Evaluating the benefit to pavements of asphalt binders modified with recycled plastic

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With the support of MacRebur Limited, Scotland, UK
### Australia

<table>
<thead>
<tr>
<th>Country</th>
<th>Population (Millions)</th>
<th>Land area (Million km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>25.5</td>
<td>7.7</td>
</tr>
<tr>
<td>Germany</td>
<td>82.9</td>
<td>0.4</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>10.6</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>UK</td>
<td>66.0</td>
<td>0.2</td>
</tr>
<tr>
<td>France</td>
<td>65.2</td>
<td>0.6</td>
</tr>
<tr>
<td>Italy</td>
<td>60.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Spain</td>
<td>46.7</td>
<td>0.5</td>
</tr>
<tr>
<td>Ukraine</td>
<td>42.2</td>
<td>0.6</td>
</tr>
<tr>
<td>Russia</td>
<td>113.1</td>
<td>3.9</td>
</tr>
<tr>
<td>All EU</td>
<td>513.5</td>
<td>4.5</td>
</tr>
<tr>
<td>USA</td>
<td>327.2</td>
<td>9.8</td>
</tr>
</tbody>
</table>
Background

Sustainable solutions are increasingly desired

- Recycled asphalt
- Crushed glass in asphalt and concrete
- Waste plastic in concrete and now asphalt

Waste plastic is a growing issue

- 30,000,000 plastic bags in Australia per annum
- 500,000,000 to 1,000,000,000 globally per annum
- Plastic drink bottles are a similar problem

Processed waste plastic as a binder modifier?
Background

Well established that recycled plastic

- Consumes waste destined for landfill
- Reduces demand on bitumen
- Improves asphalt deformation resistance
- Increases asphalt modulus
- Improves asphalt fatigue life

But what does this mean for pavement thickness and/or life?
Background

Recycled plastic modified producer MacRebur
Established in 2015
Based in Scotland
Developed a solution to
- Productively consume local plastic waste
- Reduce the cost of road maintenance
- Increase the strength and durability of roads

First MR 6, then later MR 8 and MR 10
Recycled plastic

MR 6
- 100% waste plastic
- Blended ‘dry’ at any asphalt plant
- Intended to be ‘plastomeric’ (like EVA)

MR 8
- Economical extender without improvement

MR 10
- Different plastics to be ‘elastomeric’ (like SBS)
Recycled plastic

This research is focused on MR 6
Recycled plastic

MR 6  
MR 8  
MR 10
The question

Can we measure?
- The modulus increase
- The fatigue life improvement

Can we quantify?
- The effect on pavement life
- The effect on pavement thickness
The methods

Standard British SMA 10 mixture (surface)
- Standard 40-60 penetration bitumen (control)
- 6% (of bitumen) of MR 6

Standard British DGM 20 mixture (base)
- Standard 40-60 penetration bitumen (control)
- 6% (of bitumen) of MR 6

Tested to British methods for
- Modulus
- Fatigue life

\{ Layered elastic characterization \}
The methods

Layered elastic pavement thickness design
- Modulus = structural contribution
- Fatigue life = asphalt cracking criteria

Circly
- Australian layered elastic software
- Developed in 1970s
- Improved and refined
- Official tool for Australian pavement design
The methods

Two styles of pavement

<table>
<thead>
<tr>
<th>Layer</th>
<th>Local road</th>
<th>Highway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface course</td>
<td>50 mm of SMA 10</td>
<td>50 mm of SMA 10</td>
</tr>
<tr>
<td>Base course</td>
<td>200 mm crushed rock</td>
<td>As required DGM 20</td>
</tr>
<tr>
<td>Sub-base course</td>
<td>As required gravel</td>
<td>150 mm of gravel</td>
</tr>
</tbody>
</table>

Subgrade – CBR 3, CBR 6 and CBR 10
Traffic – $1 \times 10^6$, $5 \times 10^6$ and $1 \times 10^7$ ESAs (trucks)
Effect of recycled plastic on modulus

Average 196% increase
Effect of recycled plastic on modulus

Average 48% increase
Effect of recycled plastic on fatigue

Average 11% increase

Log (load cycles to failure) vs. Log (initial single load microstrain)

SMA 10

- y = -4.07x + 14.03
- R² = 0.91

40-60

MR 6

- y = -6.39x + 18.64
- R² = 0.93

Average 11% increase
Effect of recycled plastic on fatigue

\[ y = -2.99x + 11.28 \quad R^2 = 0.75 \]

\[ y = -3.01x + 11.14 \quad R^2 = 0.99 \]

Average 52% increase
Layered elastic modelling

<table>
<thead>
<tr>
<th>Material</th>
<th>Standard</th>
<th>With plastic modifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMA 10 modulus</td>
<td>3,300 MPa</td>
<td>6,470 (↑ 196%)</td>
</tr>
<tr>
<td>DGM 20 modulus</td>
<td>1,500 MPa</td>
<td>2,200 MPa (↑ 48%)</td>
</tr>
<tr>
<td>SMA 10 fatigue</td>
<td>Shell standard</td>
<td>11% longer</td>
</tr>
<tr>
<td>DGM 20 fatigue</td>
<td>Shell standard</td>
<td>52% longer</td>
</tr>
</tbody>
</table>

Granular materials automatically sub-layered
The answers

- Allowable load repetitions without recycled plastic modification
  - $y = 1.22x - 126$
  - $R^2 = 0.95$

- Pavement thickness with recycled plastic modification
  - $y = 4.43x + 3E+06$
  - $R^2 = 0.27$
Conclusions

Recycled plastic can

- Improve asphalt fatigue
- AND
- Increase asphalt modulus

Similar to EVA polymer modified binder

Modelled in layered elastic software

- Three subgrade conditions
- Three levels of traffic
- Local road and Highway pavement

Reduced average thickness by 3% and 16%
Life increased by 150% and 900%
THANKS FOR YOUR ATTENTION