Asphalt concrete mixtures with high RA content
Design and performance

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Background: Hot mix asphalt recycling in Portugal

> 1999 - First known applications of RA in the production of hot mix asphalt concrete in Portugal

> Growing interest in asphalt recycling since then


> 2009 – Review of E 472
Background: Hot mix asphalt recycling in Portugal

2009 – New specifications for highway works (Estradas de Portugal) include provisions for use of RA in Hot Mix Asphalt Concrete (HMAC)

Many CE marked HMAC in Portugal include up to 20% of RA

Higher percentages of RA are used in specific cases
Objectives

> To discuss the main issues associated with the used of high RA contents in HMAC

> To present research results concerning mix design and performance of HMAC with high RA
  • Project REPARE (LNEC + FCT UC + UM)
Main issues associated with high RA content in HMAC

> Technology No longer an issue

> Mix design
  > Grading of aggregate mixture Too many fines
  > Binder properties Properties of final blend?

> Variability
Control of variability in HMAC with RA
At the asphalt plant

> Separation of RA into 2 or more stockpiles
  ● According to RA particle size
  ● More flexibility to adjust aggregate gradation
  ● Better consistency of binder content (finer particles will have higher content)

> Blending the materials to get a uniform stockpile
Control of variability in HMAC with RA

At the lab

> Test several samples for aggregate gradation and binder content and properties
  - Reblend the materials if variability is too high

> Use representative samples of RA for mix design
  - Blend different samples to get a representative sample
Early applications of HMAC using RA Rehabilitation of EN 105 road pavement (1999)
Rehabilitation of EN 105 Mix composition (binder course)

- 40 % Reclaimed Asphalt
- 15 % Aggregate 14/20
- 10 % Aggregate 10/14
- 10 % Aggregate 6/10
- 23 % Fine aggregate 0/6
- 2 % Aded filler

Virgin bitumen: pen 35/50
Final binder content: 5.4 %
Rehabilitation of EN 105
Grading of aggregate mixture

EN 105
Hot mix asphalt concrete with 40% RA
Rehabilitation of EN 105
Binder properties

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Recovery of binder properties

0 20 40 60 80 100
Penetration, 0.1 mm

0 20 40 60 80 100
Softening point, ºC

0 20 40 60 80 100
Content of virgin bitumen in the final blend

Virgin bitumen PEN 35/50
Recovered binder (from RA)

t_{AB}(ºC) 50/58
Final blend

Final blend
Rehabilitation of EN 105 Stiffness and fatigue

FWD tests
E > 5000 Mpa (@ ~20°C)

Field testing

Lab testing

4 PB (f=10Hz; t = 22°C)

Stiffness: E ≈ 4000 MPa

Field testing

Lab testing

Vigas de mistura reciclada em central
Mistura convencional, tipo macadame betuminoso

Extensão (µm)

Número de aplicações de carga

Road Pavements: Materials, design and performance
Lisboa, LNEC, 25 March 2010
Rehabilitation of EN 105 Resistance to permanent deformation

Wheel tracking tests \((t = 60^\circ C)\)

\[
\begin{array}{c}
\text{Tempo (minutos)} \\
\text{Deformação (mm)}
\end{array}
\]

\(L_1\) and \(L_2\)

\(V_{105-120}^{10^{-3}\text{mm/min}}\)

(WT, LNEC)
Rehabilitation of EN 105

Still in good shape after 10 years!

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Design and performance
HMAC with high RA content
Laboratory investigation

> Laboratory mixtures produced with the following materials:

- RA milled from motorway A1 (Pombal / Condeixa); 5.1% binder content (pen 14 x 0.1mm).
- Virgin binder:
  - Pen 35/50
  - Pen 50/70
  - Pen 70/100
- Virgin aggregates: limestone

> Follow-up of previous studies concerning mixtures with up to 40% RA (António Baptista, 2006)
HMAC with 60 - 70% RA Aggregate grading

- No added filler
- Only 15/25 mm virgin aggregates
Marshall mix design for HMAC (1/3)
70% RA; pen 50/70 virgin binder

Density

![Density graph]

Void content

![Void content graph]
Marshall mix design for HMAC (2/3)
70% RA; pen 50/70 virgin binder

Marshall stability

Flow
Marshall mix design for HMAC (3/3)
70% RA; pen 50/70 virgin binder

Voids in Mineral Aggregate

Selected binder content: 5,0 % (total)
HMAC with 70% RA; 50/70 pen virgin binder
Marshall characteristics and water sensitivity

<table>
<thead>
<tr>
<th></th>
<th>Bulk Density (Mg/m³)</th>
<th>Void content (%)</th>
<th>Marshall Stability (kN)</th>
<th>Marshall Flow (mm)</th>
<th>VMA (%)</th>
<th>ITSR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Results</td>
<td>2,395</td>
<td>2,9</td>
<td>25,4</td>
<td>2,8</td>
<td>13,4</td>
<td>100</td>
</tr>
<tr>
<td>EP specification</td>
<td>-</td>
<td>3 - 6</td>
<td>7,5 - 15</td>
<td>2 - 4</td>
<td>≥ 14</td>
<td>-</td>
</tr>
</tbody>
</table>
HMAC with 70% RA; 50/70 pen virgin binder
Wheel tracking test
HMAC with 70% RA; 50/70 pen virgin binder

Stiffness (MPa) vs Temperature (°C) for different frequencies (Hz):
- f=0.2Hz
- f=0.1Hz
- f=1Hz
- f=10Hz
- f=5Hz
- f=2Hz
- f=1Hz
- f=0.5Hz

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HMAC with 70% RA; 50/70 pen virgin binder

Stiffness

Phase angle (°)

Temperature (°C)

f=0.1Hz

f=0.2Hz

f=0.5Hz

f=1Hz

f=2Hz

f=5Hz

f=10Hz
HMAC with 70% RA; 50/70 pen virgin binder
Fatigue (25°C; 10 Hz)
HMAC with high RA content
Laboratory mixtures

<table>
<thead>
<tr>
<th>RA</th>
<th>Virgin binder (pen grade)</th>
<th>Final binder content</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>35/50</td>
<td>-</td>
</tr>
<tr>
<td>20 %</td>
<td>35/50 50/70</td>
<td>-</td>
</tr>
<tr>
<td>30 %</td>
<td>35/50 50/70 70/100</td>
<td>4.4%</td>
</tr>
<tr>
<td>40 %</td>
<td>35/50 50/70 70/100</td>
<td>4.7%</td>
</tr>
<tr>
<td>70 %</td>
<td>- 50/70 70/100</td>
<td>5.0%</td>
</tr>
</tbody>
</table>
Fatigue of laboratory mixtures with RA (4PB @ 25ºC; 10 Hz)
Fatigue of laboratory mixtures with RA (4PB @ 25°C; 10 Hz)
Fatigue of laboratory mixtures with RA (4PB @ 25°C; 10 Hz)
Final remarks

> Using high RA content in HMAC
  ● Need extra care to control variability
  ● Difficult to comply with standard (empirical) specifications
  ● You can still achieve good performance!

> Future work
  ● Assess ageing of mixtures with high RA
  ● Move to performance specifications