The Use of Natural Rubber Latex in Modified Asphalt Road Binders in the UK

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Introduction.

- Asphalt roads have been in existence since early 20th century.
- Asphalt road surfacing is extremely versatile, easy to apply, cost effective, and quiet.
- The binder (bitumen) is adequate for most situations, but in harsh conditions it properties are not sufficient.
- By as early as 1920-30’s researchers were assessing additives to enhance asphalt binder properties.
- Natural Rubber was studied as a polymer modifier for asphalt extensively in the 1950-70’s in the UK and abroad.
Early Studies into Use of Natural Rubber Latex in Roads in UK

- Joint research by NRPRA and Road Research Laboratory in UK into use of NRL in Asphalt Roads took place during 1950-60’s.

- This ultimately lead to publication of ‘Road Note 36’.
Early Research Articles 1950 – 1960’s
Observed Natural Rubber modified binder properties (1950-1960’s).

- Increased Softening Point
- Penetration of base bitumen enhanced
- Increased level of binder stiffness and viscosity.
- Penetration index improved
- Greater resistance to cracking at low temperatures
Early Research Articles 1950 – 1960’s

• Early research studied natural rubber both in powder (unvulcanised and scrap tyre) and latex form.
• Road Note 36 provided details on how to prepare the modified binder…. But the process had some drawbacks.
Road Note 36: Schematic of Latex / Bitumen Preblend Plant

- Bitumen Tank/s
- Dosing pump
- Agitator
- Steam Condenser
- PMB Storage Tank
- NRL Storage
- Heating Coils
- PMB Blending Vessel
- PMB Pump
- Foam
- To Asphalt plant
Road Note 36: Schematic of Powder / Bitumen Preblend Plant

- Bitumen Tank/s
- High Shear Mixer
- Heating Coils
- PMB Blending Vessel
- PMB Pump
- Latex powder Storage
- Powder transfer funnel
- PMB Storage Tank
- To Asphalt plant
Early Research Articles 1950 – 1960’s

Powder Form:
Advantages:
• Non foaming

Disadvantages:
• High dosage needed (>10%)
• Long mixing time
• High mixing temp.
• Inconsistent performance (Tyre Scrap)

Latex Form:
Advantages:
• Low dosage vs powder (<5%)
• Lower mixing temp.
• Faster mixing time

Disadvantages:
• Foaming
• Ammonia vapour
• Heat loss

Thermal degradation on storage.

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Conclusions and Actions Taken to Overcome Processing Issues (1960’s onwards)

- Latex addition was most energy and cost efficient option.
- Powder from scrap tyres was inconsistent and difficult to manage supply.
- Availability of NRL powder (unvulcanised) had ceased by the early 1970’s.
- A natural rubber latex was readily available that was ammonia free (LCS Revertex).
- Experiments found an inexpensive and efficient method for adding Natural rubber in latex form…..
- Addition of latex at asphalt plant was not only faster, but also eliminated thermal degradation problems.
Improved method for Latex Metering System at Asphalt Plant
(Latex Addition)

Bitumen  Aggregate/filler

Spray Bar

Dosage Control

Filter

Dosage Pump

'Lugmill' (Asphalt Mixer box)

LCS Revertex™ (Drum or IBC)

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Optimised NR Latex Addition Process.

- Adding NR latex at asphalt plant required minimal plant or mixing time adjustments.
- In practice a NRL dosage of between 3-5% d/d was found to give best compromise between cost and performance.
- Simple NR latex modification coupled with source of Ammonia-free NR latex stimulated research and regular use of NR modified binders on UK roads.
- Research focussed on solutions to persistent problems on UK road network or on new road surfacing materials.
- Some Studies also included synthetic polymers that were beginning to be promoted at this time.
Road Trials/ Applications 1970 – 1990’s

NRL modified Asphalt as Concrete Overlay ca.1970.


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Effect of NR Latex on Bitumen and Asphalt Properties

Natural rubber latex:
- Cis-1,4 polyisoprene
- Colloidal dispersion
- Water based
- pH ca. 11.0 (LCS)
- TSC ca 68% (LCS)
- Particle Size: 0.1 - 5µm
- Unsaturation allows cross-linking reactions
- However for asphalt application’s X-linking is undesirable (unvulcanised).
Effect NR Latex on Bitumen/Asphalt Properties

- Softening point of base binder is increased.
- Penetration of base binder is reduced.
- Fraass Point is reduced.
- Viscosity is increased.

<table>
<thead>
<tr>
<th></th>
<th>Pen., dmm</th>
<th>Softening Pt. (R&amp;B), °C</th>
<th>Viscosity @25 °C, Pa.s</th>
<th>Fraass, °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bitumen</td>
<td>50</td>
<td>48.5</td>
<td>2.56x10^6</td>
<td>-18</td>
</tr>
<tr>
<td>+1.0% NRL</td>
<td>45</td>
<td>54</td>
<td>4.35x10^6</td>
<td>-18</td>
</tr>
<tr>
<td>+2.5% NRL</td>
<td>30</td>
<td>62</td>
<td>1.01x10^7</td>
<td></td>
</tr>
</tbody>
</table>
Same effects are even seen when NRL is added as separate phase into bitumen emulsions…

<table>
<thead>
<tr>
<th>Emulsion Type</th>
<th>Pen., dmm (R&amp;B), °C</th>
<th>Softening Pt. (R&amp;B), °C</th>
<th>Fraas, °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unmodified</td>
<td>K1-70</td>
<td>200</td>
<td>35</td>
</tr>
<tr>
<td>+4% d/d NRL</td>
<td>K1-70</td>
<td>110</td>
<td>47</td>
</tr>
<tr>
<td>Unmodified</td>
<td>K3-60</td>
<td>125</td>
<td>46</td>
</tr>
<tr>
<td>+4% d/d NRL</td>
<td>K3-60</td>
<td>85</td>
<td>56</td>
</tr>
</tbody>
</table>
Effect of NRL modification on Wheel Tracking (Rutting).

35%/ 14mm Rolled Asphalt (TBC 7.4%)

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Rut Depth, mm</th>
<th>Wheel Tracking Rate, mm/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spec 50 Pen</td>
<td>+4% NRL</td>
</tr>
<tr>
<td>45°C</td>
<td>&lt;4 3.9 2.8</td>
<td></td>
</tr>
<tr>
<td>60°C</td>
<td>&lt;7 11.6 5.9</td>
<td></td>
</tr>
</tbody>
</table>
Effect of NRL on Penetration.

Log Pen Vs. Temperature

- Temperature, °C
- Log Pen

100 Pen - 100 Pen + LCS
50 Pen - 50 Pen. + LCS

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Effect of NRL modification on Binder Drainage

14mm SMA / 100 pen vs. 100 pen +3%(dry) NRL.

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Natural Rubber Latex in Cationic Bitumen Emulsions in UK.

- In 1960’s cationic bitumen emulsions were replacing anionic and hot mix systems for surface dressing, tack coats and slurry seals.
- Unmodified CBE’s were satisfactory for low traffic volume roads but restricted wider application on road network.
- This ultimately lead to research and introduction of first polymer modified CBE system: ‘Ralumac’.
Ralumac: Natural rubber latex modified cationic bitumen emulsion

- System is 2 stage process:
  Stage 1: NRL is made compatible with cationic emulsion.
  Stage 2: NRL is mixed with emulsifier acid in aqueous phase and then converted to CBE.
- Process not suited to continuous bitumen emulsion plants, however introduction of proprietary NRL and Synthetic latexes suitable for direct addition to CBE’s has increased use enormously.
- Typical NRL latex is 1497C/HS. This product allows NRL to be used on both batch and continuous bitumen emulsion plants.
Schematic of bitumen emulsion plant incorporating NRL addition

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Natural Rubber Latex in Cationic Bitumen Emulsions in UK.

• In UK, natural rubber latex modified emulsions are used mainly for micro-surfacing and tack coat systems.
• Surface dressing is predominantly based upon SBS binders.
• Tack coats based upon NRL are preferred due to their high adhesion properties.
# Properties of NRL Cationic Bitumen Emulsions Vs. Synthetics.

<table>
<thead>
<tr>
<th></th>
<th>Unmodified</th>
<th>Natural Rubber Latex</th>
<th>Styrene Butadiene Rubber Latex</th>
<th>SBS Block Copolymer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Polymer Level, %dry/dry</strong></td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td><strong>Emulsifier Dosage, %dry/dry</strong></td>
<td>0.25</td>
<td>0.12</td>
<td>0.17</td>
<td>0.25</td>
</tr>
<tr>
<td><strong>Emulsion Properties: Binder Content, %d/d</strong></td>
<td>70</td>
<td>72.4</td>
<td>71.9</td>
<td>70.0</td>
</tr>
<tr>
<td><strong>Viscosity (Redwood II), s</strong></td>
<td>30</td>
<td>37</td>
<td>23</td>
<td>20</td>
</tr>
<tr>
<td><strong>Recovered Binder Properties:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Penetration, dmm</td>
<td>200</td>
<td>112</td>
<td>135</td>
<td>155</td>
</tr>
<tr>
<td>Softening Point (R&amp;B), °C</td>
<td>35</td>
<td>47</td>
<td>42</td>
<td>58</td>
</tr>
<tr>
<td>Fraass, °C</td>
<td>-10</td>
<td>-26</td>
<td>-22</td>
<td>-18</td>
</tr>
<tr>
<td><strong>Toughness &amp; Tenacity, N:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>@ 5°C</td>
<td>-</td>
<td>1356</td>
<td>1608</td>
<td>-</td>
</tr>
<tr>
<td>@ 25°C</td>
<td>-</td>
<td>93</td>
<td>66</td>
<td>41</td>
</tr>
<tr>
<td>@ 35°C</td>
<td>-</td>
<td>21</td>
<td>18</td>
<td>-</td>
</tr>
<tr>
<td><strong>Performance Testing:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vialit Test, % Retained Chippings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>@ -10°C</td>
<td>90</td>
<td>97</td>
<td>68</td>
<td>94</td>
</tr>
<tr>
<td>@ 0°C</td>
<td>98</td>
<td>100</td>
<td>97</td>
<td>99</td>
</tr>
<tr>
<td>@ 20°C</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>@ 40°C</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Mini Fretting Test, % Retained</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>@ -10°C</td>
<td>89</td>
<td>89</td>
<td>81</td>
<td>91</td>
</tr>
<tr>
<td>@ 40°C</td>
<td>91</td>
<td>91</td>
<td>81</td>
<td>89</td>
</tr>
</tbody>
</table>

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Performance of NRL modified Bitumen Emulsions versus EU Specifications

<table>
<thead>
<tr>
<th>Emulsion Properties</th>
<th>K1-70 NRL</th>
<th>K1-70 Spec</th>
<th>K3-60 NRL</th>
<th>K3-60 Spec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Bitumen Pen, dmm</td>
<td>171</td>
<td>125</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Emulsifier Level, %d/d</td>
<td>0.23</td>
<td>0.8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Binder Content, %</td>
<td>69.2</td>
<td>69 – 71</td>
<td>63.9</td>
<td>58 - 65</td>
</tr>
<tr>
<td>Viscosity BTA (4mm) @20°C, S</td>
<td>7</td>
<td>≥ 7</td>
<td>6.2</td>
<td>&lt; 15</td>
</tr>
<tr>
<td>Viscosity Englera, °E</td>
<td>-</td>
<td>-</td>
<td>4.3</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>Coagulum (0.5mm Sieve), %</td>
<td>1.5</td>
<td>&lt; 5</td>
<td>0</td>
<td>&lt; 0.2</td>
</tr>
<tr>
<td>Sedimentation (5 Days), %</td>
<td>1.5</td>
<td>&lt; 5</td>
<td>4.9</td>
<td>≤ 5</td>
</tr>
<tr>
<td>Adhesion to Basalt, %</td>
<td>100</td>
<td>≥ 85</td>
<td>100</td>
<td>≥ 85</td>
</tr>
<tr>
<td>Adhesion to Granite, %</td>
<td>100</td>
<td>≥ 85</td>
<td>100</td>
<td>≥ 85</td>
</tr>
<tr>
<td>Breaking Index, g/100g</td>
<td>74</td>
<td>&lt; 90</td>
<td>125</td>
<td>&gt; 120</td>
</tr>
</tbody>
</table>
Performance of NRL modified Bitumen Emulsions versus EU Specifications

Recovered Binder Properties:

<table>
<thead>
<tr>
<th></th>
<th>K1-70 NRL</th>
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<td>Base Bitumen Pen, dmm</td>
<td>171</td>
<td></td>
<td>125</td>
<td></td>
</tr>
<tr>
<td>Emulsifier Level, %d/d</td>
<td>0.23</td>
<td></td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>Pentration, dmm</td>
<td></td>
<td>70 – 240</td>
<td>85</td>
<td>70 – 240</td>
</tr>
<tr>
<td>Softening Point (R&amp;B), °C</td>
<td>44</td>
<td>≥ 42</td>
<td>56</td>
<td>≥ 37</td>
</tr>
<tr>
<td>Fraass, °C</td>
<td>-21.5</td>
<td>≤ -15</td>
<td>-18.5</td>
<td>≤ -15</td>
</tr>
<tr>
<td>Elastic Recovery @ 25°C, %</td>
<td>35</td>
<td>≥ 60</td>
<td>51</td>
<td>&gt; 40</td>
</tr>
<tr>
<td>Vialit Test @ -15°C, % retained</td>
<td>100</td>
<td>≥ 5</td>
<td>95</td>
<td>&gt; 40</td>
</tr>
<tr>
<td>Vialit Test @ 60°C, % retained</td>
<td>100</td>
<td>≥ 85</td>
<td>100</td>
<td>&gt; 80</td>
</tr>
</tbody>
</table>
Performance of NRL modified Bitumen Emulsions.

- NRL modified bitumen emulsions perform extremely well alongside synthetic polymers.
- Both at low and high temperatures NRL modified emulsions perform as well as synthetic polymers.
- Elastic Recovery does not correlate with low or high temperature performance of the recovered binder.
- Some EU specifications require compliance with Elastic recovery. As NRL does not meet requirements for Surface dressing systems, but can be blended with Synthetic polymers to meet requirements.
- UK market does not have ER requirements, however there is no data that indicates UK emulsion based systems do not perform as good as systems in other EU countries.
Conclusions

• Natural rubber latex has been used successfully on UK roads for over 5 decades.
• Natural rubber latex has found uses in both traditional and modern hot mix pavement systems and in bitumen emulsions.
• Natural rubber latex can be added efficiently and provide cost effective high performance road surfacing.
• Natural rubber latex continued use may be at risk through improper specification of application tests that do not accurately reflect polymers properties in practice.
• Natural rubber offers unique opportunity to road industry as a performance enhancing, renewable, sustainable and ecologically beneficial resource available to the road sector.
• Carbon Trading and other environmental factors will ensure natural rubber latex will have a future as polymer modifier in roads.
Thank You For Listening!