Blend Design of High-content reclaimed asphalt mixes for surface courses

Davide Lo Presti, Euro PhD

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The Pavement Research Building is a purpose-built £2.4m state-of-the-art centre for research and development in all areas of pavement engineering - design, performance, maintenance and materials.

Professor Gordon Airey
Director

- 9 academics
- 5 Post-docs
- about 35 PhD students
- 7 technicians

www.nottingham.ac.uk/ntec
Personal involvement at NTEC

- **Personal progress**
  - Mar 2014, Senior Research Fellow (SUP&R ITN, AB2P, KTP, HERMES)
  - Since Oct 2010, R. Associate/Postdoctoral fellow (EU FP7 Re-Road)
  - Mar 2011, EuroPhD from UNIPA-UNOTT

- **Research projects and grants**
  - 2014 – HERMES fellowship - €25k – Rheology of complex fluids (PI)
  - 2013 – 2017 EU FP7 – Marie Curie SUP&R ITN’ - €4M (main author, Project Manager and CI)
  - 2013 – 2015 EU CEDR - ‘ALLBACK2PAVE’ - €460k (co-author and CI)
  - 2013 – 2015 UK Knowledge Transfer Partnership - £147k (Co-PI)
  - 2012: UoN “Bridging the Gaps”’ - £10k (PI)
Sustainable development of transport infrastructures

Characterization and Design of Sustainable Transport Infrastructures Technologies

- **Secondary materials**
  - RAP
  - Tyre Rubber
  - Old ballast
  - biomass

- **Testing**
- **Modelling**
- **On-site Experience**
- **Design**

**Maximise recycling**

**Minimise impact**

Sustainability metrics and Labelling

- Lifecycle Assessment (LCA)
- Lifecycle Cost Analysis (LCCA)

Dr. Davide Lo Presti
Lausanne, CH - 25 Nov 2014
AB2P - CEDR 2012 Recycling

WP1: Coordination, Management, Advisory board and Dissemination

WP2: Mix and Blend design
- Raw Material characterisation
- Blends design
- Mix design
- Validation of Mix Design of 0.30, 60 → 100 % RA

WP3: Plant scale manufacturing and End-users manual
- WP4: Performance prediction
- Mixes and Binder Characterisation
- Pavement Life prediction

WP5: Sustainability Assessment
- End-users manual
- Sustainability assessment methodology
- Other sustainability metrics
- LCA and LCCA

High Content RA-Warm asphalts for wearing courses

Dr. Davide Lo Presti
Lausanne, CH - 25 Nov 2014
AB2P WP2 - Mix and Binder design

WP2
Binder’s blend design

Two case study:
- German SMA
- Italy HMA

Source: Zaumanis et al. 2014
Outline

Binder’s blend design – AB2P

- **Background**
  - Partial blending concept
  - Replaced Virgin Binder (%RVB)
  - Summary of International binder’s blend designs

- **AB2P binder’s design: German and Italian cases**
  - Identify properties of target mix and binders
  - Selection and Characterisation of materials: RA binder, Rejuvanatours (type, dose)
  - Blending charts with EU, USA, approaches
  - Inputs for mix design

- **On-going research and Other approaches**
- **Conclusions**
• Partial blending concept
Background

- Partial blending concept

![Graph of Grading Italian RA](image)
Background

- Partial blending: RA30white, RA60white – IT HMA
Background

- Partial blending: RA90grey80, RAgrey60 – IT HMA
Background

• \( \%RVB = \text{Replaced Virgin Binder} \)

This can be estimated by knowing the RA binder content, targeting the asphalt mix binder content and making an assumption on the extent of binder released from the RA during the asphalt mixing.

\[
\%RVB = \%\text{RAb mass} \div \text{MIX binder mass}
\]

\[
\text{MIX binder'blend} = \text{RA binder} + \text{Virgin binder}
\]
Background

• %RVB = Replaced Virgin Binder

%RVB = RAb.mass */MIX binder mass

• RAb.mass = RAagg.mass*RAb content
• RAagg.mass=Ramass/(1+%RAb content)
• MIX binder mass = MIX agg.mass*MIX binder content

*Example (full blending):*
MIX mass = 1000 Kg
MIX binder content = 7.2%
%RAmix = 30%
RAb content = 5.83%

RAagg.mass = 300/(1+4.86%) = 286.1 Kg
%RAb.mass = 286.1*4.86% = 16.6 Kg
%RVB = 16.6/(7.2%*(1000/(1+7.2%))) = 20.7%
### Background

- **%RVB = Replaced Virgin Binder**
- **Binder content 7 – 7.4%**
- **Blending rate 100% - 60%**

<table>
<thead>
<tr>
<th>%RA</th>
<th>Blending</th>
<th>%Binder</th>
<th>%RVB</th>
</tr>
</thead>
<tbody>
<tr>
<td>30%</td>
<td>White 100%</td>
<td>7%</td>
<td><strong>21.25</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.20%</td>
<td><strong>20.70</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.40%</td>
<td><strong>20.18</strong></td>
</tr>
<tr>
<td></td>
<td>Grey 80%</td>
<td>7%</td>
<td>17.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.20%</td>
<td>16.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.40%</td>
<td>16.14</td>
</tr>
<tr>
<td></td>
<td>Grey 60%</td>
<td>7%</td>
<td>12.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.20%</td>
<td>12.42</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.40%</td>
<td><strong>12.11</strong></td>
</tr>
</tbody>
</table>

white 100  
grey 80  
grey 60
AB2P design: German case

- German case
  - Target asphalt mix: SMA 8s - PmB 25/55-55 (surface course)
  - Grading curve -> 70 RA% maximum amount
  - 30% RA, 60% RA, 70% RA

**APPROACH:**
Accuracy selection of RA from several stockpiles, in order to have a recovered binder similar to the target binder
AB2P design: German case

- Characterisation of materials: target binder

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Units</th>
<th>Test method</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Needle penetration at 25°C</td>
<td>0.1mm</td>
<td>EN-1426</td>
<td>25 to 55</td>
</tr>
<tr>
<td>Ring and ball softening point</td>
<td>°C</td>
<td>EN-1427</td>
<td>≥55</td>
</tr>
<tr>
<td>Breaking point by Fraass</td>
<td>°C</td>
<td>EN 12593</td>
<td>≤-10</td>
</tr>
</tbody>
</table>

Bitumen type: Elastomeric Polimer modified bitumen
Bitumen Type and grade: PmB 25/55-55
Bitumen content: Min 7.2%
Nomenclature per German Standard: PmB 25/55-55 A
Governing spec: TL-Bitumen-StB 2007
AB2P design: German case

- Characterisation of materials: RAb-D and VB-D
  - RAb-D  Binder recovered from the German RA (PMB)
  - VB – D  Virgin binder (PMB 25/55)

Table 1. Reproducibility of RA binder recovery procedure EN 12694-4:2005

65.7
Blending charts - EU binder’s blend design

Characterization and classification of RAP binders in Europe is based on empirical properties. Each European country has fixed different limits for penetration and softening point of RAP binder properties in order to be used in new asphalt mixes.

<table>
<thead>
<tr>
<th>Property</th>
<th>Belgium</th>
<th>France</th>
<th>Germany</th>
<th>Ireland</th>
<th>Poland</th>
<th>Portugal</th>
<th>Slovenia</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetration (1/10 mm)</td>
<td>&gt;10</td>
<td>&gt;5</td>
<td>&gt;15</td>
<td>&gt;15</td>
<td>&gt;15</td>
<td>&gt;15</td>
<td>-</td>
<td>&gt;15</td>
</tr>
<tr>
<td>Softening point (°C)</td>
<td>-</td>
<td>&lt;77</td>
<td>&lt;70</td>
<td>-</td>
<td>&lt;70</td>
<td>&lt;70</td>
<td>&lt;70</td>
<td>&lt;77</td>
</tr>
</tbody>
</table>

The binder class of the virgin binder may be used unaltered if the mix design includes less than 10% RAP for surfacing layers and less than 20% RAP for base layers and binder courses.

AB2P design: German case

- **Blending charts - EU binder’s blend design**

If higher proportions than 10% RAP are used, the penetration and softening point values of the binder blend are to be determined using blending models.

\[ a \log(\text{pen}_1) + b \log(\text{pen}_2) = (a+b) \times \log(\text{pen}_{\text{mix}}) \]

- pen_1 = penetration of the binder recovered from the RAP
- pen_2 = penetration of the added virgin binder
- pen_mix = calculated penetration value of the binder in the mixture containing RAP
- a, b = ratios by mass of the binder from the RAP and of the virgin binder respectively (a+b=1.0)
Blending charts - EU binder’s blend design

If higher proportions than 20% RAP are used, the penetration and softening point values of the binder blend are to be determined using blending models.

\[ T_{(R&B \ mix)} = a \ T_{(R&B \ 1)} + b \ T_{(R&B \ 2)} \]

\( T_{(R&B \ 1)} \) = softening point of the binder recovered from the RAP
\( T_{(R&B \ 2)} \) = softening point of the added virgin binder
\( T_{(R&B \ mix)} \) = softening point of the binder in the mixture containing RAP

\( a, b \) = ratios by mass of the binder from the RAP and of the virgin binder respectively (a+b=1.0)

\( a = %RVB \ ; \ b = (1-%RVB) \)
**AB2P design: German case**

- **Blending charts - %RVB calculation**

<table>
<thead>
<tr>
<th>%RA</th>
<th>Blending</th>
<th>%Binder</th>
<th>%RVB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>White 100%</td>
<td>7.20%</td>
<td>41.40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.40%</td>
<td>40.36</td>
</tr>
<tr>
<td>60%</td>
<td>Grey 80%</td>
<td>7%</td>
<td>34.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.20%</td>
<td>33.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.40%</td>
<td>32.29</td>
</tr>
<tr>
<td></td>
<td>Grey 60%</td>
<td>7%</td>
<td>25.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.20%</td>
<td>24.84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.40%</td>
<td>24.22</td>
</tr>
<tr>
<td></td>
<td>White 100%</td>
<td>7%</td>
<td>21.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.20%</td>
<td>20.70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.40%</td>
<td>20.18</td>
</tr>
<tr>
<td>30%</td>
<td>Grey 80%</td>
<td>7%</td>
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<td></td>
<td></td>
<td>7.20%</td>
<td>16.56</td>
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<tr>
<td></td>
<td></td>
<td>7.40%</td>
<td>16.14</td>
</tr>
<tr>
<td></td>
<td>Grey 60%</td>
<td>7%</td>
<td>12.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.20%</td>
<td>12.42</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.40%</td>
<td>12.11</td>
</tr>
</tbody>
</table>
AB2P design: German case

• Blending charts - EU binder’s blend design

If higher proportions than 10% RAP are used, the penetration and softening point values of the binder blend are to be determined using blending models.

• \[ a \log(\text{pen}_1) + b \log(\text{pen}_2) = (a+b) \log(\text{pen}_{\text{mix}}) \]

• \[ T_{(\text{SP mix})} = a T_{(\text{SP 1})} + b T_{(\text{SP 2})} \]
AB2P design: German case

- Blending charts - EU binder’s blend design

\[ y = -0.003x + 1.6335 \]

- Penetration (25°C) (log d mm)

- %RVB

- 12.11 % RVB (30%RA - grey60)
- 42.51 % RVB (60%RA – white100)
AB2P design: German case

- Blending charts - EU binder’s blend design

\[
\begin{align*}
\text{SP}_{\text{30\%RA-white100}} &= 61.5 \\
\text{SP}_{\text{30\%RA-grey60}} &= 61.0 \\
\text{SP}_{\text{60\%RA-white100}} &= 62.6 \\
\text{SP}_{\text{60\%RA-grey60}} &= 61.6
\end{align*}
\]

\[
y = 0.0527x + 60.4
\]

12.11 % RVB
(30%RA - grey60)

42.51 % RVB
(60%RA – white100)
AB2P design: German case

• Blending charts - EU binder’s blend design

EU binders blend design results

%RA in the mixture

36.6

RESULT (EU):
VB-D can be used as a virgin binder for all RA mixes
AB2P design: German case

• Blending charts - USA binder’s blend design

RAP binder classification and characterization are based on rheological performance. In order to classify and use RAP binders, their PG has to be determined through DSR and BBR tests according to Superpave.

<table>
<thead>
<tr>
<th>Table 1. Binder Selection Guidelines for RAP Mixtures (NCHRP, 2001b)</th>
<th>RAP Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended Virgin Asphalt Binder Grade</td>
<td>Recovered RAP Grade</td>
</tr>
<tr>
<td>No change in binder selection</td>
<td>PG xx-22 or lower</td>
</tr>
<tr>
<td>Select virgin binder one grade softer than normal (e.g. select a PG58-28 if a PG64-22 would normally be used)</td>
<td>&lt;20%</td>
</tr>
<tr>
<td>Follow recommendations from blending charts</td>
<td>20-30%</td>
</tr>
</tbody>
</table>

AB2P design: German case

USA binder’s blend design

NCHRP Report 452 (2001) describes the procedure to obtain blending charts according to SUPERPAVE. This procedure is based on critical temperatures of materials and follows the prediction law:

\[
T_{\text{blend}} = TRAP \times \%\text{RAP} + TVB \times \%\text{VB}
\]

*Tblend* = critical temperature of the final blend of binders
*TRAP* = critical temperature of the RAP binder
*TVB* = critical temperature of the virgin binder used as rejuvenator
\%RAP = percentage of RAP in the blend
\%VB = percentage of virgin binder in the blend

\[
\text{TRAP}_{\text{high}}(\text{DSR}), \text{TRAP}_{\text{int}}(\text{RTFOT, DSR}), \text{TRAP}_{\text{low}}(\text{RTFOT, BBR})
\]

\[
\text{TVB}_{\text{high}}(\text{DSR}), \text{TVB}_{\text{int}}(\text{RTFOT, DSR}), \text{TVB}_{\text{low}}(\text{RTFOT, BBR})
\]
NCHRP Report 452 (2001) describes the procedure to obtain blending charts according to SUPERPAVE. This procedure is based on critical temperatures of materials and follows the prediction law:

\[ T_{\text{blend}} = TRAP \times \% \text{RAP} + TVB \times \% \text{VB} \]
AB2P design: German case

- Blending charts - EU binder’s blend design

Critical temperatures of binders

12.76 % RVB (30%RA - grey60)
44.77 % RVB (60%RA – white100)
AB2P design: German case

- Blending charts - EU binder’s blend design

**Table 1. Performance-related binder blend design results, for a target binder content of 7% and with the assumption of 100% blending**

<table>
<thead>
<tr>
<th>Final Blend (30% RA – white100)</th>
<th>High Tc (°C)</th>
<th>Intermediate Tc (°C)</th>
<th>Low Tc (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final Blend (60% RA – white100)</td>
<td>79.7</td>
<td>20.5</td>
<td>-15.0</td>
</tr>
<tr>
<td>Final Blend (70% RA – white100)</td>
<td>79.7</td>
<td>20.8</td>
<td>-14.8</td>
</tr>
<tr>
<td>Target (VB-D)</td>
<td>&gt;79.3</td>
<td>&lt;19.2</td>
<td>&lt;-16.0</td>
</tr>
</tbody>
</table>

RESULT (USA):
VB-D can be used as a virgin binder, but attention should be paid at low temperature properties
AB2P design: German case

• **Input for mix design**

Comparing results from the binder blend design with the requirements for the binder to be used in the German mix and considering the following assumptions:

• With a RA binder content equal to 4.86%
• With a final binder content of 7.0 – 7.4%
• With a partial blending effect of 100% to 60%

it is possible to conclude that:

• **VB-D can be used for the mix with 30% RA**, but tests on the mixes should provide a confirmation.

• **For the 60%RA and 70%RA, another type of virgin binder (softer)**, rather than the selected PMB 25/55 is advisable to enhance intermediate and low temperature properties of the final blend. **VB-D can also be used but tests on the mixes should provide a confirmation.**
AB2P design: Italian case

- **Italian case**
  - Target asphalt mix: HMA 11 – Pen 50/70 (surface course)
  - Grading curve > 70-90 RA% maximum amount
  - **30% RA, 60% RA, 90% RA**

**APPROACH:**
Use a quite aged RA and perform the design with rejuvenator oils
# AB2P design: Italian case

- **Characterisation of materials: target binder**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Units</th>
<th>Test method</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Needle penetration at 25°C</td>
<td>0,1mm</td>
<td>EN-1426</td>
<td>50 to 70</td>
</tr>
<tr>
<td>Ring and ball softening point</td>
<td>°C</td>
<td>EN-1427</td>
<td>46-54</td>
</tr>
<tr>
<td>Rotational Viscosity</td>
<td>mPAs</td>
<td>EN</td>
<td>295</td>
</tr>
<tr>
<td>Breaking point by Fraass</td>
<td>°C</td>
<td>EN 12593</td>
<td>≤8</td>
</tr>
</tbody>
</table>

Bitumen type: Conventional bitumen
Bitumen Type and grade: Pen 50/70
Bitumen content: Min 6,5%
AB2P design: German case

- Characterisation of materials: RAb ad VB

- RAb  Binder recovered from the Italian RA
- VB  Virgin Bitumen: target binder to be used in Italy (Pen 50/70)

<table>
<thead>
<tr>
<th></th>
<th>Penetration (mm)</th>
<th>Softening Point (°C)</th>
<th>Fraass (°C)</th>
<th>Viscosity (135°C) (mPa.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAPb</td>
<td>8,3</td>
<td>71,4</td>
<td>+ 8,7</td>
<td>1827</td>
</tr>
<tr>
<td>Virgin Binder</td>
<td>68</td>
<td>47,6</td>
<td>- 8,0</td>
<td>272,6</td>
</tr>
<tr>
<td>(Pen 50/70 Target)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
• Characterisation of materials: Rejuvanatours

**TYPE:**
Two rejuvenators were considered because of the significant difference in price. In fact **RejA is almost three times more expensive than RejB.**

**RejA** is an additive which consists of special regenerated oil and a Fischer-Tropsch

**RejB** is an additive characterized by having high viscosity and free of polycyclic aromatic hydrocarbons.

**DOSAGE:**
Rejuvenators/RAb ratios were selected following the instructions of the products supplier, so that RejuvanatedRA binders are composed as follows

**RejuvanatedRAb - RejA = 0.2 RejA + 0.8 RAb**
**RejuvanatedRAb - RejB = 0.3 RejB + 0.7 RAb**
AB2P design: German case

- **Characterisation of materials: RAb-D, VB-D and Rejs**
  - RAb  Binder recovered from the Italian RA
  - VB    Virgin Bitumen: target binder to be used in Italy (Pen 50/70)
  - Rejuvenated RAb - RejA  RAb with Rejuvenator A (0.20)
  - Rejuvenated RAb - RejB  RAb with Rejuvenator B (0.30)

Average value of conventional properties of Italian binders
AB2P design: italian case

- **Blending charts**

  **EU**  
  \[ a \log(pen_1) + b \log(pen_2) = (a+b) \log(pen_{mix}) \]
  \[ T(SP_{mix}) = a \ T(SP_1) + b \ T(SP_2) \]

  **USA**  
  \[ Tblend = TRAP \times %RAP + TVB \times %VB \]
AB2P design: italian case

- Blending charts – EU Pen

\[ y = 0.0013x + 1.8325 \]

\[ y = 0.0025x + 1.8325 \]
AB2P design: italian case

• Blending charts – EU SP

![Blending charts diagram]

- $y = 0.208x + 47.6$
- $y = 0.181x + 47.6$
AB2P design: italian case

- Blending charts – USA critical temperatures

Critical temperatures of binders

\[ y = 0.053x + 65.8 \]
\[ y = -0.0834x + 19.036 \]
\[ y = -0.062x - 14.989 \]

%RVB

Tc (°C)

RejA (wax)
AB2P design: Italian case

- Blending charts – USA critical temperatures

Critical temperatures of binders

\[ y = 0.0505x + 65.8 \]

\[ y = -0.0955x + 19.036 \]

\[ y = 0.0224x - 14.989 \]
AB2P design: Italian case

INPUTS for mix design

Conventional properties blend design results for binder with RejA and RejB with limits indicating 100% and 60% blending

%RA in the mixture

87.2 64.7

RESULT (EU): With these dosages both RejA and RejB do not match the targets
AB2P design: Italian case

• INPUTS for mix design

Performance-related blend design results, for a target binder content of 6.5% and with the assumption of 100% blending

RESULT (USA):
With these dosages the final blends with RejA (wax) have similar, or even better, properties than target. Higher amount of RejB could be needed to improve low temperature properties.
INPUTS for mix design

Comparing results from the binder blend design with the requirements for the binder to be used in the German mix and considering the following assumptions:

- With a RA binder content equal to 5.83%
- With a final binder content of 6.0 – 7.0%
- With a partial blending effect of 100% to 60%

It is possible to conclude that:

- VB and Rej A (0.20 RA/Rej dosage) can be used for all the mixes 30%RA, 60 and 90%

- Rej B could be used as well, but another dosage should be proved to improve low temperature properties. Tests on the mixes should provide a confirmation.
On-going Research and Other approaches

- **Validation of AB2P design**
  - Manufacturing of the blends at different blending percentages (100 – 60)
  - 200 – 100 Rotational Viscosity curves
  - 80 – 0°C Dynamic Mechanical Analysis by means of DSR
  - Below 0°C Low temperature characterization (DSR, BBR)
  - Ageing effect

- **Rejuvanatour dosage based on viscosity**
  - TARGET: Preliminary characterization by using only Rotational Viscometer (rheology based, cheap, little amount of material)
  - Several rejuvenators and RAs
  - Applications of several “Blending models” based on viscosity
On-going Research and Other approaches

- **AUS binder’s blend design**

According to AUSTROADS (2013), actual RAP binder requirements have not been defined by the Australian Asphalt Pavement Association, but the AUSTROADS report AP-T66/06 (AUSTROADS, 2006) contains typical criteria for blends of RAP binders and virgin bitumen or rejuvenators as shown in Table 5.

<table>
<thead>
<tr>
<th>Property</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetration at 25°C</td>
<td>Min: 35 d mm</td>
</tr>
<tr>
<td></td>
<td>Max: -</td>
</tr>
<tr>
<td>Viscosity at 60°C</td>
<td>Min: 350 Pa.s</td>
</tr>
<tr>
<td></td>
<td>Max: 900 Pa.s</td>
</tr>
<tr>
<td>Viscosity at 45°C (heavy traffic)</td>
<td>Min: -</td>
</tr>
<tr>
<td></td>
<td>Max: 4.5 log Pa.s</td>
</tr>
<tr>
<td>Viscosity at 45°C (light traffic)</td>
<td>Min: -</td>
</tr>
<tr>
<td></td>
<td>Max: 4.2 log Pa.s</td>
</tr>
<tr>
<td>Softening point</td>
<td>Min: 52°C</td>
</tr>
<tr>
<td></td>
<td>Max: 56°C</td>
</tr>
</tbody>
</table>


On-going Research and Other approaches

• AUS binder’s blend design

A recent report published by AUSTROADS (2013) describes a guideline for carrying out RAP binder blend design. Once the RAP binder has been recovered, they recommend determining the complex viscosity of the RAP, the virgin binder and the rejuvenator (if it is the case) in the DSR at 60°C and 1 rad/s according to AASHTO T315-12. Then, the viscosity of the blend can be predicted as follows:

\[ VBI_i = \frac{\log \vartheta_i}{3 + \log \vartheta_i} \]  
\[ VBI_\beta = \sum_{i=1}^{n} x_i VBI_i \]  
\[ \mu = 10 \left( \frac{3 VBI_\beta}{1 - VBI_\beta} \right) \]

\( \vartheta_i \) = viscosity of ith component (cP)  
\( VBI_i \) = viscosity blending index of ith component  
\( VBI_\beta \) = viscosity blending index of ith component  
\( x_i \) = volume fraction of ith component  
\( \mu \) = viscosity of the blend (cP)
On-going Research and Other approaches

• Software optimisation of blends

Software able to optimise the content of component of a mix basing on restrictions and several criteria

How does it work?
1. Choose the model
2. Introduce mix components and restrictions
3. Introduce criteria (including costs)
4. Introduce inputs
5. Output analysis and optimisation
On-going Research and Other approaches

- Software optimisation of blends

Analysis of results and optimisation towards the definition of Response Surface Models and optimised formula.
On-going Research and Other approaches

• Summary of International binder’s blend designs

- EU blend design (Pen and SP)
- USA blend design (critical temperatures)
- Australian method (Viscosity at 60°C)
- Software optimisation (Customisable)

Diagram:

RAb | Rejuvenator | Virgin binder | RAb+Rejuvenator | AB2P

- R&B test
  Penetration 25°C
- DSR, RTFOT, BBR
- DSR
- customisable
On-going Research and Other approaches

• Why do we need binder recovery??

Classification on mortar and mastic

• Preliminary AASHTO specification
• Currently 1 PhD student working within SUP&R ITN
• Another PhD starting March 2015 with forecasted collaboration with UC Davis
• Intensive use of rheological characterisation (majority of USA lab do not have Pen and R&B anymore!)

Classification of the RA

• RILEM round robin is trying to define protocols to classify “activity or RA” without recovery (published soon)
Conclusions

What is needed to design high-content RA asphalt mixes for wearing courses?

• Especially for surface courses, **composition analysis of RA and a comparison with the selected grading curve** are necessary to establish the maximum feasible amount of recyclable RA.

• Preliminary characterization of the **binding properties of the RA** are fundamental (i.e. binder recovery, characterization of mastics, mortar of RA itself).

• **If binder recovery is needed**, it must be **consistent** and extraction procedures should **avoid residual of solvent** (Rotovapor twice) and **employ non-toxic solvents** (N-propyl bromide).
Conclusions

What is needed to design high-content RA asphalt mixes for wearing courses?

• **Blending charts are a very useful tools**, however once again conventional properties such as Pen and SP, are not always reliable with more complex material than neat bitumen. They have been designed for bitumen only!

• **USA Blending charts**, entirely based on rheology of materials, provide a more reliable characterization for the design of high-content RA asphalt mixes

• **A more scientific based and user-friendly procedure to preliminarily assessing the dosage of rejuvenators, especially oils, is still needed**
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Questions?