SUMMARY

ADVANTAGES OF ASPHALT RUBBER BINDER
FOR POROUS ASPHALT CONCRETE

By Alain SAINTON
Technical Director of BEUGNET Group - France

In France, after 10 years of scattered experiments, Porous Asphalt Concrete (PAC) mixes are expected to solve the problems of aquaplaning, water projection, noise reduction and the mirror effect at night.

There were some apprehensions regarding the adaptability of the material to winter maintenance and the gradual reduction in draining properties with time on heavy traffic roads or turnpikes.

A French contractor specializing in roads and turnpikes construction carried out in 1982 laboratory studies of a new modified binder composed of an Asphalt Ground Rubber mix. This binder has remarkable rheological properties (viscosity at 200°C 10 times over for pure asphalt and elastomer properties with high elongation even at low temperature) and a very good resistance to aging.

The first use of Asphalt Rubber Binder (ARB) was the stressed absorbing membrane (SAM) and the stressed absorbing membrane interlayer (SAMI). But ARB qualities conducted the engineers to formulate Porous Asphalt Rubber Concrete (PARC) and to investigate them comparatively to other formula by very sophisticated laboratory tests as following:

1. Compressive tests data with water stripping resistance
2. Gyratory test for workability of the mixes
3. Mechanical properties with ERDT method (ESSO Road Design Technology)

   These are assessed through:
   a) Dynamic modulus test
   b) Push-pull fatigue test
   c) Dynamic creep test
4. Freeze-thaw cycle tests and resistance to de-icing salts.
At the same time, experiments on site have been carried out, particularly on the A26 turnpike in the North of France, since 1983, and French Roads and Bridges Laboratory (LCPC) made rolling noise test and a complete assessment of PARC characteristics after 3 years of traffic (roughness, draining, and eveness properties).

Laboratory tests data clearly show the advantages of Asphalt Rubber Binder in porous mixes, compared to pure asphalt and polymer modified asphalt. Moreover, all the works site tests made on Porous Asphal Rubber Concrete during the last 5 years on heavy traffic turnpikes confirm the excellent durability of PARC.
ADVANTAGES OF ASPHALT RUBBER BINDER
FOR POROUS ASPHALT CONCRETE

By Alain SAINTON
Technical Director of BEUGNET Group - France

INTRODUCTION

Asphalt Rubber Binders (ARB) came out in France in 1982, after "exhaustive" studies in laboratory, where the composition of rubber powder, the choice of the extender oil and the kind of asphalt have been the subject of a long research which lead to the final adjustment of a high performance binder, with remarkable elastomeric properties, in particular at low temperature.

The first use of ARB was the stress absorbing membrane (SAM) or stress absorbing membrane interlayer (SAMI). Within 6 years, more than 3 000 000 m² have been implemented on different types of pavements: turnpikes, parkways, highways and on airport runways.

At the same time, came out the idea of making hot asphalt concrete with this new binder, in particular, porous mixes and very thin overlays; rheological properties of ARB fitted perfectly those formulations.

I. CHARACTERISTICS OF ARB

ARB is obtained by mixing at high temperature (> 200°C) ground rubber powder (15 to 25 % in weight) in asphalt with extender oil (2 to 10 % in weight). The basic asphalt is most of the time a 80/100 grade with special chemical composition. The extender oil is a crude oil fraction with aromatic properties that extends insaturated elastomers as the polybutadiene and the polyisoprene, main ingredients of ARB.

Ground rubber powder comes from old or retreaded scrap tires. It is mainly made of one part of natural and synthetic rubber, the other part being mainly of stabilizing and anti-oxidizing filler. Its granular size is inside a grading envelope shown by laboratory tests.

The hot mix is followed by an important elevation of viscosity (swelling of rubber particles) with a fall that progressively slows down (devulcanization) after one hour and a half, the dynamic viscosity is stabilized about 10 poises and the binder is ready to use.
I.1. Main physical characteristics of ARB

- Penetration at 25°C in 1/10 mm : 50 to 80
- Softening point in °C : > 60
- Penetration index (LCPC) : + 1.5 to + 5
- Density at 18°C : 1.03

I.2. Elastomeric properties

Tensile tests indicate a high elongation even at low temperature and after aging in a thin film (3 mm) at 50°C and a good resilience.
Figure 3: Loss of tensile stress curves of AR and asphalt

![Graph showing loss of tensile stress for AR and asphalt](image)

I.3. Adhesive capacity of ARB

Adhesion test inspired by "Vialit test" at very low temperature shows that ARB has tacky properties with stones much better than pure asphalt 50/70.

Figure 4: Shock resistance of AR according to temperature

![Graph showing shock resistance of AR and asphalt](image)
II. POROUS ASPHALT RUBBER CONCRETE (PARC)

II.1. Advantages of porous mixes in general as following:

a) High skid resistance at high speed and in rain fall (no aquaplaning)
b) No spraying, no splashing
c) No light reflecting when wet pavement
d) Decreasing of tyre rolling noise
e) Low cost because low density.

II.2. Why PARC?

Pure asphalts have neither cohesion nor flexibility to give porous asphalt concrete (PAC) resisting at heavy traffic. Asphalt content must be limited to 4.5 - 5.5%, if not, we have rutting asphalt concrete. With such contents, the stones are stuck, but fatigue resistance is weak and the life is limited. Moreover, the thin asphalt film, is sensible to air aging.

Polymers Modified Asphalt (PMA) have at first good rheological mechanical properties, but these are not stable through the time and after aging by oxidation PMA become brittle at low temperature.

ARB has:
- a high cohesion
- high flexibility at low temperature
- strong creeping resistance (softening point from 60 to 75°C)
- a remarkable aging resistance because no fluxing agent and with anti-oxidant agent in rubber powder.

Because of the high viscosity of the binder, it is possible to have a high content, which is good for:
- stones binding strongness
- fatigue resistance
- aging resistance (thick film).

II.3. PARC composition and laboratory data

Studies led to:
- a 0/10 granular size
- voids content > 20% (density about 2)
- a ARB content from 6 to 7% according to thickness, structural state of support, traffic and weather.

As an example: for a PARC to be implemented in 4 cm deep and under heavy traffic:
As an example: for a PARC to be implemented in 4 cm deep and under heavy traffic:

Formulation

<table>
<thead>
<tr>
<th>Crushed</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/10</td>
<td>87%</td>
</tr>
<tr>
<td>0/2</td>
<td>11%</td>
</tr>
<tr>
<td>Filler</td>
<td>2%</td>
</tr>
<tr>
<td>ARB</td>
<td>6.8%</td>
</tr>
</tbody>
</table>

Figure 5: Granular size - 0/10 PARC

II.3.1. Laboratory tests results

II.3.1.1. Duriez-LCPC test

Compaction rate: 79.2% (20.8% voids)
% efficient voids: 12%

Compressive strength in psi
(8 days - 18°C) \( R = 410 \)

Compressive strength in psi
(7 days immersion - 18°C) \( r = 393 \)

\( r/R = 0.96 \)
The water stripping resistance is remarkable (the same formula with 4,5 % of asphalt 60/70 gives r/R index = 0.8).

II.3.1.2. Gyrotary test

Compaction rate at n1 gyrations (C1)

\begin{align*}
C_1 &= 65.4 \% \\
C_{10} &= 70.8 \% \\
C_{20} &= 73.4 \% \\
C_{40} &= 74 \% \\
C_{200} &= 77.8 \%
\end{align*}

avec \( K_1 = \frac{C - C_1}{\log n_1} = 2.34 \)

**Figure 6**: Gyrotory test
EXXON Company supplier for asphalt and extender oil entering into the composition of asphalt rubber binder carried out in laboratory, a comparative study on 3 porous mixes with the same granular size but with 3 different binders and 3 binder contents using ERDT method (ESSO Road Design Technology), developed by Mont-Saint-Aignan Research Center Engineers.

Characteristics of porous mixes

- Granular size

<table>
<thead>
<tr>
<th>6/10 crushed</th>
<th>porphyry</th>
<th>87 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0/2 crushed</td>
<td>Limestone filler</td>
<td>11 %</td>
</tr>
</tbody>
</table>

- Binder content

<table>
<thead>
<tr>
<th></th>
<th>Asphalt 60/70</th>
<th>Polymer Modified Asphalt PMA</th>
<th>Asphalt Rubber Binder ARB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binder content</td>
<td>4,7 %</td>
<td>5,5 %</td>
<td>6,8 %</td>
</tr>
</tbody>
</table>

- Binders properties

<table>
<thead>
<tr>
<th></th>
<th>Asphalt 60/70</th>
<th>Polymer Modified Asphalt</th>
<th>Asphalt Rubber Binder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density at 25°C</td>
<td>1,030</td>
<td>1,01</td>
<td>1,030</td>
</tr>
<tr>
<td>Penetration (1/10 mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50°F 10°C</td>
<td>15</td>
<td>18</td>
<td>22</td>
</tr>
<tr>
<td>59°F 15°C</td>
<td>-</td>
<td>-</td>
<td>32,5</td>
</tr>
<tr>
<td>48°F 20°C</td>
<td>-</td>
<td>52</td>
<td>46</td>
</tr>
<tr>
<td>77°F 25°C</td>
<td>61</td>
<td>97</td>
<td>68</td>
</tr>
<tr>
<td>86°F 30°C</td>
<td>96</td>
<td>135</td>
<td>105</td>
</tr>
<tr>
<td>Softening point in °C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>122°F</td>
<td>50,2</td>
<td>83</td>
<td>63,2</td>
</tr>
<tr>
<td>101°F</td>
<td>-</td>
<td>-</td>
<td>145°F</td>
</tr>
<tr>
<td>Breaking point in °C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10°F</td>
<td>-12</td>
<td>-19</td>
<td>-</td>
</tr>
<tr>
<td>18°F</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Mixing temperature with asphalt 60/70

- PMA: 160°C 320°F
- ARB: 180°C 355°F
- Dynamic modulus

Determination of hot mixes stiffness at 4 temperatures (10, 20, 30, 40°C) and 5 frequencies (20, 10, 3, 1, 0.3, 0.1 Hz).

Figure 7: Dynamic modulus test
Figure 8: Compared dynamic modulus, temperature 10°C

- Porous asphalt concrete (PAC)
- Porous asphalt rubber concrete (PARC)
- Porous modified asphalt concrete (PMAC)

Figure 9: Compared dynamic modulus, temperature 20°C
Figure 10: Compared dynamic modulus, temperature 30° C

Figure 11: Compared dynamic modulus, temperature 40° C
We can see that porous mixes have a lower stiffness compared to dense mixes (the structural strengthening is approximately half for porous mixes). At low temperature, PARC is more flexible (a great advantage in very cold winter).

- Dynamic creep (or rutting test)

The test is made at 30°C under an axial compressive stress amplitude (\(\sigma_v\)) equal to 0.3 MPa (45 psi) in applying an isotropic stress (\(\sigma_v\)) all over the specimen equal to 0.1 MPa (15 psi).

**Figure 12 : Dynamic creep test**

![Dynamic creep test diagram](image)

**Figure 13 : Dynamic creep**

![Dynamic creep graph](image)
Although less stiff, PARC have a good behaviour against creep or rutting.

- Fatigue test

The specimen is prepared in the same way as for dynamic modulus test, but the central portion is reduced in diameter to ensure rupture in the part during the test. An alternating (push-pull) axial sine wave stress $\sigma$ of amplitude $\sigma_0$ is applied, without rest periods, until the specimen breaks. The applied stress induces an axial sine wave strain of amplitude $\varepsilon_0$, which increases during the test. The number of cycles to failure (Nf) and the initial strain amplitude $\varepsilon_0$ are recorded. The temperature is 10°C.

Figure 14: Fatigue test
For an initial strain $= 7 \times 10^{-5}$ PARC specimen have a lifetime 13 times superior to PAC and 23 times superior to PHAC.

II.3.1.4. Freeze-thaw cycles tests and resistance to de-icing salts (by EXXON European Research Center in Mont-Saint-Aignan, FRANCE)

- Sensibility to freeze-thaw cycles comparison between PARC and PAC for dry specimen and water saturated specimen with fatigue tests (as described in II.3.1.3)

Test conditions: 24 h at $-20^\circ$C  
24 h at ambient temperature

Fatigue test has been carried out for an initial strain of $8 \times 10^{-5}$ with PAC and $12 \times 10^{-5}$ with PARC.
Figure 16

Dry Test Tubes

Number of cycles at the breaking point of dry test tubes versus number of freeze-thaw cycles.

- PAC
- PARC

Figure 17

Saturated Test Tubes

Number of cycles at the breaking point of saturated test tubes versus number of freeze-thaw cycles.

- PAC
- PARC
Saturated specimen evolves faster than dry specimen, PARC has a better fatigue behaviour than PAC.

- De-icing salts effect

The point of this study was to assess the mechanical properties effect of PARC and PAC after immersion at 18°C and -5°C in water and the following de-icing salts solutions:

- potassium salt,
- Nivacal (CaCl₂)

Fatigue tests have been implemented on different PAC and PARC specimen before and after immersion during 8 days in water, potassium salt solution (0.25 kg/l) and Nivacal (0.8 % of calcium dichloride).

Figure 18: Fatigue resistance - Porous Asphalt Concrete (PAC)
Fatigue resistance of PARC is not sensible to water or de-icing salts solutions after 8 days immersion, but that one of PAC (with asphalt 60/70) is reduced of 25 to 60% (Figures 18 and 19).

II.4. Tire rolling noise

The aim of tests is to obtain a comparison between the sound levels in city areas by tyre pavement-contact, before and after the implementation of PARC.

The method is the one given by the French Roads and Bridges Laboratories (LCPC). Tests have been done in situ near Lille in the North of France.

The test gives the level noise pressure in weighted decibel dB(A) obtained by a free wheeled vehicle, engine cut off, on the pavement. The microphone is at 7.5 m from the axled path of the vehicle and at 1.20 m above the pavement (speed of the vehicle : 80 km/h).
## Results data

### Figure 20

<table>
<thead>
<tr>
<th>Experiment Test Area</th>
<th>PAVEMENT</th>
<th>SOUND LEVEL IN dB(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>OLD: Smooth portland cement concrete</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>NEW: PARC</td>
<td>72</td>
</tr>
<tr>
<td>2</td>
<td>OLD: Dense asphalt concrete</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>NEW: PARC</td>
<td>71</td>
</tr>
</tbody>
</table>

### Figure 21

<table>
<thead>
<tr>
<th>FREQUENCY BAND ON 1/3 OCTAVE IN Hz</th>
<th>1st INTERVENTION 3/7/85: INITIAL STATE SMOOTH PCC</th>
<th>2nd INTERVENTION 5/9/85 PARC</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 Hz</td>
<td>74</td>
<td>70.5</td>
</tr>
<tr>
<td>125 Hz</td>
<td>74.5</td>
<td>74</td>
</tr>
<tr>
<td>160 Hz</td>
<td>68.5</td>
<td>66</td>
</tr>
<tr>
<td>200 Hz</td>
<td>66</td>
<td>64</td>
</tr>
<tr>
<td>250 Hz</td>
<td>63</td>
<td>62</td>
</tr>
<tr>
<td>315 Hz</td>
<td>63.5</td>
<td>61.5</td>
</tr>
<tr>
<td>400 Hz</td>
<td>63</td>
<td>61</td>
</tr>
<tr>
<td>500 Hz</td>
<td>62</td>
<td>59.5</td>
</tr>
<tr>
<td>630 Hz</td>
<td>62.5</td>
<td>63</td>
</tr>
<tr>
<td>800 Hz</td>
<td>66</td>
<td>66.5</td>
</tr>
<tr>
<td>1000 Hz</td>
<td>70</td>
<td>69.5</td>
</tr>
<tr>
<td>1250 Hz</td>
<td>68</td>
<td>68</td>
</tr>
<tr>
<td>1600 Hz</td>
<td>66.5</td>
<td>63</td>
</tr>
<tr>
<td>2000 Hz</td>
<td>65</td>
<td>58.5</td>
</tr>
<tr>
<td>2500 Hz</td>
<td>63.5</td>
<td>53.5</td>
</tr>
<tr>
<td>3150 Hz</td>
<td>60</td>
<td>51</td>
</tr>
<tr>
<td>4000 Hz</td>
<td>59.5</td>
<td>48.0</td>
</tr>
<tr>
<td>5000 Hz</td>
<td>56</td>
<td>48.0</td>
</tr>
</tbody>
</table>
Comments

- Compared to smooth Portland cement concrete pavement, PARC improves the whole noise level by 3 dB(A).

- Compared to smooth dense asphalt concrete, PARC improves the whole noise level by 1 dB(A).

- Spectrum examination in 1/3 octave shows that the gain is mainly important (5 to 10 dB(A) in 1/3 octave frequency bands above 1600 Hz corresponding to treble frequencies.

II.5. Tracking results on PARC implemented on A1 turnpike in the North of France (over 1 000 000 m² since 1984)

A1 characteristics | 40 000 vehicles/day
35% heavy trucks

a) Evolution of roughness

Figure 22: Hot mix overlays performance analysis according to cumulate traffic on A1 turnpike
PARIS-LILLE

<table>
<thead>
<tr>
<th>SKID RESISTANCE INDEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFL AT 120 KM/H ON SLOW LANE</td>
</tr>
</tbody>
</table>

Cumulate traffic in Millions of vehicles by way of traffic

LEGEND

- Porous AC - 1984 and 1985
- Open graded AC - 1982--1985
- Open graded AC - 1985
c) Stability of PARC

The slow lane cross section after 2 years does not show significant deformation at wheel track areas (no rutting).

III. CONCLUSION

Different experimental sections have been made in France, in the 1970s, without significant results. The approach until then seemed too empiric to achieve a reliable solution which corresponds to a necessity (rain doubles the risk of accident on dense asphalt concrete pavement).

Since 1982, the laboratory studies implemented in France have shown clearly the advantages of Asphalt Rubber Binder in porous mixes; AR gives the following criteria of durability:

- constant draining properties,

- good behaviour under heavy trucks traffic (fatigue and rutting resistance),

- shearing stress resistance,

- insensitivity to bad weather.

Works made in France for 5 years confirm the excellent durability of PARC.