FROM THEORETICAL ACOUSTICS STUDIES TO IMPLEMENTATION ON A WORKSITE: A MAJOR STEP TOWARDS ROLLING NOISE REDUCTION

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**Target of the research programme:**
New urban surface layer with improved acoustic efficiency

**3 sets of tools available:**
- Surface texture
  - size of aggregates
  - laying and compaction techniques
- Mechanical impedance
- Acoustic absorption

Urban pavement -> limited speed
-> absorption key factor
**Acoustic absorption: INRETS - LCPC model**

JF. Hamet - M. Bérengier

Acoustic energy dissipation through thermal and viscous exchange between solid structure and air within the void network.

Based upon the knowledge of 4 parameters:
- Layer thickness
- "efficient" porosity
- Specific resistance to air flow $R_s$
- Shape factor $K$

Characterisation through Kundt Tube (LCPC) or Impédance Tube (Brueil & Kjaer at C.S.T.)
Acoustic absorption: INRETS - LCPC model

Influence of two parameters

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**DLα index**

Absorb, ... but in the right frequency range

-> DLα index, inspired from screening walls characterisation  
*(NF EN 1793-1)*

\[
DL\alpha = -10 \log \left( 1 - \frac{\sum \alpha_i 10^{0.1L_i}}{\sum 10^{0.1L_i}} \right)
\]

\[
DL\alpha = -10 \log \left( \frac{\sum 10^{0.1L_i} - \sum \alpha_i 10^{0.1L_i}}{\sum 10^{0.1L_i}} \right)
\]

\[
DL\alpha = +10 \log \left( \sum 10^{0.1L_i} \right) - 10 \log \left( \sum (1 - \alpha_i) 10^{0.1L_i} \right)
\]

**Incoming signal**

**Reflected signal**

\(\alpha_i\): acoustic absorption coefficient in the i\textsuperscript{th} third octave band

\(L_4\): A-weighted acoustic pressure level of traffic in the i\textsuperscript{th} third octave band
Tests on unbound materials

Impedance tube in a vertical position

glass beads, single graded chips
(quarry aggregates, expanded clay, calcined bauxite)

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Tests on unbound materials

Determinations of $V_{\text{calc}}$, $R_s$, and $K$ parameters by adjustment real data and theoretical curve under Matlab.

Variation of $D\alpha$ with respect to layer thickness.

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Tests on unbound materials

Thermal and viscous exchanges on particles surface: The centre of too large pores does not contribute

Absorption optimum w.r.t. particle size: between 1,5 and 2,0 mm
Tests on asphalt mixes

23 different asphalt mixes tested, i.e. 130 samples:

- BBDr, BBTM, BBSG, Specific products
- Thickness between 25 and 72 mm
- Determination of $V_{\text{calc}}$, $R_s$, K parameters for each sample
- Classification and average values per type of mixes

Variation of DL$\alpha$ for a BBDr 0/6 with respect to thickness
Two different asphalt mixes families:
- porous $d/D$
- others

- Both series cross for $D \leq 3$ mm
Almost one-to-one relation
(as d/D porous asphalt mixes have all similar K values)
Rs vs « real voids »

Two different asphalt mixes families:
- porous d/D
- others

Both series cross for $D \leq 3 \text{ mm}$
Determination of absorption performances

Precision on $K$ value with respect to $V_{\text{real}}$

Precision on $R_s$ value with respect to $V_{\text{real}}$

Precision on $V_{\text{calc}}$ value with respect to $V_{\text{real}}$

Real void content of the mix absorption performances known with 1 dB(A) bias
Conclusions:

The absorption model is well adapted to describe the absorption phenomenon, for unbound materials such as glass beads or aggregates, as well as porous asphalts but also more conventional products.

Difference between “real” and “efficient” void content

Absorption optimum for 1,5 – 2,0 mm particles

Absorption performances predicted from “real” void content (except for d/D porous asphalts), since model parameters are indeed linked together for asphalt mixes

Optimum thickness depends also on real void content
**Targets for the mix design laboratory:**

Physical and mechanical properties which are appropriate for the different types of rural and urban road and motorway pavements whether it is used in very thin or thin layers,

A good and durable skid resistance at all traffic speeds

A good surface drainability that reduces rain water splashes

An homogeneous and aesthetical texture

A good resistance to rutting

A considerable and lasting reduction in rolling noise.
The on-site achievement of those efforts
The on-site achievement of those efforts

- 0/4 mm optimized grading curve
- SBS modified bitumen
- Laying thickness between 25 and 40 mm
- Conventional paver and drum compactors

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### Long lasting mechanical performances

<table>
<thead>
<tr>
<th>Tests</th>
<th>New product</th>
<th>BBTM 0/6 NF P 98-137 Class 2</th>
<th>BBM 0/10 NFP 98 132 Class 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>P.C.G. (NF EN 12697-10 et 31), Void content after 200 gyrations</td>
<td>25 ≤ V ≤ 30</td>
<td>20 ≤ V ≤ 25</td>
<td>-----</td>
</tr>
<tr>
<td>Duriez test (NF P 98-251-1) Immersion / compression ratio</td>
<td>≥ 0.80</td>
<td>≥ 0.80</td>
<td>≥ 0.75</td>
</tr>
<tr>
<td>Rutting test (NF EN 12697-22), in % at 60 °C, 5 cm thickness, highly SBS-modified binder</td>
<td>≤ 15</td>
<td>≤ 20</td>
<td>≤ 10</td>
</tr>
<tr>
<td>Traffic ≤ T 3 = BBM class 2 = 10 000 cycles</td>
<td>≤ 10</td>
<td>-----</td>
<td>≤ 10</td>
</tr>
<tr>
<td>Traffic ≥ T 2 = BBM class 3 = 30 000 cycles</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Very good skid resistance at all speeds**

Despite the very small grading size

<table>
<thead>
<tr>
<th>Longitudinal Friction Coefficient</th>
<th>New product 0/4</th>
<th>BBTM 0/10 Reference</th>
<th>French specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Measures after 6 months, traffic T 1</strong></td>
<td></td>
<td></td>
<td>Lower limit</td>
</tr>
<tr>
<td>40 km/h</td>
<td>0.68</td>
<td>0.65</td>
<td>0.36</td>
</tr>
<tr>
<td>60 km/h</td>
<td>0.62</td>
<td>0.50</td>
<td>0.25</td>
</tr>
<tr>
<td>90 km/h</td>
<td>0.57</td>
<td>0.39</td>
<td>0.14</td>
</tr>
<tr>
<td><strong>Texture Mean Depth (NF EN 13 036-1), in mm</strong></td>
<td>0.6 to 0.8</td>
<td>0.95</td>
<td></td>
</tr>
</tbody>
</table>

*RD 974 near Dijon*
9 dB(A) reduction compared to traditional pavements

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<tr>
<th>Acoustic properties</th>
<th>New product 0/4</th>
<th>BBTM 0/10 Reference</th>
</tr>
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<tbody>
<tr>
<td>SPB measurements (NF EN ISO 11819-1) After 6 months, traffic T1, at 20°C and 90...km/h, $L_{a_{max}}$ in dB (A)</td>
<td>69.4</td>
<td>78.6</td>
</tr>
</tbody>
</table>

RD 974 near Dijon
9 dB(A) reduction compared to traditional pavements

Boulevard de La Madeleine - Lille

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<tr>
<td>CPX measurements (XP S 31-145)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After 2 months, at 20°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$L_{a_{\text{max}}} \text{ in dB (A)}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>at 50 km/h</td>
<td>82.0</td>
<td>90.1</td>
</tr>
<tr>
<td>at 90 km/h</td>
<td>91.1</td>
<td></td>
</tr>
</tbody>
</table>
Nanosoft: « nano » for « - 9 »

Committed for more than 15 years to fighting against traffic noise

First pavement which laboratory design was guided by a theoretical performance based approach

A 9 dB(A) noise reduction, due to the 4 mm grading curve, with optimised void shape and content

Skid resistance, mechanical behaviour, aesthetical aspect
Thank you for your attention