USE OF CRUMB RUBBER IN SLURRY AND MICROSURFACING.

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ABSTRACT:

The problem of disposal of tyre rubber is well known. Many methods of disposal have been used including burning, burying, and recycling to other rubber products. In some countries tyre rubber has been used in road applications to enhance performance or merely use the road as a horizontal land fill.

The increase in popularity of emulsions in many countries for environmental and energy reasons has meant that the traditional hot applied methods using rubber have become an increasingly unattractive final destination for tyre rubber and emulsion alternatives are required.

The application of crumb rubber in emulsions has been somewhat limited, this is not because rubber cannot be emulsified but because the other components in crumb rubber and the crosslinked nature of the product have meant that even the best wet process blends are distinctly two phase. The solution has been to add the rubber into dry aggregate mixes with emulsion or create a dispersion in a suitable diluent One such process is the subject of this paper.

In this paper the properties and manufacturing methods of such emulsions are discussed. The properties of the emulsion are discussed in terms of stability and general properties, the application and performance are discussed in the areas of slurry and microsurfacing.

Laboratory mix design methods indicate that the use of crumb rubber can reduce deformation in slurry and microsurfacing, increase allowable asphalt content without bleeding, increase flexibility and abrasion resistance. The combination with latex additives appears to give even greater improvements and this system needs to be examined more closely. Adhesion too is improved and this may be partly attributable to the oil fraction used in the product manufacture. This was checked using different solvents and it was found that solvent has a significant effect. This would be attributed to enhanced wetting.

1. INTRODUCTION:

Scrap rubber, crumb rubber, reclaimed rubber are all terms describing rubber recycled
from other uses, principally car tyres. It is not a pure polymer but a blend. However most car tyres in USA are mainly vulcanizes, i.e. crosslinked SBR or polyisoprene and carbon black which acts as a reinforcing agent. Other fillers and chemicals are often used. The principal components have been used as additives in many places, natural rubber has been used with success in Malaysia and in the Middle East, SBR has long been used in USA and carbon black has been used as a stabilizing agent for asphalt, on the face of it scrap rubber should be of interest.

The rubber in the system however has been crosslinked or vulcanized. This in fact gives the rubber its high elasticity and thus ability to rebound as well as imparting some physical strength. In SBR or natural latex systems the rubber is added in as a latex usually and any crosslinking that occurs is due to heat and or aging. This vulcanization reduces significantly the dispersion capability of the rubber molecules and reduces stability. Thus creating a two phase system with asphalt. For these reasons the morphology and physical properties are quite different from simple SBR addition.

Scrap rubber has been used in road applications since the 50's in Australia and USA in sealing applications such as SAM and SAMI, as well as in crack sealing and joint filling. With the availability of synthetic polymers of known composition and performance and moderate cost there seems to be no particular economic benefit in using scrap rubber. It may be made from recycled tyres but the processing cost is substantial, so the final consumer cost is comparable to synthetics in most instances.

In many countries the material is either not used at all or confined to traditional users who are loath to change to synthetics or, as was the case in an isolated South Africa, used because the synthetics are not available.

In USA 282 million tyres per year are discarded. (NAPA 1993) They are used in various ways however the excess has lead to a stockpile of 1-2 billion tyres. NAPA have resisted their use in paving preferring to recommend incineration as fuel or landfill. However this may not be enough.

The main object of using crumb rubber has been often to simply dispose of them in vertical landfill, but tyre rubber has a valuable polymer component that might be expected to improve properties such as cohesion, elasticity, tensile strength and deformation resistance.

2. METHODS OF USE.

2.1 Hot Applications:

There are two basic systems for using scrap rubber in hot applications.

1.- Wet Process.

2 - Dry process

Each begins with scrap rubber in a convenient form.

This may be with buffings from a retreading operation (0.5 inch sizing) or from a tyre processing plant. This may also be ground rubber and such materials may be ground at ambient temperature or cryogenically. The advantage of ground rubber is that it may be digested or mixed faster than larger particles. It was found in work carried out at the Australian Road Research Board in the 80's (Oliver 1989) that the morphology of the rubber influenced the physical properties of the final binder. The ambient ground rubber
appeared to give better results.


The loading rate of rubber is 15-20%.

The rubber is mixed and digested in the bitumen by either low or high shear mixing. The rubber undergoes a specific process with the bitumen. This is often referred to as a reaction. It is rather a physiochemical reaction rather than simply a chemical one. The rubber swells in components of the bitumen to produce a composite. In the wet process this is aided by the use of added aromatic oils.

The particle size and shape has a large effect on this digestion rate along with the temperature.

The wet process is used mostly in Australia, South Africa and USA. (RTA 1995), (Polgeiter 1989)

The addition of scrap rubber should:

Reduce thermal cracking:

Reduce Rutting.

Reduce Reflective Cracking.

Aging Resistance.

Chip Retention.

How well properties are achieved depends on bitumen/rubber compatibility.

b) Dry process (Epps 1992)

This is sometimes called the "rubber aggregate" process. This is a mixture of bitumen, mineral aggregate and granulated rubber. The aggregate grading is gap graded to allow for space for the 3% of rubber that is added. The time at "reaction" temperature is limited by limiting mixing time and the rubber retains its integrity. The surface only interacts with the bitumen creating a durable bond.

A percentage of the rubber granulate will be fine and can affect the bitumen as in the wet process.

The system should produce:

Reduction in Reflective Cracking.

Ice Disbonding.

Raveling (increase)

Flushing.

Flexibility.

Improved Surface texture.

The surface texture five better draining, skid resistance and noise reduction.

The rubber that disperses in the bitumen should improve low temperature flexibility, rut resistance, fatigue properties and increase viscosity, allowing higher binder contents hence better durability.

The low void content of plus ride can improve moisture resistance and durability.

How well the property improvements are achieved depends on the mix design and the translation of this into practice.

### 2.2 Emulsion Addition.

Polymer emulsions have been used to a great extent in chip sealing and slurry/microsurfacing (Holleran 1996, ibid 1996). The polymers generally are preblended with the asphalt, comilled as latex or post added as latex. Crumb rubber is a case where these methods are not available. Preblended crumb, if completely digested might be able to be emulsified but crumb rubber systems in asphalt are generally two phase and additives such as carbon black are more difficult to emulsify into a stable dispersion.

The methods by which the material may be incorporated in emulsion are thus largely confined to post addition.

Ground solid crumb rubber has been added into slurry mixes as a dry ingredient, like in the dry process mentioned above. In such a case the rubber becomes a part of the aggregate phase and acts mainly as a filler. The abrasion resistance of the rubber should give a thin coating a reasonable wearing life, especially if modified with another polymer such as SBR latex. Such processes are in general use in USA.

However to create much change in elasticity and other desirable properties the rubber needs to be fully or partially digested so that it may coat particles. This is the basis of the process to be discussed.

The increase in cohesion should improve properties such as deformation resistance (in rut filling) surface abrasion resistance, crack resistance and allow increased binder films without flushing.

### 2.3 Solvent Dispersion.

The process referred to as the wet process may be adapted for use with emulsions. If a suitable solvent can be used that allows dispersion in the emulsion water phase then a post added material may be produced. The solvent type is of obvious importance as it must not create an environmental hazard nor degrade either the asphalt properties nor those of the rubber. On the other hand if the solvent is able to swell or soften the rubber then it may improve wetting and adhesion.

A range of solvents has been used to optimize the dispersion and other additives such as wetting agents and carbon black. In general terms an oil additive is preferable with a high aliphatic content and a boiling range that meets VOC requirements but also allows swelling of the rubber. The formulation is proprietary and will not be discussed further. The material will be referred to by its designation of RG-1.

### 3. Emulsion Properties and RG-1.

RG-1 is a semi swelled dispersion of crumb rubber (40-50%) in a petroleum solvent. It is

http://www.slurry.com/papers/useof.htm
supplied as a free running high viscosity material that can be readily poured and pumped.

RG-1 is used by post addition into the emulsion with simple mixing. Figure 1. As may be seem the emulsion is not greatly affected by addition of RG-1 except that the sedimentation rate is high. This is not surprising as the RG-1 is a separate phase and indicated that the emulsion must be thoroughly mixed before use. There is no obvious breaking caused by the presence of the RG-1 and this is true to concentrations in excess of 20%.

**Figure 1 - Emulsion Properties**

<table>
<thead>
<tr>
<th>Emulsion Type</th>
<th>% RG1</th>
<th>Viscosity (13% H)</th>
<th>Settlement (3 days)</th>
<th>Residue (AS1160)</th>
<th>Break (AS1160)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRS-2</td>
<td>5</td>
<td>120</td>
<td>3</td>
<td>67</td>
<td>&lt;3 mm</td>
</tr>
<tr>
<td>CRS-2</td>
<td>10</td>
<td>160</td>
<td>5</td>
<td>68</td>
<td>&lt;3 mm</td>
</tr>
<tr>
<td>CRS-2</td>
<td>20</td>
<td>210</td>
<td>10</td>
<td>69</td>
<td>&lt;3 mm</td>
</tr>
<tr>
<td>PMCRS-2</td>
<td>10</td>
<td>170</td>
<td>6</td>
<td>69</td>
<td>n/a</td>
</tr>
<tr>
<td>CQS-1h</td>
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<td>39</td>
<td>7</td>
<td>60</td>
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</tr>
<tr>
<td>LMSCQ-1h</td>
<td>10</td>
<td>65</td>
<td>9</td>
<td>61</td>
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</tr>
<tr>
<td>Micro</td>
<td>10</td>
<td>70</td>
<td>7</td>
<td>61</td>
<td>n/a</td>
</tr>
</tbody>
</table>

The residual properties of the binder were similar to that expected for about 2.5-10% residual crumb rubber. This was torsional recovery up to 10% and viscosity increase. This is indicative of the recovery method and the digestion of the rubber into the asphalt due to the application of heat. (Figure 2). It is interesting that the penetration actually increased, this may have been due to retained solvent. It is not unusual with elastomer systems that viscosity increases but penetration indicates increased softness. The normal assessment of hardness or softness does not apply, this indicates that the rheological type of the binder has changed and hence the physical properties such as thermal susceptibility have been improved. Dynamic Shear Rheometer measurement is difficult with two phase systems, particularly with recovered emulsion samples but indications are that the binder has lower stiffness at low temperatures and higher stiffness at higher temperatures than the base asphalt and hence improved crack and rut resistance. This is shown approximately in figure 3. These results are consistent with increases in elasticity as indicated by the torsional recovery and increases in ring and ball softening point with viscosity increase.

**Figure 2 - Residual Properties**

<table>
<thead>
<tr>
<th>Emulsion Type</th>
<th>Addition</th>
<th>Torsional Recovery</th>
<th>Penetration (25°C)</th>
<th>Viscosity (60°C)</th>
<th>Viscosity Post RTFO</th>
<th>RBSP</th>
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<tr>
<td>CRS-2</td>
<td>0</td>
<td>0</td>
<td>121</td>
<td>764</td>
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<td></td>
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<td>195</td>
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<td></td>
<td>50</td>
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<tr>
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</tr>
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<td>2500</td>
<td>4500</td>
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<td>49</td>
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<tr>
<td></td>
<td>15</td>
<td>7</td>
<td>95</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
4. Slurry Seal and Micro Surfacing.

4.1 Laboratory Method.

ISSA guidelines were followed exactly with the RG-1 mixed in the emulsion with hand stirring.

http://www.slurry.com/papers/useof.htm
A single rock was chosen, Granite Rock Romas. To gauge the effect of the rubber a 5% by weight rubber level was chosen to compare the tests. To put this in perspective the results were compared to similar mixes with different polymers. To ensure that a comparison could be made the emulsion content was equalized as optimum for the asphalt design. This was about 8% bitumen or 13.5% emulsion on the type II rock. The RG-1 was added at 5% residual as recommended and the other polymers were at 2.5% residual for the latex and 3% for the SBS. In the RG-1+ case this was 3% latex with the rubber added.

Mixing was changed by the addition of rubber and retarder levels needed to be increased significantly compared to asphalt emulsion from 0.25% to 1.0%. Water levels too were increased by around 25-30%.

For flex testing samples were prepared according to ISSA 146. However as the ISSA device was not available a method was devised where the strips of metal with the slurry covering were bent in a continuous rate of about 5cm per minute and the onset of visible cracks observed. The lateral distance that the strip was bent from the horizontal was measured and the difference noted. This is obviously very operator dependent but appeared to be as reproducible as the ISSA 146 test. The results may only be taken as an indication however and more work is required.

4.2 Results:

a) Wet Track testing. (Figure 4).

Wet Track showed that the rubber additive gave improved resistance to stone loss under this test compared to asphalt. This may give the opportunity to reduce binder levels.

In combination with latex the results were further improved. This showed less improvement than with latex alone. This is probably due to the presence of particles of rubber in the surface that are taken out by the abrasion head. This is not an unexpected result. It should not be interpreted in terms of insufficient binder however.

The general increase in resistance to abrasion does indicate that binder levels may be increased for these systems by at least 1%. This will have the effect of increasing durability as film thickness is the determining factor for this property (Holleran 1996).
b) Loaded Wheel Test (Figure 5).

Showed improvement resistance to deformation relative to asphalt but not as good as the polymer modification. When combined with latex the results were improved significantly. These results show the effect of increased viscosity and modulus. Shear resistance cannot be gauged by this test but the results are consistent with improvements in rut resistance and indicate an application.
c) Cohesion (Figure 6).

The setting of the slurry/microsurfacing was not compromised by the addition of the rubber, in fact it is improved. The polymer materials were still better.

This is a result of higher green strength of the polymer modified system. It probably does not cure at any faster rate but the shear strength of the curing material is simply higher.

Figure 7 shows this for the Vialit plate test for these binders. The polymer definitely improves stone retention in early life.

This may also be in part due to improved wetting due to the softening effect of residual solvent in the system, increasing adhesion.

Standard boiling tests for adhesion showed some improvement and Shulze Breuer testing showed higher compatibility so this effect is real.

![Figure 6 - MICROSURFACING COHESION](http://www.slurry.com/papers/useof.htm)
d) Flexural Strength - Crack Resistance.

Within the limitations previously indicated the rubber modified material does appear to have better crack resistance in flexure. This is unlikely to be sufficient to allow the use of such materials as membrane applications. However as a means of improving resistance to traffic flexing in rut filling and as an improvement in the slurry coat of a cape seal it should improve performance.

4.3 Field Results.

Field trials have been carried out using RG-1 and the long term effects are being quantified.

The general conclusions on application are:

1. RG-1 was easy to blend into the emulsion using an in line blending system and ensuring that the emulsion was well mixed before use.

2. The emulsion mixed easily with the mixes and although higher levels of retarder and water were required laid as normal.

3. The slurry set and cured normally.

http://www.slurry.com/papers/useof.htm
4. Long term effects of traffic and aging cannot be concluded from results to date.

5.0 Economics.

The cost is about 1.5-3.0c per square foot depending on the dose rate.

No extra equipment is needed as the additive may be added at the plant using the transfer pumps in existence. Little change is required to laying procedures.

6.0 Conclusions.

1. Crumb Rubber has extensive uses in road surfacings and mixes.
2. Emulsion processes are limited in method of incorporation.
3. A solvent dispersed ground rubber, partially swelled can be easily mixed with emulsions.
4. In slurry seal and microsurfacing mixes improvements in abrasion resistance, deformation resistance and cohesion are observed in laboratory mixes. Flexural resistance is also improved. The binder appears to be improved in thermal susceptibility and in elasticity.
5. Such slurry seals and microsurfacing are easy to apply but may require extra retarder.
6. The addition of this material is an effective way to dispose of tyre rubber.

7.0 References: