*$ of the mix will depend on the stiffness $G^*$ of the binder.
- A 10/20 might be suitable (e.g. Netherland).
- A 10/20 might not be suitable (e.g. Cesch Rep.).
- A 20/30 might be suitable (e.g. South Africa).
**Mix design**

- Basically, the stiffness modulus of the mix will depend on the stiffness of the binder
  - A 10/20 might be suitable (e.g. Netherland)
    - Pen 19 G* 82 MPa
  - A 10/20 might not be suitable (e.g. Cesch Rep.)
    - Pen 18 G* 35 MPa
  - A 20/30 might be suitable (e.g. South Africa)
    - Pen 28 G* 80 MPa

- Bitumen used for EME:
  - Straight run bitumen (e.g. Netherland)
  - Propane bitumen (e.g. South Africa)
  - Blown bitumen (e.g. Australia)
Mix Design

- Basically, the stiffness modulus of the mix will depend on the stiffness of the binder
- A 10/20 might be suitable (e.g. Netherland)
- A 10/20 might not be suitable (e.g. Cesch Rep.)
- A 20/30 might be suitable (e.g. South Africa)
- A (SBS) modified bitumen will provide the mix with improved fatigue resistance
**Mix Design**

- A summary of this history

<table>
<thead>
<tr>
<th></th>
<th>GB2</th>
<th>GB3</th>
<th>GB4</th>
<th>EME1</th>
<th>EME2</th>
</tr>
</thead>
<tbody>
<tr>
<td><em><em>E</em> (Mpa)</em>*</td>
<td>9000</td>
<td>9000</td>
<td>11000</td>
<td>11000</td>
<td>14000</td>
</tr>
<tr>
<td><strong>ε6 (µs)</strong></td>
<td>80</td>
<td>90</td>
<td>100</td>
<td>100</td>
<td>130</td>
</tr>
</tbody>
</table>

- Binder pen ↓
- Binder content ↑
- Pavement thickness ↓

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PAVEMENT DESIGN: ROAD PAVEMENTS

- How to make the best use of the characteristics measured in the laboratory taking into account the actual service conditions?
PAVEMENT DESIGN: ROAD PAVEMENTS

- How to make the best use of the characteristics measured in the laboratory taking into account the actual service conditions?
- 1st step
PAVEMENT DESIGN: ROAD PAVEMENTS

- How to make the best use of the characteristics measured in the laboratory taking into account the actual service conditions?
- 2nd step
PAVEMENT DESIGN: ROAD PAVEMENTS

- How to make the best use of the characteristics measured in the laboratory taking into account the actual service conditions?
- 2nd step

\[ \varepsilon_t < \varepsilon_{t,ad} \]
\[ \varepsilon_z < \varepsilon_{z,ad} \]
PAVEMENT DESIGN: ROAD PAVEMENTS

- PF3: 120 Mpa
- TC6: 6.5 to 17.5 ESAL
- t°: 15°C

Road base asphalt: 21 cm
EME: 15 cm

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- 29%
PAVEMENT DESIGN: ROAD PAVEMENTS

- In France, EME is a commonly used technique
- A technique that is used for both new construction and strengthening works
- The main difficulty is to source appropriate bitumen at an acceptable cost
- A major site: the « tamarin road » in the Réunion Island (Indian Ocean)
PAVEMENT DESIGN: ROAD PAVEMENTS

A major (and exotic) reference: the « tamarin road » in the Réunion Island (Indian Ocean)

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PAVEMENT DESIGN: ROAD PAVEMENTS

- A major (and exotic) reference: the « tamarin road » in the Réunion Island (Indian Ocean)
  - 200,000 T of EME
  - Basaltic local aggregates (high specific gravity)
  - Impact of the porosity: part of the bitumen is not « active »
  - B 20/30 from Engen (South Africa)
  - Impact of the binder content
    - 5.8%: 128 µs
    - 6.2%: 132 µs
PAVEMENT DESIGN: AIRPORTS

- In France, airport pavement design has been based on the use of structural numbers

- Structural numbers:
  - Bituminous concrete 2.0
  - Road base asphalt (GB) 1.5
  - Crushed graded material 1.0 (reference)

- Structural numbers for « new » materials
  - EME 1.9
  - BBME 2.5
PAVEMENT DESIGN: AIRPORTS

- Road base asphalt (GB)  1.5
- EME  1.9

\[
\begin{align*}
\text{GB} & \quad \text{Crushed graded material} & \quad \text{EME} \\
10 \text{ cm} \times 1.5 & = 15 \text{ cm} & : 1.9 & = 7.9 \text{ cm}
\end{align*}
\]
PAVEMENT DESIGN: AIRPORTS

- Use on CDG (Paris) airport in 2002: runway 2
PAVEMENT DESIGN: AIRPORTS

- An existing concrete pavement
- Pavement design:
  - Linking concrete slabs
  - 2 cm SAMI: PMB sand asphalt
  - 7 cm EME (B20/30)
  - 6 cm BBME (PMB) high modulus asphalt concrete
MANUFACTURING AND PLACING

- Nothing very specific compared to conventional asphalt mixes
- Manufacturing temperature: 160 to 190°C
- Placing and compaction:
  - High bitumen content may lead to fating up
  - Specific care to the joints
  - The use of RAP eases compaction
  - Aim a low void content (spec: < 6%)
MANUFACTURING AND PLACING

- First warm EME has been used in Dec. 2007 (city of Meaux)
- Morning temperature: -1°C
- Manufacturing temperature: 140°C
MANUFACTURING AND PLACING

- A (warm) thin overlay was placed on the EME base course
DEVELOPMENTS (OUTSIDE FRANCE)

- Preliminary remark:
- Pavement design methods vary (empirical, rationnal, combination)
- Testing methods vary
- Local conditions vary
  - Temperature, axle load, traffic
DEVELOPMENTS (OUTSIDE FRANCE)

- Example: modulus assessment

  Sinusoidal dynamic deflection

  Appendix A
  15°C 10 Hz
  2 PB-TR

  Appendix B
  20°C 8Hz
  3-4 PB-PR

  Impulsion

  Appendix C
  20°C 124ms
  IT-CY

  Direct Tension

  Appendix D
  15°C 0.02s
  DTC-CY

Correlation between value
DEVELOPMENTS (OUTSIDE FRANCE)

- Local assessment needs to be made:
  - Testing methods
  - Performances
- Example in South Africa: testing methods

Table 1: French performance tests and selected South African equivalents

<table>
<thead>
<tr>
<th>Parameter</th>
<th>French test method</th>
<th>Selected South African equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workability</td>
<td>EN 12697 - 31: Gyratory compactor</td>
<td>ASTM D6926: SUPERPAVE gyratory compactor</td>
</tr>
<tr>
<td>Durability</td>
<td>EN 12697 - 12: Duriez test</td>
<td>ASTM D4867: Modified Lottmann test</td>
</tr>
<tr>
<td>Permanent deformation</td>
<td>EN 12697 - 22: Wheel tracker</td>
<td>AASHTO 320-03 SUPERPAVE shear test</td>
</tr>
<tr>
<td>Dynamic modulus</td>
<td>EN 12697 - 26: Flexural beam</td>
<td>AASHTO TP 62 dynamic modulus</td>
</tr>
</tbody>
</table>
DEVELOPMENTS (OUTSIDE FRANCE)

Local assessment needs to be made:
- Testing methods
- Performances

Example in South Africa: performances

Latest tests confirm outstanding durability characteristics of high modulus asphalt

<table>
<thead>
<tr>
<th>Workability</th>
<th>after 45 gyrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture sensitivity</td>
<td>Modified Lottman</td>
</tr>
<tr>
<td>Permanent deformation</td>
<td>RSST-CH, 55C, 5á000 repititions</td>
</tr>
<tr>
<td>Dynamic modulus</td>
<td>Dynamic modulus test at 10Hz, 15°C</td>
</tr>
<tr>
<td>Fatigue</td>
<td>Beam fatigue test at 10 Hz, 10C, to 70% stiffness reduction</td>
</tr>
</tbody>
</table>
DEVELOPMENTS (OUTSIDE FRANCE)

- Local assessment needs to be made:
  - Pavement design
- Example in the United Kingdom
Pavement Design
DEVELOPMENTS (OUTSIDE FRANCE)

- DBM50: 320 mm
- EME2: 260 mm

Same Traffic and subgrade

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DBM50: 320 mm
EME2: 260 mm
DEVELOPMENTS (OUTSIDE FRANCE)

- Poland
- Morocco
  - First worksite in 2000
  - Often used on highways
  - Mix design includes RAP 25%
- Australia
- Mauritius
DEVELOPMENTS (OUTSIDE FRANCE)

- Mauritius
  - Several road projects since 2010
    - Triolet bypass
DEVELOPMENTS (OUTSIDE FRANCE)

- Mauritius
  - SSR international airport
DEVELOPMENTS (OUTSIDE FRANCE)

- Mauritius
  - SSR international airport
- Runway overlay and parallel taxiway works
  - Owner: Airports of Mauritius
  - Engineer: Jacobs (UUK) and Gibb (Mauritius)
- Design system: FAARFIELD
- Alternatives main goal: to save materials
- Basic design (new taxiway)
DEVELOPMENTS (OUTSIDE FRANCE)

- Basic design (new taxiway)
- Alternative design
  - 105 mm thickness saving
CONCLUSIONS

- EME is a fully reliable technique that has been used for more than 20 years.
- Developments outside France have confirmed its efficiency.
- The selection of the right binder is a crucial issue.
- Development should include a careful study of its mechanical characteristics, to be used in the pavement design model.
- All of you are more than welcome to visit our main lab facilities and worksites in progress.